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Relative Abundance and Risk Assessment of Lace Monitors (*Varanus varius*) on Fraser Island, Queensland: Are Monitors Habituated to Human Presence?

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Abstract - As the human population continues to increase throughout the world, more land is being converted into urban environments. This imposes significant pressures on wildlife living in modified landscapes, where some will be able to survive, and others will not. In order to determine whether the lace monitor (*Varanus varius*) can live in human modified landscapes, *V. varius* were observed in several natural and modified habitats on Fraser Island. Relative abundances and risk assessment were measured in areas of high and low human densities. Direct and tangential approaches were used to record flight initiation distances and investigate risk perception of the monitors. *Varanus varius* were observed more frequently in campsites where people were present than in natural habitat, but only up to a certain level of development. Monitors also perceived people as less of a threat inside campsites than in natural habitats where human presence was much lower. The direction of approach by the observer also led to different levels of risk assessment, with a direct approach perceived as more threatening. *Varanus varius* on Frasier Island seem to be able to thrive around the edges of human development, as long as some natural habitat is available, and are therefore classified as urban adapters.

Introduction

Anthropogenic activity is rapidly changing natural landscapes. One of the most important and rapidly occurring changes to landscapes is urbanization, where land is modified to create suitable environments for people to live in (Miller & Hobbs, 2002). This change in land use can have direct impacts on the organisms that live in and around affected areas. Some organisms, such as pigeons (*Columbia livia*) and brown rats (*Rattus norvegicus*) are able to thrive in city centers lacking natural habitats, and are known as urban exploiters (McKinney, 2006). Others, such as many of the large mammal and predatory bird species, cannot live near urban environments, and are known as urban avoiders. Urban exploiters become dependent upon urban resources, while urban avoiders are extremely sensitive to change and disappear quickly (McKinney, 2006).

Understanding which species will be able to survive urbanization has important conservation implications. A third category of organisms that are able to adapt and survive in human-altered landscapes are known as urban adapters. These species occur where elements of natural landscapes are still intact and where they can continue to use natural resources, but are also able to make use of anthropogenic food and shelter (McKinney, 2006). This category includes opportunistic mesopredators such as red foxes (*Vulpes vulpes*), coyotes (*Canis latrans*), and raccoons (*Procyon lotor*) that are able to thrive in and around urban environments, and sometimes achieve greater abundances than in natural landscapes (Bateman & Fleming, 2012).

Monitor lizards (*Varanus spp*.) are common native predators in Australia, and depending on the presence of larger predators such as the dingo (*Canis lupis dingo*), they can fill either the role of apex predator or mesopredator (Sutherland *et al*., 2011). The lace monitor (*V. varius*) is the second largest monitor lizard in Australia, and is distributed along much of the east coast (Shine, 1986), which also supports the highest human population

density in the country. Therefore, it is inevitable that *V. varius* will come into contact with humans in modified landscapes throughout its range, where they may or may not be able to adapt to urbanization.

Varanus varius has a very broad and opportunistic diet, including arthropods, mammals, birds (including their eggs), and other reptiles (Guarino, 2001). It also commonly seeks out carrion, and has also been known to consume human garbage (Weavers, 1989). A previous study on another species of monitor lizard found that *V. salvator* occurred in significantly greater abundances around areas of human presence on Tinjil Island, Indonesia than in natural, un-modified landscapes. Although here human presence was only in the form of small campsites, *V. salvator* were attracted to human food refuse (Uyeda, 2009).

The introduction of a trophic subsidy to a landscape has the potential to alter the population dynamics of a species in an environment by adding non-natural resources. Jessop *et al.* (2012) studied the effects of human trophic subsidies in the form of human food refuse on population dynamics and morphological traits of *V. varius* in southeastern Australia and found that the overall abundance of *V. varius* was much higher around human food refuse sites than natural landscapes. Additionally, Jessop *et al.* (2012) found that *V. varius* reached much larger sizes in these altered environments, and that the population was male-biased. Although this study was not conducted near a large urban area, it does indicate that monitors are able to take advantage of human-mediated resources in the environment, which enables them to survive on the fringes of human settlement, and that this behavior influences morphology and population characteristics (Jessop *et al.* 2012).

Varanus varius are highly active lizards that maintain large home ranges exceeding 150 ha which tend to overlap with those of conspecifics (Guarino, 2002). If there is a location in an environment where conditions are more favorable for monitors, such as a site containing human food refuse, it is plausible that many individuals could congregate around the same area and have overlapping home ranges. Such reductions in home range sizes and tolerance of conspecifics are typical of urban adapters in areas with abundant food resources (Bateman & Fleming, 2012).

As *V. varius* seek out human trophic subsidies, an increase in the frequency of human-monitor interactions is expected. Monitor lizards have been hunted by Australian aboriginal people for thousands of years, and therefore perceive humans as predatory threats (Bird *et al.*, 2008). Optimal escape theory predicts that prey should flee from an approaching predator at the point when the risk of predation is equal to the cost of escape (Ydenberg & Dill, 1986). Several factors such as the speed and direction of approach by the predator, along with the direction of gaze can influence the level of risk represented by the predator, as well as escape decisions (Bateman & Fleming 2011, 2012, 2014; Stankowich & Blumstein, 2005). A common method of measuring how a prey animal perceives a predator as a risk is through flight initiation distances (FID), which is the distance between a prey animal and predator when the prey begins to flee (Ydenberg & Dill, 1986). It can be a useful metric as it is easy to collect, is repeatable, and variables influencing FID can be easily manipulated; however, when an animal is living in an urban environment with humans present, it can become exposed to a range of different stimuli from potential predators. In order to become successful, urban adapters and exploiters must be able to distinguish between legitimately threatening stimuli and non-threating stimuli. This distinction inevitably leads to human habituation, since humans are a common stimulus in urban environments (Bateman & Fleming, 2014). A study conducted on black-girdled lizards (*Cordylus niger*) in South Africa found that FID was significantly shorter when subjects were exposed to human presence than when people passed by infrequently (Cooper & Whiting, 2007). This shorter FID is a result of the lizards becoming habituated to the presence of humans and perceiving them as less of a threat. Therefore, as *V. varius* encounter more humans by seeking out human trophic subsidies, it can be predicted that they will become habituated to the presence of people and perceive them as less of a threat.

This study seeks to determine how the abundance of *V. varius* changes in areas of differing human densities, and to observe how *V. varius* perceive humans as a threat on Fraser Island, Queensland. Due to the added level of protection around campsites and the possibility of gaining trophic subsidies, it is predicted that *V. varius* occur in greater abundances in campsites than on the trails. To determine how *V. varius* perceive people as risks, their FID was measured inside and outside campsites, and a direct and tangential approach towards the animal was implemented to observe how FID changed with a predator's (*i.e.*, the observer's) direction of approach. Conversely, in areas of greater human density, *V. varius* is expected to have a much lower FID than in areas of low human density, which would be an indicator of habituation to human presence.

Methods

Study Sites

Fraser Island, located off the southern coast of Queensland, is the world's largest sand island, and attracts over 360,000 tourists a year. This UNESCO World Heritage Area is also a part of the Great Sandy National Park, and supports a vast array of forest types and wildlife (Department of Environment and Resource Management, 2008). The island is known for its dingo (*Canis lupis dingo*) population, which is a primary attraction for tourists visiting the island (Thompson *et al*., 2006). This abundance of wildlife and tourists has led to many interactions between these groups. Unfortunately, in 2001 a nine year-old boy was attacked by a pack of dingoes, which prompted some landscape changes on the island. In order to minimize negative interactions between humans and dingoes, the park service works to educate tourists, and has also erected dingo fences around all campsites and popular tourist destinations (Georgette & Howard, 2003). Typically, these wire fences are approximately 1.5 m tall, and have large square openings between the wires measuring approximately 15 cm wide, though the specific style of fencing is not uniform throughout the island. During the summer months when they are much more active, *V. varius* make up a large portion of the dingo's natural diet (Angel-E., 2006). Since monitors are able to slip through the gaps in dingo fences, campsites enclosed by fences also offer a degree of protection from the island's apex predator. The combination of added protection from dingo fences with the possibility of human trophic subsidies is expected to result in much higher abundance of *V. varius* near areas of human settlement on Fraser Island.

Surveys were conducted between 12-27 April 2015 on sunny days when *V. varius* would be expected to be active (Booker & Wombey, 1986). To measure the difference in monitor abundance and risk assessment between areas of high and low human densities, all high human density areas were located in campsites that the Queensland Park and Wildlife Service enclosed with dingo fences, while low human density areas did not have any fencing. Four different locations were selected within dingo fences to represent high human density areas (see Fig. 1).

1. Dilli Village Environmental Camp run by the University of Sunshine Coast (25º 36′ 0.36″ S; 153º 5′ 31.56″ E). Both students from the university and tourists use the facilities at this campsite. At Dilli Village, a 355 m transect along the edge of the campsite, along with a 100 m transect through the middle of the campgrounds were surveyed.

2. Lake Boomanjin (25º 33′ 24.12″ S; 153º 3′ 55.1″ E). This site used to be a popular campsite, but since the lake flooded several years ago, many tourists have dismissed it as a good camping location (Anonymous, pers. comm.). Although not many people camp here overnight, the site has become a popular picnic lunch spot. This campsite was rectangular in shape, measuring 1,736 m^2, and was easily observed.

3. Central Station (25º 28′ 40.8″ S; 153º 3′ 41.4″ E). This campsite is located in the center of the island and is considered a very popular camping destination. It is set among some of the island's largest forests and also supports a large abundance of wildlife. Central Station consists of two different campsites; the Kauri site and Satinay site. Transect surveys were conducted along the roads in each campsite with the Kauri transect measuring 430 m, and the Satinay transect measuring 500 m in length.

4. Eurong Village (25º 30′ 41.4″ S; 153º 7′ 14.5″ E). This large area supports the Eurong Beach Resort and several residential homes. Many tour companies travel to Eurong during the day for tours and lunch. Two transects were surveyed in Eurong; one around the resort (895 m in length), and one around Second Valley (600 m in length), where locals live along with rental houses.

Since traffic on Frasier Island is limited to large trucks, the hiking trails remain relatively empty. To measure *V. varius* abundance and risk assessment in low human density areas, two trails were hiked through the middle of the island, which covered a total of 14.6 km. The first hike (Trail 1) was from Central Station to Lake Benaroon and measured 6.9 km. The second hike (Trail 2) was from Central Station to Lake McKenzie and measured 7.7 km. Each trail was hiked twice. Due to inclement weather, Dilli Village and Eurong were sampled over two days, whereas all other campsites were sampled over three full days.

Measuring abundance

At campsites enclosed by dingo fencing, transects

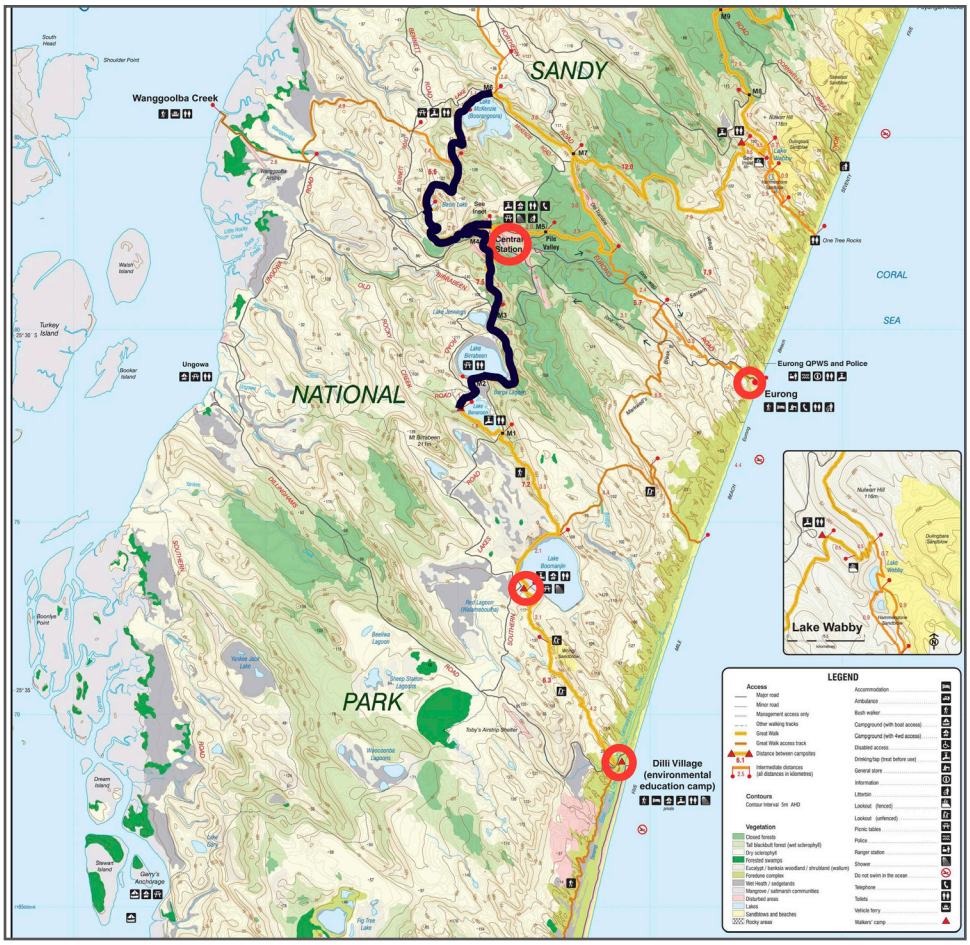


Fig. 1. Topographical map of central Fraser Island depicting the study area. Red circles represent campsites surveyed, and black lines represent the trails surveyed. The trails hiked were part of the Fraser Island Great Walk.

were conducted at least 10 m away from the fence. Transects were scanned to approximately 10 m on either side of the observer. Each time the observer walked around a campsite, the number of paces to complete a transect were counted. The paces were then averaged for each replicate, and then converted into meters (116 paces = 100 m) to find the total length of the transect. In campsites, transect surveys were conducted three times a day, based on established activity periods of *V. varius* (Seebacher & Grigg, 2001): 0800-0900 h, 1200-1300 h, and 1500-1600 h. This led to a total of nine replications at each site at differing times of the day. Along trails outside the dingo fences, each side of the trail was scanned about 5 m into the bush for the entire length of the transect. All hikes were conducted between the hours of 1000 and 1500 h.

Monitors that were spotted were classified as adult (> 1.5 m total length [TL]), sub-adult (1.0–1.4 m TL), or juvenile (< 1.0 m TL) based on visual approximations. The distance from the observer and the distance to cover (*i.e.*, a large tree or thick vegetation) were estimated for each individual. The distance of the monitor from the observer was also assumed to be the alert distance. Along with recording monitor abundance, data on the number of people present in each campsite, or encountered along each trail were also recorded, categorizing what they were doing as inactive, active, or eating.

Measuring risk assessment

When a monitor was spotted, two different approaches were implemented. The first was a direct approach towards the lizard at a slow pace of approximately 1–2 km/hr. This direct approach would eventually force the monitor to flee for cover. The second approach was a tangential approach, where the observer walked past a monitor at a minimum bypass distance of 3 m at the same pace. This minimum bypass distance was established based on tourists' experiences with encountering monitors on the island. This technique was used because risk assessment decreases as minimum bypass distance increases, so *V. varius* may not always flee. Once a monitor was spotted, it was approached by either of these approaches, alternating approaches.

Table 1. Summary of *Varanus varius* observations at each location. Relative abundance assumes that each observation represented a different individual. Abbreviations used: A = adults; S = subadults; J = juveniles).

Location	Transect Length (km)	No. Replicates	No. Observations (Total [A.S.J])	Relative Abundance (Individuals/km)
Dili Village	0.455	6	19 [11.8.0]	41.7
Lake Boomajin	0.1736	9	5 [0.5.0]	28.8
Central Station	0.93	9	20 [5.13.2]	21.5
Eurong Beach Resort	0.895	6	0	0
Eurong- 2nd valley	0.6	6	2 [2.0.0]	3.3
Trail 1	34.5	2	2 [0.0.2]	0.06
Trail 2	38.5	2	0	0

Sometimes the area where the animal was spotted would not allow a tangential approach due to some kind of obstruction such as vegetation or a truck. In order to record FID, the distance between the lizard and the observer when it began to flee to cover was measured. The typical flight response for *V. varius* is to run away from a predator and climb up a tree, or hide under a log or in thick vegetation for cover. To accurately measure this distance, a tape-flagged pencil was dropped when the monitor fled, and the distance from it to the point of cover was measured. Monitors that did not flee from a tangential approach were recorded with a FID of zero meters.

Results

Abundance

A total of 48 *V. varius* observations were recorded over the course of this study; 46 were in fenced campsites, and only two were made on trails (see Table 1). All monitors observed within campsites were recorded as adults or sub-adults (Fig. 2), with only two juveniles observed at Central Station. Both observations on trails were of juveniles. Central Station had the most observations, with 20 observations recorded over three days. Dilli Village had the highest relative abundance, with around 42 observations per km, followed by Lake Boomanjin with 29 observations per km. Eurong had the lowest relative abundance of monitors, with none observed by the resort, and only two observed in Second Valley. While there were a total of two observations in both Eurong and both trails, the trails covered a much greater distance, leading to a lower relative abundance. Since none of the monitors were photographed or captured to identify individuals, it cannot be determined if these observations were independent of one another, and it must be assumed that the chances of counting individual monitors twice or more were the same at all locations, leading to a relative measure of abundance.



Fig. 2. The typical flight response for *V. varius* is to flee for cover up a tree, as seen here near a family campsite in Dilli Village

The number of observations recorded in each location differed, along with the number of people encountered at each location (see Fig. 3). Eurong Beach Resort had the highest average number of people observed per day (31 people), although there were many more people observed on average (54 people) during noon transect surveys. Similarly, the average number of people observed at Lake Boomanjin was greatest during noon transect surveys (4 people) as opposed to morning (0 people) and afternoon (2 people) surveys. This increase in the average number of people observed during noon transects is influenced by the popularity of Lake Boomanjin and Eurong Beach Resort as lunch destinations. Conversely, the average numbers of people observed in Dilli Village and Central Station were greater in the morning (18 and 13 people, respectively), than noon (7 and 1, respectively) or afternoon (8 and 2, respectively) surveys. In both of these popular camping locations, people were present in the morning, but later ventured away from the campsite to explore the island.

Monitors were much more likely to be found during morning and noon transect surveys than afternoon surveys. The greatest number of monitor observations recorded at Central Station was during noon surveys, which was the same time as the lowest average number of people recorded at this location (1 person). Similarly, at Lake Boomanjin, the highest numbers of monitor observations were recorded when the campsite saw the lowest number of people, during the morning and afternoon surveys. No monitors were recorded at Eurong Beach Resort, which also supported the largest average number of people; only two people were recorded on the trails. The behavior of people in campsites did not appear to influence monitor abundance or behaviors.

Flight initiation distances

Flight initiation distance was measured for each *V. varius* observed. There were a total of 26 direct and 20 tangential approaches made in campsites, and only one of each approach on the trails. FIDs, for both direct and tangential approaches, were lower in all campsites than on trails (see Fig. 4). An individual observed at Eurong had the shortest FID, where a tangential approach did not cause the monitor to flee, and a direct approach revealed a FID of 1.8 m. At Lake Boomanjin, direct approaches resulted in an average of 4.1 m (n = 2), and tangential approaches resulted in an average of 2.7 m (n = 1). Central Station and Dilli Village yielded very similar results. The average FID on direct approaches at Dilli Village was 5.8 m (n = 11), and 5.5 m (n = 11) at Central Station. Tangential approaches yielded fairly similar results between locations, where the average FID for tangential approaches at Central Station was 4.9 m (n = 4), and 4.3 m (n = 4) at Dilli Village. Out on Trail 1, a direct approach yielded a FID that was much

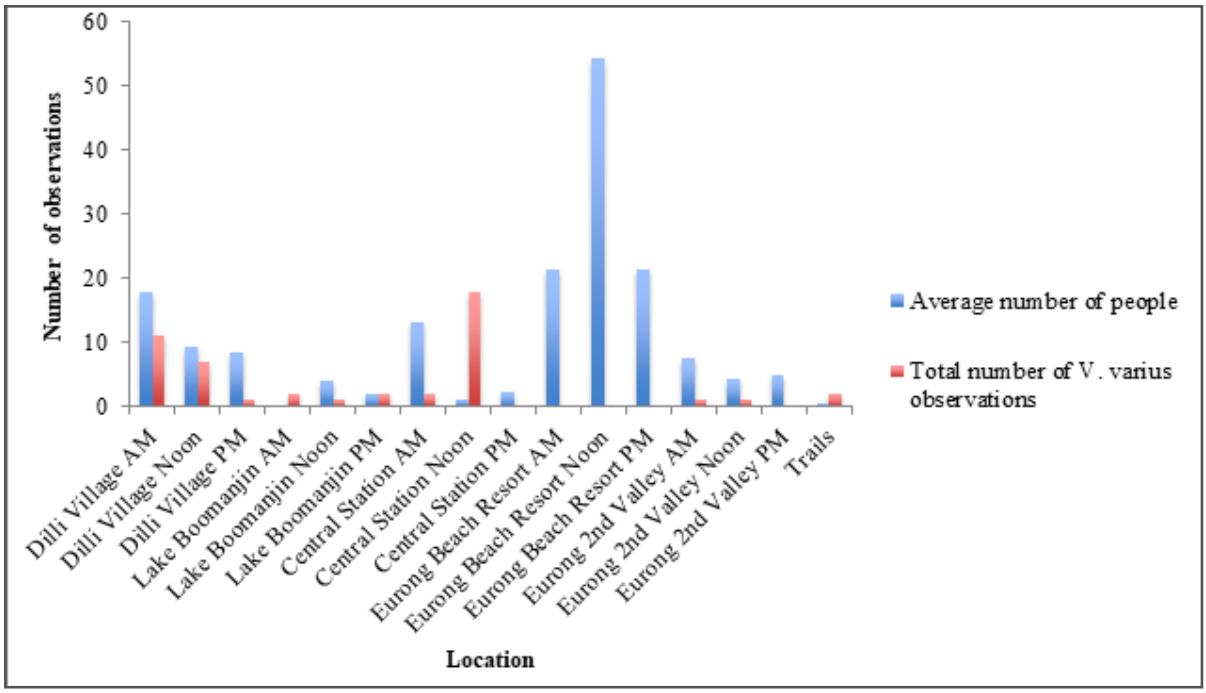


Fig.. 3. Average number of people and total number of *V. varius* observations made in each location. Trails 1 and 2 have been combined.

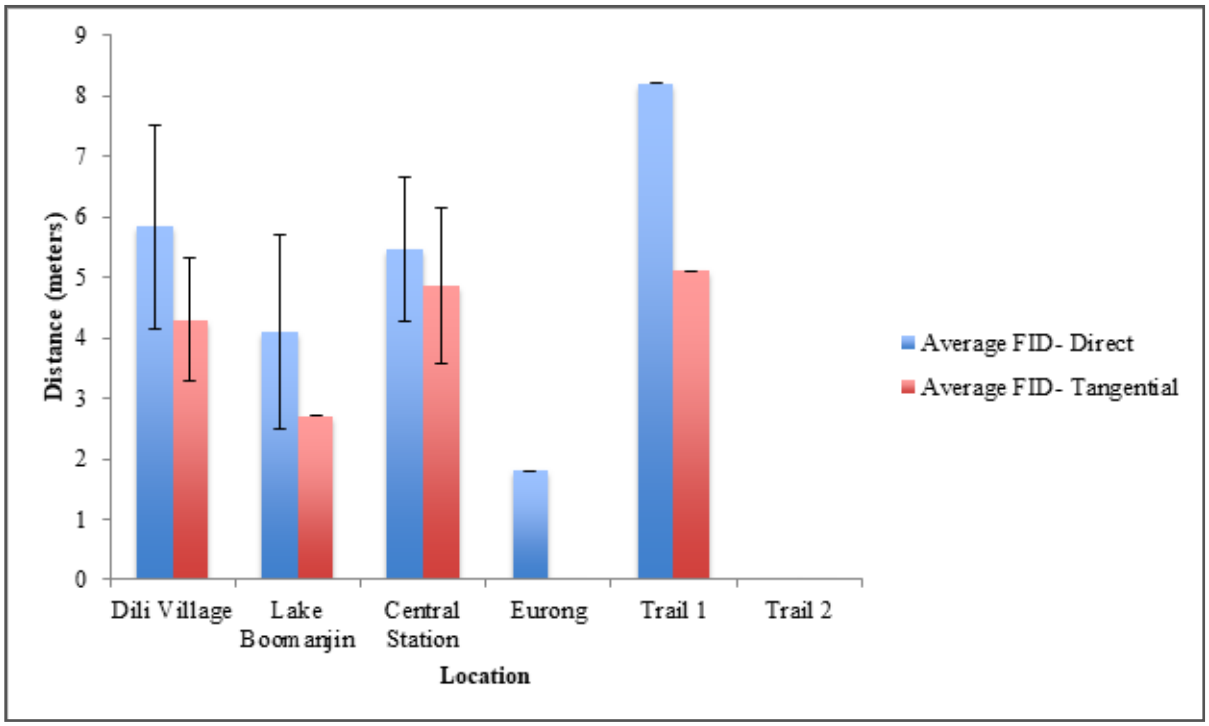


Fig..4. Average FID of both approaches in all locations with standard error bars. (Eurong Beach Resort and Second Valley have been condensed to just Eurong since no monitors were recorded in Eurong Beach Resort).

larger than the average at any campsite, at 8.2 m (n = 1); whereas the FID for a tangential approach was also higher at 5.1 m (n = 1). No monitors were recorded on Trail 2, so FID could not be measured.

Of the 20 *V. varius* that were tangentially approached, 55% (n = 11) of them did not flee (see Fig. 5). At Second Valley in Eurong, the only monitor tangentially approached did not flee. Two out of three monitors at Lake Boomanjin did not flee from a tangential approach; whereas 56% (n = 9) of individuals in Central Station, and 43% (n = 7) of individuals at Dilli Village did not flee. All *V. varius* fled while out on the trail. When a monitor did not flee, it generally moved slowly away from the observer, while still watching the observer's actions. On several occasions inside campsites, a monitor was tangentially approached while they were eating and they failed to leave their food source. In other times they seemed indifferent to the observer's presence, and would not move at all.

Discussion

Abundance and behavior

From the data collected, it appears that *V. varius* preferentially inhabits campsites. Although the dingo fence adds a large degree of protection from predators, there may be a limit to how much human presence they can tolerate. No *V. varius* were observed in the Eurong Beach Resort, although two individuals were recorded in Second Valley. The resort represents a highly developed area on the island with a large number of people and buildings and little natural habitat remaining; however, the absence of recorded observations in this study does not completely rule out *V. varius* from inhabiting this location. Second Valley is separated from Eurong Beach Resort by a sand dune, and is surrounded by dense native vegetation, along with non-native plants planted by homeowners which offer a greater degree of cover than Eurong Beach Resort within the same dingo fence. The locations with the greatest number of *V. varius* observations (Dilli Village and Central Station) represent human-modified landscapes that still retain many natural elements as well. Although Dilli Village had several buildings such as bunk houses and restrooms, it is surrounded by a natural environment and has relatively few human visitors. Central Station was surrounded by a large and dense forest, which provided plenty of cover options for the monitors. Many more observations were made inside campsites than outside them. Though the trail represents the unmodified natural environment in which *V. varius* would inhabit, campsites

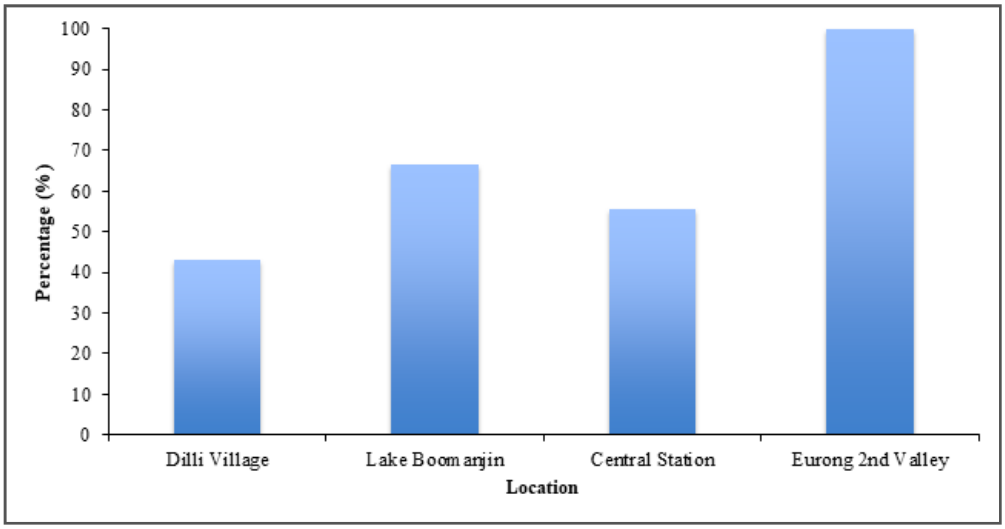


Fig. 5. Percentages of *V. varius* at each location that did not flee from a tangential approach.

provide protection from dingoes, and also offer a human mediated trophic subsidy.

Inside campgrounds, *V. varius* were often observed searching for food remains. Frequently while conducting transect surveys, monitors were found eating small food scraps left on the ground and were even seen tearing open a trash bag in Dilli Village. Although Fraser Island management encourages people to always keep their food sealed and stored away, multiple instances of people blatantly leaving food or food refuse out in the open were observed, which will inevitably attract *V. varius* to campsites. Previous work has found that *V. varius* in areas with human trophic subsidies have decreased numbers of enzymes that infer metabolic syndromes, decreased plasma corticosterone (a marker of stress) and decreased blood parasites (Jessop *et al.*, 2012). Although no blood samples were collected during this study, it is likely that the *V. varius* on Fraser Island may have similar physiological markers due to their consumption of human trophic subsidies.

A study on *V. salvator* in Indonesia found that the lizards had become conditioned to the arrival of food refuse (Uyeda, 2009). When the regular 0600 h dumping of food scraps stopped, *V. salvator* still arrived at that time to search for food (Uyeda, 2009). At Central Station, almost all observations were recorded during noon transects, but a few were made in the morning. Although the people observed in Central Station did not all leave at the same time, almost everyone had departed by noon. It seems that the monitors in this location have become conditioned to the daily departure of tourists as an opportunity to forage. Similar behavior was also observed at Lake Boomanjin, where only one *V. varius* observation was recorded around noon, when most people were at the campsite. The highest number of *V. varius* observations at this site occurred during the morning and afternoon, when the least amount of people were present. These observations suggest that *V. varius* try to avoid interactions with people since they are perceived as a threat, but still view humans as a potential source for food. Since there were so many people at the Eurong Beach Resort, along with plenty of inaccessible garbage cans, there may not be much of an incentive for monitors to venture towards the resort, when they still have access to the same degree of protection in Second Valley.

The body sizes recorded within campsites are consistent with a previous study that looked at *V. varius* around human trophic subsidies (Jessop *et al.*, 2012). In the present study, the vast majority of recorded individuals were classed as an adult or sub-adult (*i.e.*, > 1 m TL). This aggregation of larger monitors has the potential to lead to competition and the exclusion of smaller individuals. It has been recorded that monitor lizards will kill and cannibalize smaller conspecifics when space is limited (Auffenberg, 1994; Johnston, 2008). While at Central Station, a dead juvenile *V. varius* was observed within the dingo fence; however, a cause of death could not be determined. Central Station was the only campsite where any juvenile *V. varius* were observed, and this could be attributed to the greater degree of cover available, along with trophic subsidies.

Special case of Lake Boomanjin

Upon arrival at Lake Boomanjin, it was initially

believed that observations could not be collected from this specific campsite. At all of the other campsites, the dingo fences were constructed of wiring along posts with large square gaps measuring approximately 15 cm wide that allowed large adult *V. varius* to pass through. However, at Lake Boomanjin, the fence was of a different construction, and had small diamond-shaped openings measuring approximately 8 cm wide. Although adult animals could not fit through this fence, smaller sub-adults were still able to squeeze through. It is reasonable to believe that as highly skilled climbers, adult *V. varius* could be capable of climbing over the fence; however, this was not observed during this study. Lake Boomanjin also differed from all of the other campsites visited in that there were no overnight visitors except for the author on two out of three nights. In contrast to Central Station and Dilli Village where people left to explore the island during the day, few people were present in the morning or afternoon at Lake Boomanjin, and people only came to see the lake briefly or have a picnic around lunchtime. Since people still visited the campsite to eat food, they often left food refuse on the ground. These scraps were enough to attract *V. varius* that were small enough to squeeze through the smaller openings in the fence. There was never more than one *V. varius* observed at the same time within the campsite, and because no methods were used to identify specific individuals, there is no way of knowing if it was the same individual each time.

The *V. varius* of Lake Boomanjin had the second lowest FID in both approaches, and also had the second highest percentage of individuals not fleeing from a tangential approach. Eurong had the highest percentage of *V. varius* that did not flee from a tangential approach, where only one monitor's FID was measured with this approach. Since Lake Boomanjin had very low FID in both approaches, and a high percentage of *V. varius* that did not flee from a tangential approach, it can be inferred that the monitors at this campsite were highly habituated to the presence of humans. Although the campsite offers a human-mediated trophic subsidy to *V. varius*, the sub-adult monitors encountered were observed slipping through the fence back to natural cover after foraging.

Eventually, these small sub-adults will mature into large lizards that cannot fit through the smaller gaps in the Lake Boomanjin fence. Since they learned to forage for human food refuse within campsites, they may still rely on this refuse as a food source as they mature and grow older. Combined with their high habituation to people, adult *V. varius* accustomed to foraging for human food refuse may disperse to other campsites across Frasier Island. The Lake Boomanjin campsite could potentially serve as a location where young *V. varius* become habituated to people and conditioned to their food refuse, while still being protected from potential predators like the dingoes and larger *V. varius*.

Improvements for future study

Several shortcomings of this study must be addressed. One major issue was the timing of the study. *Varanus varius* are considerably more active during the summer months than winter months, and April is typically when some *V. varius* become inactive due to cooler temperatures (Guarino, 2002). This activity level in *V. varius* is represented in dingoes' diets, since their diet shifts away from *V. varius* during winter months, because the lizards are much less active. (Angel-E., 2006). Although *V. varius* were still active on the island in the present study, they may not have been foraging over larger distances, which could partially explain the low numbers of observations out on the trails. Additionally, the shorter scanning distance and the thickness of vegetation on the trails may have obscured potential observations. Temperatures during the day also were progressively cooling while data was collected on the island, which led to particularly cold days (*i.e.*, 15–20 °C) when *V. varius* would not be active. This cold weather precluded data collection for two days in the campsites, and three days on the trails. To resolve these issues, conducting this study during the warm summer months of October through March would be ideal. Additionally, having a longer timespan to collect data would allow researchers to wait out any inclement weather and resume surveys when *V. varius* is most active.

Another limitation to this study was that there were no methods introduced to identify and distinguish between individual monitors. This could have been accomplished either by photographing each individual's unique pattern or potentially by capturing and marking individuals. However, capturing the monitors may have the potential to influence their fear perception and flight behavior. Due to the inability to differentiate individual lizards, measures of abundance must be viewed in relative terms since it is assumed that chances of counting individual monitors multiple times were the same at all locations.

Ultimately, this study should be viewed as a pilot study. It was not possible to collect a robust dataset to yield sufficient statistical power across the very large island, but enough data was collected where a descriptive general trend could be recognized. *Varanus varius* were

clearly more abundant in campsites than on trails, they were observed actively searching for food in campsites, and they frequently encountered humans. In order to conserve energy by not fleeing constantly, they should eventually habituate to humans (Bateman & Fleming, 2014). Although the data collected in low human density areas could not be replicated to the same level as in high human density areas, it appears that *V. varius* is able to habituate to human presence.

Conclusions

From the observations and data collected, it is clear that *V. varius* on Fraser Island seek out human food refuse as part of their opportunistic diet, and have consequentially become habituated to the presence of humans. The dingo fences surrounding campsites also provide an important source of protection from the monitors' main predator on the island, which may be another incentive to inhabit campsites. It appears that *V. varius* will be able to persist alongside human settlement on the island, but only up to a point. The Eurong Beach Resort may represent the upper limit of an environment that *V. varius* can live in due to the high density of people with little available human food refuse. If the island was to continue being developed, and more establishments like the Eurong Beach Resort are created, this could lead to a decrease in the *V. varius* population. However, due to Fraser Island's UNESCO World Heritage title and protection as part of the Great Sandy National Park, extensive development is unlikely.

In a global perspective, more and more land is being transformed through urbanization (Miller & Hobbs, 2002). Some species will be able to adapt to the changing landscape, while others will perish or avoid such landscapes. Based on these preliminary findings on Fraser Island, it is believed that *V. varius* is an urban adapter, since it can still persist in the presence of humans and gain some resources from them such as food, but still rely on natural elements such as trees and vegetation for cover. *Varanus varius* may be successful on the fringes of cities as long as some aspects of the natural landscape remain intact.

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