Habitat Fragmentation and its effects on pollinators Tirumala hamata and Euploea core

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ABSTRACT: The Urban landscape of Queensland has been growing exponentially in recent years, with remnant vegetation continually being cleared to create more liveable infrastructure and cope with the growing population. Queensland's population is also increasing rapidly with a current rate of 1.53% with over 5,170,313 people currently living in the state, and its largest city Brisbane spanning over 15,826 kilometres (Queensland Government, 2020). Although this development is needed to provide housing and essential localities for the general population, it is causing extreme environmental impacts, including habitat fragmentation. This habitat fragmentation is affecting Queensland's insect pollinators significantly. As these animals, in particular the order lepidoptera, occupy a vital position in ecosystem functions and are a valuable indicator of the health of any given terrestrial biotope, a decline in the number and health of these animals is concerning. Butterflies belonging to the subfamily Danainae, are one of the most prevalent species in Australia, and the most prevalent in its largest city Brisbane. Two individual species of interest belonging to this group are the Tirumala hamata and Euploea core. These two species are of interest as they are extremely prevalent in the urbanised areas of Queensland. An analysis of the populations of Tirumala hamata and Euploea core and their corresponding host plants in areas of varying fragmentation, can be used to determine patterns of abundance across the different populations as well as predict potential responses to future habitat fragmentation and the impacts it will have on this subfamily from a conservational point of view.

BACKGROUND:

Habitat fragmentation in Queensland

In 2016 more than 400 ecologists, including conservation scientists from Australia and around the world, issued a declaration of warning outlining the devastating impacts of land clearing on Australian native animals, their biodiversity and abundance. However, this warning was ineffective as in the time period of July 20, 2016 to February 28, 2017 a plan was developed to clear 273,000 hectares of remnant regrowth bushland in Queensland. Habitat that is extremely valuable to many native animals. This destruction of valuable habitat would be approaching the scale of the total area cleared in 2014-15 of 296,000 hectares (Commonwealth of Australia, 2017). Land clearing causes species death and habitat loss, but also exacerbates other threatening processes, particularly when this clearance results in Habitat Fragmentation. Data collected over 35 years spanning multiple continents focusing on the impacts of Habitat fragmentation has shown trends that indicate a reduction of biodiversity of 13-75% in areas of extreme fragmentation. Studies support the conclusion that habitat loss and fragmentation are the greatest threats to terrestrial biodiversity (Noss, 1991, United Nations Environment Program, 1995).

It has also been established that habitat fragmentation impairs vital ecosystem functions by decreasing overall biomass and altering the nutrient cycle. These effects are greatest in the smallest and most isolated fragments, and they magnify as time passes. This increased loss of biomass is due to the reduced gene pool caused by isolation. This increases the risk of population bottlenecks, disease and genetic deformities in remaining animal populations (Zainab Reza, 2017). Some areas of Queensland that have been severely affected by habitat fragmentation in recent years are the Brigalow Belt, Central Queensland Coast, New England Tableland, Southeast Queensland and Wet Tropics bioregions (ABC news, 2018). As an example, Figure 1 (below) displays the large-scale urbanisation of an area of South East Queensland from the years 1998 to 2013. This habitat fragmentation is having long term impacts on Australia's natural ecosystems and the fragile and complex bionetworks that make the continent so unique. The impact of urban development has put pressure on the remaining natural resources and habitat, initiating long-term changes to the structure and function of the remaining habitat fragments.

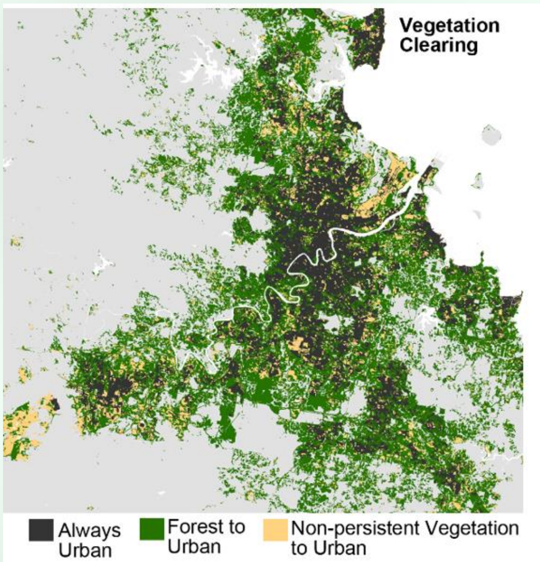


Figure 1 (Mitch Lyons, The Moreton Bay Foundation Limited, 2018)

Habitat Fragmentation and its impact on insects

These changes are easily detectable in large animal species such as the well documented extirpation of large mammals in areas of habitat fragmentation. However, species with less scientific presence and r-strategists with "boom bust" life cycles, are much less documented, such is the case for many insects. Invertebrates, particularly insects, make up more than 75% of global species diversity however there are relatively few studies investigating the effects of habitat fragmentation on invertebrates (Richard EMajor, 2003). Recent studies have shown a serious decline in many insect populations. Rather than the loss of single species, the most recent studies have determined a decline across majority of arthropod lineages, with collapses in total abundance rather than a single species. One of the most relevant studies suggests that approximately 40% of insect species are in decline and insects are facing extinction rates that are eight times higher than vertebrates. In Germany, scientists have recorded losses of up to 75% of the total mass of insects in protected areas. These collapses in overall insect abundance can cause extensive damage that destroys trophic webs and can cause the degradation of ecosystem services (David L. Wagner, 2019). Foremost among these, and of immediate concern due to environmental impact and economic concern, are the pollination services of insects (Adam J Vanbergen, 2013) (Carol A. Kearns, D.W.I, N.M.W, 1998).

Habitat Fragmentation and its impact on insect pollinators

There is sufficient evidence that shows a direct correlation between habitat size and connectivity and pollinator diversity. Population size has also been continuously shown to decrease in correspondence with the decrease in habitat connectivity. A disconnected habitat is harmful to pollination dynamics and has been proven to alter pollinator behaviour. This altered behaviour can lead to unsuccessful pollination, a decrease in offspring survival rates and reproductive fitness. These changes in reproductive fitness as well as pollinator behaviour is widely believed to be caused by the greater amount of energy required to navigate an urban environment as well as the lack of pollinator friendly plants found in these areas. This lower pollination rate also impacts plant numbers and therefore puts the pollinators even more at risk. Figure 2 (to the right) displays the effect of habitat fragmentation on pollinators.

Social and solitary bees, wasps, flies, beetles, butterflies, and moths comprise the vast majority of the world's pollinators. These insects are crucial for the pollination of many plants, including fruits vegetables and food plants that are essential for the survival of many animal species (Adam J Vanbergen, 2013). Approximately three-quarters of all crop species are dependent on insect pollination and these crop species feed 90% of the world. Honeybees, Apis mellifera, alone are responsible for 30 billion dollars a year in crops (BBC, 2020), In addition, insects pollinate many plants that provide erosion control, essential for the health of waterways.

Insect pollination is also a critical life-support mechanism underpinning biodiversity as well as maintaining healthy ecosystem services (Jeff Ollerton, R.W, S.T, 2011). The Mutualistic interactions, or mutualisms that these insects maintain with plants, play a key role in maintaining a healthy bionetwork. This interaction involves the exchange of goods or services between two species, called mutualist partners (Carol L. Landry, 2010). There is a large diversity of interactions between plants and their pollinators, with numerous complex functions, and many have coevolved with florae resulting in body sizes and behaviours that directly correlate to the reproductive structure of the plants they pollinate. Due to the specificity of these relationships, they are vulnerable to environmental change and are easily damaged or destroyed (The Netherlands Entomological Society, 2018) (Ethel M. Villalobos). When pollinator/plant interactions are destroyed, it can cause a total ecosystem collapse. The animals that rely on these interactions, for food or otherwise, are unable to maintain their role in the bionetwork, causing a "ripple affect" through the food chain. These ripple effects can cause isolated extinction events, population bottlenecks, a lack of genetic diversity and mass mortality events.

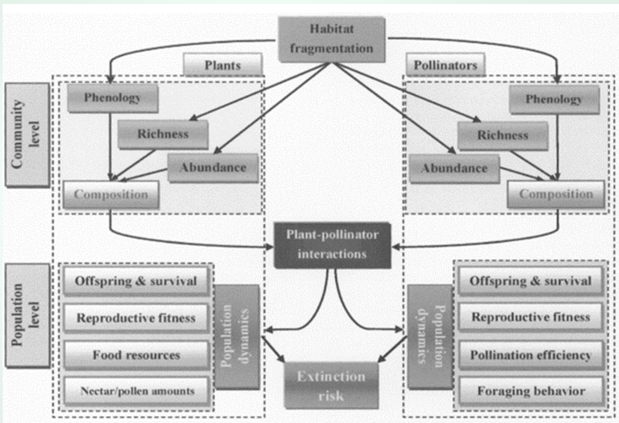


Figure 2 (Brian J. Spiesman, B.D.I, 2013)

Limitations of current data

Although there has been significant evidence found to support the negative effects of habitat fragmentation on insects and insect pollinators, there are some limitations. It has also been theorised that habitat fragmentation may benefit some insects but be detrimental to others. Furthermore, much of the data available that focuses on the effects of habitat fragmentation on insects is focused on one single group of insects in select locations. This data is specific to the one area and may not be applicable to determine the effects of habitat fragmentation on this species as a whole in other geographical locations. Much of the data for the effects of habitat fragmentation is also undertaken over short time periods (1–2 years) that are not relevant for assessing the long-term effects on the differing populations and locations, as each location possesses a unique bionetwork. This complexity has so far limited the evidence on the impact of habitat fragmentation on insects, insect pollinators and the ecological processes these animals underpin (Jonathan Wentworth, 2020). The most limited data collected is that of long-term studies in a variety of locations, be it focusing on a select number of pollinators specifically, or pollinator diversity as a whole (Jochen Krauss, 2003). By assessing these factors at varying locations for a longer period of time, the effect of habitat fragmentation would be able to be more clearly assessed.

Experimental methods

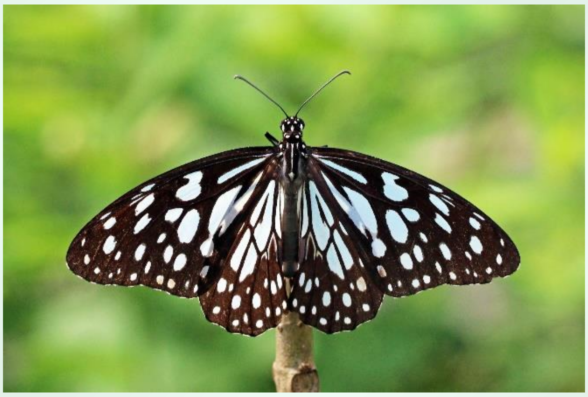
AIM AND HYPOTHESIS:

The overall aim of this study is to determine the numbers of Tirumala hamata and Euploea core and their milkweed host plants (Apocynaceae), in areas of varying habitat fragmentation. An investigation into the abundance of these pollinators will act as inferences regarding the response of habitat fragmentation on these species. In turn this will aid in establishing a clear correspondence between habitat fragmentation and pollinator abundance as well as assist in creating comparative models assessing the urban impact on these two species. It is expected that the ecological data collected will represent the current affects of habitat fragmentation on the two species as well as determine the continuing affects it will have as urbanisation continues without preventative efforts. Evidence of variance of abundance of both host plants and butterflies between the sites of less fragmented habitat and those of largely fragmented habitat would support the hypothesis regarding the detrimental impact of habitat fragmentation on the butterfly species and the impact that habitat fragmentation has on pollination dynamics, offspring survival rates and reproductive fitness.

Target Species

The subject species of Tirumala hamata and Euploea core are two butterfly species that both belong to the subfamily Danainae. The majority of species are found in both Old and New World tropics, including Queensland Australia. Although this group is one of the most common in Queensland and the most common in its largest city Brisbane , the affects of habitat fragmentation on these pollinators remains understudied. The data obtained by observing the abundance of these two species in areas of varying habitat fragmentation, as well as the abundance of their host plants will be used to draw comparisons between the species and summarise the potential responses that the species' distributions may have made with regards to the historical and ongoing urbanisation.

(Malcom, Green Path, 2018)



(Charles J Sharp, 2017)

The target species are Tirumala hamata and Euploea core (Stephen R. Madigosky, 2004). As this group of butterflies are the most prevalent in Queensland's largest city Brisbane, an area severely affected by habitat fragmentation, they are relevant when assessing the effect of habitat fragmentation on pollinators in this area. By assessing the populations of these two pollinators in areas of varying fragmentation theories can be developed regarding the impact of habitat fragmentation on these two species, due to environmental change caused by urban development, and conservation strategies can be devised.

Procedure

Mark and recapture, Butterflies of these species will be captured, marked, recorded and released as to determine a more accurate assessment of butterfly numbers at the varying locations, as well as how the butterflies move through the habitat. The abundance and diversity of host plants in the areas will also be recorded through the use of a selected size quadrat in all locations. These results will then be examined and compared as well as used to create comparative models to propose possible relationships between the data.

Mark and Recapture

At three locations of varying habitat fragmentation Butterflies will be captured and given a distinctive mark with a harmless sticker on the base of the underside of the forewing. Initial sampling will be taken at each site for 2 hours, with all butterfly sex and species being recorded. These butterflies will then be tagged and released. The location will be resampled the following day for the same period of time. The butterflies captured on the resampling will be examined carefully and each individual will again be recorded on species and sex, but also if they have a sticker at the base of the underside of the forewing. If they have a sticker, then they were previously captured and recorded. If not, then it is a new butterfly individual. All times of captures will be recorded. This data will then be analysed using the Petersen method and the formula of N = M * C/R, where N = the estimate of population size at the time of marking, M = the number of individuals marked in the first sample, C = the total number of individuals captured in the second sample and R = the number of individuals in the second sample that were previously marked (i.e., recaptures). The appropriate confidence intervals will be determined to give an accurate population estimate of both butterfly species at the selected locations (University of Miami, Ecology). The abundance of the butterfly's host plants will also be recorded through the use of quadrats and sampling

Use of Quadrats

At each site a transect line was measured that spans 10 metres, a 1m x 1m quadrat was then used to measure at each metre along the transect line. The plants of interest, the Asclepias genus that exist within this quadrat were recorded. These plants will be sampled, identified and preserved. The number of Asclepias recorded will indicate the population density of this plant in a 10m2. This data was then extrapolated to determine an estimate for the overall abundance of this genus in a given area.

Analysis

The data collected were analysed through the use of statistical processes to determine a relationship between the variables of butterfly numbers, host plant numbers and their interaction with the factor of habitat fragmentation. The program RStudio will be used to perform these statistical analysis

Justified Research Question –

How do different levels of habitat fragmentation affect the abundance and of Tirumala hamata and Euploea core butterfly populations at Mimosa creek – Toohey Forest and Glinderman Park – Urban Mnt. Gravatt?

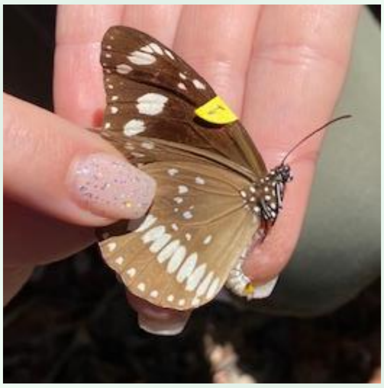
This Topic will be informative and important to research as 'Due to habitat fragmentation, the loss of species diversity has been extensively studied. On the contrary, the effects of habitat fragmentation on functional diversity is still poorly understood' (Tian-Hao Tu, 2019). By comparing areas of differing levels of habitat fragmentation as well as how urban development has affected other insects in the past, through research a suitable hypothesis can be developed outlining how and why butterfly abundance may differ at the two sites. By also focusing on the abundance of the butterflies host plant this possible influence can also be identified, as well as how this abundance may be affected by urban development (loss of native vegetation etc.) as *"Biological invasions are today the second-largest global threat for biodiversity. Once introduced, exotic plant species can modify ecosystem composition, structure and dynamics, eventually driving native species to local extinction"* (Laure Gallien, 2016). These different sources of discussion can lead to a strong argument and many devices for research and construction of this research. In total, this research question will give us an insight into how these two species of butterflies interact with their habitat and give us a better understanding of the impact of habitat fragmentation on Queensland's native pollinators.

Hypothesis – The population size of both Tirumala hamata and Euploea core butterflies will be greater at the Toohey Forest Mimosa creek track, than at Glinderman Park, due to the differing levels of habitat fragmentation. As differences in habitat fragmentation and host plant abundance have been shown to have an impact on butterfly abundance in certain areas. The Abundance and species of both Toohey Forest (Mimosa creek track), an area with little to no habitat fragmentation, and Glinderman Park, urban Upper Mnt Gravatt, an area suffering from extreme habitat fragmentation. The Butterfly abundance at the Toohey forest site will be greater than that of Glinderman as the habitat fragmentation found at the Glinderman site will impact habitat flow and will lead to greater mortality rates amongst the populations. Therefore, Glinderman park will have a much higher mortality rate amongst butterflies and therefore a lower butterfly abundance in both species. The butterflies recorded may also be less healthy, and fatalities possibly caused by urban development should be recorded.

Null Hypothesis: Glinderman park will have a similar or greater abundance of butterflies than Toohey forest. The butterflies will also be of the same species and similar in appearance

Results:

Toohey Forest Mimosa Creek Butterflies Recorded: September 26, 2020

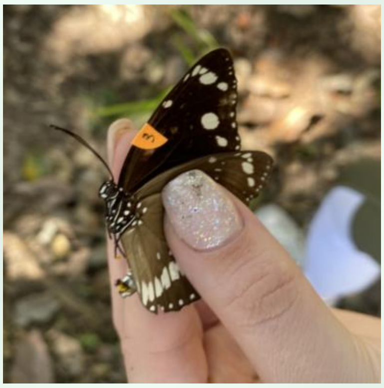
Time	*Species*	*Sex*	*Tag*	
9:40am	Euploea core	Male	Pink : 4	
9:45am	Euploea core	Female	Yellow: 1	
9:52am	Euploea core	Male	Pink: 6	
10:06am	Euploea core	Female	Yellow: 3	

				
10:26am	Euploea core	Male	Pink: 8	
10:42am	Euploea core	Male	Pink: 10	
11:11am	Euploea core	Male	Pink: 12	
11:29	Euploea core	Female	Yellow: 5	

11:31	Euploea core	Male	Pink:14	
11:35	Tirumala hamata	Male	Pink: 5	
11:42	Euploea core	Male	Pink:7	

Glinderman Park Butterflies Recorded: September 26, 2020

Time	*Species*	*Sex*	*Tag*	
12:29pm	Euploea core	Female	Orange: 1	
1:00pm	Euploea core	Female	Orange: 3	
1:02	Euploea core	Female	Orange: 5	
1:18pm	Tirumala hamata	Female	Orange : 7	

1:33pm	Euploea core	Male	Green: 2	
2:30	Tirumala hamata	-	Deceased	

Toohey Forest Mimosa Creek September 27, 2020

Time	*Species*	*Sex*	*Tag*	
9:07am	Euploea core	Male	-	
9:18	Euploea core	Male	Tagged	
9:27	Euploea core	Female	-	
:31	Euploea core	Male	-	

9:42	Euploea core	Female	-	
10:02	Euploea core	Male	-	
10:18	Euploea core	Female	-	
10:22	Euploea core	Male	-	

10:30	Euploea core	Female	-	
10:44	Euploea core	Male	-	
10:53	Euploea core	Male	-	
11:00	Euploea core	Female	-	

11:10	Euploea core	Male	-	

The number of Euploea core butterflies at Toohey Forest was as expected, in high abundance. However, the numbers of Tirumala hamata were significantly lower at this site than at Glinderman park. This result was unexpected and will be further looked into in the discussion.

Glinderman Park

September 27, 2020

Time	*Species*	*Sex*	*Tag*	
12:13pm	Euploea core	Male	-	
12:18	Tirumala hamata	Female	-	
12:30	Tirumala hamata	Male	-	
12:42	Euploea core	Male	-	

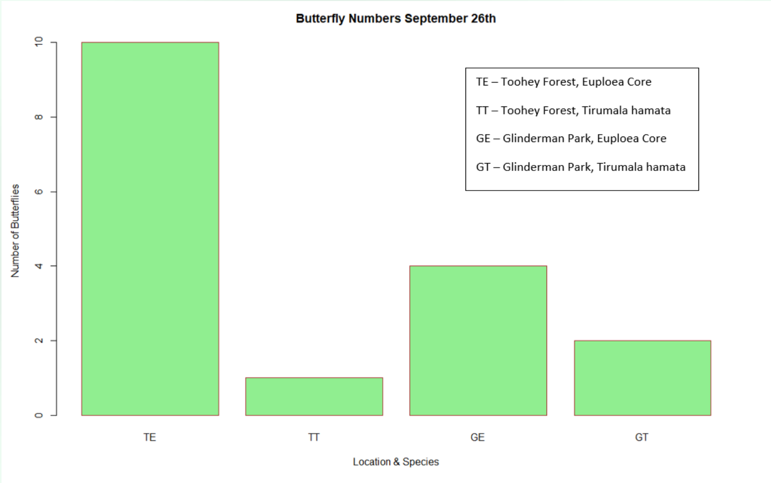
12:49	Euploea core	Male	-	
12:50	Euploea core	Male	-	
1:10	Tirumala hamata	Male	-	
1:30	Tirumala hamata	Male	-	

1:45	Tirumala hamata	Female	-	
2:15	Tirumala hamata	Female	-	

While the overall abundance of butterflies was significantly less at Glinderman Park, the number of Tirumala hamata was significantly more. This as well as the diversity of species at this location was not expected and should be researched further.

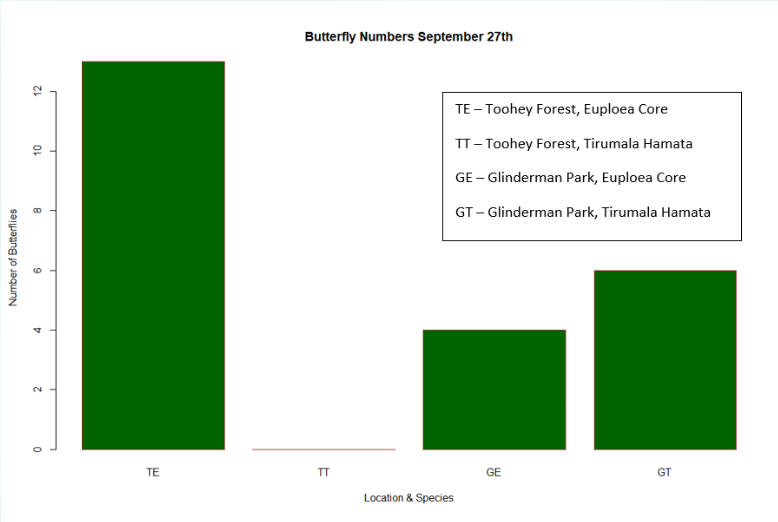
Figures

Figure 1



Significantly higher numbers of Euploea, as well as overall abundance of butterflies at the Toohey forest site on September the 26th, however, there was significantly less Tirumala hamata butterflies at Toohey forest than at Glinderman park.

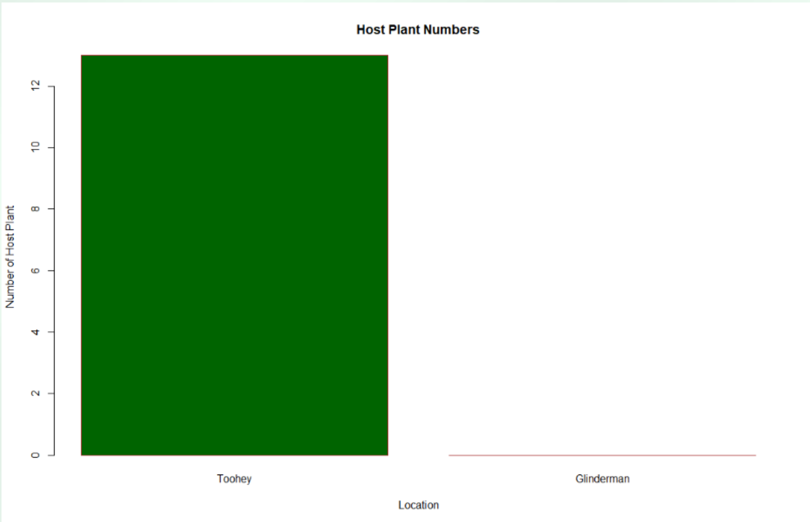
Figure 2



These results were replicated the following day, but to an even greater extent, with 0 Tirumala hamata butterflies being recorded at Toohey forest on day two of research.

Plant numbers

Figure 3



A large number of host plants found at the Toohey forest site, however none recorded at Glinderman.

The Petersen method

The Petersen method is the simplest mark-and-recapture method because it is able to be calculated with only one period of tagging, and a second single period of recapturing individuals. The basic procedure is to mark a number of individuals over a short time, release them, and then to recapture individuals to check for marks. All individuals can be marked in the same way. The second sample must be a random sample for this method to be valid; that is, all individuals must have an equal chance of being captured in the second sample, regardless of whether they are marked or not. The data obtained are

M = Number of individuals marked in the first sample

C = Total number of individuals captured in the second sample

R = Number of individuals in second sample that are marked.

From these three variables, we need to obtain an estimate of

N = Size of population at time of marking

By a proportionality argument, we obtain: N = M * C/R

However, as this method proves to be somewhat bias the estimator below will be used.

$$N = \frac{(M+1)(C+1)}{R+1} - 1$$

Population estimate Euploea core Toohey Forest =

$$N = \frac{(10+1)(13+1)}{1+1} - 1 = 76$$

Population estimate Tirumala hamata Toohey Forest =

$$N = \frac{(1+1)(0+1)}{0+1} - 1 = 1$$

Population estimate Euploea core Glinderman park =

$$N = \frac{(4+1)(4+1)}{0+1} - 1 = 24$$

Population estimate Tirumala hamata Glinderman park=

$$N = \frac{(1+1)(6+1)}{0+1} - 1 = 13$$

If Euploea core butterflies were the only species undergoing sampling within this research, the hypothesis *"Glinderman Park will have a much higher mortality rate amongst butterflies and therefore a lower butterfly abundance than Toohey Forest"* would be strengthened, however, due to higher numbers of Tirumala hamata butterflies being recorded at Glinderman park than at Toohey Forest, the null hypothesis of *"Glinderman park will have a similar or greater abundance of butterflies than Toohey forest. The butterflies will also be of the same species and similar in appearance"* cannot be rejected.

Discussion

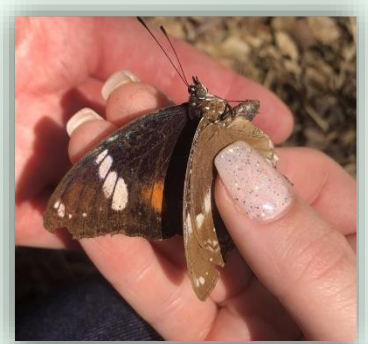
This Topic is informative and important to research *as 'Due to habitat fragmentation, the loss of species diversity has been extensively studied. On the contrary, the effects of habitat fragmentation on functional diversity is still poorly understood'* (Tian-Hao Tu, 2019). Through this research we aimed to explore the effect of habitat fragmentation on butterflies Tirumala hamata and Euploea core. The results of this research can be seen in Figures 1, 2 and 3 on page 18. Through interpretation of these graphs, it can easily be noted that the number of Euploea core butterflies was much greater at Toohey forest than Glinderman park with population estimates of 76 and 24 respectively. This is most likely attributed to the large number of butterfly host plants found at the Toohey forest location (a comparison between the host plants at each site can be seen in Figure 3).

However, the populations of Tirumala hamata butterflies were significantly higher at Glinderman park than Toohey forest, which was unexpected, with population estimates of 1 and 13 respectively. Although this result may seem unconventional, as it contradicts the original hypothesis of – *The population size of both Tirumala hamata and Euploea core will be greater at the Toohey Forest Mimosa creek track, than at Glinderman Park, due to the differing levels of habitat fragmentation.* However, upon further examination it shows a different aspect of habitat fragmentation and its impact on butterflies.

The data collected in this research can be corroborated with a study completed by Hemchandranauth Sambhu, which was published in 2018. Sambhu and team researched butterfly abundance and diversity in areas of differing habitat fragmentation and human development and were met with similar results. The urban areas experiencing extreme habitat fragmentation exhibited the highest diversity of butterflies, with low abundance, and the Forest areas and areas with little to no habitat fragmentation consistently had a very high abundance of one or two species of butterfly but a low diversity. When assessing other findings of Glinderman park it was clear that diversity was extremely high, with other species (displayed top right of this page) such as the varied eggfly and cabbage white butterfly, as well as blue triangle and swallowtail butterflies being seen and/or recorded.

Sambhu explains that this high diversity but lack of abundance is most likely attributed to the butterflies being forced into a small amount of habitat, this can be corroborated with an article written by Laura Bies that explains how habitat fragmentation can create a clump of many small communities of different species due to limited resources (Laura Bies, 2014). This habitat limitation coupled with the diversity in non-native garden plants *"likely due to variation in natural green areas and residents' landscaping preferences … may create an environment where numerous species of butterflies are present throughout the year"* (Hemchandranauth Sambhu ,2018).

Female varied eggfly butterfly *(Hypolimnas bolina)*



Cabbage white butterfly *(Pieris rapae)*

Although this high diversity may give illusion to a healthy biosystem this is not always the case. As can be seen by the small variety of pictures below, majority of the butterflies caught in Glinderman park were not of great condition, with many suffering wing tears and abdomen damage, as well as one deceased individual being found beside the road.

These wing and abdomen damages could be attributed to the lack of canopy cover and invasive bird species that are present in extremely urbanised and fragmented habitat, like that found at Glinderman park (Peter H. Roos, 2019). Although the abundance of Tirumala hamata was considerably less at Toohey forest, the one individual tagged was in completely perfect condition with no wing or abdomen damage. So why would there be less Tirumala hamata butterflies at Toohey forest?

In the case of Toohey Forest, there was little to no species diversity with Euploea core being the most abundant and dominant species. This is most likely attributed to the age of the forest, with the mountains that make up this forest being formed 380 million years ago, and the forest being named by James Toohey in 1872 (Brisbane City council, 2020). Due to the forests' long history, Euploea core butterflies have had an established relationship with the habitat for an extended period of time and, as such have adapted to it and established niches in the specific location of Mimosa creek. It is likely that the same diverse number of species found at

Glinderman park would be present in Toohey forest, however these different species would most likely be found in large numbers in completely different areas of the forest with their own established niches.

Overall, the data collected within this research task was extremely relevant as the decline in number of Australia's native pollinators is of urgent concern. While the original results of sampling may not have appeared to demonstrate the harmful affect habitat fragmentation has on pollinators Tirumala hamata and Euploea core, upon further research, these results display a bigger underlying issue across all of the Lepidoptera order. Habitat fragmentation was found to increase diversity, but lower abundance which can lead to population bottlenecks, competition and other problems within communities that does not allow for sustainable generational growth and reproduction. In order to better understand these results, in the future more sampling should be completed in order to strengthen these findings.

Conclusion:

In conclusion, by the data collection and analysis of this research task, it can be determined that habitat fragmentation does affect the abundance of Euploea core and Tirumala hamata butterflies in Queensland Australia. It can also be noted that factors such as diversity and dispersal of native pollinators also appear to be impacted by urban development and habitat fragmentation. Toohey forest and Glinderman park both had very different levels of habitat fragmentation and host plant abundance so therefore had very different levels of butterfly abundance. Abundance at Glinderman park was impacted by lack of canopy cover, small segmented habitat size as well as an increased number of predators. These are all factors that can cause collapse of an ecological system and limit the ability to maintain a functioning habitat and ecosystem. In contrast Toohey Forest was an area of no habitat fragmentation and had a very high abundance of Euploea core butterflies and their milkweed host plant. This location however, lacked an abundance of Tirumala hamata butterflies, possibly due to the impact of environmental niches. Furthermore, as the canopy cover and host plant abundance of this location was high, this area was much less likely to be exposed to predators. Overall, a clear difference can be seen in the abundance of Tirumala hamata and Euploea core Butterflies at the two locations and further research should be undertaken on the diversity of butterflies at each site to better understand the preventative measures that need to be taken in order to protect Australia's native pollinators.

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