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Spatial ecology and habitat preference of yellow-spotted monitors (Varanus panoptes) at Lizard Island National Park, QLD, Australia

Ryan Snyder
SIT Study Abroad

Spatial ecology and habitat preference of yellow-spotted monitors (*Varanus panoptes)* at Lizard Island National Park, QLD, Australia

By Ryan Snyder
Project Advisor: Zachary Amir, Ph.D student
School of Biological Sciences, University of Queensland
Lizard Island, QLD, Australia

Academic Director: Tony Cummings
Home Institution: Butler University
Majors: Biology and Environmental Studies

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SIT SCHOOL FOR INTERNATIONAL TRAINING
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ISP Ethics Review

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The ISP paper by _______Ryan Snyder _______________ (student) does/does not* conform to the Human Subjects Review approval from the Study Abroad Review Board (SARB), the ethical standards of the local community, and the ethical and academic standards outlined in the SIT student and faculty handbooks.

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Completed by: James Anthony Cummings

Academic Director:

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Abstract

Lizard Island National Park is an area of strong habitat diversity, especially given its small size. There are several distinct habitats represented, including open sclerophyll woodlands, mangrove swamps, dune grasslands, foothills elevations, and of course anthropogenically modified human habitats. The object of this study was to observe the abundances and behaviors of the yellow-spotted monitor lizard (*V. panoptes*) in each of these habitat settings to answer the question of which habitat type is preferred amongst *V. panoptes* in the landscape context of Lizard Island National Park.

Study transects were conducted over the course of one month measuring abundance of *V. panoptes*, size and behavioral trends of detected lizards, and risk assessment displayed by flight initiation distances. After abundance and behavioral data were collected, each habitat represented in the study was assessed using a structural vegetation proforma to see if habitat complexity influences *V. panoptes* spatial ecology. Results show that abundance was highest at the anthropogenically modified habitat at the Lizard Island Resort and the foothills habitats at Cooks Look Track. This supports previous findings that species of Varanids have adapted to human modified habitats but leaves room for speculation as to why the natural habitat at Cook's Look is just as abundant despite its seemingly average level of habitat complexity. The limitations of this study restricted my ability to explore the potential explanations experimentally, but prior knowledge that prey availability influences habitat preference in predators drives the conclusion that Cook's Look offers a habitat rich in available food sources which draws high numbers of large, fearless lizards compared to adjacent areas.

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Acknowledgements

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Introduction

Spatial ecology is never a concrete reality across habitable ecosystems for any species of plant or animal. Trends and correlations can be observed to generalize what patterns are likely to appear within a given habitat; however, in most species, abundance (and behavior) is dependent on a vast number of confounding variables where trends in one area may not be seen anywhere else (Blamires 2004). Lizard Island National Park has an environment unique to tropical island regions, and it undoubtedly plays a role in the ecology of its inhabitants. This study seeks to explore the spatial ecology of yellow-spotted goannas (*V. panoptes)* in the varying habitats across Lizard Island to see which ones are most preferrable, and how this may be similar or different compared to habitats in mainland Australia. Surveys on the main island to see how the ecology of the island is reflected in the abundance and behavior of the predatory varanids.

Though similar body morphology has led many to believe that different species of varanids are all generally unspecialized carnivores, further studies have identified key differences between several Varanus species in terms of habitat use and dietary habits, among other ecological trends (Shine 2006). Hence, as a sub-taxa of the family Varanidae, *V. panoptes* shows specialized diets and uses of habitats; these are similar to a few other species of large varanids but different from others among the 37 known species across the world. *V. panoptes* are mainly found in riparian habitats and feed on aquatic or coastal invertebrates, as well as some larger vertebrates. They have been found to be feeding on various species of arachnids, hexapods, crustaceans, scincids, colubrid snakes, Aves, other varanids, and the eggs of any of these animals (Shine 2006). They are also known to feed on agamids, acrochordus snakes, and small rodents, though the distribution of these species does not extend to Lizard Island National

Park. Species of *Varanus* that lives in different habitats experience differences in food availability, prey type, and microclimate. These correlate with differences food habits and behaviors, not to mention abundance (Shine 2006).

One thing that is common in ecosystems across the world – including on Lizard Island – are partially modified habitat due to human presence. In most cases (Lizard Island exhibits at least one exception), anthropogenic habitats attract a higher abundance of *V. panoptes* from adjacent natural habitats. One reason for this is because anthropogenic influences on habitats introduce the opportunity for resource subsidies (Jessop et al., 2012). Food production and its inevitable disposal into adjacent habitats increases the level of nutrients that are introduced to a food chain. The un-natural human addition of resources to surrounding habitats are considered human trophic subsidies, and they often offer native animals nutrition that differs from what they would naturally eat (Jessop et al. 2012). For many species of varanids, individuals found close to human activity tend to be larger than those in other areas, and they are less likely to be intimidated by the presence of people (Pettit et al., 2021). The larger morphology of most detections of *V. panoptes* indicate that most of these individuals are males (Pianka et al. 2004). This and other anthropogenic influences on natural ecosystems may impose numerous consequences, whether positive or negative, for species like *V. panoptes* in the long term. Larger, male lizards have an advantage in the modified habitat (Pettit et al., 2021). If large body size is a key factor in mating success, then males may develop into body sizes that are hardly sustainable given the energy available in natural ecosystems. Increased nutrients from human subsidies therefore helps against that disadvantage by providing the energy necessary for lizards to sustain larger body sizes more easily (Pettit et al., 2021).

As predators, *V. panoptes* are naturally attracted to habitats of high food availability; it is a strong ecological cue that the area makes for a good habitat. Higher food availability in human trophic subsidized areas creates a mirage for the benefactors of the subsidies. The resulting population would reflect larger, male lizards thanks to the greater protein availability; however, this could also mean negative effects on overall fitness including growth rates, fat stores, reproductive efforts and immunocompetence (Jessop et al., 2012). In many cases, modified habitats also lead to a higher risk of predation or mortality rates (Pettit et al 2021). For large predatory lizards like *V. panoptes*, a common risk is the invasion of cane toads which cause high mortality rates (Jolly et al. 2016). At Lizard Island National Park, however, the presence of cane toads is of no concern, nor is any other invasive species that may threaten them. The only added risk for *V. panoptes* that comes with anthropogenically modified habitats is from other member of the same species. Disproportionate sex ratios would lead to more competition between the males for mates. The ultimate result in this case is abnormal reproduction success for males and continuously skewed sex ratios (Robertson et al. 2006).

Regardless of any consequences, *V. panoptes* tend to strategically select their preferred habitats based on food availability. For example, from around September to November, *V. panoptes* is quite common around beach or dune habitats in mainland Australia (Blamires 2004). This is in response to the abundance of sea turtle nesting locations, from which *V. panoptes* will feed from the eggs (Lei et al. 2017). Habitat preference varies from location to location since different habitats have different prey availabilities at any given point during the year. That is why spatial ecology is often fluid for predators. Lizard Island is an example due to the general absence of terrestrial diurnal mammals which are a significant part of the diet for *V. panoptes* in the mainland (Pianka et al., 2004). At Lizard Island, *V. panoptes* relies on being soil engineers, which is what allows them to thrive in their preferred habitats anywhere. Foraging activity of soil engineers is naturally influenced by the availability of resources, and foraging location for *V. panoptes* is likewise dependent on diet, capacity to excavate soil, and habitat preference (Eldridge et al., 2023). *V. panoptes* at Lizard Island likely select their preferred habitats based on the abundance of prey that they can forage for on the island, which may explain why they exist in higher numbers one location over another. This is evident by the high concentration of burrows and foraging pits along Cook's Look Track, where the highest abundance of *V. panoptes* was recorded.

Positive predator-prey relationships are common across a range of ecosystems. For example, hierarchical co-abundance models have detected positive predator-prey trends in southeast Asian temperate ecosystems, implying that predation does not regulate the abundance of prey (Amir et al., 2022). The decline in prey abundance would cause a similar trend among their predators, and vice versa. As this model for predator-prey interactions can be applied across different species and ecosystems (Amir et al., 2022), it is also applicable to the relationship between *V. panoptes* and its prey at Lizard Island. Invertebrates are a significant part of the diet of *V. panoptes*, and this significance is compounded at a place such as Lizard Island because of the lack of mammals which they normally feed on elsewhere in mainland Australia (Shine, 2006). In a survey conducted on the island, numerous morphospecies of beetles (Coleoptera) were found in a variety of habitats, including some that were used as survey transects for this study (Mccormack & Cotoras, 2021). Three of the five most diverse species of Coleoptera found on Lizard Island (Carabidae, Curculionidae, and Scarabaeidae) are among the more popular species of beetles within the diet of *V. panoptes* (Shine, 2006). Species richness and biodiversity of Coleoptera reflects high forest complexity and vegetation diversity, as the two are correlated for several morphospecies (Mccormack & Cotoras 2021). Of the locations used to study beetles, three (Cook's Look Track, Research Road, and Blue Lagoon Track) were also used for this study of *V. panoptes* abundance. Surveys resulted in 56 different morphospecies of Coleoptera found along Research Road alone, a number far higher than any other location (Mccormack & Cotoras 2021). It follows that the habitat along Research Road is the most productive and complex on the island. It has the highest canopy and is diverse in vegetation and ground level nutrients. This is shown by the vegetation proforma conducted for the *V. panooptes* survey site. High activity from *V. panoptes* as soil engineers over the years may have played a part in the productivity of this habitat. Foraging pits and burrows benefit both the species and the habitat itself, as engineered structures such as foraging pits are known to trap litter, water, and sediment; this enhances the surrounding microbiome, improving the productivity of plant germinants and soil microbes (Eldridge et al., 2023).

However, regardless of its ecological richness, Research Road is not the area with the highest density of *V. panoptes* detections. This once again speak to the unpredictability of spatial patterns across habitats. While *V. panoptes* abundance remains high in the woodlands surrounding Research Road, there is some difference in habitat that exists which causes an even greater density of *V. panoptes* in forests such as Cook's Look that may not be on the same level of ecologically complexity.

As an extremely isolated cluster of islands, the environment of Lizard Island is favorable for *V. panoptes.* The absence of predators or toxic invasive species that threaten the large varanids allow the species to flourish as one of the top predators on the island. For that reason alone, V. *panoptes* abundance is perhaps far higher here than in other places in Australia (Amir, 2018). Further, as it lays within a protected UNESCO World Heritage site, the Australian government does all that it can to preserve the ecology of the island and to protect its native species. This study aims to assess the abundance and behavior of *V. panoptes* within the unique environment on Lizard Island. To take a deeper look into their spatial ecology, abundance surveys were conducted across different sites to see which habitats on the island attracted more lizards. Then, the habitats were assessed using a structural vegetation survey to compare flora richness which may point to why certain locations are more preferrable.

Methods and Materials

Location of Study

The study was carried out at Lizard Island National Park (14° 40'S 145° 28'E). The island sits among a stretch of the Great Barrier Reef off the coast of north Queensland, Australia, an area that is heavily protected by the Australian government. The island cluster is classified as a national park, meaning nothing can be hunted, taken, or introduced on the island unless authorized. The sea surrounding the island cluster is also protected by the Great Barrier Reef Marine Park Authority, which has declared the area a marine national park and a "no-take" zone to protect native wildlife ("State"). The population of the island is small, only about 280 people, most of whom are staff members at the Lizard Island Resort or the Research Station. Aside from the 5-star resort, world class research station, and the airstrip, the rest of the small main island is left in its natural state.

The landscape of the nature refuge on Lizard Island is diverse for its small size. Across the seven square kilometers, there are at least three distinct landscapes. The geology of the island comes from granite parent rock, which creates infertile soil that does not retain water well in the dry climate. Most of the interior of the island consists of grasslands and wooded slopes. 60 percent of the island is covered by grasslands (“State”). The woodlands that cover the island are open sclerophyll forests dominated by different species of acacia. Eucalypt and acacia woodlands grow in the northern parts of the island, but eucalypts are not as abundant on the southern side (“State”).

A few areas around Watson’s Bay, Crystal Beach, and Blue Lagoon (shown on map) are characterized by mangroves forests. These are most common in tidal areas and thrive in saltwater conditions. Paperbarks and pandanus are also common near Watson’s Bay, and swamps form among the mangroves and pandanus forests from accumulated rainwater (“State”).

The other distinct landscape type on Lizard Island are dune grasslands that extend to the rocky coasts and beaches. These habitats are characterized by dense grasses and shrubs that protect the dunes from wind erosion. The geology of the dunes is fine-grained granite sands that is quite infertile, supporting mainly acacias and *Thryptomene oligandra* which is also common in other landscapes (“State”). Figure 1 shows a map of the main Lizard Island cluster which significant landmarks pointed out, including the sites used as transects for this study of *V. panoptes*.

Study Sites

Study sites were selected to include each of the distinct landscapes represented on Lizard Island. This includes several transects at the resort and the research station to analyze results of anthropogenically modified habitats as well. Data was collected from April 10 - May 2, 2023, so that each transects had seven days’ worth of data. Transects varied slightly in length, but I surveyed roughly ten meters into the surrounding habitat on each side of the accessible path for a width of about 20m per transect.

Four transects represented anthropogenically modified habitats, although three of them (Casuarina Beach, Loomis, and Suntory transects) were ultimately combined to represent the research station as a whole. My access to the Lizard Island Resort was limited, so I was only able to use one short transect to collect data representing that area.

The first collection of data is from the research station to show abundance and behavior in an area of relatively high human activity. There were only every around 15-30 people active during the time of the study, but there was an above average amount of foot and vehicle traffic compared to the rest of the island.

1. Loomis Loop – The first transect at the research station was a 355m loop from the main building of the station past several of the housing bungalows that the researchers were living in. This is the most used path at the station, as researchers walk to and from their houses to get to the lab, office, library, or the beach. Encircled by the path is a small area of semi-forested and semi-grassland habitat.
2. Casuarina Beach – The second transect at the research station was roughly 770 meters, half of which was along the top edge of the beach searching for *V. panoptes* basking or burrowing directly next to the shore, and the other half was back towards the main building about 30 meters inland along a path used to tow boats in and out of the water. This transect covered a narrow strip of dune grasslands that doubles an anthropogenically modified habitat. Along the beach there is a grill and picnic tables used by people staying

at the station, which was a popular spot for *V. panoptes* especially after weekly barbecue nights every Saturday.

3. Suntory Transect – The final research station transect was about 530 meters in length and extended roughly 400 meters from the main building along the road to the resort before coming back and making a triangle-shaped loop by walking to the Kirby house, and finally back to the station past the Suntory house. This area was generally quieter since it was out of the way of the rest of the activity that happened at the station, except for a week during the study when a group of high school students stayed in Suntory and Kirby for a school trip.

After all the data was collected for each of these three transects, it was all compiled into one dataset. This includes the total area that was used to calculate the average density of individuals based on detections spanning all three locations.

One transect was conducted at the Lizard Island resort to increase the validity of results among anthropogenically modified habitats. The resort covers a far wider area than the research station, and far more people live there. There are typically around 80 staff members who live on site, and anywhere from 20 to 80 guests at a time. The facilities require a higher level of maintenance, so there is also a higher level of foot and vehicle traffic daily.

1. The lone resort transect was a 435-meter paved road from the western end of the airstrip towards the resort. As planes usually arrived 2-3 times per day, the road experiences vehicle traffic every day from staff members driving to pick up guests form the plan, and the grounds crew mowing the grass or doing any number of maintenance jobs. Short

grass extends about 10 meters from either side of the road before it reaches the forest fragment. The grass is mowed every week, but the transect is still used by *V. panoptes* quite often to bask in the sun.

Not far from the airstrip and resort is a network of hiking trails that leads through several of the different landscapes that tourists love to see when they come to stay on the island. Between four trails, one of each winds through areas of woodlands, dune grasslands, mangrove and pandanus swamps, and an elevated woodland habitat along the ridge of Cook's Look. Each of these represents natural habits relatively free from human influence, and each offers its own unique ecology that was used to analyze which is most preferrable for *V. panoptes.*

1. Research Road – The first trail used was a 1.66km segment of Research Road which goes from the edge of the Suntory transect to the far end of the airstrip and is surrounded by dense acacia woodlands on either side. The road is typically free from traffic, except on occasions when research station staff drives to the resort to pick up guests or supplies.
2. Pandanus Track – This next trail is roughly 1.37 km on the north side of the airstrip that spits out onto Watson's Beach at the base of Cook's Look Track. This trail begins to cut through more acacia and eucalypt woodland, but eventually leads to an area of thick pandanus and then mangrove swamp.
3. Cook's Look Track – This track is about two kilometers up and down, and *V. panoptes* were detected both ways. From the ridge to the peak is in the foothills elevation range (300-360m peak elevation) and there is a fairly continuous mixed eucalypt and acacia forest along the ridge where most detections were made.

4. Blue Lagoon Track – The final remote transect represented a dune grassland habitat, in contrast with Casuarina Beach because of the low level of human activity. This track is about 1 kilometer in length and includes the 400-meter track along the dunes as well as the width of the beach itself.

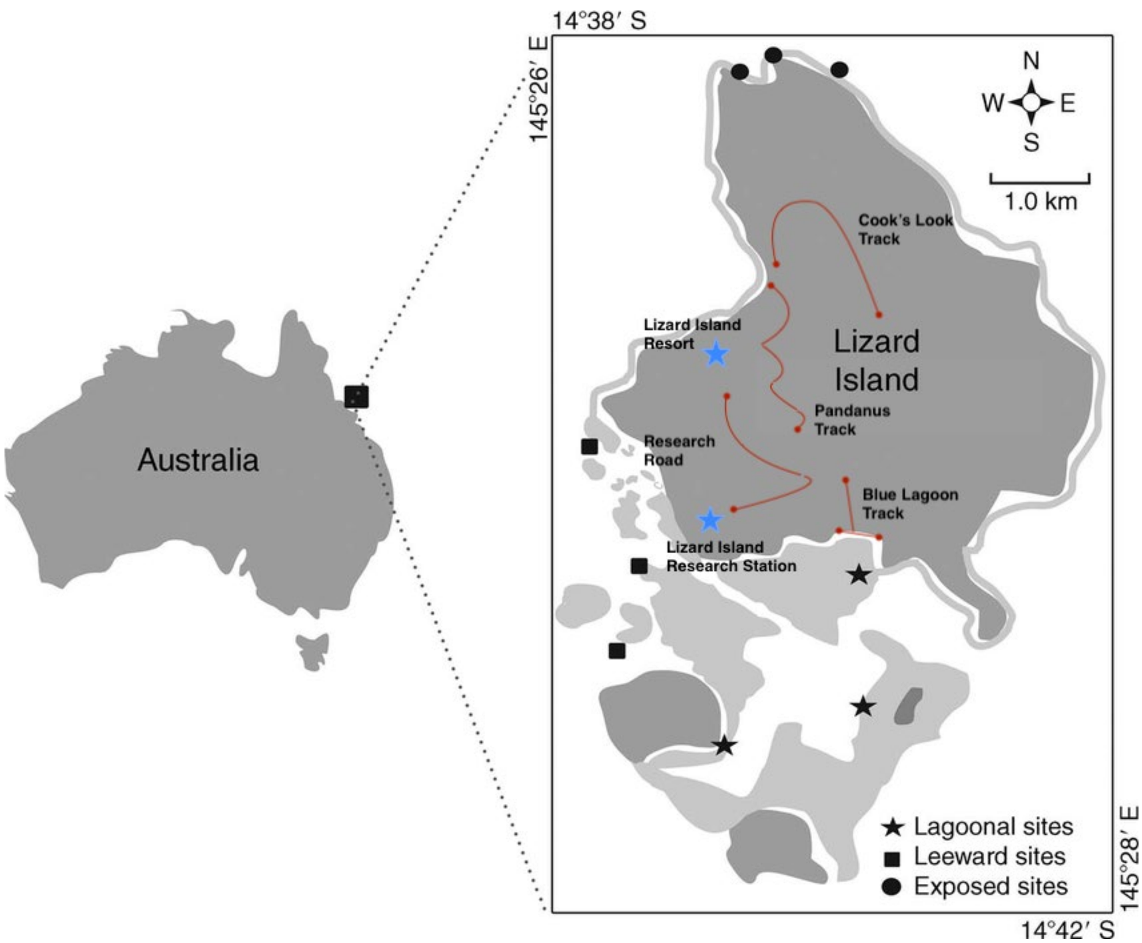

Figure 1. A map of Lizard Island National Park including several different geographical landscapes, and the study sites used to survey *V. panoptes.* Blue stars indicate the anthropogenically modified habitats, while red lines highlight the remote trails.

Methods for Measuring Abundance

Each of the eight transects were divided into nearby and remote categories. The three research station transects were the spots that were nearby, and the remaining five were considered remote. Since I had to travel everywhere by foot, I alternated days surveying nearby and remote transects. Given the weather cooperated, I would collect data one day at the research station, and the next I would spend the day walking the trails. Since each of the four transects at the research station and resort were shorter and more easily accessible, I conducted surveys at each of them three times per day. The first was between 8-9 am when *V. panoptes* tend to wake up and bask in the sun. The second trial for the day was between 11am and 1pm when they tend to be most active, and the last trial was between 4-5pm when the lizards begin to conclude daily activity (Amir, 2018). For remote transects, I only had time enough to walk each transect once per day. For these days, I carried out surveys between 9am and 2pm to observe *V. panoptes* when they are most active. With this schedule, I executed 21 trials for each of the shorter transects, and seven trials for the longer more remote transects.

While collecting data, I would search the footpath around me and about 10 meters into the surrounding habitat on either side of the path. Only detections where size and behavior were evident got recorded. Often times, I could quite obviously hear a *V. panoptes* rustling in the bush, but it was either too far away or too hidden to observe its appearance and behavior. For size, I sorted detections of *V. panoptes* into three size classes: adult, sub-adult, and juvenile. Sizes were estimated since this was only an observational study, but the three size classes were easily distinguishable. Adults very roughly 1.5 meters or longer, sub-adults were between 1.0 and 1.4 meters, and juveniles were 1.0 meters or shorter (Amir, 2018).

Methods for Measuring Behavior

Several points of behavior were recorded after a detection of *V. panoptes* was made. First, a way to analyze the level of habituation in *V. panoptes* in anthropogenically modified habits is by measuring flight initiation distances, or FID (Amir, 2018). This was done by using two alternating approaches to detected individuals. Using the first approach, I walked slowly towards the lizard, stopping when it began to flee. Then, I measured the distance between myself at the point where it was before it fled. The second approach mimicked more an interaction that humans would have with *V. panoptes.* I would approach tangentially, walking past the detection from at least three meters away. If the lizard fled, I measured the distance the same way as with the direct approach. Sometimes, however, the detected lizard did not flee at all, in which case I assigned it a flight initiation distance of 0 meters (Amir, 2018). I found that the easiest way to measure the distance between myself and the lizard was to walk off the approximate distance and calculate it based on the measurement of my feet.

The second point of behavior that I recorded for each detection was the activity that it was doing. The three behaviors that I could notice throughout the study were foraging, basking, and burrowing. The location where I found the *V. panoptes* played a role in determining what the behavior was. If it was detected in the middle of the path or just off the side of it, it was clear that the lizard was basking in the sun. if it was found crawling around the bush, it was considered to be foraging. And finally, it was clear when a lizard was digging into the ground that it was burrowing. *V. panoptes* that were found burrowing were much easier to measure since they were unable to detect any threat until they came up from digging in the hole.

Methods for Measuring Habitat Complexity

Once the abundance surveys were completed, I returned to each transect to complete a physionomic and structural proforma of the habitat. This habitat assessment was structured to determine differences in the geology or vegetation between the study sites which may indicate a higher level of forest complexity at one place or another. The main points used to determine forest complexity were soil description, canopy height and density, density of ground cover, understory feature and special life forms that were present (See Table 1). The abundance of certain landscape features was scored from 0-3, with 0 indicating non-existence and 3 indicating commonality throughout the transect. Then using land zone definitions provided on the Queensland government website, I assigned a land zone to each transect, and scored its complexity accordingly on a scale of 0-3 to compare each transect to each other.

Table 1. The structural proforma used to assess habitat complexity.

Structural Proforma	
Canopy Height	**Special Life Forms (0-3)**
Density of Main Canopy	*Acacia*
Closed	*Gum Trees*
Dense with a few breaks	*Paperbarks*
Mid-dense with many small breaks	*Small-stemmed vines*
Numerous Gaps	*Woody vines*
Open Canopy	*Terminalia*
Density of Ground Cover	*Fig trees*
Uniform and sparse	*Coconut palms*
Uniform and dense	*Thryptomene olligandra*
Sparse w/ occasional dense clumps	*Pandanus*
Dense w/ occasional open areas	*Mangroves*

Absent or nearly so	
Prominence of Different Vegetation Levels	**Rooting Features (0-3)**
One layer obvious	*Spreading surface roots*
Two layers obvious	*Stilt roots*
More than two layers which merge	
Uniformity of Main Stems	**Rainfall (mm)**
Mostly equal	**Soil (color, texture, etc.)**
Mostly unequal	
Understory Features (0-3)	
Grasses	
Shrubs	
Broadleaf plants	
Swamp	
Dunes	

Results

For Abundance

This study yielded high numbers of detections of *V. panoptes* across all transects. A total count of 143 detections were made while collecting data from April 10 to May 2. Every trial yielded an average of at least one detection, except for Blue Lagoon Track, which only recorded two detections over seven trials (See Table 2). Density of *V. panoptes* detections was calculated to negate the difference in the areas of transects. The densities indicate that the anthropogenically modified habitats at Lizard Island Research Station and Resort have higher populations of *V. panoptes* than in the more natural habitats, except for one outlier. Cook's Look Track was the transect with the highest number of total detection (44), and despite covering the largest area of habitat, it also had one of the highest density of detections per km^2 (157.3). There were 27 detections made at the resort, which is smaller compared to the 51 detections at the research station and 44 along Cook's Look Track; however, because the area of the resort transect was far smaller, the numbers reflect the highest density of individuals (158.7 per km^2). While this is the highest abundance of *V. panoptes* of all study sites, Blue Lagoon Track shows the lowest abundance. An average of 0.29 detections yields a density of only 13.8 detections per km^2 for that habitat.

Table 2. The data for total detections, average detections per trial, and density of V. panoptes at each study transect, including the areas and number of trials conducted per site.

Transect	Area (km^2)	Trials	Total Detections	Avg. Detections	Density (Avg. Detections/km^2)
Cook's Look	0.040	7	44	6.29	157.3
Pandanus Track	0.027	7	7	1.00	37.0
Research Road	0.033	7	10	1.43	43.3
Blue Lagoon Track	0.021	7	2	0.29	13.8
Research Station	0.033	21	51	2.43	73.6
Resort	0.0087	21	29	1.38	158.7

For Size Trends

The size trends of *V. panoptes* on Lizard Island are similar to that of population abundance. Detections at the sites with higher densities also show a higher percentage of larger lizards. On Cook's Look Track, 77.3 percent of detections (n=44) were adults, 22.7 percent were sub-adults, and no juveniles were detected. This is by far the widest disparity between adults, sub-adults, and juveniles of all study sites (Figure 2). The research station (n=51) and resort (n=29) had the next highest percentages of adults detected, at 49.0 percent and 48.3 percent respectively. The remaining remote transects showed an equal or higher percentage of sub-adults and juveniles compared to adults. At Blue Lagoon Track, the only two detections were split between one sub-adult and one juvenile; no adults were recorded. Only a few adults were detected at Research Road and Pandanus Track. Most of *V. panoptes* there were sub-adults.

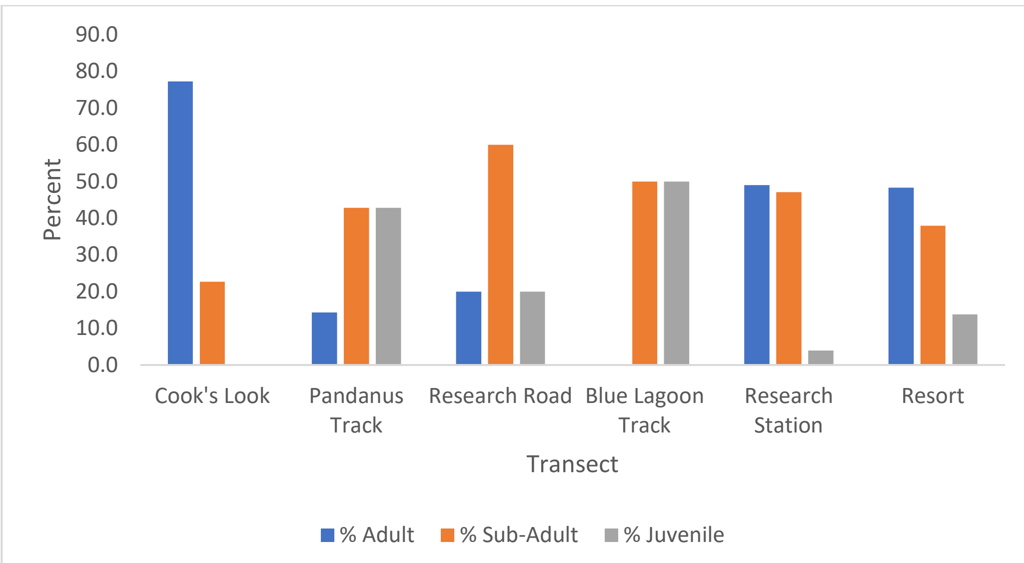

***Figure 2*. Size percentages of V. panoptes per transect**. Detections were classified as adults, sub-adults, or juveniles. Percentages of each size class out of the total number of detections for each study transect are shown above.

For Behavior

Risk assessment in *V. panoptes* did not seem to show a significant amount of difference across habitats. Average flight initiation distances were generally similar throughout the duration of this study. For anthropogenically modified habitats, the research station shows an average FID of 2.86 meters. This is the lowest of all transects, but the resort had the highest average FID of 4.86 meters (Figure 3.1). The remote transects all displayed average FIDs between 3.05 meters and 4.05 meters, and all transects had average FIDs that were within 2.0 meters of each other. For 62 detections, the tangential approach was used to measure FID leaving 81 where the direct approach was used. Differences in average FID between the two approaches is also not very significant in most places. The average FID from tangential approaches at the research station (1.82, n=23) is lower than that of direct approaches (3.75, n=28), but this trend is not particularly evident anywhere else. The other transect each showed similar averages, or the average for direct approaches was larger than for tangential approaches (Figure 3.2). There did not seem to be a consistent pattern for FID in *V. panoptes* detections.

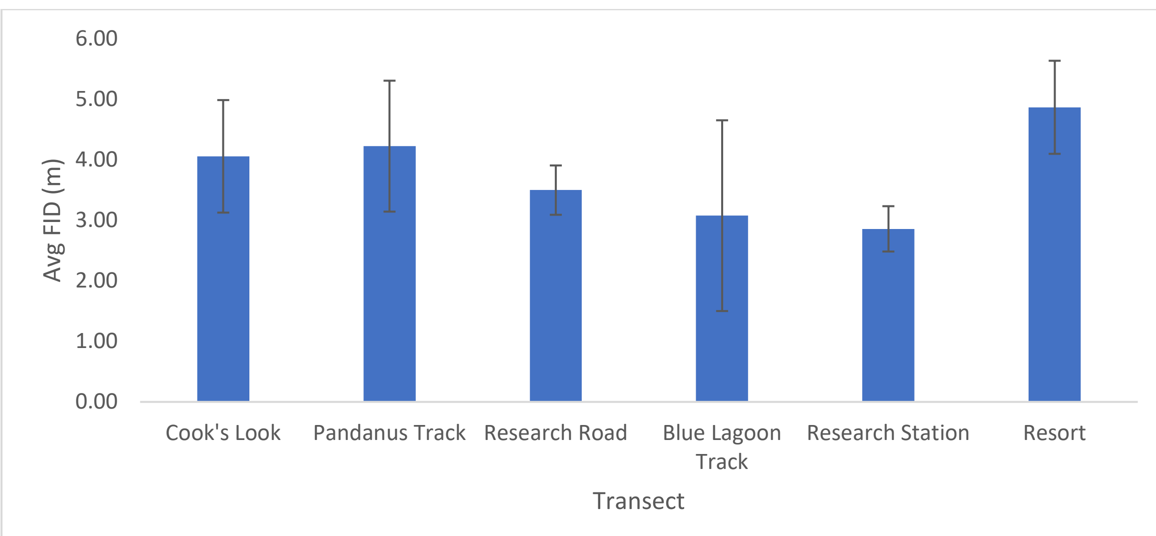

Figure 3.1. **Average FID of V. paonptes detections per transect.** Averages were calculated for the FID of individual detections at each transect, with error bars indicating standard error.

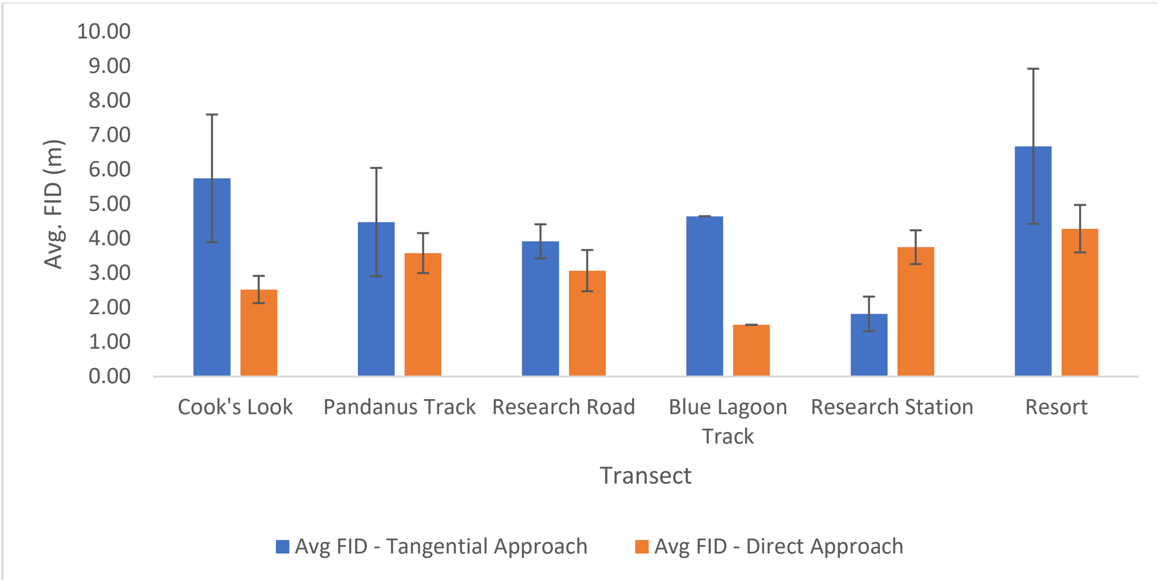

Figure 3.2. **Average FID per approach style at each transect.** Averages were further calculated for each of the two approach methods (Tangential and direct) at each transect. Error bars indicate stand error.

Behavior of *V. panoptes* was largely dependent on the time of day they were observed. Most of the time, lizards were spotted either basking (n=77) or foraging (n=54). The remainder of detections were found burrowing (n=12) Generally, *V. panoptes* were more likely to be found basking at the anthropogenically modified sites, while numbers were more evenly distributed between foraging and basking at remote transects (Figure 4.1). To analyze changes in behavior throughout the day, the transects at the research station and resort were split up into the three times of day that data was collected. At both sites, there was a wide margin in the mornings and evenings between the percentage individuals basking versus foraging or burrowing. However, during the middle of the day between 11am and 1pm, there was a higher percentage of detections foraging compared to other times of the day (Figure 4.2).

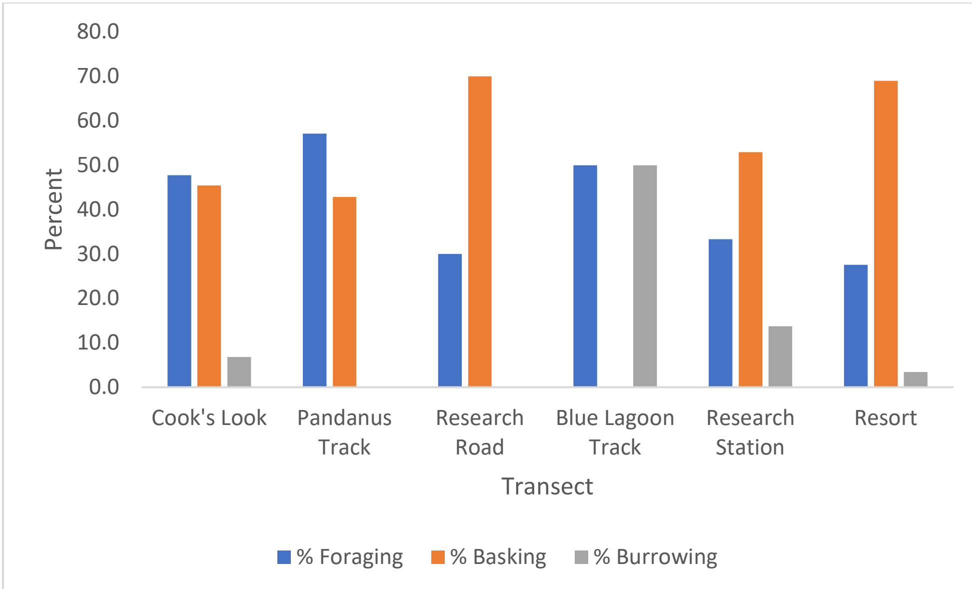

Figure 4.1. **Behavior of V. panoptes per transect.** The percentage of detected individuals was calculated for either of three main actions which were observed over the course of the study – foraging, basking, or burrowing.

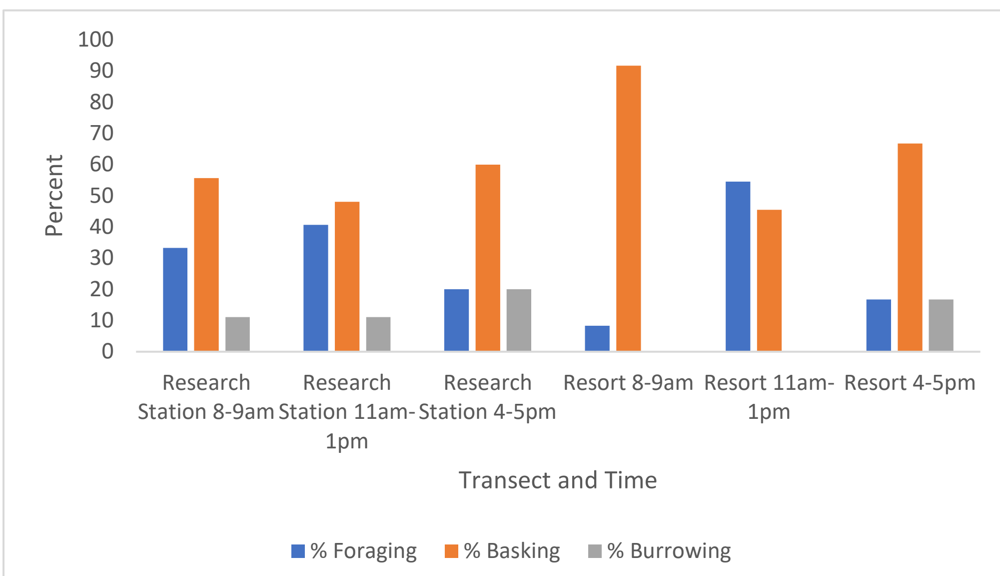

Figure 4.2. **Behavior of V. panoptes at anthropogenically modified habitats at each time of day.** Trials were conducted three times of the day at the research station and resort. Percentages were calculated for each time of day to determine changes in behavior over the course of a day.

For Habitat Assessment

In many facets of the habitat assessment that was used to determine complexity, each study site shared commonalities. For being on such a small island, the fundamental geographic details are in many cases the same. The geology of the island is granite, though some areas showed higher or lower levels of coherence and water-retention. Blue Lagoon Track and the Casuarina Beach transect at the research station both had extremely sandy soil that is characteristic of dune grasslands. On the other hand, Pandanus Track had soil that was more coherent and mud-like where the landscape turned into mangrove swamps. The remaining woodland study sites contained soil that was somewhere in between, a dark-ish brown that was quite crumbly and incoherent. Each habitat (or pair of habitats for the research station and resort) had at least one unique feature from all the rest. The resort and research station represented the anthropogenically modified habitat which made them unique. Cook's Look Track had a higher elevation and a sparse ground level compared to the other sites. Blue Lagoon Track was unique for its thick grass/shrub layer and sandy geology. Pandanus Track displays a section of pandanus and mangrove swampland, and Research Road indicated the highest level of complexity based on its canopy height, density of understory, and abundance of special life forms. Beyond these individual differences, each transect had large amounts of acacias and eucalypts, grasses, and shrubs at ground level, and at least two prominent vegetation levels. Appendix B lists the land zone definitions given by the government of Queensland. Of these defined land zones, Loomis, Casuarina Beach, and Blue Lagoon Tracks fit under the type 2 definition of "Coastal dunes." The complexity scoring for those three from 0-3 relative to each of the other transects are 2, 1, and 1, respectively. Next, the Research Road, resort, and Suntory transect fit under the land zone type 5 definition of "Old loamy and sandy plains." This is because the soil was more coherent at these places, and it was able to support taller forests with denser understories and canopies. The complexity scoring for these transects were 3, 2, and 3 respectively. Pandanus Track fits the description of "Tidal flats and beaches," especially because of the muddy soil and swampland; the complexity scoring here was 1, as *V. panoptes* seemed to avoid the swamps. Finally, Cook's Look Track is land zone 12, "Hills and lowlands on granitic rocks." This is due to the steeper slopes while still being of granite origin. The canopy and vegetation showed a level of complexity, so the complexity score here was 2 (See Appendix A for full evaluation).

Discussion

For Abundance and Habitat Preference

The abundances of *V. panoptes* detections reflects a preference of certain habitats over others at Lizard Island. Excluding Cook's Look Tack as an outlier, the densities support previous findings that species of Varanid lizards including *V. panoptes* have habituated to anthropogenically modified habitats and tend to be more abundant in these areas over others (Amir, 2018). This could be for several reasons, perhaps most likely being the fact that human trophic subsidies draw them in from other habitats (Pettit et al., 2021). The resort has a fairly high amount of people walking or driving from place to place, and there is also a significant amount of food that is handled between the bars, restaurants, and houses. The surplus of food received either directly from resort guests who feed the lizards or indirectly by foraging through any food waste has built a habitat where large adult male lizards are common. Skewed sex ratios at these human subsidized sites are driven by the competition for local resources, and further mating competition ensues as a result (Clark, 1978). Some of the largest detections over the course of this study were found either at the resort or the research station. The research station, though it is an anthropogenically modified habitat, had a lower density by over 50 percent. This may be because of the smaller population of people at the station compared to the resort. Food waste at the research station is also handled meticulously. Organic compost is dumped into closed off composting pits in the ground, and the people are conscious about throwing trash on the ground or feeding the native wildlife. Food scraps are occasionally left on the beach by the grill following barbecue nights; aside from that, *V. panoptes* receives minimal human trophic subsidies at the research station though it is still more than they would in a purely natural habitat.

The data of the four unmodified habitats indicate which habitats *V. panoptes* prefer over others. The dune grasslands of Blue Lagoon were clearly undesirable during this time of year. The vegetation and soil of the dune reflect an unproductive landscape. However, habitat preferences are known to change seasonally. The Varanid species at Fog Bay is abundant in dune habitat because of the availability of prey from September to November when sea turtles make their nests (Blamires, 2004). Since this study was done outside of that time range, seasonal abundance may shift if sea turtles around Lizard Island follow the same reproduction schedule. Research Road has one of the more complex structural habitats of the island, as suggested by the landscape survey and previous the previous surveys of beetle diversity on the island (Mccormack and Cotoras). As such, it shows a strong abundance of *V. panoptes* for lacking human food subsidies, though it is not the highest among natural habitats. The habitat preference for lizards living far from human activity seems to be the higher elevation of Cook's Look Track. Though it is not the most structurally complex habitat, there is some variable which draws a high density of *V. panoptes* to the area. This anomaly is discussed in depth in a later section.

For Behavior

V. panoptes are highly active animals. They have typical daily routine between resting and actively searching for food, as do most known species of Varanids (Christian and Weavers, 1994). As thermoregulators, they spend time in the morning basking in the sun and warming themselves up before they become active for the day (King, 1980). This explains the results showing a higher number of detections seen basking from 8-9am compared to other times during the day, and why foraging is higher during the middle of the day when they are most active. Each study site, regardless of habitat, provides an important resource for *V. panoptes* to carry out this daily activity. The footpaths or roads were an extremely popular spot for lizards to sit and warm themselves at any point in the day. Many times, I would not even have to look into the surrounding bush to find one. If I was not paying attention in between periods of data collection, it was easy to get startled simply by walking along the path and nearly stepping on an individual before it darted off into the woods. *V. panoptes* are surprisingly good at camouflaging despite their large size. I relied heavily on my hearing, as I often heard them rustling before I could see them with my eyes. If they are sitting in the bush, foraging, or burrowing before being approached, the initial reaction was commonly to stop and remain still, assuming they blended in well enough to not be seen. They would typically not run off until I got close enough to where it became obvious that I could see it, although this was not guaranteed behavior. If I used the tangential approach to measure FID, the detected lizard would sometimes feel comfortable enough to not flee at all and remain still until I had passed. Even using the direct approach, the larger *V. panoptes* tended to flee at first, but only a few meters out of the way before stopping; Or it would continue walking away slowly to keep a certain distance between us. That boldness is characteristic of lizards within the context of Lizard Island, which is likely why FID was less significant there versus other locations. In terms of terrestrial animals, lizards make up the vast majority on the island. Outside of lizards, snakes, and other reptiles, there are only a few species of nocturnal mammals ("State"). *V. panoptes* is the top predator, and there are no animals like cane toads that can consistently threaten their population. That is why *V. panoptes* numbers flourish on the island, and why they are generally unbothered by humans or other environmental factors.

Cook's Look Outlier

The habitat at Cook's Look Track stands out as an outlier in this study, with just about the same density of *V. panoptes* per square kilometer (157.3) as the resort which represents the highest of all (158.7). Despite the remoteness of the transect and the lack of consistent human activity, there were 44 detections over seven trials. There is a clear reason why *V. panoptes* would prefer the anthropogenically modified habitats, but the reason for Cook's Look Track being on the same level of density is less obvious. With the limitations of time and resources for this purely observational study, it is largely up to speculation why that area is much more preferred. As far as natural habitats go, Cook's Look Track is about as close to human modified as you can get on the island. Cook's Look is one of the top attractions as things to do for guests, so the trail gets more traffic than do the others. This may mean that some (although very few) food subsidies could become available from hikers along the trail. Other possibilities are that there is some other factor in the woodlands makes it more desirable. Perhaps the higher elevation creates a milder climate that is more suitable for *V. panoptes* thermoregulation. When assessing the vegetation of this transect, it was noted that the understory and ground level were more open than the other remote trails. There was more room to forage around on the ground, and space to bask in the sun. The many breaks in the canopy also lets in ample amount of light that reaches the ground. A strong assumption for the high habitat preference at Cook's Look, however, is the paralleled abundance of prey in that area. *V. panoptes* tend to inhabit areas based on prey availability (Jessop et al., 2012). Furthermore, studies show that a high population of predators in an area does not drive down the population of their prey; in fact, it does the opposite (Amir et al., 2022). The correlation is positive, meaning the increase of predators implies the increase of prey as well. Since there is a high density of *V. panoptes* at Cook's Look, the density of its prey must be proportionally high. As seen in the sea turtle nesting example at Fog Bay, this could be a fluid trend that changes before too long (Blamires 2004). If the population of insects, birds, reptiles, or anything else that *V. panoptes* consistently relies on along the ridge decreases, it is likely that many of the lizards would migrate to a new spot. However, the isolation of being at an altitude and the ideal conditions that exist seem as though they would dissuade lizards from making the difficult trek down steep, rocky terrain to get to another habitat. The risk of leaving probably outweighs the benefit of changing habitats, if there is any benefit at all.

Conclusion

This study sought to explore the spatial ecology of *V. panoptes* on Lizard Island and determine which habitat is most preferrable among landscapes that are unique to small coastal islands off the coast of the Cape York Peninsula. The partial aims were to replicate a past study of lace monitors (*Varanus varius*) on Fraser Island, QLD, which found that goannas are habituated to anthropogenically modified habitats with high human activity (Amir, 2018). Here, the same question was pursued, with an extension to further habitats conveniently present on the island; this included elevated woodlands, dune grasslands, mangrove swamps and sclerophyll forests at sea level. Results show that once again, Varanid lizards tend to prefer ecosystems with added human resource subsidies over alternative naturally subsidized habitats. This was seen in the densities of *V. panoptes* at the Lizard Island research station and resort compared to all other remote trails, except for the transect at Cook's Look Track which was an outlier among the other natural habitats. It is more obvious why *V. panoptes* might prefer human subsidized areas, since they would have an opportunity to have easy availability of food which is so important to the way they choose habitats. While it is less understood why Cook's Look would have an equally high density, the odds are that it once again has something to do with food availability or habitat structure which produces ideal conditions for the species to thrive.

This experiment was considerably limited in terms of what could be observed. Improvements for further study, if possible, would be to look more deeply into the habitat at Cook's Look to determine the likely factor which makes it more desirable. There are so many possibilities that can be explored, and it would take a great amount of time and resources to test each one to and make a more confident conclusion. If this can be done, however, it would be significant towards any conservation effort for *V. panoptes.* Overall, the productivity of *V. panoptes* in the context of Lizard Island can already be used towards conservation of the species if need be. Yellow-spotted monitors are extremely abundant across the island, and they live unthreatened. Conservation agencies need only look to Lizard Island to see a model for habitat preference and ecological productivity of *V. panoptes.*

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Appendix A. Completed structural proforma assessing habitat complexity at each site. The final row shows the land zone type that defines each habitat and the relative complexity scoring for the case of this study.

Structural Proforma	**Loomis**	**Suntory**	**Casuarina Beach**	**Resort**	**Research Rd**	**Pandanus**	**Blue Lagoon**	**Cook's Look**
Canopy Height	8m	10-12m	5-6m	8m	12m	8m	5m	10m
Density of Main Canopy - Closed - Dense with few breaks - Mid-dense, many small breaks - Numerous gaps - Open	Numerous gaps	Mid-dense, many small breaks	Absent or nearly so	Dense with a few breaks	Dense with a few breaks	Dense with a few breaks	Absent or nearly so	Numerous gaps
Density of Ground Cover - Uniform and sparse - Uniform and dense - Sparse w/ occasional dense clumps - Dense w/ occasional open areas - Absent or nearly so	Dense with occasional open areas	Dense with occasional open areas	Dense with occasional open areas	Dense with occasional open areas	Dense with occasional open areas	Sparse with ocassional dense clumps	Uniform and dense	Sparse with ocassional dense clumps

Prominence of Different Vegetation levels - One layer obvious - Two layers obvious - More than two layers which merge	More than two layers which merge	More than two layers which merge	Two layers apparent	More than two layers which merge	More than two layers which merge	More than two layers which merge	Two layers apparent	More than two layers which merge
Uniformity of Main Stems - Mostly equal - Mostly unequal	Mostly equal	Mostly equal	Mostly equal	Mostly equal	Mostly equal	Mostly equal	Mostly equal	Mostly equal
Understory Features (0-3)								
Grasses	3	3	3	3	3	3	3	3
Shrubs	3	3	3	3	3	3	3	3
Broadleaf plants	3	3	2	2	3	3	3	3
Swamp	0	0	0	0	0	2	0	0
Dunes	1	0	2	0	0	0	0	0
Special Life Forms (0-3)								
Acacia	3	3	1	3	3	3	3	3
Gum trees	0	1	0	2	3	2	0	3
Paperbarks	0	0	0	2	1	2	0	3
Small-stemmed vines	1	2	1	2	3	2	0	2
Woody vines	0	0	0	0	0	0	0	0

Terminalia	3	3	3	2	2	2	1	1
Fig trees	0	1	0	0	2	1	1	1
Coconut palms	0	0	0	0	0	0	1	0
Thryptomene oligandra	1	1	0	1	3	1	3	3
Pandanus	0	0	0	0	0	3	0	0
Mangroves	0	0	0	0	0	3	0	0
Rooting Features (0-3)								
Spreading surface roots	1	2	1	1	1	3	3	2
Stilted roots	0	0	0	0	0	3	0	0
Rainfall (mm)	1784 mm	1784 mm	1784 mm	1784 mm	1784 mm	1784 mm	1784 mm	1784 mm
Soil description	Light brown, sandy but darker than pure sand. No ribbon	Slightly coherent, <1mm ribbon, light brown color	Incoherent, rocky and sandy, white/brown color, no ribbon	Slightly coherent, no real ribbon, darker brown	Slightly coherent, <5mm ribbon, light brown color	Damp, retains a bit of water, light brown, abt. 1mm ribbon	Gravel and granite sand, incoherent, white colored, no ribbon	Slightly coherent, no real ribbon, darker brown
Land Zone Definition (Complexity Score)	Land Zone 2 (2)	Land Zone 5 (3)	Land Zone 2 (1)	Land Zone 5 (2)	Land Zone 5 (3)	Land Zone 1 (1)	Land Zone 2 (0)	Land Zone 12 (2)

Appendix B. Land zone types of the Cape York Peninsula Bioregion and their definitions, as provided by the Queensland government at https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/descriptions/land-zones

Land Zone 1 *Tidal flats and beaches*	Quaternary estuarine and marine deposits subject to periodic inundation by marine waters. Includes mangroves, saltpans, off-shore tidal flats and tidal beaches. Soils are predominantly Hydrosols (saline muds, clays and sands) or beach sand.
Land Zone 2 *Coastal dunes*	Quaternary coastal dunes and beach ridges. Includes degraded dunes, sand plains and swales, lakes and swamps enclosed by dunes, as well as coral and sand cays. Soils are predominantly Rudosols and Tenosols (siliceous or calcareous sands), Podosols and Organosols.
Land Zone 3 *Alluvial river and creek flats*	Recent Quaternary alluvial systems, including closed depressions, paleo-estuarine deposits currently under freshwater influence, inland lakes and associated wave built lunettes. Excludes colluvial deposits such as talus slopes and pediments. Includes a diverse range of soils, predominantly Vertosols and Sodosols; also with Dermosols, Kurosols, Chromosols, Kandosols, Tenosols, Rudosols and Hydrosols; and Organosols in high rainfall areas.
Land Zone 4 *Clay plains*	Tertiary-early Quaternary clay deposits, usually forming level to gently undulating plains not related to recent Quaternary alluvial systems. Excludes clay plains formed *in-situ* on bedrock. Mainly Vertosols with gilgai microrelief, but includes thin sandy or loamy surfaced Sodosols and Chromosols with the same paleo-clay subsoil deposits.
Land Zone 5 *Old loamy and sandy plains*	Tertiary-early Quaternary extensive, uniform near level or gently undulating plains with sandy or loamy soils. Includes dissected remnants of these surfaces. Also includes plains with sandy or loamy soils of uncertain origin, and plateau remnants with moderate to deep soils usually overlying duricrust. Excludes recent Quaternary alluvial systems (land zone 3), exposed duricrust (land zone 7), and soils derived from underlying bedrock (land zones 8 to 12). Soils are usually Tenosols and Kandosols, also minor deep sandy surfaced Sodosols and Chromosols. There may be a duricrust at depth.
Land Zone 6 *Inland dunefields*	Quaternary inland dunefields, interdune areas, degraded dunefields, and associated aeolian sandplains. Excludes recent Quaternary alluvial systems, which may traverse this zone, and intermittent lakes and claypans (land zone 3). Soils are predominantly Rudosols and Tenosols, some Kandosols and minor Calcarosols.
Land Zone 7 *Ironstone jump-ups*	Cainozoic duricrusts formed on a variety of rock types, usually forming mesas or scarps. Includes exposed ferruginous, siliceous or mottled horizons and associated talus and colluvium, and remnants of these features, for example low stony rises on downs. Soils are usually shallow Rudosols and Tenosols, with minor Sodosols and Chromosols on associated pediments, and shallow Kandosols on plateau margins and larger mesas.

Land Zone 8 *Basalt plains and hills*	Cainozoic igneous rocks, predominantly flood basalts forming extensive plains and occasional low scarps. Also includes hills, cones and plugs on trachytes and rhyolites, and associated interbedded sediments, and talus. Excludes deep soils overlying duricrust (land zone 5). Soils include Vertosols, Ferrosols, and shallow Dermosols.
Land Zone 9 *Undulating country on fine grained sedimentary rocks*	Fine grained sedimentary rocks, generally with little or no deformation and usually forming undulating landscapes. Siltstones, mudstones, shales, calcareous sediments, and labile sandstones are typical rock types although minor interbedded volcanics may occur. Includes a diverse range of fine textured soils of moderate to high fertility, predominantly Vertosols, Sodosols, and Chromosols.
Land Zone 10 *Sandstone ranges*	Medium to coarse grained sedimentary rocks, with little or no deformation, forming plateaus, benches and scarps. Includes siliceous (quartzose) sandstones, conglomerates and minor interbedded volcanics, and springs associated with these rocks. Excludes overlying Cainozoic sand deposits (land zone 5). Soils are predominantly shallow Rudosols and Tenosols of low fertility, but include sandy surfaced Kandosols, Kurosols, Sodosols and Chromosols.
Land Zone 11 *Hills and lowlands on metamorphic rocks*	Metamorphosed rocks, forming ranges, hills and lowlands. Primarily lower Permian and older sedimentary formations which are generally moderately to strongly deformed. Includes low- to high-grade and contact metamorphics such as phyllites, slates, gneisses of indeterminate origin and serpentinite, and interbedded volcanics. Soils are mainly shallow, gravelly Rudosols and Tenosols, with Sodosols and Chromosols on lower slopes and gently undulating areas. Soils are typically of low to moderate fertility.
Land Zone 12 *Hills and lowlands on metamorphic rocks*	Mesozoic to Proterozoic igneous rocks, forming ranges, hills and lowlands. Acid, intermediate and basic intrusive and volcanic rocks such as granites, granodiorites, gabbros, dolerites, andesites and rhyolites, as well as minor areas of associated interbedded sediments. Excludes serpentinites (land zone 11) and younger igneous rocks (land zone 8). Soils are mainly Tenosols on steeper slopes with Chromosols and Sodosols on lower slopes and gently undulating areas. Soils are typically of low to moderate fertility.

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Ryan Snyder May 12, 2023

Student Signature Date

Academic Director has reviewed student reason(s) for withdrawing permission to use and agrees it does not violate the SIT Study Abroad Policy on Ethics.

James Anthony Cummings May 12, 2023

Academic Director Signature Date

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