Embry-Riddle Aeronautical University
SCHOLARLY COMMONS

Journal of Aviation/Aerospace Education & Research

Volume 32 | Number 1 Article 3

2023

Using Unmanned Aircraft Systems to Investigate the Detectability of Burmese Pythons in South Florida

Joseph Cerreta Ph.D.
Embry-Riddle Aeronautical University, cerretaj@erau.edu

William Austin Ed.D.
Warren County Community College, will@warren.edu

David Thirtyacre Ph.D.
Embry-Riddle Aeronautical University, thirtyad@erau.edu

Scott S. Burgess Ph.D.
Embry-Riddle Aeronautical University, burgesco@erau.edu

Peter Miller
Warren County Community College, pmiller2@warren.edu

Introduction

Burmese pythons are an invasive, non-native species of snake to southern Florida. According to the Florida Fish and Wildlife Conservation Commission (FWC), Burmese pythons can be found throughout south Florida, including the Everglades National Park, Southern Glades Wildlife and Environmental Area, and Big Cypress National Preserve, among others (FWC 2021a). The FWC has also reported these snakes were beginning to migrate to the North, potentially affecting areas near Naples (FWC, 2021b). Hart et al. (2015) radio tracked the movement patterns of pythons in this region and determined the mean area covered by an individual snake was 22.5 km^2. It is suspected that these snakes appeared in southern Florida as released pets in the 1980s (Hart et al., 2015; Willson et al., 2011).

In 1992, Hurricane Andrew made landfall in South Florida. The hurricane destroyed a breeding facility that released thousands of Burmese pythons into the 1,900 km^2 of Everglades National Park, significantly increasing the number of this invasive species that were already abandoned by pet owners prior to the hurricane (Morrison, 2018). Pythons have increased in number and have decimated the native species of mammals, as well as native flora and fauna. The number of snakes is estimated to be between 10,000 to upwards of hundreds of thousands of snakes, but the exact number is unknown (Frazier, 2019).

Attempts at eradicating Burmese pythons in southern Florida have yielded mixed results. The United States Geological Service (USGS) invasive species science program attempts to detect their location, contain the animals, and control their spread in the Everglades Ecosystem Mission Area (Campbell, et al., 2019). The FWC sponsors an annual competition for amateurs and professional snake hunters to capture and kill Burmese pythons. In 2021, the yearly Florida Python Challenge only harvested 223 pythons by 600 people attempting to find these reptiles

(Jankowski, 2021). There are an estimated 300,000 Burmese pythons in the southern Florida region (Driggers et al., 2019).

Since pythons are cold-blooded reptiles, the ability to search for these animals with thermal cameras has had limited success (Hewitt et al., 2021; VolAero, 2017). VolAero (2017) demonstrated that UAS equipped with thermal cameras enabled hunters to detect pythons at night during their prime hunting time. Hewitt et al. (2021) suggested that using thermal cameras to detect pythons was only practical in the first few hours after sunset because the snakes' thermal radiation dissipated at a slower rate than the surroundings.

The current rate of detection had been reported as 0.05% (M. Skinner, personal communications, December 14, 2021). The purpose of this research was to determine if using uncrewed aircraft systems (UAS) equipped with a red-green-blue (RGB) and near-infrared (NIR) camera can provide a method of detecting Burmese pythons. Currently, such research has largely been done from road-based vehicles, leaving large areas of the Everglades unexamined because of the difficult terrain and lack of roads (Hewitt et al., 2021). By comparison, in other areas of the world, such as Thailand, densely forested areas made it extremely difficult to detect Burmese pythons, and researchers relied on visual encounters from locals instead (Smith et al., 2016). UAS can capture images of Burmese pythons from nadir-oriented angles instead of high-oblique angles. Imaging the pythons from an overhead perspective may provide an increased rate of detection. A greater detection rate from UAS may provide an additional, practical method for detecting the snakes and assist wildlife management officials with controlling the expansion of this invasive species.

Two research questions were investigated. These questions were:

https://commons.erau.edu/jaaer/vol32/iss1/3
DOI: https://doi.org/10.15394/jaaer.2023.1952

(1) What was the likelihood of detecting a Burmese python using a UAS equipped with either an NIR or RGB camera?

(2) Is an NIR camera more capable of detecting a Burmese python than a RGB camera on a UAS?

Review of Literature

Pythons in the Everglades

Burmese pythons can be found throughout south Florida, including the Everglades National Park, Southern Glades Wildlife and Environmental Area, and Big Cypress National Preserve, among others (FWC, 2021a). The FWC has also reported that these snakes were beginning to migrate to the North, potentially affecting areas near Naples, Florida (FWC, 2021b). Hart et al. (2015) radio tracked the movement patterns of pythons in this region and determined the mean area covered by an individual snake was 22.5 km^2. Radio tracking programs in south Florida have also enabled biologists to capture over 2,000 pounds of Burmese pythons in 2020 alone (I. Bartoszek, personal communication, December 15, 2021).

In areas of the Everglades where Burmese pythons are known to exist, an 80% decline was found in in animal survey counts of common mammals, including raccoons, opossums, and nearly 100% of rabbits (Dorcas et al., 2012; Willson, 2017). Based on the success of pythons as a predator hunter and their high predation rates of the mammal population, Orzechowski et al. (2019) suggested the snakes' diet had evolved to include bird populations. Dove et al. (2011) reported that 25% of the Burmese pythons harvested in a five-year period contained bird remains in their intestinal tracts. This change in the predatory conditions has had a negative environmental impact on the Everglades and the Florida ecosystem for over a decade (Reed et al., 2012). Recent evidence suggests that the python diet has even evolved to include small

American alligators native to the Everglades, as well as deer and bobcats (Roaring Earth Staff, 2020). The problem of expansion of the invasive Burmese python remains a major concern and threat to native species and people (Lisenbee, 2022).

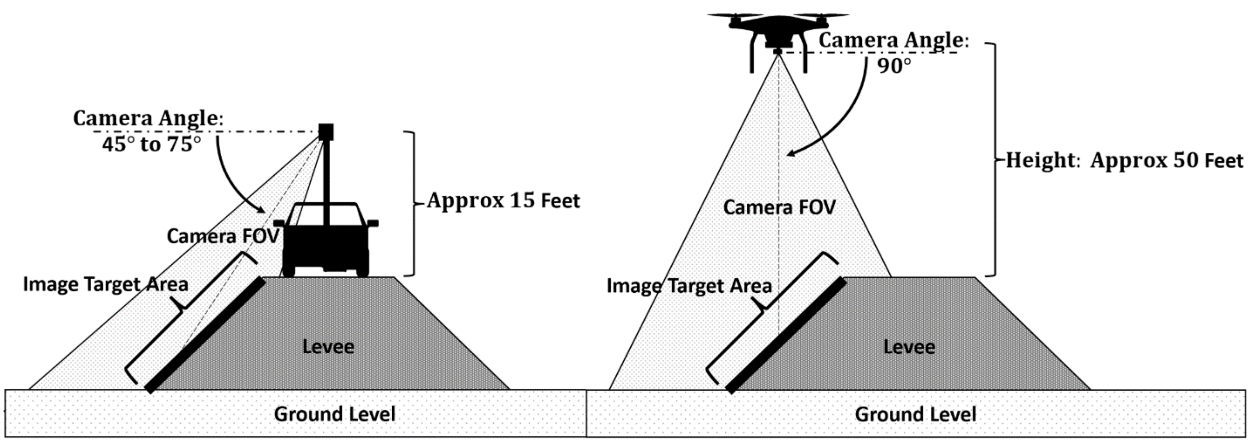
Remote Sensing

Using UAS can provide a means of capturing image data from low-oblique or nadir-orientated angles. The angles captured from a UAS can result in less terrain and vegetation masking, potentially increasing the rate of detecting exposed pythons along levees and tall grasses. Furthermore, UAS may not be constrained to searching along levee roads throughout the Florida Everglades, leading to less dependency on traditional transportation routes, boats, or walking, since UAS have been demonstrated as a safe means of data collection without disturbing the environment (Zhou et al., 2021). When attempting to collect data in harsh environments, UAS have been shown to provide a cost effective, safe solution (Anderson et al., 2021; Barnas et al., 2018). Although remote sensing using UAS can provide a practical solution, determining and equipping the UAS with the appropriate payload for the object being captured would be vital to the success of any data collection methodology. Currently, the most appropriate payload to test for remote sensing Burmese pythons would be the NIR band according to the recent literature (Hewitt et al., 2021). In their research, the rate of detecting pythons from NIR images was higher than compared to traditional RGB images.

Existing methods of using NIR cameras to detect pythons along levee roads were previously employed by researchers at the University of Central Florida (Driggers et al., 2019; Hewitt et al., 2021); however, the cameras had a high-oblique orientation when detecting exposed pythons along the banks of the levee system (see Figure 1). This angle could cause vegetation or terrain masking along the levee banks. Using a UAS equipped with an NIR camera to fly directly over the levee bank can yield a low-oblique or even nadir-oriented image position of the side of the levee, which can reduce terrain and vegetation masking. Additionally, the flying height of the UAS can be adjusted to safely avoid obstacles as it is not constrained by a fixed-height mast.

Figure 1

Differences Between Ground Vehicle and UAS-Mounted Camera Positions and Orientation



Python Identification

Burmese pythons have evolved with a natural camouflage suited to their environment. Hewitt et al. (2011) suggested that the use of a traditional camera (RGB bands) to detect pythons has been demonstrated to be ineffective as a data collection methodology because the difference between the snake and the surrounding vegetation had little contrast and color differences. Also, since pythons are cold-blooded reptiles, the ability to search for these animals using thermal cameras also has had limited results (Hewitt, et al., 2021; VolAero, 2017). Stahl et al. (2016) reported that for most of the day, a python’s core body temperature was less than 2°C compared to the surrounding terrain and had largest differences of less than 5°C at the peak time of day.

Some UAS thermal cameras have a sensitivity of 0.05°C and an accuracy of 2°C (DJI, 2022). It may be very difficult to detect pythons using a thermal camera. Hewitt et al. (2021) suggested that using thermal cameras to detect pythons was only practical in the first few hours after sunset because the snakes' thermal radiation dissipated at a slower rate than the natural surroundings.

Hewitt et al. (2021) also used NIR cameras to determine if these sensors could improve the reliability of detecting Burmese pythons. Their research concluded that using NIR cameras did not rely on temperature differences. They were able to use NIR cameras during daylight and nighttime hours with artificial illumination. Hewitt et al.'s (2021) research also used cameras oriented in high oblique angles, mounted on the top of vehicles to capture images of the pythons. In their study, participants were asked to select the location of a python in RGB and NIR images. A True Positive Rate (TPR) index calculation was used to determine a rate of correctly identified sections of images containing the snakes. Their research indicated a significant improvement in the ability to detect snakes with greater reliability and at distances of up to 15 meters with an NIR camera compared to a RGB camera. This research is fundamentally based on the work done by Hewitt et al. (2021), but with a UAS instead of a vehicle-mounted camera.

Methodology

The purpose of this research was to determine if a UAS equipped with an NIR camera could be used to detect pythons at a higher rate than a RGB camera. The approach involved collecting a series of images of an outstretched and coiled Burmese python from different distances with NIR and RGB cameras mounted on UAS. For this research, RGB images were defined as capable of sensing RGB wavelengths of light from 350nm to 700nm. NIR images could sense near-infrared wavelengths of light, which are not visible to the human eye, at a wavelength of 850nm.

Researchers operated a UAS equipped with either an NIR or RGB camera to answer these questions. A nadir-oriented camera angle of 90 degrees was used at different flying heights to provide variation of likely conditions to observe the snakes. The angle and varying flying heights of 3 to 15 meters above the ground provided a practical balance to detect pythons in this research.

UAS Image Collection

Data was collected using a DJI Mavic 2 Pro (M2P) equipped with a full spectrum converted camera. The full spectrum conversion was performed by Kolari Vision, which enabled the camera sensor's sensitivity from ultraviolet through near-infrared wavelengths of light (Kolari Vision, 2021). The process involved removing the integrated IR-cut filter, which blocked ultraviolet and NIR wavelengths of light. A hot mirror filter was then used over the sensor to capture RGB imagery. An NIR cut filter at 850nm with a halfwidth of 50nm was used to capture the NIR imagery. Figure 2 depicts the UAS configuration and sensor specifications.

Figure 2

UAS Configuration Used for Python Detection Research

Aircraft	Sensor Configuration	Sensor Specifications
DJI Mavic Enterprise Dual with Full-Spectrum Converted Camera 	Full-spectrum camera with Hot Mirror filter	Type: 1/2.3" CMOS Lens: HFOV 85° Resolution: 4000 x 3000 pixels Wavelength frequency: 350nm-750nm
	Full-spectrum camera with NIR cut filter	Type: 1/2.3" CMOS Lens: HFOV 85° Resolution: 4000 x 3000 pixels Wavelength frequency: 850nm

An outstretched 3-meter python carcass was located along a levee road in southeastern Florida. The snake was also oriented into a coiled position later. The UAS collected images with the NIR cut filter installed to image the 850 nm spectrum, then again with the hot mirror filter installed to image the RGB spectrum. Flying heights of 3, 6, 9, 12, and 15 meters were used to vary the images' resolution. A camera angle of 90 degrees was used to provide a consistent perspective of viewing angles between NIR and RGB image sets from a direct overhead position. Fifteen images collected were of an outstretched python and 15 images were of a coiled python. Another 25 images were collected with no python in the image at all. To reduce the chance of an expectation bias, both the coiled and outstretched python images were positioned in different directions. Changing the direction served to minimize the ability of participants to look for the same orientation in scanning and detecting the coiled or outstretched python orientations. The differences in python orientation, camera configuration, and flying height were compared to determine how reliably a python could be detected. This approach aimed to recommend a best practice between these parameters to biologists using UAS technology in real-world python detection situations.

Research Limitations

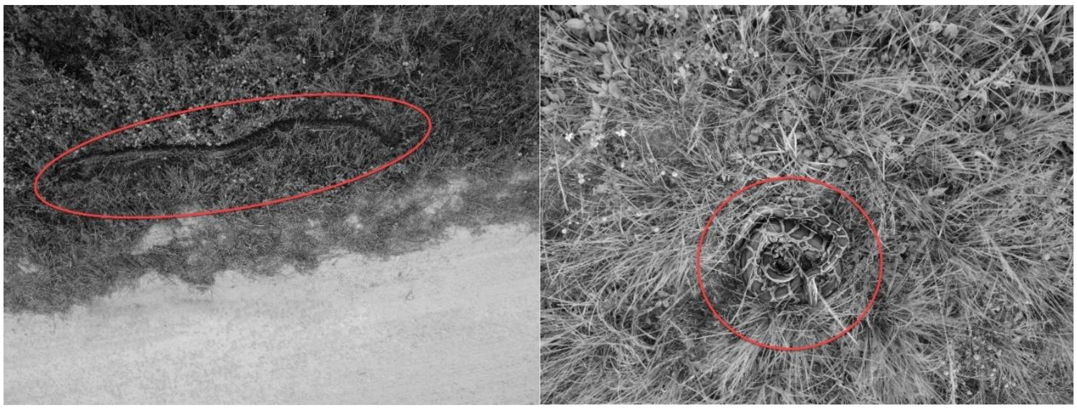
The research was limited to a single location in south Florida. The location selected was along a levee surrounded by marl prairie and freshwater slough. Other locations with different types of vegetation, such as hardwood hammock, pineland, or cypress would likely have different results. Two 3-meter pythons were used in this research. Although Burmese pythons in south Florida can grow to 6 meters length (Dove, et al., 2011), larger or smaller snakes may have a different rate of detection.

Survey Data Preparation

A total of 55 images were collected between RGB and NIR cameras, an outstretched python, coiled python, or no python at all. Also, flying heights of 3, 6, 9, 12, and 15 meters were used respectively. The sensor settings were set to auto shutter speed and ISO. The images were organized by snake orientation type, camera type, and flying height. Because the M2P could not change the camera white balance to compensate for the NIR filter without creating a distracting image to a survey participant, the NIR images were converted to grayscale by desaturating the images. The RGB images were captured in auto white balance, and no color changes were made. The focus plane was set to the center of the snake. All images were cropped to 100% from the center of the images and bound to the same image size of 1500 x 1200 pixels at 240 pixels per inch. The resulting image size was six and a quarter inch by five inches. All images had a box in the lower left corner indicating a message, “I don’t see a python in this image,” to enable a selectable portion of the image if a participant could not detect a python. At the beginning of the survey, participants were shown isolated images of an outstretched and coiled python, as depicted in Figure 3.

Figure 3

Examples of an Outstretched and Coiled Python Shown to Participants at the Beginning of the Survey in RGB



Note. Circles indicate an outstretched python (left) or a coiled python (right) in RGB.

Using the click map feature on the popular online survey tool SurveyMonkey (https://www.surveymonkey.com), the location on the image where the participant clicked was recorded when they submitted their answer. The participant could change their click location as many times as they liked until they submitted their answer; the initial click location was not recorded. Each participant was given the option to select if they did not see a python in the image. A box was provided in the lower-left corner of each image (see Figure 4) should a participant not see a python in the image.

DOI: https://doi.org/10.15394/jaaer.2023.1952

Figure 4

Example of Image Presented to Participants with a No Python Detected Box Selection

To measure the accuracy of participants' selections, the clicked locations were compared to the python locations in the images. The participant's click location was obtained by exporting survey results from SurveyMonkey to a Comma Separated Value (CSV) file that contained the pixel location of each participant's click for each image in the survey. If the participant clicked on the python's location in the image, the result was labeled as a true positive. If the participant clicked on a location that a python was not located, the result was labeled as a false positive.

Treatment of Participant Response Data

A convenience sample of 101 survey participants participated via SurveyMonkey. The participants were recruited from Embry-Riddle Aeronautical University and Warren County Community College staff, faculty, and student populations. Participants were not screened for color-blindness, which would have influenced RGB findings. Participants were presented with images of pythons in outstretched and coiled positions to familiarize them with the orientations used in this research. Fifty-five images were presented to each participant in random order. Participants were asked to click on the image portion where they thought a python was located.

If the participant did not detect a python in the image, they were asked to click on the button titled "I don't see a python in this image." There was no time limitation for the participants to respond. The mean time to complete the survey was 11 minutes. Although the images were presented in random order, and survey participants could stop taking the survey at any time, the mean completion rate of the survey was 84%.

As shown in Table 1, a response from each participant's selection on each image was collected as true positive, false positive, true negative, or false negative, depending on the location and presence of a python in each image.

Table 1

True/False Positive or True/ False Negative Condition Based on the Presence of a Python in an Image and Participant Response

Python Present	**Clicked on python**	**Clicked off python (TOP) or on Button (Bottom)**
Python Present	True Positive	False Negative
Python Not Present	False Positive	True Negative

Thirty images contained a python. For images containing a python, if the participant's selection was correctly located on the python's location, the observation was counted as a "True Positive." If the selection was on the wrong location on the image, the observation was counted as a "False Negative." If the selection was on the box labeled "I don't see a python in this image," the observation was recorded as a "False Negative."

Twenty-five images contained no python at all. For the images without a python, if the participant selected anywhere on the image except the "I don't see a python in this image" box,

DOI: https://doi.org/10.15394/jaaer.2023.1952

the observation was counted as a “False Positive.” If the participant selected the box labeled “I don’t see a python in this image,” the observation was counted as a “True Negative.”

A true positive rate (TPR) was depicted in Equation 1. These data showed the observation rate of correctly detecting a python when one was present in the image. The calculation was a function of true positive responses (*Tp*) by the total true positives (*Tp*) and false negative (*Fn*) responses. The sum of the TPR was compared by camera type, python orientation, and flying height to determine if these factors affected the rate of detecting the pythons by the survey participants under the respective condition.

$$\mathrm{TPR} = \frac{\mathrm{T}p}{\mathrm{T}p + \mathrm{F}n} \tag{1}$$

For the overall comparison between the NIR and RGB camera types, a likeliness ratio calculation was used. The likeliness ratio measured the relative risk of probability for selecting a python when the python was present in the image compared to the probability of not selecting a python when there was no python in the image. As depicted in Equation 2, the likelihood ratio is a ratio of the true positive rate over the false positive rate.

$$\text{Likelihood Ratio} = \frac{\dfrac{\mathrm{T}p}{\mathrm{T}p + \mathrm{F}n}}{\dfrac{\mathrm{T}n}{Fp + Tn}} \tag{2}$$

The likelihood ratio did not provide any information about the absolute risk of a detected python in an image, but rather the higher or lower likelihood of detecting a python when one was present compared to detecting a python when one was not present in the image.

Results

A true positive rate (TPR) comparison between the NIR and RGB cameras by flying height is depicted in Table 2. Differences were observed between heights. Although participants showed variability in detecting pythons by camera type, the participants had a higher accuracy detection rate at lower flying heights. The highest TPR rate occurred with the NIR camera for both the outstretched and coiled python at a rate of 100%, meaning every participant correctly detected a python in those images when one was present. When examined by individual flying height, the RGB camera consistently had lower TPR rates compared to the NIR camera. The lowest rate of accurately detecting a python from these survey responses was using the RGB camera at a flying height of 15 meters over an outstretched python, which was 59%.

Table 2

True Positive Rate by Flying Height, Camera Type, and Python Orientation

Flying Height	RGB- Outstretched	NIR - Outstretched	RGB - Coiled	NIR- Coiled
3 Meters	0.99	1.00	1.00	1.00
6 Meters	0.98	0.98	0.95	1.00
9 Meters	0.92	0.95	0.98	0.98
12 Meters	0.96	0.95	0.95	0.98
15 Meters	0.59	0.94	0.80	0.98

Note. Values are a percentage of accurately detecting a python when one was presented in an image.

A likelihood ratio was used to measure the percentage of correctly detecting a python when one was presented in an image. Not all the images shown to the participants contained a

DOI: https://doi.org/10.15394/jaaer.2023.1952

python. The likelihood ratio was determined as a ratio of the true positive rate, or the sensitivity of detecting a python when one is present in an image, over the rate of false positives made by participants in the survey. Participants were able to detect pythons (outstretched and coiled combined) from the NIR camera with greater likelihood ($M = 6.05$, $SD = 1.94$) than the RGB camera ($M = 4.74$, $SD = 1.32$), $t(10) = 1.77$, $p = .048$. The data suggests that survey participants correctly detected pythons in images containing the pythons at a 1.3x greater rate with the NIR camera than with the RGB camera.

Likelihood ratios were calculated from 101 participants, responding to 55 randomly presented images containing an outstretched python, coiled python, or image with no python at all. The results indicated that a UAS equipped with a NIR camera had a 1.3x greater accurate detection rate with both python orientations combined; however, there was variability in some of the python images and flying heights. The likelihood of detecting a python was increased with a UAS equipped with a NIR camera compared to a RGB camera, answering research question 1.

The largest difference between camera types was noted at the 15 meters flying height over an outstretched python; there was a 35% increase in detection accuracy using the NIR camera compared to the RGB camera. This conclusion answers research question 2. Although these data were collected from carcass pythons, there could be differences when using live specimens; however, the results suggest that a UAS equipped with an NIR camera flying between 3 and 15 meters in a nadir-oriented position of 90 degrees can be used to detect pythons. Therefore, using a UAS with an NIR camera over the levees searching for exposed pythons may help biologists responsible for managing this invasive species determine if a python is present.

The flying heights influenced the TPR rate of participants' ability to detect a python in an image accurately. Lower flying heights of 3 and 6 meters had much higher TPR rates than the further distances of 12 or 15 meters in this study. These results indicated that UAS with a flying height of 3 or 6 meters above the ground in a real-world situation could have a better chance of detecting a python compared to higher flying heights of 12 or 15 meters; however, the practicality and safety of flight must be considered when selecting the optimal height for each situation.

Conclusion and Recommendations

Based on the results of the survey responses, using a UAS equipped with a NIR camera had an increased likelihood of detecting a Burmese python over a UAS equipped with a RGB camera. The UAS equipped with a NIR camera was more capable of detecting a Burmese python than a RGB camera. Further research is needed to understand if a low-oblique or nadir-oriented camera angle in images captured from a UAS directly over the levee banks could have an influence on the detectability of pythons when compared to a high-oblique camera angle from an elevated camera position over a vehicle driving on the levee. Also, additional research is needed to better understand if NIR artificial lighting installed directly on a UAS equipped with a NIR camera could have any differences in detecting pythons during nighttime hours.

DOI: https://doi.org/10.15394/jaaer.2023.1952

References

Anderson, C. J., Heins, D., Pelletier, K. C., Bohnen, J. L., & Knight, J. F. (2021). Mapping invasive *Phragmites australis* using unoccupied aircraft system imagery, canopy height models, and synthetic aperture radar. *Remote Sensing, 13*(16). https://doi.org/10.3390/rs13163303

Barnas, A. F., Felege, C. J., Rockwell, R. F., & Ellis-Felege, S. N. (2018). A pilot(less) study on the use of an unmanned aircraft system for studying polar bears (*Ursus maritimus*). *Polar Biology, 41*(5), 1055-1062. https://doi.org/10.1007/s00300-018-2270-0

Campbell, E., Tam, C. K., & Soileau, S. C. (2019). *Invasive Species Research - Science for Detection, Containment, and Control, Fact Sheet 2018-3080*. U.S. Geological Survey. https://doi.org/10.3133/fs20183080

DJI (2022). Mavic 2 Enterprise Advanced Specifications. https://www.dji.com/mavic-2-enterprise-advanced/specs

Dorcas, M. E., Willson, J. D., Reed, R. N., Snow, R. W., Rochford, M. R., Miller, M. A., Meshaka, W. E., Jr., Andreadis, P. T., Mazzotti, F. J., Romagosa, C. M., & Hart, K. M. (2012). Severe mammal declines coincide with proliferation of invasive Burmese pythons in Everglades National Park. *PNAS: Proceedings of the National Academy of Sciences of the United States of America, 109*(7), 2418-2422. https://doi.org/10.1073/pnas.1115226109

Dove, C. J., Snow, R. W., Rochford, M. R., & Mazzotti, F. J. (2011). Birds consumed by the invasive Burmese python (*Python molurus bivittatus*) in Everglades National Park, Florida, USA. *The Wilson Journal of Ornithology, 123*(1), 126-131. https://doi.org/10.1676/10-092.1

Driggers, R., Furxhi, O., Vaca, G., Reumers, V., Vazimali, M., Short, R., Agrawal, P., Lambrechts, A., Charle, W., Vunckx, K., & Arvidson, C. (2019). Burmese python target reflectivity compared to natural Florida foliage background reflectivity. *Applied Optics*, *58*(13), D98-D104. https://doi.org/10.1364/AO.58.000D98

Frazier, I. (2019, July 1). The snakes that ate Florida. *Smithsonian Magazine*. https://www.smithsonianmag.com/science-nature/snakes-ate-florida-180972534/

Florida Fish and Wildlife Conservation Commission. (2021a). Burmese pythons in Florida. https://myfwc.com/wildlifehabitats/nonnatives/python/

Florida Fish and Wildlife Conservation Commission. (2021b). Burmese python (*Python molurus bivittatus*): Species Status. https://myfwc.com/wildlifehabitats/profiles/reptiles/snakes/burmese-python/

Hart, K. M., Cherkiss, M. S., Smith, B. J., Mazzotti, F. J., Fujisaki, I., Snow, R. W., & Dorcas, M. E. (2015). Home range, habitat use, and movement patterns of non-native Burmese pythons in Everglades National Park, Florida, USA. *Animal Biotelemetry*, *3*. https://doi.org/10.1186/s40317-015-0022-2

Hewitt, J., Furxhi, O., Renshaw, O. K., and Driggers, R. (2021). Detection of Burmese pythons in the near-infrared versus visible band. *Applied Optics, 60*(17), 5066-5073. https://doi.org/10.1364/AO.419320

Jankowski, J. (2021, August 4). 223 Burmese pythons removed from Everglades during July contest. *ClickOrlando.com*. https://www.clickorlando.com/news/local/2021/08/04/223-burmese-pythons-removed-from-everglades-during-july-contest/

Kolari Vision. (2021). Everything You Need to Know About Infrared Photography. https://kolarivision.com/articles/

Lisenbee, L. (2022, January 11). Planning a trip to Florida this winter? Be careful when you're outside. *Democrat & Chronicle*. https://www.democratandchronicle.com/story/news/2022/01/10/planning-trip-florida-winter-be-careful-when-you-are-outside/9136268002/

Morrison, M. (2018, October 26). Burmese python invasion in Florida a hidden legacy of Hurricane Andrew. *CBS News*. https://www.cbsnews.com/news/burmese-python-invasive-species-in-florida-hurricane-andrew-legacy-cbsn-originals/

Orzechowski, S. C. M., Romagosa, C. M., & Frederick, P. C. (2019). Invasive Burmese pythons (*Python bivittatus*) are novel nest predators in wading bird colonies of the Florida Everglades. *Biological Invasions, 21*, 2333-2344. https://doi.org/10.1007/s10530-019-01979-x

Reed, R. N., Willson, J. D., Rodda, G. H., & Dorcas, M. E. (2012). Ecological correlates of invasion impact for Burmese pythons in Florida. *Integrative Zoology, 7*(3), 254-270. https://doi.org/10.1111/j.1749-4877.2012.00304.x

Roaring Earth Staff. (2020, December 2). Giant Burmese python eats alligator. *Roaring Earth*. https://roaring.earth/python-eats-alligator/

Smith, B. J., Cherkiss, M. S., Hart, K. M., Rochford, M. R., Selby, T. H., Snow, R. W., & Mazzotti, F. J. (2016). Betrayal: Radio-tagged Burmese pythons reveal locations of conspecifics in Everglades National Park. *Biological Invasions*, *18*, 3239-3250. https://doi.org/10.1007/s10530-016-1211-5

Stahl, R. S., Engeman, R. M., Avery, M. L., & Mauldin, R. E. (2016). Weather constraints on Burmese python survival in the Florida Everglades, USA based on mechanistic bioenergetics estimates of core body temperature. *Cogent Biology, 2*(1). https://doi.org/10.1080/23312025.2016.1239599

VolAero UAV & Drones Holdings Inc. (2017, November 16). *VolAero drones fights Everglades' python invasion with thermal cameras* [Press release]. Cision PR Newswire. https://www.prnewswire.com/news-releases/volaero-drones-fights-everglades-python-invasion-with-thermal-cameras-300557781.html

Willson, J. D. (2017). Indirect effects of invasive Burmese pythons on ecosystems in southern Florida. *The Journal of Applied Ecology, 54*(4), 1251-1258. https://doi.org/10.1111/1365-2664.12844

Willson, J. D., Dorcas, M. E., & Snow, R. W. (2011). Identifying plausible scenarios for the establishment of invasive Burmese pythons (*Python molurus*) in southern Florida. *Biological Invasions, 13,* 1493-1504. https://doi.org/10.1007/s10530-010-9908-3

Zhou, H., Zhu, J., Li, J., Xu, Y., Li, Q., Yan, E., Zhao, S., Xiong, Y., & Mo, D. (2021). Opening a new era of investigating unreachable cliff flora using smart UAVs. *Remote Sensing in Ecology and Conservation, 7*(4), 638-648. https://doi.org/10.1002/rse2.214