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Calling Behaviour in the northern Queensland subpopulation of Petaurus australis

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Calling Behaviour in the northern Queensland subpopulation of *Petaurus australis*

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Abstract

Vocalizations are a common form of inter- and intraspecies communication for mammals. Yellow-bellied Gliders, *Petaurus australis*, are the most vocal of the Australian Gliders emitting low frequency calls at high intensities. I explored the frequency of calls in relation to season, temperature and humidity, as well as the behavioral context in which the calls were emitted. Along with my field crew, I observed current feed and den trees for gliders during their most active time, dusk. Observations were performed over the course of two years during the wet and dry seasons, for a total of four observation seasons. I found a significantly higher mean call frequency during the dry season than the wet season. I determined that temperature has no apparent relationship to call frequency; however, humidity is positively correlated with call frequency. One call type was distinguished during this study, the full call. It was determined to be used for a number of purposes by the gliders, including cohesive group traveling and to defend food resources of a home range from gliders of other species. This study suggests that with an understanding of glider vocalizations, they can be used as a time and energy efficient method to monitor and survey populations.

Keywords: *Peaturus australis,* Yellow-bellied Glider, Fluffy Glider, vocalizations, conservation, behaviour, calling, humidity, temperature, seasonality, northern Queensland

Introduction

In order to develop effective conservation management plans, there are certain characteristics of a species which must be known. Some of these characteristics are the habitat requirements such as food and shelter and the population size of the species in question. However, during recent years it has become apparent that the knowledge of behavioural aspects of a species can greatly contribute to its conservation (Buchholz, 2007). Without knowing these basic characteristics it is nearly impossible to design a comprehensive management strategy to ensure the population's survival.

Knowledge on inter and intraspecific communication is one behavioural aspect that can assist in conservation efforts. Communication is defined as the sending or transfer of information from one individual to another individual or group of individuals that affects the current or future behaviour of the receiver(s) (Pearce, 2008). There are many forms of communication used by organisms including vocal and chemical. Both of these forms of communication are used for both inter and intra species communication (Pearce, 2008). Vocalizations occur at many different frequencies and are not limited to only those that humans can hear.

Yellow-bellied gliders (YBG), *Petaurus australis* are a nocturnal glider species endemic to Australia. These marsupials are found in high elevation areas on the eastern coast of Australia. Yellow bellied gliders occur intermittently throughout the mature eucalyptus forests of Queensland, New South Wales and Victoria (Brown, 2006). The main food source for YBGs is the sap of trees which is rich in carbohydrates (Blume et al., 1999). YBG home ranges have been found to be anywhere from 25ha to 85ha (Brown, 2006). YBGs are social animals which live in family groups of up to 6 members and communicate with each other using vocalizations (Winter, 1997). They are extremely mobile creatures, which makes mapping and the understanding of their home ranges challenging. These family groups are territorial with each family residing in different areas of the forest and using different feed trees.

The cuts made by YBGs extrude sap even when the YBGs are not feeding from them. This provides a food source for many other organisms such as Sugar and Feather-tailed gliders, bats, insects and honeyeater species (Russell, 1981). It is believed that there is temporal niche partitioning of the three species of gliders pertaining to the use of the feed cuts (Jacobs, 2012). YBG have been observed to display aggressive behaviour towards intruding YBG gliders and other glider species (Russel, 1984; Russell, 1981; Jacobs, 2012).

There are many subpopulations of YBGs on the eastern coast of Australia including the subpopulation in Far North Queensland, where my study took place. This particular area of Australia is characterized by its wet and dry seasons due to the relative stability of the temperature and seasonal fluctuation of rainfall (Kottek et al., 2006). The wet season is characterized by high humidity and relatively warm temperatures, while the dry season is characterized by low humidity and relatively lower temperatures (Australian Government, 2015). Along with the genetic differences between the northern and southern yellow-bellied glider populations, behavioural differences have also been found between the northern and southern populations of YBGs. It is understood that the northern subpopulation of gliders has been isolated for hundreds of thousands of years possibly resulting in a genetically distinct group of gliders (Brown et al., 2006).

The northern sub-population of YBGs are found in a band of wet sclerophyll forests neighboring the World Heritage Area where they use certain trees for denning during the days and for feeding on sap at night (Winter, 1997). The YBGs in this region eat the sap of only one species of tree, *Eucalyptus resinifera*, and only use, *Eucalyptus grandis*, as den trees (Winter, 1997). When available, YBGs supplement their sap intake with flowers, pollen and macro invertebrates. In the wet season these gliders use all of the above available food sources however in the dry months the gliders are much more dependent on the sap trees for nourishment (Smith and Russell, 1982).

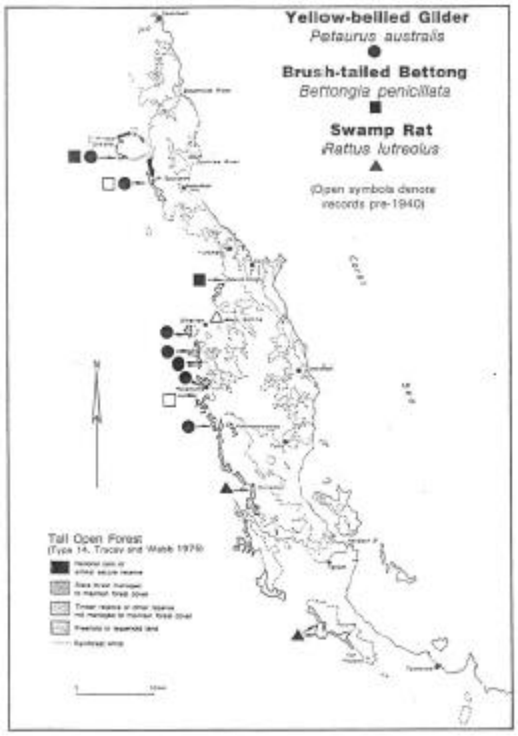

Figure 1: Known distribution of Yellow-bellied glider in North Queensland(Winter, 1997).

There is still much to learn about inter and intraspecies communication of these marsupials. The calls of Yellow-bellied gliders are believed to be influenced by food availability, time of day and mating season (Kavangh and Rohan-Jones, 1982). YBG are one of the most vocal of the Australian marsupials, using serval loud calls which can be heard by humans up to a distance of 400m (Kavangh and Rohan-Jones, 1982). Besides the distinction of about 15 vocal calls, there has not been much further research into the use and purpose of these calls in this northern sub-population (Russell, 1984). Vocalizations are used to communicate throughout and possibly beyond the gliders home range. The northern population has home ranges as small as 2ha but most home ranges are about 30 ha in size (Goldingay et al., 2001; Russell, 1984). It has been proposed that the yellow-bellied gliders of this region use vocalizations for territorial purposes similar to their southern counterparts (Clafiore, 2014; Goldingay, 1994). It has also been considered that calling also serves the function of allowing gliders to travel in pairs or groups to different food sources (Goldingay, 1994; Kavangh and Rohan-Jones, 1982; Clafiore, 2014).

The purpose of my study is to further understand the calling behaviour of the northern subpopulation of yellow-bellied gliders. By understanding the purpose behind different glider calls it is possible to quantify glider activity without visual observation. Visual observation has proven difficult to achieve with gliders because they often have more than one active feed tree or food sources (Winter, 1997). I predicted that there would be a higher nightly call frequency in the wet season than in the dry season due to food availability. An increase in available food may lead to more food associated calls and territorial calls. This could be the reason for the change in season call frequency observed in past studies of the area (Clafiore, 2014; Russell, 1984). I also predicted a correlation between call frequency and temperature and call frequency and humidity. By understanding the purpose of the glider calls it would be possible to use the calls as a non-invasive recognition method to determine population size. This could then be used to more efficiently map family territories and the areas of the forest that are of high priority for conservation efforts.

Methods

Study Site

The sites I used to conduct the study were within the Tumoulin Forest, near Ravenshoe, QLD, (17˚35.733'S to 17˚35.419'S, 145˚28.264' to 145˚29.374'E) and Gilbey Creek Catchment of Bluff Forest Reserve, near Herberton, QLD, (17° 27' 35.5''S, 145° 27' 17.6''E). Three of these sites were Robinson Creek, Sawmill Gully and a Conservation Area. The fourth site was at the Gilbey Creek Catchment. Both of these forests are Wet Sclerophyll forests, formerly characterized as "very tall open woodland" (Type 14, Wells et al., 1982). I selected these areas because it is known that gliders reside in these forests, which feed trees are of active status along with some active den trees because of an ongoing study of the Yellow-bellied Glider habitat authorized by the Environmental Heritage and Protection agency as part of its community yellow-bellied glider project overseen by Dr. John Winter.

Data Collection

The observations were carried out over the course of two wet seasons, April 2014 and 2015, and two dry seasons, November 2012 and 2013. The observation period for each of the trees during both wet season and November 2013 was 2 hours long beginning at 18:30 and ending at 20:30. The observations of November 2012 were full night long surveys beginning at 18:30 and ending at 5:30 the next day. Therefore, I only included the first two hours of observations in my data analysis.

For the duration of the observation period there were 2-4 people stationed around a tree at various vantage points. This was to allow the entirety of the tree trunk to be observed with little movement by the observers. Groups of observers hung a Nielsen Kellerman Kestrel 300 from the tree to monitor the humidity and temperature. One observer recorded the temperature and humidity every 30 minutes beginning at 18:30. Each observer stationed around the tree would record the time and direction of occurrence for each call heard. If the glider was in visible to the observers then they would record the glider's activity at the time of the call. We used torches with red light filters to observe the glider's activities. A Sony Stereo IC ICD-UX533F audio recorder was used at each tree to record the entirety of the observation period's noises for further review. It was also asked that the observers take note of any other animals present on the observed tree during the observation period. If these animals were species of gliders other than YBGs, their behaviours were also recorded on the observation sheet.

Data Analysis

I compiled the data for the April 2015 season along with the data from the past years into a master data sheet. The calls per night were compiled by taking the date, time, tree and direction the call was heard from and cross referenced against calls made on the same night in the same location. If calls were found to be coming from a similar location within 2 minutes of each other and recorded on separate data sheets then the call was only counted once. This was done to ensure that calls were not counted more than once in a night.

The calls were then counted for each night. A t-test was used to compare the nightly call frequency between the dry season nights and wet season nights. In order to see if temperature or humidity possibly influence call frequency, each call was allocated to a certain temperature and humidity. The temperature and humidity used to classify each of the calls was based on what time the call occurred. If the call was heard from more than one tree, an average of the temperature and humidity measurements taken from the trees from which the call was heard was used. We used a regression analysis determine the presence of a relationship between call frequency and temperature and humidity respectively.

The calls that occurred at tree F064 in the Robinson Creek area of the Tumoulin Forest were looked at further for the behavioural context of the calls. The calls from the nights of April 10^{th}, 11^{th}, 13^{th} and 14^{th} of 2015 were analyzed because these were nights when both visual and auditory observations of the gliders occurred. The call types were determined along with the glider's behaviour at the time preceding the call, at the time of the call and immediately following the call. Interactions with other animals including the other animal's reactions to the YBG calls were also analyzed. From this data the frequency of each of the behaviours congruent with the YBG call were calculated as a percent. All analysis was done using Microsoft Excel.

Results

Call frequency in relation to season, temperature and humidity

The mean nightly call frequency in the wet season was 4.95, while the dry season's mean nightly call frequency was 12.75 (Fig. 2). There was a significantly greater number of calls in the dry season than in the wet season (p=0.025, t= 0.024, df=22).

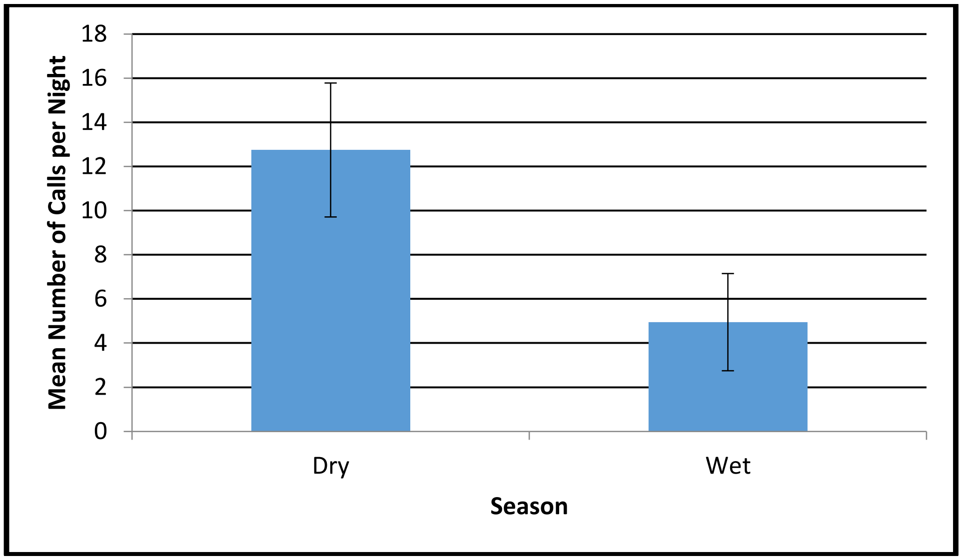

Figure 2: The average number of calls per night during the two seasons, wet and dry.

There was no significant relationship between temperature and call frequency during the observation period for data from the two wet season and the two dry seasons (R=0.05, R^2=0.0024, df=64, F=0.70, p=0.224, Fig. 3).

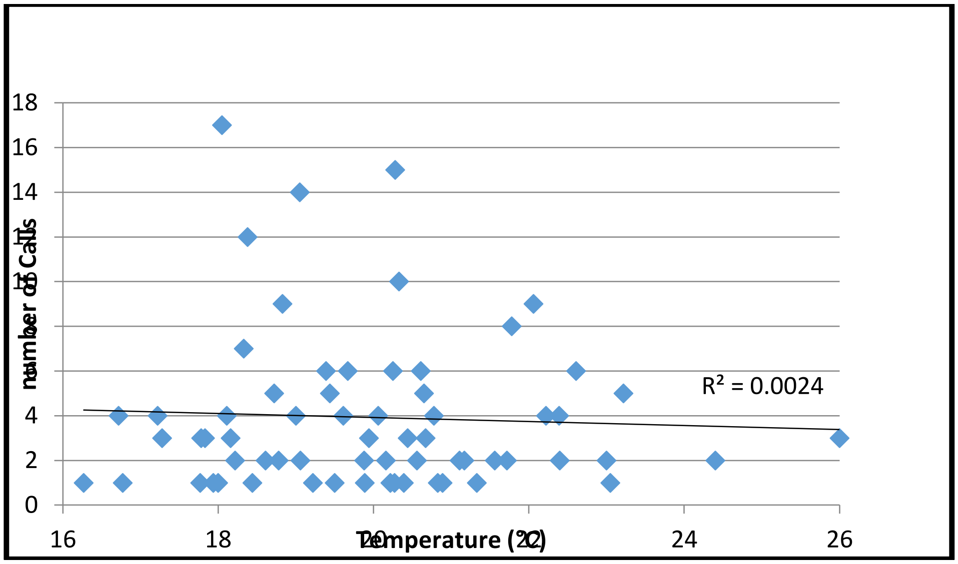

Figure 3: The relationship between temperature (°C) and call frequency for both of the observed seasons.

There was a significant positive relationship between humidity and call frequency during the observation period for data from the two wet season and the two dry seasons (R=0.44, R^2=0.193, df= 39 F=9.11, p=0.005, Fig. 4).

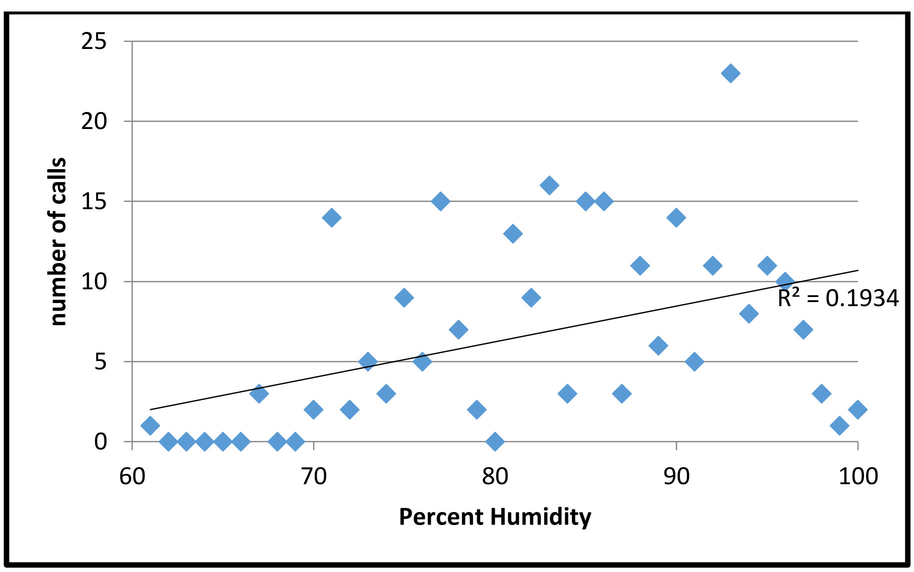

Figure 4: The relationship between percent humidity and the call frequency for both of the observed seasons.

Behavioural context of calls

The vocalizations and connected behaviours of yellow-bellied gliders observed on Feed tree 64 of Tumoulin forest are displayed in Table 1 over a series of their most active nights. The temperature for each of these nights began warm and then continued to drop lower as the night continued on. The percent humidity for each of the nights was at least 90%.

The gliders displayed what has been named as a “full call” by Rupert Russell (1984) along with some shortened versions of the full call, making up just over 95% of the heard calls. Of the full calls that were visually observed 28.57% occurred upon a glider landing upon a new tree. 63.41% of the calls heard occurred during an interaction between two or more gliders, when one glider would call and successively (up to 2 mins later) another glider would answer. The full call was used in all of the observed call and answer situations between two or more gliders.

More calling occurred during the nights when two yellow-bellied gliders were observed on the feed tree. On these nights the gliders called most frequently when gliding to and from the tree. For example during the observation on April 13th, 2015 at tree F064 glider 1 landed upon the tree and called. Shortly after, another glider arrived to the tree to also feed (glider 2). Upon glider 1’s departure a call was heard from the direction of the departure, glider 2 called from the tree. In a similar way, when glider 1 called glider 2 departed in the direction of the glider 1’s call. Two more calls were heard one after another at a point east and distant from the feed tree almost 10 minutes after the glider 2’s departure.

Interactions between YBG and other gliders

Of the two nights that only one YBG appeared on the tree, vocalizations were only heard during one of these nights. The night of April 11th, 2015 the YBG chased the sugar glider from the tree using a vocalization. The YBG, upon climbing out onto the edge of the branch, was alerted to the presence of the sugar glider and called. The YBG leapt from the tree branch before the call terminated and glided down to where the sugar glider was eating sap from a cut in the tree. Upon hearing the call, the sugar glider left the tree, leaving just before the YBG landed on the tree trunk. Shortly after the Sugar Glider was observed gliding from a tree neighbouring the feed tree to a tree further into the forest. No sugar gliders returned to the feed tree for the duration of the observation period after this incident.

The sugar gliders left the tree when YBGs arrived on two of the nights. On one of the nights a sugar glider returned after the YBGs left and remained there for approximately 20 minutes before leaving on its own accord. On April 10th, 2015 the sugar glider did not arrive to the feed tree until after the YBGs left the tree for the remainder of the observation period.

Table 1: Summary of observations at tree F064 in Tumoulin forest.

Date (dd/mm/yyyy)	# of YBG on tree	Number of Calls	Type of calls	Other Gliders	Feeding	Interactions	Other observations
10/4/2015	2	22	Full calls and abbreviated full calls	Sugar Glider	Yes	2 Gliders calling to each other	YBG calls from tree; sugar glider arrives after YBGs leave
11/4/2015	1	5	Full calls and Clicking call	Sugar Glider	Yes	Chased sugar glider off of the tree	YBG calls from tree
13/4/2015	2	10	Full calls and abbreviated full calls	Sugar Glider	Yes	2 Gliders call to each other; the sugar glider leaves	YBG calls from tree; sugar glider

						upon YBG arrival	returns after YBGs leave
14/4/2015	1	2	Full calls	Sugar Glider	Yes	Sugar glider leaves upon YBG arrival;	Glider does not call from tree

Discussion

The purpose of yellow-bellied glider vocalizations is largely unknown. It is believed that they serve the purpose of both inter- and intraspecies communication as is the case in other marsupials (Kavanagh and Rohan-Jones, 1982). This study aimed at exploring the frequency of calls in relation to weather and season as well as the behavioural context in which the calls were emitted. Upon conclusion of the study I found that there is a greater mean nightly call frequency in the dry season than in the wet season, rejecting my original null hypothesis that there would be a higher mean nightly call frequency in the wet season than in the dry season. I have found that there is no relationship between the temperature and the frequency of calls of this subspecies of yellow-bellied gliders; therefore rejecting my original hypothesis that there would be an increase in calling behaviour with an increase in temperature. There was, however, a positive relationship between percent humidity and frequency of calls of this subspecies of yellow-bellied gliders; supporting my original hypothesis.

The seasonality of the nightly call frequency has been proposed to relate to food availability and variability. Many plants flower during the wet season as they are under less water stress than in the dry season when water is scarce (Barbour et al., 1987). Many eucalypts in the wet sclerophyll flower during the wet season for this reason (Brooker and Kleining, 1994). The flowers also attract arthropods to the area, which provides another alternate food source for the gliders. This provides high protein food resources for the gliders. The abundance of food would mean an increase in the threshold for territorial behaviour displays. As calls are often used in territorial behaviour this would decrease the number of calls displayed in an area (Goldingay, 1994). In the dry season there are less flowers and arthropods readily available as alternative food sources, decreasing the threshold for territorial behaviour resulting in the increase of calling frequency. The seasonal changes in food availability could explain the results that there is a lower frequency of nightly calls during the wet season when there is an abundance of food as compared to the dry season when food is much more limited.

High levels of vocalization in the dry season could also be a result of the presence of young in the mother’s pouch. Most births occur in August –April (Lee and Cockburn, 1985) in YBG in North Queensland, however pouch young are found year round (Russell, 1984). The increase in vocalizations during the dry season could be related to the presence of new gliders in the family. Based on observations a function of the full call would be group-cohesion while traveling from one location with food to the next. An increase in call frequency during the young’s dependent stage would allow the young to become familiar with the calls of its family group. This would also assist in familiarizing young gliders with the forest so that once the young gliders begin to forage on their own they would be able to recognize calls from their family members and successfully traverse to food sources. This learned behaviour has yet to be studied in gliders however bats have been found to have a period when they are pups during which they learn colony specific calls for group cohesion (Knornschild et al., 2012). This critical learning period has also been found in a number of other mammals and birds and without it the young are not able to produce their species’ vocalizations (Nottebhom, 1972). During a study where glider calls were played in different home ranges, the gliders of that home range arrived to the location of the call. If a glider call was played in its own home range, there was no response, indicating that gliders are able to differentiate individuals by their calls (Kavanagh and Rohan-Jones, 1982).

The positive relationship between humidity and call frequency could be attributed to the physics of sound travel. Sound waves are longitudinal waves meaning that they need a medium to travel through (Wiley and Richards, 1978). In high humidity environments the sound wave lose energy faster and become more scattered than in low humidity environments due to large number of dense water molecules present in the air. Due to increased loss of energy and large amount of scattering, sound does not travel as far through humid air as through dry air (Wiley and Richards, 1978). Therefore, a glider's call will travel farther and more clearly in low humidity than in high humidity. Gliders do not have to call as frequently during low humidity circumstances as they need to call in high humidity conditions in order for their message to be received. In terms of conserving energy it would be maladaptive for gliders to call at a greater frequency than necessary during the low humidity conditions resulting in a lower call frequency than in high humidity conditions. YBG calls have been analysed in New South Wales at the frequency level. It was suggested by these studies that the low frequency calls, 700-6,500 Hz, remain more intact and undergo less scatter during transmission than high frequency calls would undergo (Kavanagh and Rohan-Jones, 1982). It would therefore be more adaptive for gliders to use these more reliable low frequency calls during high humidity weather than it would to use other forms of communication.

Temperature and humidity were tested because the major biomes of the earth are often defined by their climates. The wet tropics are defined by having a relatively stable temperature throughout the year with a larger fluctuation in the moisture level resulting in the dry and wet seasons (Kavanagh and

Rohan-Jones, 1982). This would explain why there was no effect on call frequency in relation to temperature but there was an effect in relation to humidity. Plants and animals often have biological cues in relation to the climates in which they live in order to indicate when to migrate, breed and hibernate, creating the animal's Circadian Rhythm (Sharma and Chandrashekaran, 2005). It would therefore be logical in a place where temperature remains relatively stable throughout the year that another less stable factor would provide the biological cues for plants and animals, such as humidity. Humidity levels have also been known to be biological cues for other organisms such as fungi and insects (Sharma and Chandrashekaran, 2005). Humidity is used by animals such as the Common Lizard, *Lacerta vivipara*, as a biological cue for dispersal (Massot et al., 2002).

Based on the context in which the calls I observed were emitted, my findings support past speculation that a high call frequency in the dry season would be based on the availability of food and the necessity of gliders to navigate to and from the food source. It was concluded in past studies of southern YBG that the calling behaviour of the gliders is also used while traveling through the forest to indicate their presence, current location and intention to move to another tree, which is concurred by my study (Kavanagh and Rohan-Jones, 1982). This has been observed in a number of arboreal fauna including Talapoin monkeys, *Miopithecus talapoin* (Gautier, 1974). It has been determined that gliders use scent as an identification tool (Russell, 1984), however a call would be much more reliable when traveling long distances in a pair or group than a scent. It is known that glider calls can be heard for up to 400m by humans and perceivably much farther by gliders themselves, while scent based identification by the gliders has only been observed when the gliders are near each other (Brown, 2006).

The pairs of gliders which were seen on trees would often have a call and response method as they travelled between trees. The full call as described by Rupert Russell was the call most commonly used during these situations (Russell, 1984). Further study would need to be carried out in this area in order to provide evidence for the specific purpose of this call. There have been studies in arboreal primates that have shown the existence of calls, commonly called contact calls, used to keep group cohesion and limit dispersion during foraging (Palombit, 1992). Besides the scent marking behaviour, very few non-vocal communication methods have been studied in yellow-bellied gliders. These areas would both need to be researched in order to support any hypothesis made here.

There was one occurrence of the full call as a form of interspecies communication with a sugar glider. This was when the YBG chased the sugar glider from the tree. Past studies have observed aggressive behaviour by yellow bellied gliders in response to feather tailed gliders being present on feed trees at the same time (Jacobs, 2012). The aggressive behaviour displayed by the YBG is most likely due to the competition of these species that occurs due to the overlap in their need to feed on sap. The reaction of the sugar glider leads me to believe that sugar gliders may have adapted to react the calls of the YBG to avoid injury, as YBGs have been shown to physically harm and predate their competitors (Jacobs, 2012). Sugar gliders may have also adapted to use the intraspecific communication system of the YBG to avoid being on a feed tree at the same time as them. This is supported by the results, as twice sugar gliders arrived at feed trees only after YBGs left the tree for the night.

According to the relationship between humidity and call frequency the wet season should have a higher mean nightly call frequency than the dry season however this is not congruent with the results of this study. The results of this study are contradictory; however, this past wet season 2015 was a relatively dry wet season. According to the Australian Bureau of Meteorology website on average the Tumoulin forest experiences 140.86mm of rain in the month of April but this season only experienced 64mm (Australian Government: Bureau of Meteorology, 2015). The observation period may have not fully represented a “typical” wet or dry season which would explain why the seasonal data conflicted with the positive relationship between call frequency and humidity. Ill represented seasonality could also affect further studies as we are unsure how this delicate climatic area will be affected by climate change.

There are a few limitations that come with doing an observational study. One of the biggest limitations is the seasonal climate. There is no way to predict if your observation time will represent the "typical" seasonality expected of the observation period. This can only be accounted for with more observation periods in different years and throughout the season in order to obtain a representative sample. The weather was also a limitation in terms of conducting the regressions because some temperatures and humidity had more sample sizes than others. The only way to account for this is to conduct observations throughout the year in order to sample a more complete range of temperatures and humidity percentages. The last limitation was the difficulties that come with observing gliders while they are calling. In order to determine a call's purpose you must observe the behaviour of the glider as it is making the call. This visual observation is more often luck than not but your chances can be increased by stationing yourself around known congregation points like feed and den trees.

This study would need to be expanded by further seasons in order for a full conclusion to be drawn from the data. It would be beneficial for this study to be repeated in the future after more data has been collected. It would also be beneficial to perform observations at a larger sample size of trees in what is believed to be different home ranges of YBGs in order to get a better representation of the population as a whole. In order for a more accurate identification of call better audio equipment would be needed to pick up subtle sounds instead of only the louder full calls. This study would also benefit from a large sample size in the future to account for the abnormal climatic seasons experienced in past years.

There are opportunities for future research stemming from this study. A long term study is needed to understand the specific functions of calls within this population of YBG. It would also be interesting to record the calls using a frequency analyser similar to the study done by Kavanagh and Rohan-Jones (1982) in New South Wales. This would be useful in determining if there are any ultrasonic vocalizations used by gliders. It would also be beneficial in determining whether or not calls could be used to determine individual gliders in a non-intrusive manner. Currently there are no ways to determine individual gliders without catching them and tagging them which is extremely intrusive.

By determining call purpose glider activity could be studied without the necessity of visual observation. One of the greatest limitations in any glider population survey is the unpredictability of glider movement. It is much harder to see a glider than it is to hear a glider. The vocalizations of Cron crakes are used to identify individuals instead of visual recognition due to the shy nature of the bird (Caro, 2007). A similar method could be used to preform population surveys of YBGs without the necessity to mark and capture the animals. Visual observation of gliders is often extremely difficult and time consuming. Vocalizations, however, can be heard at great distances and are much easier to hear during an observation period than actually witnessing a glider. Past studies have also had trouble spotting gliders and trapping gliders for tagging and/or radio collaring (Blume et al., 1999; Goldingay et al., 2001).

Vocalizations could also be used to map home ranges of the different glider families. The area that this sub-population lives in is currently under consideration to be reopened to logging and grazing. For this reason, a definite understanding of the resources and space required by the gliders is important. With this information, glider areas could be kept safe from the unknown influence of logging and cattle grazing. A conservation management plan needs a spatial scale to be successful, and vocalizations have to potential to provide that spatial scale.

Many of the earth’s ecosystems are under threat of being lost due to logging and agriculture. The wet sclerophyll areas that Queensland YBGs call home is no exception. This area needs to be protected for its unique fauna and flora many of which are endemic to Australia. By protecting the YBG this area would also in turn be protected. The integration of behaviour in terms of YBG vocalizations has the potential to be beneficial when designing conservation management plans to ensure the survival of the species.

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