Patterns of Foraging Behaviour of the Black-throated Finch during Breeding Season

Thesis Submitted By:

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ABSTRACT

Black-throated finches are granivorous birds that feed primarily on seeding grasses. The Black-throated finch *Poephila cincta cincta* is listed as Endangered and has suffered a dramatic decline from almost two thirds of its former range (BTFRT, 2004). Substantial declines and range contraction in recent years are thought to be from development of pastoralism and clearance of vegetation, with other possible reasons for this decline including alteration of fire regimes, invasion by exotic weeds and predation.

How the threatened species of Black-throated finch *Poephila cincta cincta*, uses the landscape to forage during the breeding season (occurring from February until August) both temporally and spatially, was studied at two sites in North Queensland within the catchment area of the Ross River Dam between May and August 2006. During the breeding season the finches are most active, but spatially restricted in their ability to forage due to the dependence of the chicks on the parents for survival. This study reveals how finches forage in relation to their nesting sites and what fine scale attributes influence where the finches forage.

During the breeding season the Black-throated finches at both sites spent the majority of their time during the day foraging and this remained relatively consistent for the duration of the study. The pairs of finches that were studied remained between 0m -350m from their respective nests and generally foraged no longer than 50 minutes. The colony of finches that were studied remained between 0m-250m from the central feature and also usually spent no longer than 50 minutes foraging at any one site. Both the pairs and colony of finches were active for the entire day. The pairs of finches used a total mean foraging area of 2.33 hectares and each pair showed similar variability in foraging behaviour, whereas the colony of finches studied used a total mean foraging area of 4.4 hectares. All finches were found to very clustered in terms of distribution. Particular grasses were found to be favoured by the finches and others avoided. Grasses such as *Alloteropsis cimicina, Chloris sp.* and *Urochloa mosambicenis* were grasses that were strongly favoured and *Heteropogon contortus, Themeda triandra* and *Aristida sp.* were grass species that were avoided.

The conservation significance of this research is that this data collection will allow better knowledge to be gained about the optimal area that is required to maintain a healthy breeding population of Black-throated finch. This study will contribute significantly to knowledge that can be used to better design conservation strategies to manage this endangered bird into the future.

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Chapter 1: General Introduction

1.1 Finch Status

There has been a major decline in many species of granivorous birds over much of Northern Australia in the last few decades (Garnett. et al, 2005). In the wet-dry tropics several species of finch in particular are under threat. The eastern subspecies of Star finch *Neochmia ruficauda ruficauda* has experienced a dramatic decline, with the last reliable sighting being at least 20 years ago. It is suggested that the finch is possibly already extinct (Garnett, 1993). *Neochmia ruficauda clarescens*, the northern subspecies of Star finch is listed as endangered and has suffered a similar decline to *N.r.ruficauda* (Garnett & Crowley, 2000). The subspecies of Crimson finch *Neochmia phaeton evangelinae* is also listed as endangered. They have experienced range contraction and are now restricted to the east coast of Cape York Peninsula (Garnett & Crowley, 2000). The Yellow rumped mannikin *Lonchura flaviprymna* and the Beautiful firetail *Stagonopleura bella* are both uncommon with limited distribution (Blakers. et al, 1984). *Lonchura flaviprymna* is restricted to the eastern Kimberley and north-western Northern Territory, whereas Beautiful firetails are restricted to the coast of south-eastern Australia (Blakers. et al, 1984; Barrett. et al, 2003). The finch that has received the most recent attention though due to its rapid decline is the Gouldian finch *Erythura gouldiae*. Although this finch has also been the most intensely studied, the reason for its decline remains unclear (Tidemann, 1993).

Black-throated finches are granivorous birds that feed primarily on seeding grasses. There are two subspecies of Black-throated finch, the northern subspecies (*Poephila cincta atropygialis*) and the southern subspecies (*Poephila cincta cincta*). The Black-throated finch *Poephila cincta cincta* is listed as Endangered and has suffered a dramatic decline from almost two thirds of its former range (BTFRT, 2004). The southern subspecies of the Black-throated finch (*Poephila cincta cincta*) historically occurred from north-eastern New South Wales to Queensland's Atherton Tablelands and west to the Longreach region of Central Queensland. It is now believed to be confined to the northern part of its former range. Substantial declines and range contraction in recent years are thought to be from development of pastoralism and clearance of vegetation, with other possible reasons for this decline including alteration of fire regimes, invasion by exotic weeds and predation. Furthermore, an analysis of historical records suggests that this decline is continuing (Figure 1.1) (Franklin, 1999; BTFRT, 2004). However, the relative importance of each of these threats is currently unknown, as our knowledge of the foraging ecology of finches is limited, especially with regard to the Black-throated finch.

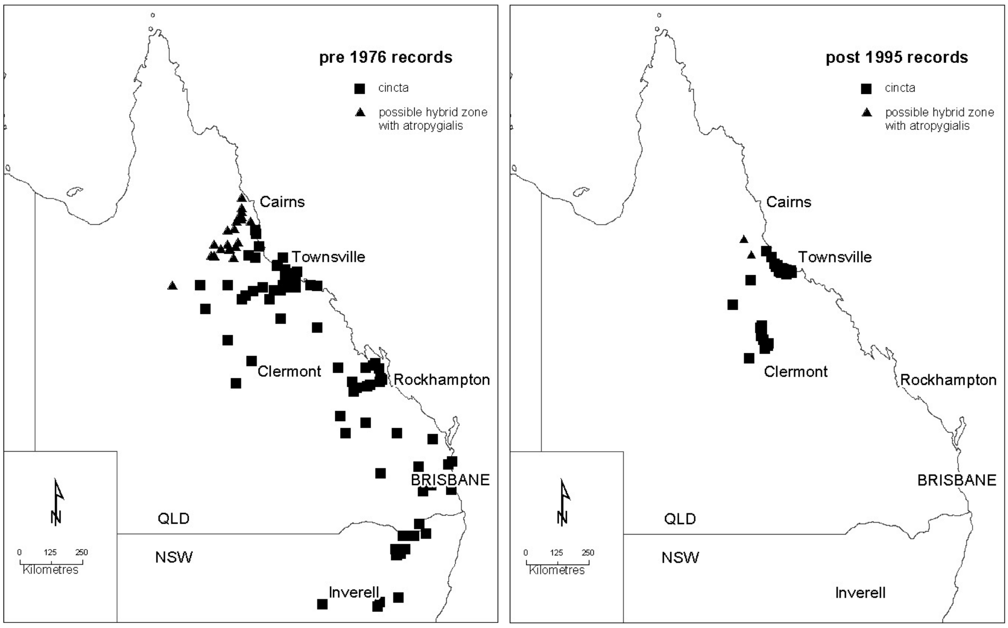


Figure 1.1. Black-Throated Finch occurrences pre 1976 and post 1995 (BTFRT, 2004).

1.2 Current Knowledge of Black-throated finch Ecology and Threatening Processes

Black-throated finches are restricted by availability of suitable seeding grasses and distance to water (Buosi, 2005). Their habitat preference is thought to be grassy woodlands that are mainly dominated by *Eucalyptus* spp., *Melaleuca* spp. and *Acacia* spp., although specific requirements and preferences require further investigation (BTFRT, 2004). Mitchell (1996) conducted the first major research into the Black-throated finch which involved monitoring how these finches use resources with different energy levels to survive and reproduce in North Queensland. This study is of significance as it contributes to the conservation ecology of how granivorous birds respond behaviourally to natural fluctuations in food availability. The food abundance and foraging effort in natural surroundings was examined Mitchell's study. Mitchell

(1996) found that the most critical time for the finch was at the beginning of the wet season when rainfall induces grass seed to germinate and food thus becomes a limiting factor. This was supported by observations made by Mitchell of the finches diversifying their diet and foraging manoeuvres after increased rainfall, a pattern consistent with a reduction in food availability according to the optimal foraging theory (Krebs *et al.* 1983; Pyke *et al.,* 1977; Mitchell, 1996).

A study conducted by Zann (1976) on the distribution, status and breeding of Northern subspecies Black-throated finches in Northern Queensland was one of the first studies to shed light on the biology of a closely related finch. Zann documented that Black-throated finches tended to occur primarily in dry open woodlands dominated by eucalypts, paperbarks or acacias. Nesting and feeding areas were characterised by open woodlands, seeding grasses and were located within approximately 400 metres (n=11) of a water source. These were the common features of all Black-throated finch habitats surveyed by Zann. A study by Buosi (2005) on the southern subspecies of Black-throated finch further supports the theory that the average distance to permanent water was 400m. The same study also suggests that finch's possible return to relatively the same area every breeding season although re-using specific nests and nesting hollows is rare. Tidemann *et al* (1999) studied the breeding biology of Gouldian finch and documented similar findings. Many Gouldian finches exhibited fidelity to their breeding area and in some cases nesting hollows. Black-throated finches monitored in this study are thought to have strong breeding site fidelity. The majority of what we know on the Black-throated finch is based on ecological studies by Zann on the northern sub-species of Black-throated finch in Mareeba and Mitchell and Buosi on the southern sub-species in Townsville.

There are many theories on general decline in granivorous birds and much speculation as to what has caused this dramatic decline in the Black-throated finch population, but it is not known for sure what the exact threats and subsequent management issues are. Although the last major study conducted on this bird was by Mitchell in 1996 there is still little known about the foraging behaviour and range and spatial patterns of habitat use which is critical to the managing and recovery of this species of finch (BTFRT, 2004). There is almost no information on wild Black-throated finches relating to adaptations to changing habitat composition or other methods they employ to survive through both the breeding and non-breeding season. Research therefore needs to focus on gaining a better understanding of the Black-throated finch breeding ecology and identifying optimal areas and resources required to maintain healthy breeding populations of the finch. This will help in the conservation of the finch by determining the factors affecting breeding success and feeding requirements and assisting in the identification of habitat characteristics that provide for the definition of Critical Habitat (BTFRT, 2004). Once critical habitat for the finch is identified, further action can be taken to manage the finer detail such as feeding and dietary requirements in relation to vegetation structure, exotic grasses, fire, stock grazing and rainfall. The area required for foraging during breeding season, and how the finches use the landscape during foraging, are also important factors in ensuring the survival of the Black-throated finch and other similarly endangered species.

A study on the decline of avifauna including the Black-throated finch carried out by Woinarski and Caterral (2004) on Coomooboolaroo, a property located in Central Queensland illustrate the reality of several of these threats. In this instance, a number of environmental changes appear to have coincided, caused significant alteration to the existing landscape. These include: fire exclusion/cessation; increased stocking rates; drought; periodic feral animal outbreaks; ring-barking of trees; clearing of brigalow and subsequent introduction of exotic pasture grasses and the degradation of watercourses. The study concluded that the negative effects from these habitat alterations were more likely to impact upon small-bodied birds, particularly those dependent on grassy habitats such as the Black-throated finch. The study also proposes that the processes experienced on the property of Coomooboolaroo are likely to be widespread, effecting much of the northern Australian savannas.

1.3 Foraging Behaviour During Breeding Season

Foraging Range

Unpublished observations suggest that the Black-throated finch forages in close proximity to the nesting site during breeding season, when resources are plentiful and adults have dependent young, and gradually range further during the non-breeding season when resource availability decreases and young become more mobile (Buosi

2006, *pers. comm.*). These observations will be formally tested and quantified as part of the current study. This type of foraging behaviour can be contrasted to the cost of foraging model. This behavioural theory puts forward the concept that the forager must assess the costs and benefits of foraging to not only maximise their net energy intake but to reduce the level of risk to obtain that energy (Emlen, 1966; MacArthur & Pianka, 1966; Pyke, 1984). A study conducted by Field and Anderson (2004) on the habitat use by breeding Tree sparrows *Passer montanus* revealed that provisioning (parents that are feeding young) Tree sparrows rarely flew more than 300 metres to forage. This supported their idea that the availability of food resources is the principal factor influencing Tree sparrow breeding distribution. In common with the Black-throated finch, the Tree sparrows are known to be reasonably sedentary during breeding season, moving only small distances to forage, although they are capable of moving much larger distances on a regular basis (which they usually do during non-breeding season).

This pattern is often found through a broader range of taxa. Weavers' (1992) study on the seasonal foraging ranges and travels at sea of Little penguins *Eudyptula minor* using radio-tracking illustrates similar foraging behavioural patterns as the Tree sparrows during the breeding and non-breeding seasons. During the breeding season when resources were abundant, radio-tagged penguins exclusively made short-term trips to forage. However, throughout the rest of the year when penguins were not breeding they went on long-term foraging trips more frequently, most likely due to the scarcity of resources in the immediate area (Hobday, 1992). Similarly, a study on the foraging distances and home range of pregnant and lactating Brown bats *Myotis lucifugus* (Henry et al. 2002) found that during nursing, foraging activity was concentrated around the colonies. This is thought to be due to constraints imposed by time required to feed young, which directly reduces the time that female bats can allocate to commuting to distant feeding sites. This lactation is usually synchronised with the mid-summer rise in the abundance of insects, therefore there would be more costs involved in foraging at locations further away. Black-throated finches also synchronise their breeding to coincide with the availability of the highest abundance of seed which is usually between September and May. The finches are known to breed all year round; peak breeding in Townsville is usually between February/March and May. At this time pairs of adults are thought to forage in a small, concentrated area close to the nest (P Buosi 2006, *pers. comm.,* 16 May; Zann, 1976).

Similarly, Common terns are also considered central place foragers during breeding season. Bugoni (2005) carried out radio-telemetry to study the feeding grounds, daily foraging activities and movements of Common terns *Sterna hirundo* in Southern Brazil. This central place foraging is influenced by the need for the *S.hirundo* to provision their chicks at the breeding site. A study carried out by Huin (2002) on the foraging distribution of the Black-browed albatross *Thalassarche melanophris*, breeding in the Falkland Islands found that nearing the end of the incubation period, birds began reducing the duration of their foraging trips. Both Huin's study and another similar study conducted by Brothers *et al* (1998) on the foraging movements of the Shy albatross *Diomedea cauta* breeding in Australia found that both species were more likely to stay close to their breeding colony during the breeding period. It makes sense for both species to stay close to their breeding colonies as there is more possibility of rapid responses to changes in vegetation composition which can result in more efficient foraging and greater chances of survival. It may be hypothisised that Black-throated finches should also forage close to their breeding colony and return to a number of the same foraging locations to increase foraging response and efficiency.

Patterns of Movement

Very little is known about the movement patterns of the Black-throated finch, particularly during the breeding season. Movements undertaken by a species are an essential component of its life history strategy and thus are a critical feature of specie's ecology and conservation (Smith & Moore, 1992). It is hypothesised that the Black-throated finch will have a relatively consistent pattern of foraging during the day in the breeding season and will have a number of specific sites at which they will spend the majority of their time foraging. The factors that influence these patterns of movement may be similar to those influencing the seasonal use of savanna landscapes by the Gouldian finch (*Erythrura gouldiae*) (*Dostine et al. 2001).* The main factor determining these movement patterns is the seed supply which is ultimately governed by the seasonality of rain. The Northern Territory has a similarly distinct wet-dry season to Queensland in that the bulk of the rain falls between December and March and the dry season occurs from May to October (Colls & Whitaker, 1990). As a result the seed density patterns are also similar; a high density of seed in the early dry season after the growing season followed by low density in the late dry season (Dostine, 2001).

Yorio *et al.* (2004) found in a study on the foraging patterns of Olrog's gull *Larus atlanticus* at Golfo San Jorge, Argentina that radio-tracked birds demonstrated an increased fidelity to feeding sites during the breeding season. The gull's use of a number of known sites with patchy resources, this is thought to reduce the time needed to search for feeding sites, as the information known about these sites they have visited previously reduces the time needed to search for new foraging sites. This may also be true for the Black-throated finch as repeatedly visiting a site of known resource abundance reduces the time that they would need to allocate to acquire food for themselves as well as additional food for chick rearing. It is hypothesised that during the breeding season Black-throated finches may also exhibit short bursts of foraging at these specific sites compared to the non-breeding season where they are expected to spend longer times foraging at more dispersed feeding sites. Bugoni's (2005) study on Common terns revealed that foraging trips were consistently longer at wintering feeding grounds when birds did not have chicks to rear. Courtney and Blokpoel (1980) found similar results whereby the mean duration of foraging trips of Common terns during chick feeding was only 17.2 minutes and involved as little as 45% of their time away from the nest.

A species' foraging behaviour can reveal much about the relationship between an organism and the environment that they utilise. The optimal foraging theory first developed by Emlen (1966) and MacArthur and Pianka (1966); assumes that organisms forage in a way that maximises energy use. The optimal foraging theory can be applied to both the Gouldian finch and possibly the Black-throated finch in regards to how much time they allocate to a patch and what speed and pattern of movements they use to forage (Dostine*. et al,* 2001; Pyke *et al.* 1977). From this theory it is thought that the Black-throated finch will intensively use a small number of patches that have a high favourable seed abundance, however as they progress into the dry season they will become more dispersive in their patterns of feeding. The expected time spent at these patches throughout the season can be indirectly compared with a study conducted by Lubin and Henschel's (1996) which explores the influence of food supplementation and food deprivation on the foraging effort of Web-building spiders (*Seothyra henscheli)*.

Spiders that were food supplemented decreased their foraging effort, whereas food deprived spiders increase their foraging effort. It is put forward that the seed availability throughout the season will have a similar influence on the Black-throated finch. Thus more time will be spent at patches with high seed abundance and less effort will be exerted to forage. On the other hand as the dry season progresses finches will spend less time at any one patch but exert more energy in terms of foraging effort as seed abundance will be low.

Resource Use

Foraging behaviour is directly linked to the distribution and abundance of resources that are encountered. Since resources are often found in patches, the forager must decide whether to accept or reject the opportunity to use the patch (Hanson & Green, 1989; Possingham, 1989). Particular studies have investigated patch preference, where the behaviour of birds in aviaries containing a set number of patches at set locations was examined (Smith & Dawkins, 1971; Smith & Sweatman, 1974; Zach & Falls, 1976). In this situation the birds learned which patches were more profitable and selectively chose to forage at these patches first. It is thought that breeding Black-throated finches will nest in the same general location every year; this may be related to the frequency of profitably patches that surround the nesting area (Buosi 2006, *pers. comm.*). An extended version of the Marginal-Value Theorem (MVT) developed by Brown (1988) predicts that a forager should exploit a patch until the benefit from the patch no longer outweighs the total (energy, predation risk and missed opportunity) costs involved. If an organism revisits patches in a preset area on a daily basis they may be conforming to the Fixed-Amount Strategy, in which a forager remains in each patch until it has harvested a preset volume of resources (Brown & Mitchel, 1989; Brown & Morgan, 1995). This model assumes that animals have a perfect knowledge of resource distribution and are free to exploit any available resource patch. If Black-throated finches are returning to the same breeding ground year after year it may be true that they have knowledge of the resource distribution of that area and that is why they continue to return. However, if a forager cannot assess resource densities in patches, a Fixed-Time Strategy may be employed, in which the forager spends equal time in all patches (Iwasa *et al.*, 1981; Valone & Brown, 1989).

According to the Optimal Foraging Theory with regard to patch exploitation, as environmental quality declines patch resources should be more severely exploited. Foragers aim to maximise energy gained by selectively exploiting patches rich in resources and by minimising foraging time in poor patches (Kohlmann & Risenhoover, 1998). Therefore, if this applies to the Black-throated finch, the finch should spend less time foraging when environmental quality is high and more time in each patch as quality declines. (Hanson & Green, 1989). Johnson *et al.* (2006) study on the intensity of interference affecting the distribution of House sparrows *Passer domesticus*, at food patches found that in the absence of interference, birds at large patches behaved as a single flock. In contrast, as patches become increasingly smaller birds more individually distributed themselves over an area. Black-throated finches may also similarly behave in this way by feeding together at rich patches where intake rates are high and dispersing themselves more widely when patches decrease in size and seed density. Johnson *et al*. (2006) also observed increased competition at small rich versus poor patches which enhanced the use of poor patches where there was less intense competitor numbers.

Erwin's (1985) study on foraging decisions, patch use and seasonality in egrets found that Snowy egrets *Egretta thula* foraged more intensively and efficiently when feeding young and showed a tendency to leave patches when the capture rate of prey or or rate of obtaining resources fell below a certain level. Birds were also observed to spend longer times in patches when other individuals were present. This study suggested that short-term memory and learning played a role in influencing location and time allocation in patches. Black-throated finches may also behave in this way if they return to particular nesting areas each year. It may be that the finches return to the same area each year because they have a knowledge or memory of the resource quality and distribution of that area from the year before. According a study conducted by Clark and Mangel (1985) on the evolutionary advantages of group foraging, foragers in groups are expected to locate resources more easily since there are more eyes available to search the habitat. In Zann's (1976) study on the distribution, status and breeding of the Northern subspecies of Black-throated finch in Northern Queensland he observed that breeding finches spent most of the time in groups in nesting areas. Zann also found that when moving from one feeding site to another the members of the flock tended to move at approximately the same time and in the same direction. These observations may suggest that Black-throated finches benefit from group foraging, particular during breeding season.

Nesting

Black-throated finches are a highly social species living in small flocks (Zann, 1976). Black-throated finches form communal nesting sites, comprising of multiple nests spread over small areas. Nests are used for both breeding and roosting, with individuals returning each night to roost (Buosi, 2006). Hole-nesting bird populations are often limited by nest-site availability during the breeding season (Village, 1983; Newton, 1994). For example, preferred nesting sites of Lesser kestrels in Spain may be restricted because the preference is to breed in higher cavities (Negro & Hiraldo, 1993). Although Black-throated finches tend not to be fussy about nest location on the scale of which tree to nest in as they will readily nest in hollows, leaf clusters and forks, they may have restrictions on suitability of preferred nesting sites in regards to resource availability. Schluter & Repasky (1991) further suggest that in finch populations around the world, densities are limited by food. Seed supply effects how the sizes of finch populations fluctuate seasonally and annually both in the breeding and non-breeding season. Since the presence of a breeding colony of birds at a foraging site indicates the availability and quality of food, the Black-throated finch may return to known areas of high seed abundance each season, especially during breeding season (Bayer, 1982). However, these particular patches may only be 'habitable patches' for certain times of the year. For example the species of butterfly *Phlebejus argus* was restricted by patchily-distributed plant species which was critical to the survival of their larvae (Thomas & Harrison, 1992). Black-throated finches may also be dependent on specific patches depending on their attributes for different stages of their lifecycle. Therefore, although the finch does not occupy any single patch for an entire season, all individual patches may be critical in the successful lifecycle and persistence of the finch.

This concept is called 'metapopulations' and can refers to a subdivided and patchy population where population dynamics operate both within patches and between patches (Levins, 1969; Begon, Harper & Townsend, 2003). In the case of the Black-throated finch this may refer to different nesting colonies in a landscape which may come together at some time, for example during the dry season. Species are known to track suitable environmental conditions, becoming locally extinct where circumstances become no longer suitable and consequently colonise where conditions improve (Thomas, 1994). The Black-throated finch population is not thought to exhibit ‘classic’ metapopulation dynamics, but are thought to most probably be driven more by immigration and emigration (local movement) rather than death and birth (Grice 2006, *pers. comm.*). Species thus persist in regions where they have the ability to track environmental attributes, and may become extinct if they are unable to keep up with shifting habitat mosaics. Heavy grazing of livestock could in areas where particular bird species are sensitive to change could also intensify the impact and frequency of habitat alteration. Martin *et al’s* (2005) study on the impact of grazing on birds found that in highly grazed areas only one of 31 species of birds analysed occurred and appeared to benefit. Heavy grazing is known to be concentrated around watering points and nearby pasture (Ahrens & Nour, 1997). This means that birds such as the Black-throated finch that may be reliant on habitats that are close to water resources are adversely affected.

1.4 Research Focus

This thesis focuses on how the threatened species of Black-throated finch *Poephila cincta cincta*, uses the landscape to forage during the breeding season (occurring from February until August) both temporally and spatially in North Queensland. During the breeding season the finches are most active, but are spatially restricted in their ability to forage due to the dependence of the chicks on the parents for survival. This study reveals how finches forage in relation to their nesting sites and what fine scale attributes influence where the finches forage

The overall objective is therefore to examine the spatial and temporal patterns of foraging behaviour of the Black-throated finch during the breeding season. Specific research questions include;

- What is the activity budget of the finch?
- How far do they travel from the nest to forage?
- How much area do the finches use?
- Where do they forage in relation to each other and their nests?

- What grass species do finches prefer?

This study will contribute significantly to knowledge that can be used to better design conservation strategies to manage this endangered bird into the future (BTFRT, 2004).

Chapter 2: Methods

2.1. Study Area

The study area was situated near Townsville-Thuringowa, North Queensland at Ross River Dam. The study area primarily focused on two different populations of Black-throated located on opposite sides of the dam catchment (Figure 2.1). The Ross River Dam was fully established in 1982 and covers 750 square kilometres. The dam reserve is bounded by the Hervey Range to the west, Mount Elliot to the east, and extends to Mount Stuart in the north and Dalrymple Shire boundary in the south, however the catchment itself reaches much further (NQ Water, 2007). The catchment of the Ross River Dam encompasses a diverse range of habitats and is managed in such a way as to promote and protect these important vegetation types. The vegetation type that was found within both study areas were Region Ecosystem (RE) 11.3.35, which comprises *Eucalyptus platyphylla, Corymbia clarksoniana* woodland on alluvial plains. Assessment from a previous study conducted by Buosi (2005) on the Black-throated finch found that most nesting sites found in the Townsville-Thuringowa region were most commonly associated with RE 11.3.5 (Buosi, 2005). The main reasons for choosing these two sites is that both sites have experienced little disturbance from cattle grazing or clearing for a three to four years and contain large easily locatable colonies of Black-throated finch (Hunt, 2006).

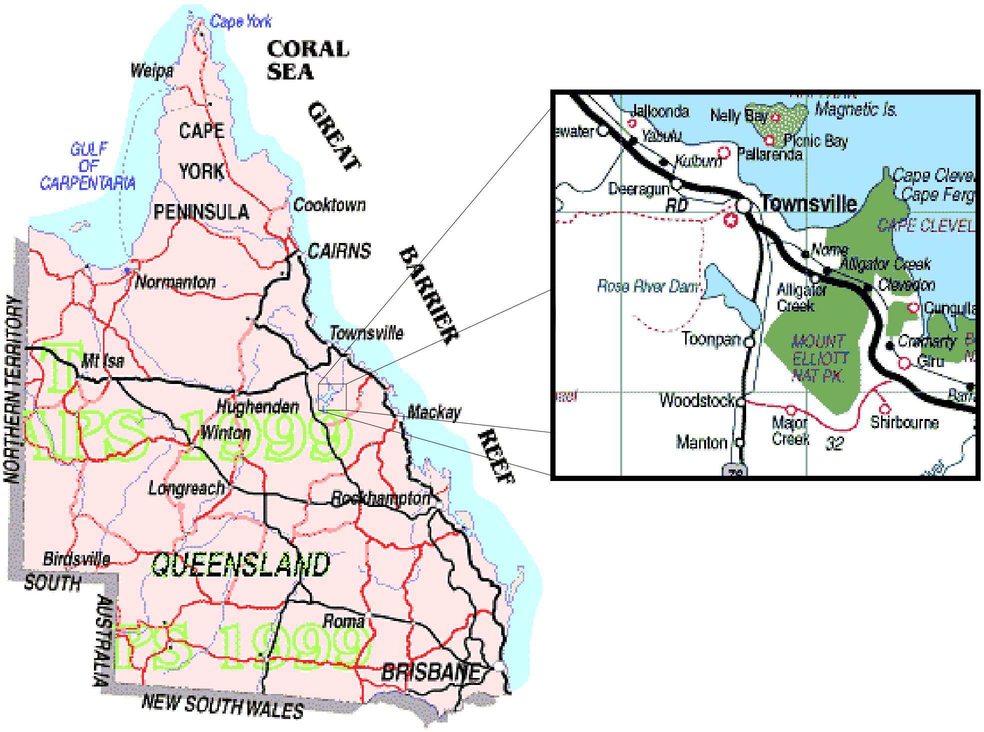


Figure 2.1. Location of study area in relation to Townsville-Thuringowa in North Queensland

2.2 Site Selection

There are only 12 nesting locations in the Townsville region, and two of thse were chosen for this study (Buosi, 2005). These two sites were selected for accessibility, colony size and independence. ####### Dam population was selected because it contained three breeding pairs of Black-throated finches, two of which had one dependent juvenile each and one that had two dependent juveniles, in relatively close proximity to each other. ####### Dam was also easy to access via 4-wheel drive and was independent from the second colony of Black-throated finches. The ********* Creek population was chosen for similar reasons; the colony size was approximately 60 individual birds or greater, the area was accessible and this colony was clearly independent of the colony at ####### Dam given the large distance and body of water between the two sites. Zann (1976) found that two breeding populations of *P.c.*atriopygialis that were separated by 700 m were independent of each other and Buosi (2005) suggests that *P.c.cincta* requires as little as 500 m between nesting sites to operate independently of each other. The combination of these sites allowed reliable data to be collected on both breeding pairs of Black-throated finches and an entire colony. The first site was located at ####### Dam, a mostly permanent body of water on the inside of the dam wall and the second site was located adjacent to ********* Creek, a watercourse located on the eastern side of the dam catchment (Figure 2.2). The combination of these sites allowed reliable data to be collected on both breeding pairs of Black-throated finches and an entire colony.

Figure 2.2. Location of both study areas located within the Ross River Dam catchment (NQ Water, 2007).

2.3 Sampling design

Each site was studied at different intensities and observations recorded addressed slightly different behaviours and objectives. At ####### Dam, baseline vegetation characteristics were measured in a grid (25ha) containing the nest sites, observations were made where pairs of finches fed, the vegetation where the pairs were foraging was described and detailed observations were made on movement and behaviour (Table 2.1). At ********* Creek, baseline vegetation characteristics were also measured in a region (5ha) that contained the colony, observations were made where groups of finches fed and the vegetation where the group was foraging was described. Each site had its own limitations in what could be studied. Time constraint was a major factor in determining the length of time spent observing birds during the day and the length of time allocated to each study site. ####### Dam site was allocated more time to undertake tasks as it was easier to locate birds and record detailed information on movement and behaviour. Observations were recorded in less detail at ********* Creek due to the difficulty in reliably tracking distinguishable pairs and locating nesting sites. A smaller area was surveyed for baseline flora at ********* Creek than at ####### Dam because after trial observations of bird behaviour were made it was established that finches used a smaller area than previously thought. The timing of this study was purposely coincided with the breeding season of the Black-throated finch, when adults had dependent juveniles and resource demands could be expected to be very high. This timing was chosen because it is an important life history stage to know about and the birds are more visible and audible and therefore allow focal tracking studies. Breeding season is generally from the beginning of March through until early May. Mitchell's (1996) study on the Black-throated finch revealed that breeding began in March and juveniles fledged in April, with juveniles remaining dependent upon the parents for food until May. However, timing and duration of breeding season is both seasonally and annually variable. However, based on Mitchell's findings data was collected every second week for each site, beginning from the second week in March and continuing through until the first week in August (Table 2.2).

Table 2.1 Major tasks undertaken at each study site

TASK UNDERTAKEN	####### DAM	********* CREEK
Baseline Flora Survey	✓	✓
Vegetation Survey at Foraging Sites	✓	✓
Group Foraging Observations	✓	✓
Pair Foraging Observations	✓	
Observations on Movements & Behaviour	✓	
Nesting Location Observations	✓	

Table 2.2 – The month and specific week (e.g. W1 = Week 1) that movement observations of the finch were collected for each study sites; ####### Dam and ********* Creek was carried out. The dates listed indicate the exact day each data collection episode was undertaken.

Location	Month												
	May				June				July				August
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1
####### Dam		10th 11th 13th		24th 26th 27th		10th 11th 12th		24th 25th 27th		3rd 4th 8th		24th 25th 26th	
********* Creek			19th		2nd		19th		1st		16th		1st

2.4 Baseline Flora Survey

Dam

Baseline vegetation was collected by mapping the habitat of the surrounding area of ####### Dam. Quadrats were pegged out with the assistance of a handheld Geographic Information System (GPS). For ####### Dam the overall sample area measured 100m by 100m, and 25 quadrats were pegged out over a 25 hectare area in a grid fashion (Figure 2.3). At ####### Dam line quadrats were spaced 33m apart and two lines were sampled per quadrat. Habitat samples (quadrats) were taken every 16m with a total of six samples recorded per quadrat line (Figure 2.3). Each quadrat was 0.5m by 0.5m. Attributes that were recorded for each habitat sample included grass species or legume species, number of seed heads, number of seed heads with seeds and without seeds and percentage of bare earth.

*********** Creek**

Baseline vegetation was collected by mapping the habitat of the surrounding area of ********* Creek. Quadrats were pegged out with the assistance of a handheld Geographic Information System (GPS). After mapping the habitat at ####### it became apparent that it was not necessary to use or map such a large sample area as the finch only utilised the innermost quadrats. Consequently, for ********* Creek the overall sample area measured were 20m by 20m and 16 quadrats were pegged out over an area of 0.64 ha. At ********* Creek line transects were spaced 25m apart and one line was sampled per quadrat. The sample area was 0.5m by 0.5m. Vegetation samples were taken every four metres with a total of five samples recorded per transect line. The same attributes were recorded as for ####### Dam.

2.5 Behaviour & Movement Monitoring

Data was collected so that each pair of finches at ####### Dam was observed during the morning and the afternoon, whereas the colony at ********* Creek was observed for an entire day. Each pair at ####### Dam was observed once in the morning for five and half hours from 6am until 11:30am and once in the afternoon for five and half hours from 12:00pm until 5:30pm (Table 2.3). The finches at the ********* Creek colony, on the other hand, were observed from 7am until 5pm. Commencement time during the morning sessions and conclusion times during the evening observing sessions vary slightly due to availability of light. If a pair flew out of sight and were relocated later coming from the same direction, it was considered that both sightings were of the same pair of finches. If a pair was lost and could not be relocated within one hour, the next pair was located and observed. It should be noted that it was not always possible to be sure if the two pairs were the same pair or not at ####### Dam.

Table 2.3 – Sequence of observing pairs of finches at ####### Dam

	Day 1	Day 2	Day 3
Morning	Pair 1	Pair 2	Pair 3
Afternoon	Pair 2	Pair 3	Pair 1

The data that was collected at each site included the location of each pair at ####### Dam or the colony at ********* using GPS WGS84 to record the *x* and *y* coordinates for each movement. The time of day, date and activity for each observation was also recorded. Activities that were recorded for each observation were pecking, perching, preening, feeding, preening and feeding, entering and exiting the nest and watering. Data was also collected on habitat composition where the finches were feeding. Data recorded included grass species present, number of seed heads, seeds heads with seed and without seed and percent bare earth. These attributes were recorded in two blocks; the first block covered all feeding episodes leading up to the first week of June and the second covered all feeding episodes after the start of June leading up to the first week of August. Every feeding episode was sampled ten times; five random 0.5m quadrats were sampled within the area the finches were known to feed and five random 0.5m quadrats where they were known not to feed. However, if the finch was feeding in the same area more than once these episodes were considered to be one and were only sampled once.

2.6 Data Analysis

Activity Budget & Distances Travelled

Data recorded on the activities of the finches was entered into Microsoft Excel, recoded for ease of use and imported into ArcGIS. This data was analysed by calculating distance between nests and pairs of finches using the point distance analysis tool and time spent during foraging at any one time. Multiply buffers were created around each nest at intervals of 50m, 100m, 150m, 200m, 250m, 300m, 350m and 400m. These buffers were intersected with the original layer and imported into Microsoft Excel and pivot tables were created to summarise the data. Error bar charts, scattergrams using SPSS and bar charts using Microsoft Excel were created from this data to compare and present information on duration of feeding, distances travelled from the nest, and activity level during different times of the day.

Occurrence of Grass Species

Habitat mapping data was imported into SPSS, aggregated by grouping data using the sum of grass species with seed head and mean of bare earth. Sum was used to aggregate seed head data to minimise distortion of data since this data contained many zeros. Error bar graphs and non-parametric tests were used to analyse whether certain species of grass occurred inside or outside the foraging area of the finch more often than by chance. The mean number of the grass specie's occurring inside the foraging range and the mean number occurring outside the foraging range was calculated and a Mann-Whitney U test was used to determine the *p* values for each grass and descriptive statistics were used to generate the mean and standard error.

Foraging

Using spatial statistics tools in ArcMap the foraging locations at ####### Dam were plotted and the mean centre of each pair's individual foraging location was analysed and compared. A minimum convex polygon was used to calculate the total foraging area for each pair and to further calculate the mean foraging area for all three pairs pooled together. The convex polygon was also used to calculate the mean foraging area for the finch colony at ********* Creek. An ellipse with one standard deviation was plotted around the mean foraging area for each pair to compare the distance and direction of each pair's foraging area.

A nearest neighbour analysis was carried out on both the ####### Dam site and the ********* Creek site. This analysis calculates the average distance of each point from its nearest neighbour, which allows us to determine whether the foraging episodes were clustered or dispersed. An index is used to determine this and is expressed as the ratio of the observed distance divided by the expected distance (expected distance is based on a hypothetical random distribution with the same number of features covering the same total area). If the index is less than 1, the pattern exhibits clustering. If the index is greater than 1, the trend is toward dispersion (Figure 2.4).

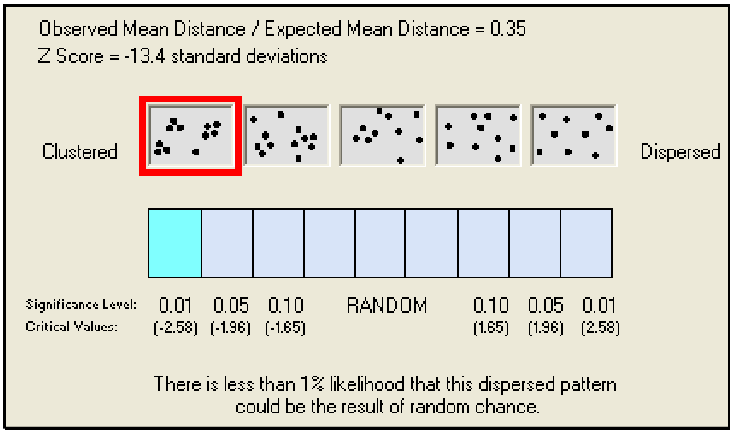


Figure 2.4. Nearest neighbour analysis showing that the index is smaller than 1 meaning the distribution is clustered. Mean distance = 5.04m. Expected mean distance = 14.34m.

Chapter 3: Results

3.1. General distribution patterns within foraging areas.

For ####### Dam the nesting locations and activities observed for each pair was plotted and was visually found to be clustered together, with the nest sites acting as a border with the majority of the activities being observed to occur in the centre (Figure 3.1). At ********* Creek the observed activities were less central; however an obvious cluster remained evident (Figure 3.2).

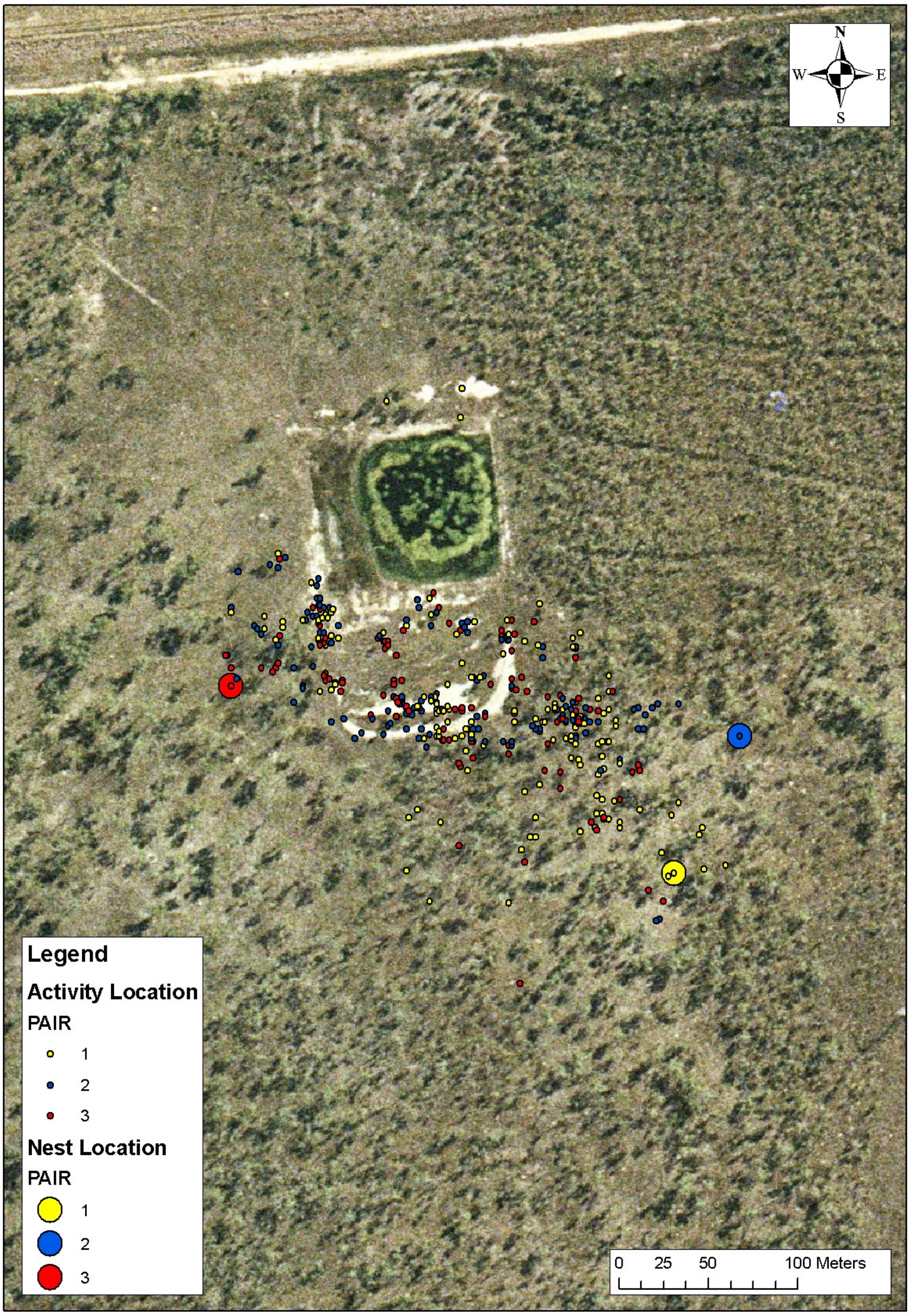


Figure 3.1. Nesting location and location of all activities for each pair of finch at ####### Dam

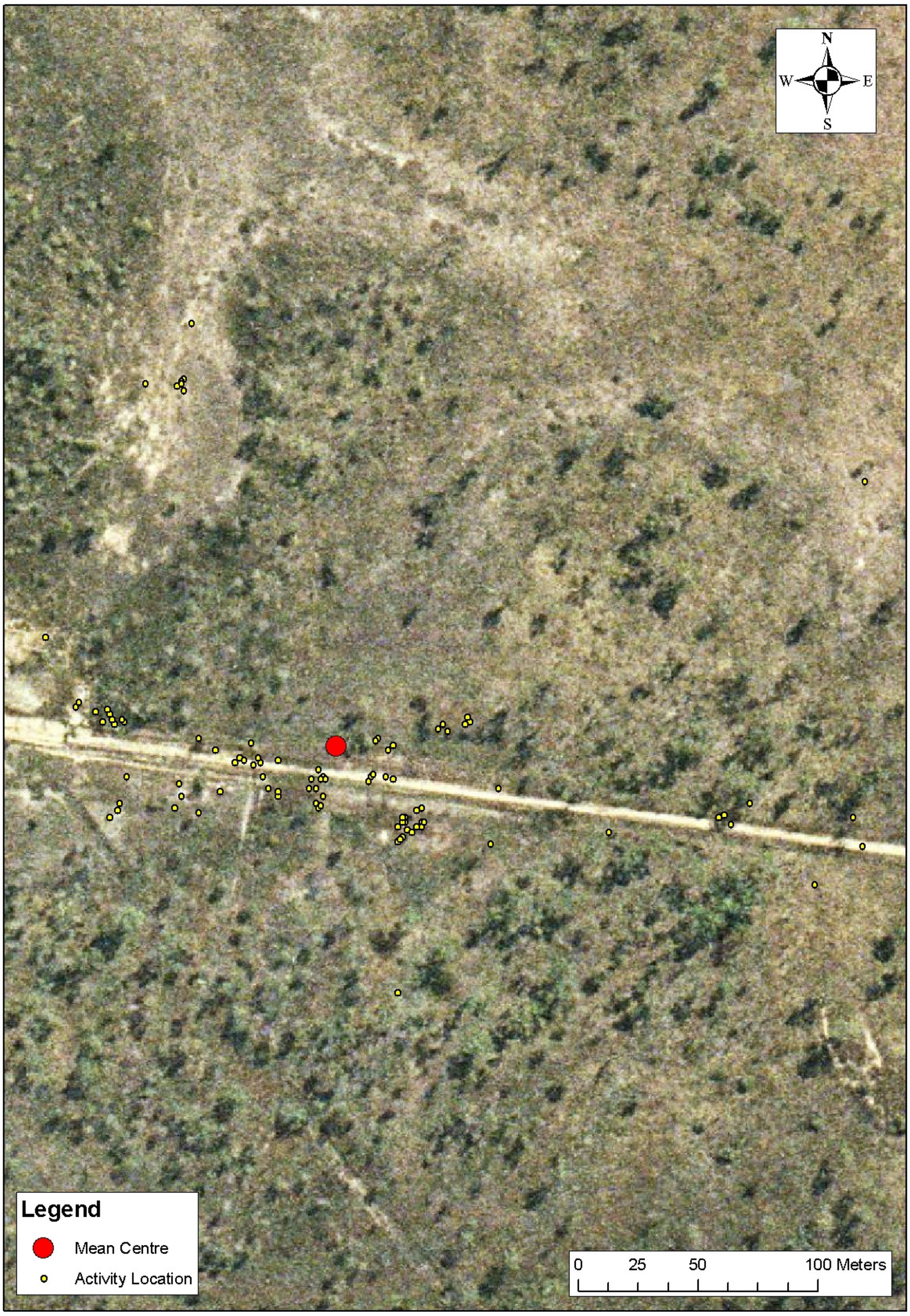


Figure 3.2. Mean Centre and location of all activities for the colony of finches at ********* Creek

3.2. Activity budgets and foraging time

For the six week period of observation, the three pairs of Black-throated finches at ####### Dam spend the majority of their time during breeding season foraging. The activity the finches spent the second longest duration at was perching, followed by feeding young and preening. The least amount of time was spent on watering and entering and exiting the nest (Figure 3.3a). Pair 2 and 3 spent a longer duration foraging and perching than pair 1; however pair 1 spent more time preening and feeding young than pair 2 and 3 (Figure 3.3b-3.3d). The colony at ********* Creek like the finches at ####### Dam was also observed to spend the majority of their time during breeding season foraging followed by perching, feeding young and preening.

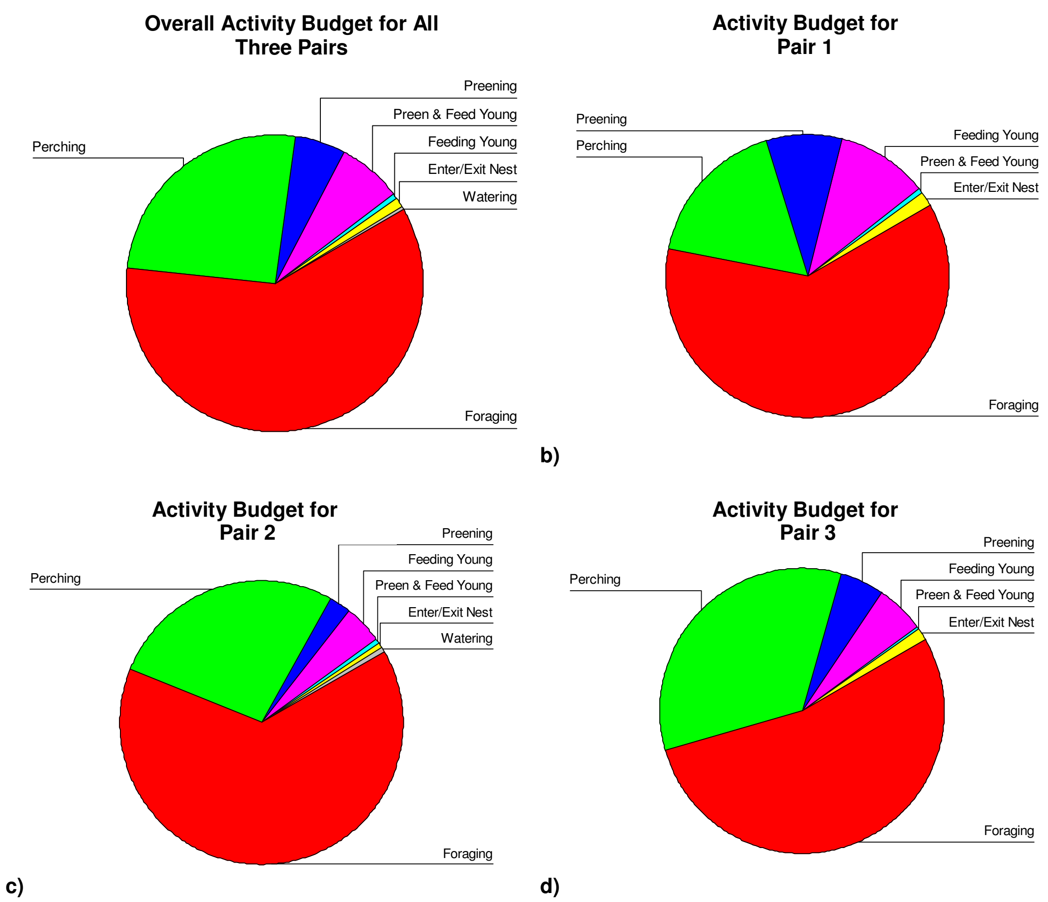


Figure 3.3. Several activities over six weeks of observation were recorded. The duration of time spent on each activity over this time is represented in a pie graph. **b)** Duration of time pair 1 spent on each activity, **c)** duration of time pair 2 spent on each activity, **d)** duration of time pair 3 spent on each activity.

There was a relative consistency in activity pattern between all three pairs of finches at ####### Dam, especially in regards to proportion of time spent foraging and perching. Both the three pairs of finches at ####### Dam and the colony at ********* Creek spent similar proportions of time foraging and perching.

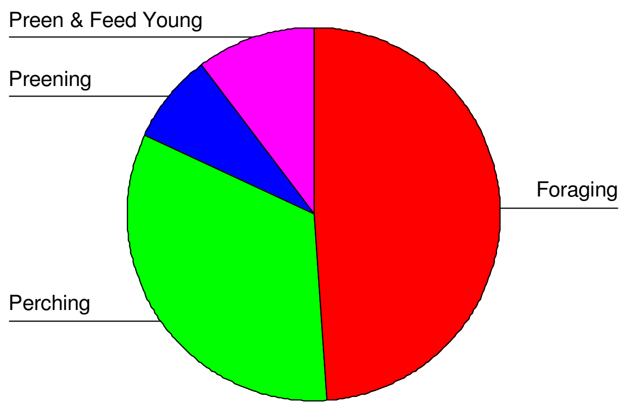


Figure 3.4. Several activities over six weeks of observation were recorded at ********* Creek. The duration of time spent on each activity over this time is represented in a pie graph. Note there were no entering and exiting the nest recorded at ********* Creek as there were no nests located.

The proportion of time spent foraging for all three pairs of finches at ####### Dam was very similar, with the main proportions of foraging not exceeding 80 percent except for during week six where pair 1 spent greater than 95 percent of time foraging (Figure 2). Pair 1 in week one and pair 3 in week 6 spent a very small proportion of time foraging, however these outlying results could be explained by lack of observations for that week or pair. The mean proportion of time spent foraging for the colony at ********* Creek was calculated to be 49 percent, with the main proportions of foraging not exceeding 60 percent. The colony spent the greatest time foraging in week two which was 56 percent and the shortest amount of time foraging during week five where they spent all of 26 percent of their time feeding.

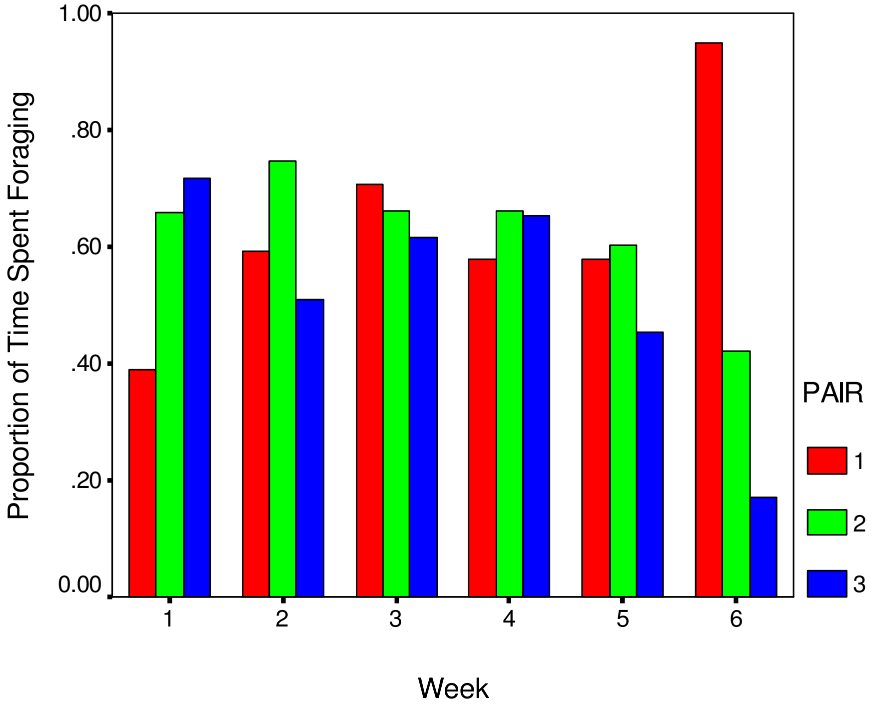


Figure 3.5. Proportion of time spent foraging by each pair of finches at ####### Dam recorded over the six week period of observation (N=216).

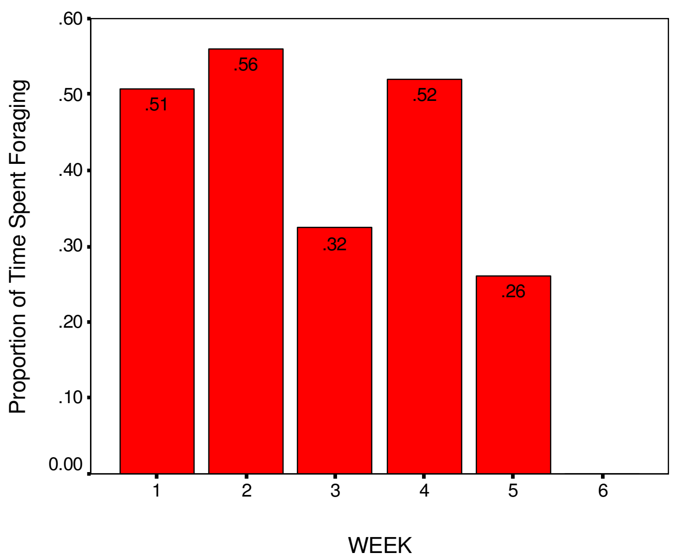


Figure 3.6. Proportion of time spent foraging by the colony of finches at ********* Creek recorded over the six week period of observation (N=117).

The three pairs of finches at ####### Dam were mainly observed between 0m and approximately 350m from their respective nest sites. The duration of foraging within this range typically lasted between 0 minutes and 50 minutes (Figure 3.7). The colony of finches at ********* Creek were also found to mainly forage for a duration of between 0 minutues and 50 minutes, however they spent most of their time foraging between 0m and approximately 250m from the central feature (Figure 3.8). The central feature Identifies the most centrally located feature within a group of points. The central feature was used to locate a central point in relation to the area being used by the colony of finches for ********* Creek, as nesting locations were unable to be found.

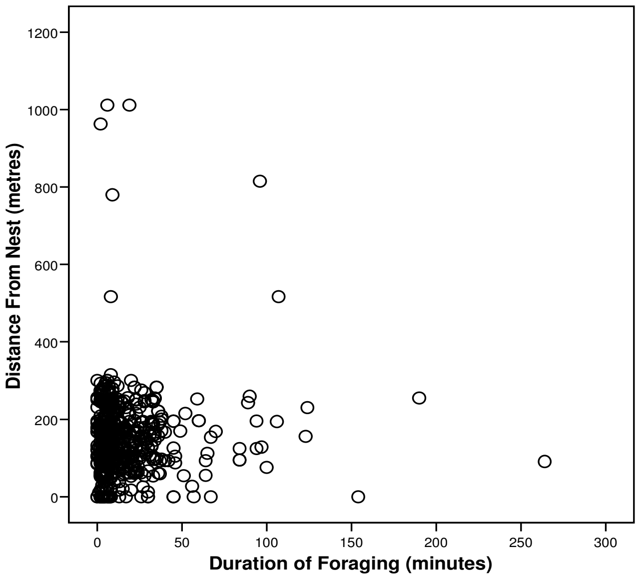


Figure 3.7. Duration of foraging at ####### Dam in relation to distance from the nest, for all three finch pairs pooled together to show duration of activity for different distances from the nest (N=629).

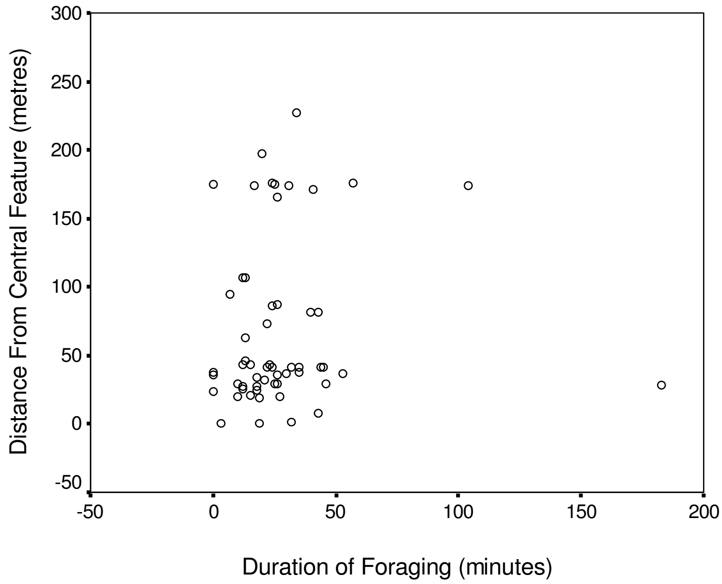


Figure 3.8. Duration of foraging at ********* Creek in relation to distance from the central feature (N=56).

3.3 Duration of foraging

All three pairs showed a very similar variability in duration of foraging and similar mean duration of time spent foraging. Duration of foraging did not differ significantly between pairs (Kruskal-Wallis, p=0.78, df=2, N=216) (Figure 3.9).

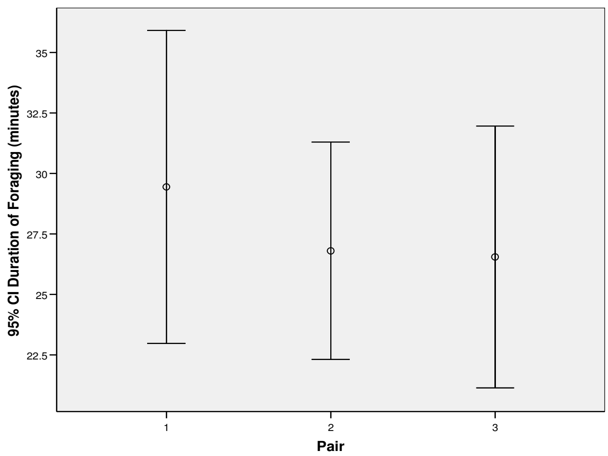
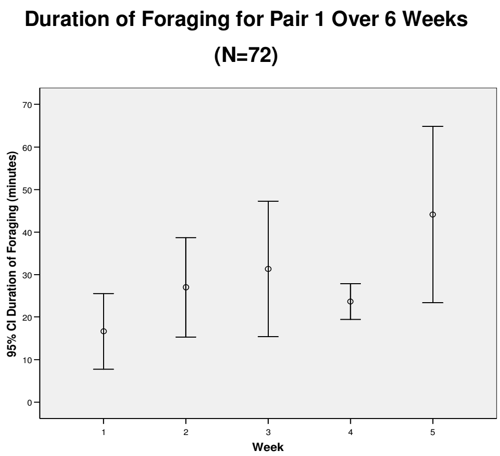
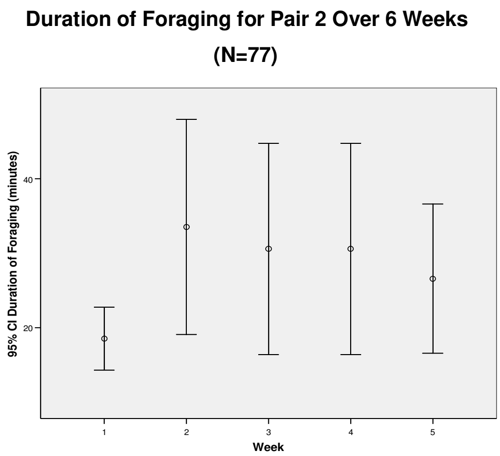


Figure 3.9. Duration of foraging for each pair over six weeks of observation. The error bar graph compares duration of time spent foraging (N=216). Confidence interval between bars is 95%.

Although, duration of foraging did not differ significantly between pairs over six weeks there are some marked difference in foraging duration within weeks between pairs. Data from week six was pooled with the data from week five due to lack of samples recorded for week six. For the first week there was a smaller variability in duration of foraging for all three pairs of finches than there was for the other four weeks and pair 1 and 2 exhibited a much lower mean for week 1 compared to other weeks. Week two to five show a much larger variability in duration of foraging with the exception of week four for pair 1. There is a significant difference between duration of foraging within weeks for pair 1 (Kruskal-Wallis, p=0.01, df=4, N=72) and pair 2 (Kruskal-Wallis, p=0.039, df=4, N=77), however there was no significant different in foraging duration within weeks for pair 3 (Kruskal-Wallis, p=0.798, df=4, N=67) (Figure 3.10).



a)



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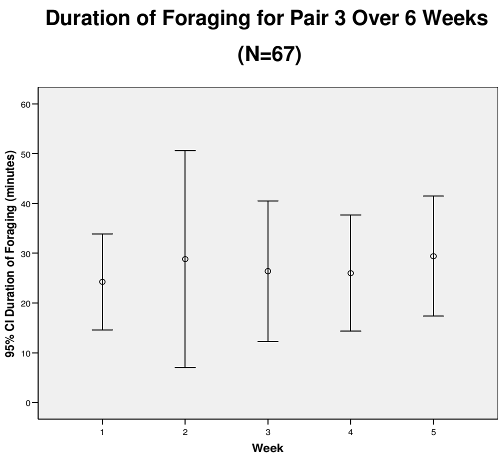


c)

Figure 3.10. Duration of Foraging for each pair of finches over 6 weeks of observation. **a)** Duration of foraging for pair 1, **b)** duration of foraging for pair 2 and **c)** duration of foraging for pair 3. Confidence interval between bars is 95%.

3.4 Foraging Distance

Distance travelled for foraging for each pair was compared and found to be significantly different (Kruskal-Wallis, p=0, df=2, N=216). Pair 1 travelled the greatest distance from the nest to forage and exhibited greater variability in distance travelled. Pair 2 and 3 exhibited similar variability; however pair 2 tended to travel further from the nest than pair 3 (Figure 3.11).

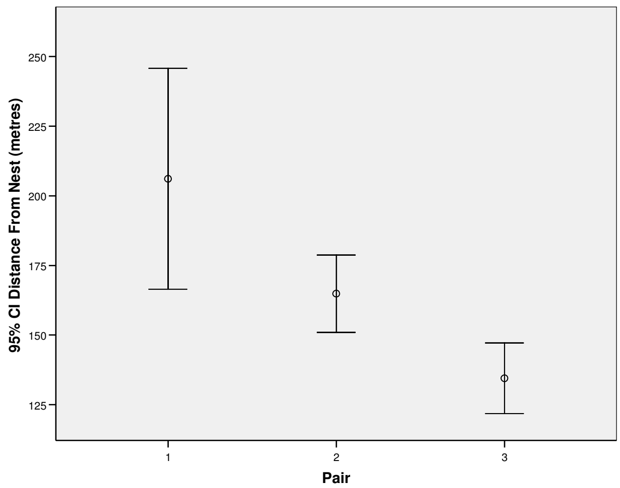


Figure 3.11. Distance travelled from the nest for foraging for each pair over six weeks of observation (N=216).

The finches at ####### Dam were found to be highly active all day; particularly within 350m of their respective nests. Other activities were recorded at distances exceeding 350m, however the activity was markedly less with fewer recorded activities occurring (Figure 3.12). The colony of finches at ********* Creek also exhibited high activity levels all day; particularly within 250m from the central feature (Figure 3.13).

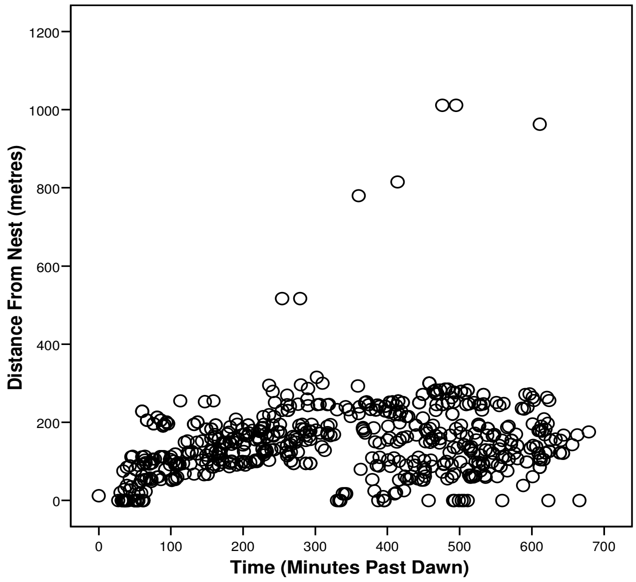


Figure 3.12. Time of day in relation to distance from nest for all three finch pairs at ####### Dam pooled together to show the activity level throughout observation during the day for different distances from the nest (N=629).

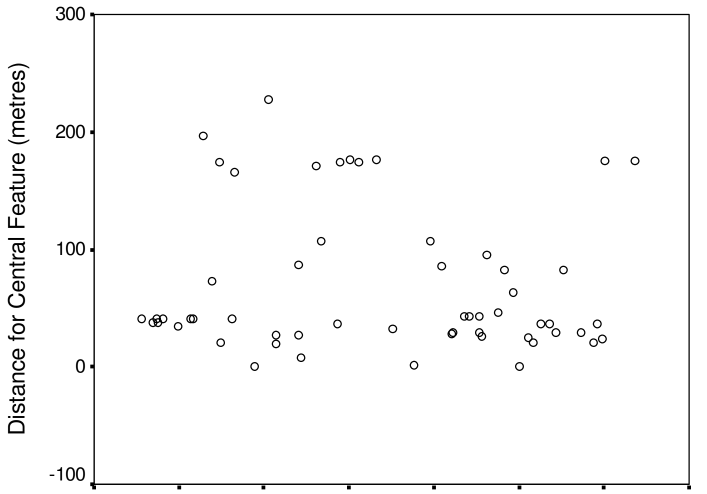


Figure 3.13. Time of day in relation to distance from nest for the colony of finches at ********* Creek, this graph shows the activity level throughout observation during the day for different distances from the nest (N=56).

Distance travelled from the nest for foraging showed greater variability for pair 2 and 3 over the entire period of observation. Pair 1 on the other hand exhibited a smaller variability in distance travelled from the nest with the exception of week one and apart from week two the mean distances remained similar as well. There was a significant difference in distance travelled for foraging within weeks for both pair 1 (Kruskal-Wallis, p=0.021, df=4, N=72) and 3 (Kruskal-Wallis, *p*=0.012, df=4, N=67), however there was no significant different for pair 2 (Kruskal-Wallis, *p*=0.186, df=4, N=77) (Figure 3.14).

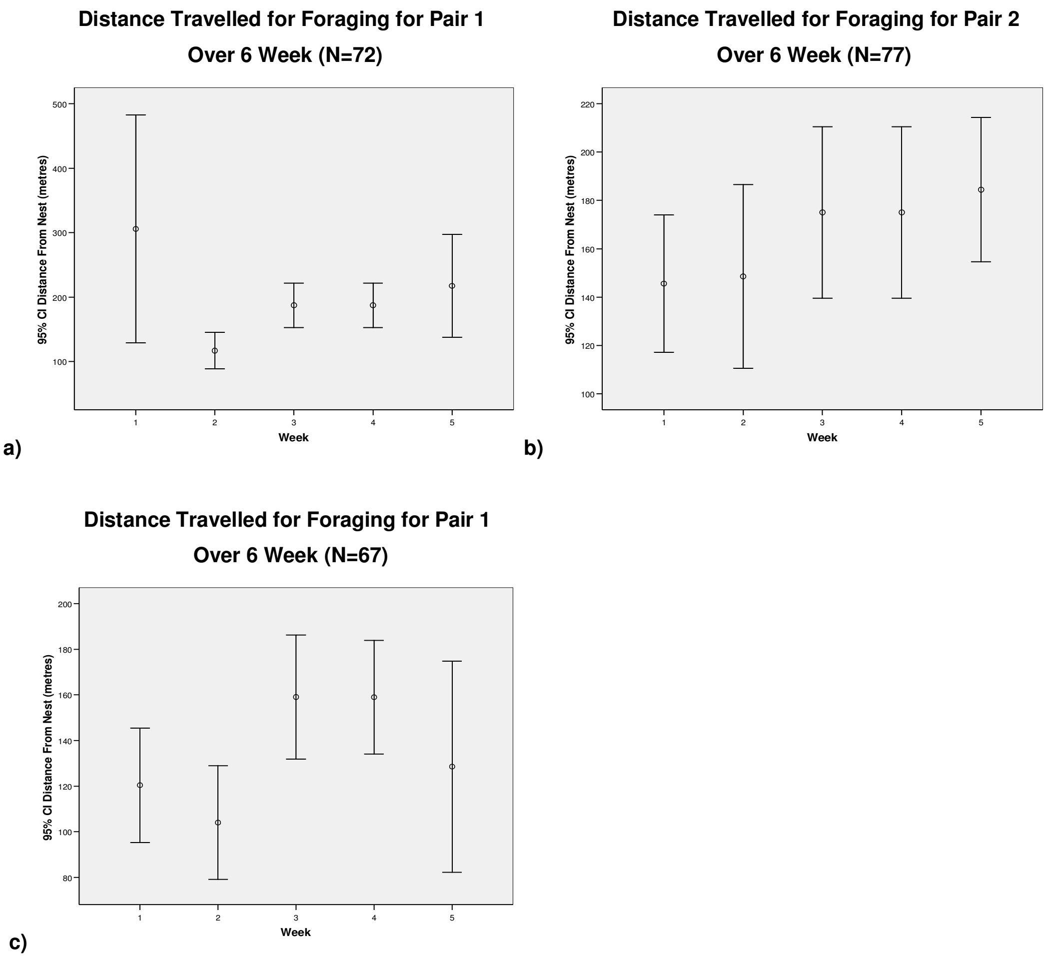


Figure 3.14. Distance travelled from the nest for foraging over six weeks for each pair of finches. **a)** Distance travelled from the nest for foraging for pair 1, **b)** distance travelled from the nest for foraging for pair 2 and **c)** distance travelled from the nest for foraging for pair 3. Confidence interval between bars is 95%.

3.5 Patterns of Foraging & Area Used

The three pairs of finches exhibited a very similar foraging geographic centre (centroid), which is the average of the x coordinates and y coordinates combined. The centroid tended to occur in a central region in relation to the nest sites (Figure 3.15).

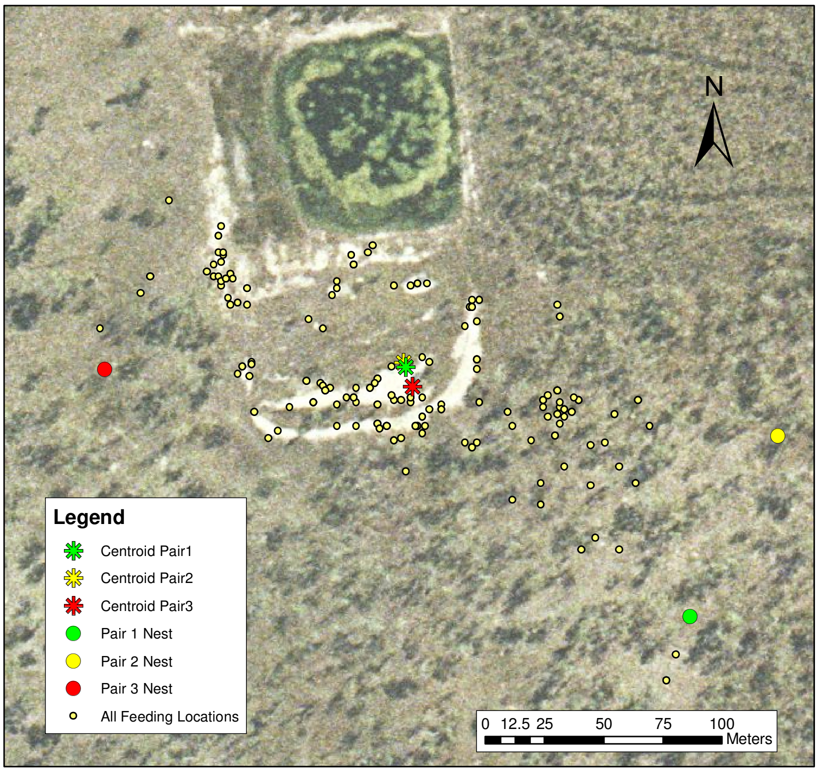


Figure 3.15. Mean (centroid) foraging centre for each pair of finch at ####### Dam

The total mean foraging area for the three pairs of finches at ####### Dam was calculated to be 2.33 hectares and generally covered a central area within the borders of the three nests (Figure 3.16).

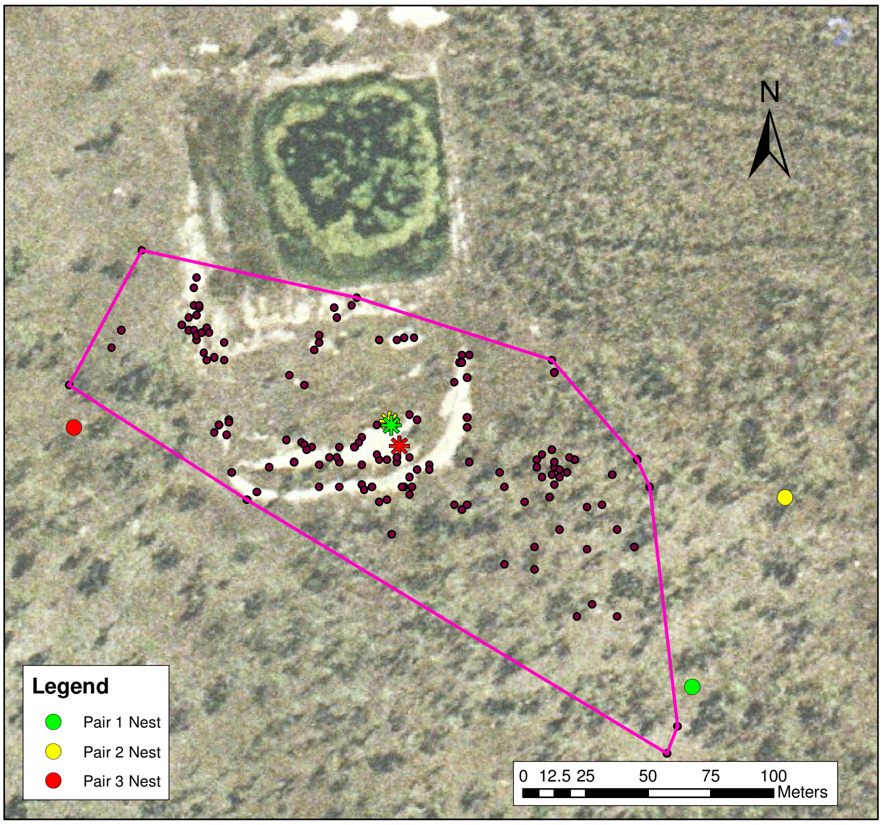


Figure 3.16 . Mean foraging area for all three pairs of finch at ####### Dam

The total mean foraging area for the colony of finches at ********* Creek was calculated to be 4.4 hectares and generally concentrated around a bare dirt road (Figure 3.17).

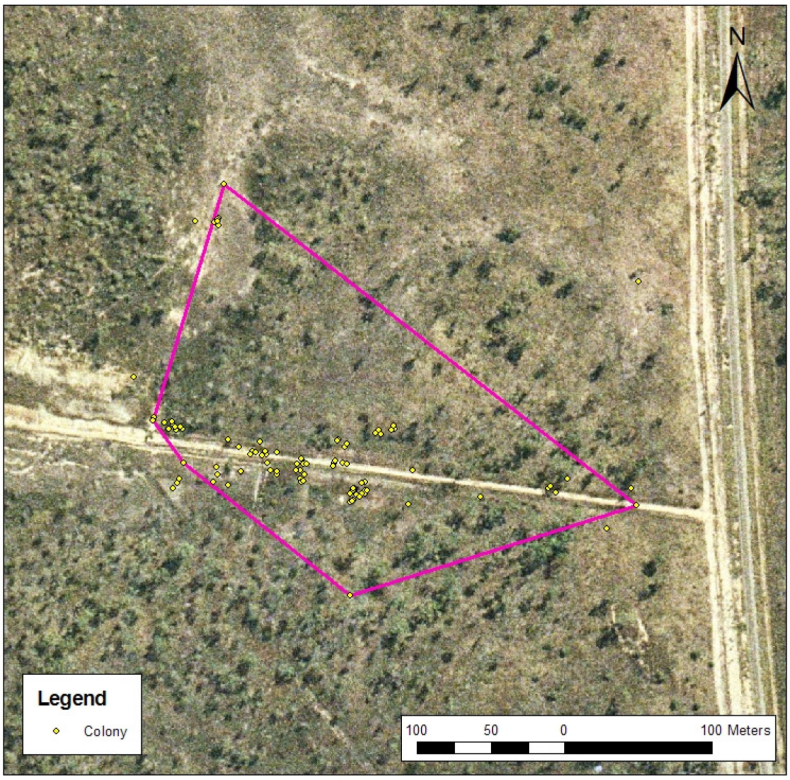


Figure 3.17. Mean foraging area for colony of finches at ********* Creek

The mean foraging area for each pair was found to be both similar in area and shape and exhibited a strong overlap in foraging areas, as well whilst also remaining central within the boundaries of the three nesting sites (Figure 3.18).

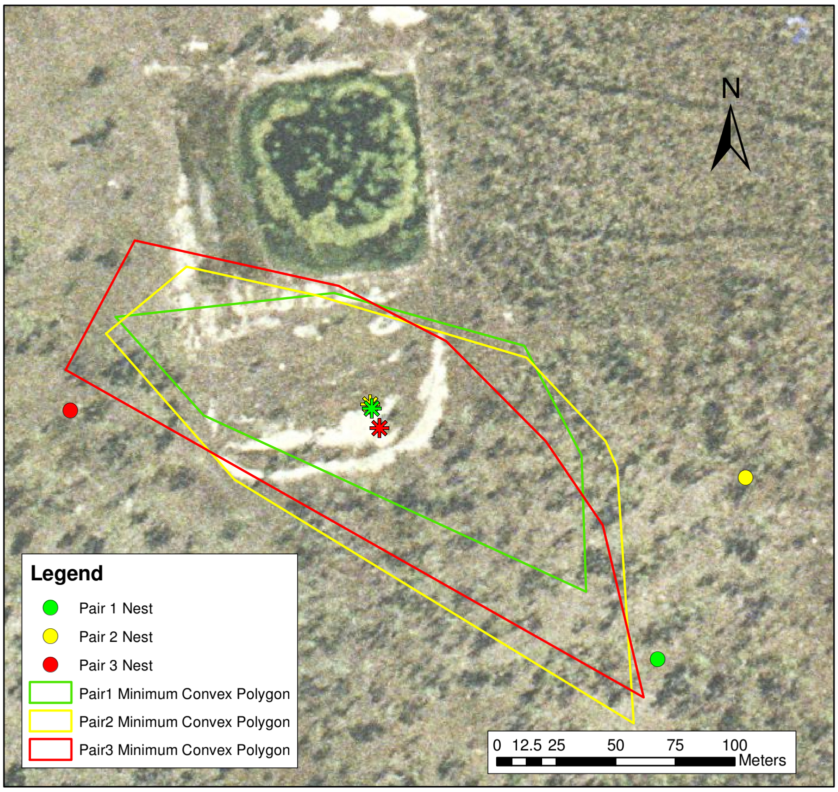


Figure 3.18. Mean foraging area for each pair of finch at ####### Dam

An ellipse of 1SD around the mean foraging location of each pair showed similar variability in distance and direction of foraging. Foraging area was not closer to any one nesting site, pairs exhibited an independence of nest location in regards to foraging zone and little independence between pairs was shown (Figure 3.19).

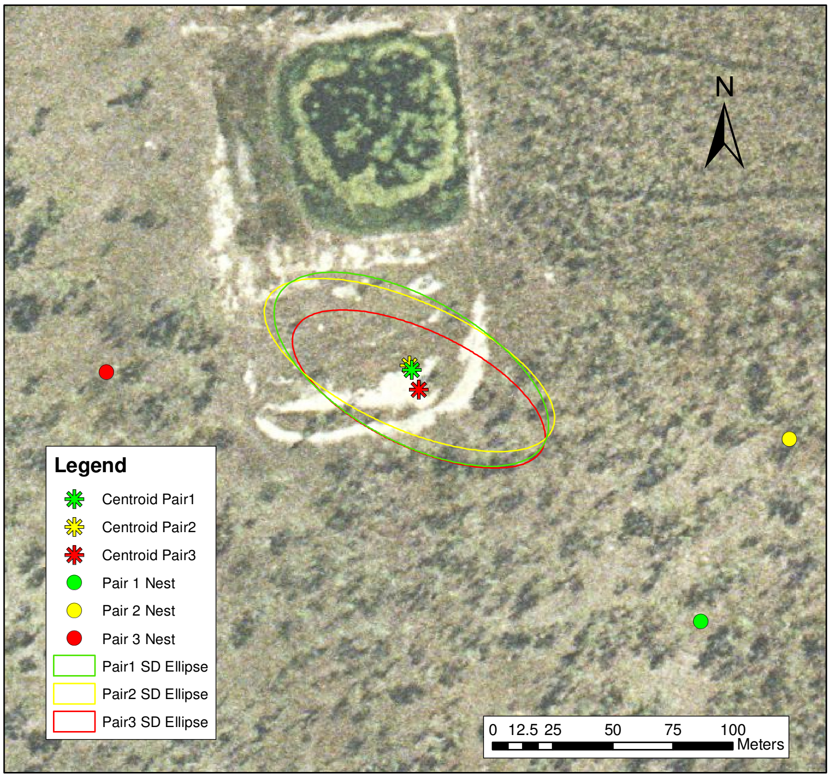


Figure 3.19. Ellipse showing one SD around the mean (centroid) foraging location of each pair at ####### Dam

Through nearest neighbour analysis the distribution of foraging for the colony of finches at ********* Creek was found to be very clustered (Table 3.1). The pairs at ####### Dam were analysed separately and as pooled data through nearest neighbour analysis and were also found to very clustered in distribution (Table 3.1).

Table 3.1. Nearest neighbour analysis showing that the index is smaller than 1 meaning the distribution at ********* Creek, ####### Dam for all pairs together and ####### Dam for each pair is very clustered.

	Observed Mean Distance (OMD)	Expected Mean Distance (EMD)	Ratio (OMD/EMD)	Z Score (Standard Deviations
********* Creek	5.04m	14.34m	0.35	-13.5
All Pairs Together	4.78m	30.64m	0.15	-23.8
Pair 1	4.86m	13.18m	0.36	-10.1
Pair 2	2.97m	11.73m	0.25	-12.6
Pair 3	4.13m	13.16m	0.31	-10.8

3.6 Grass species preference

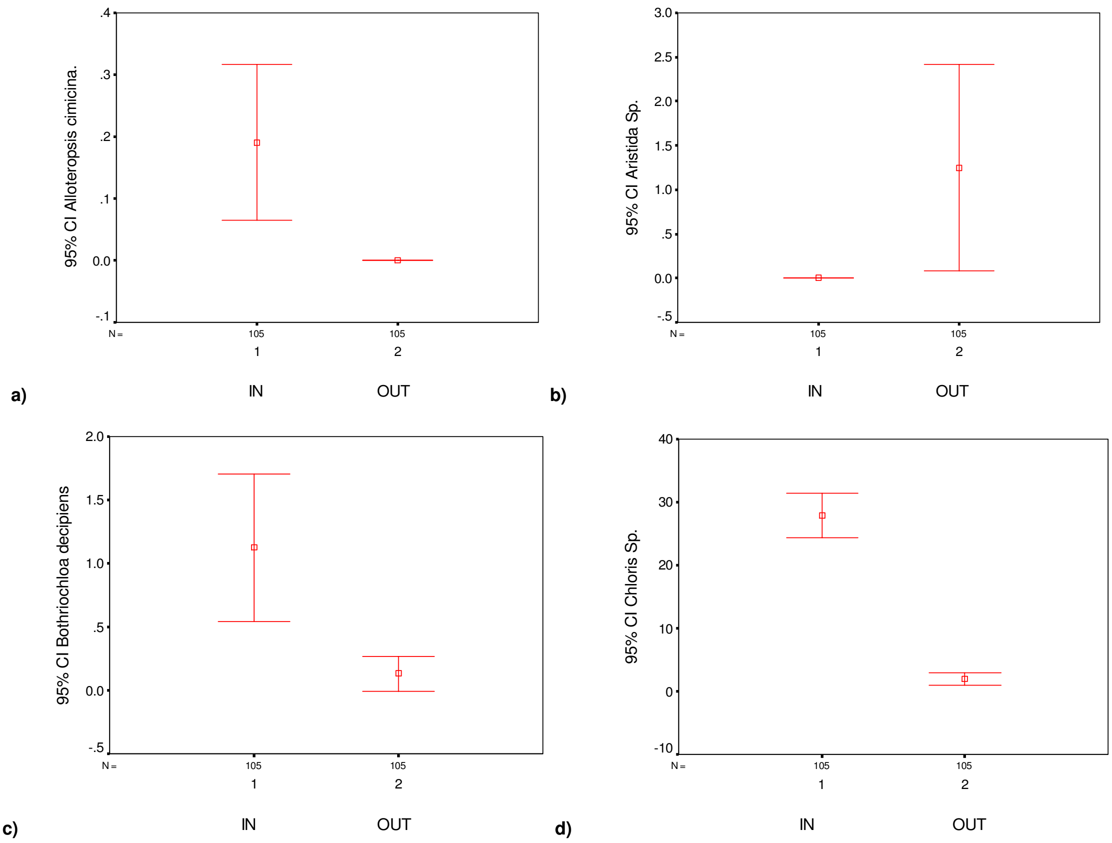
Dam

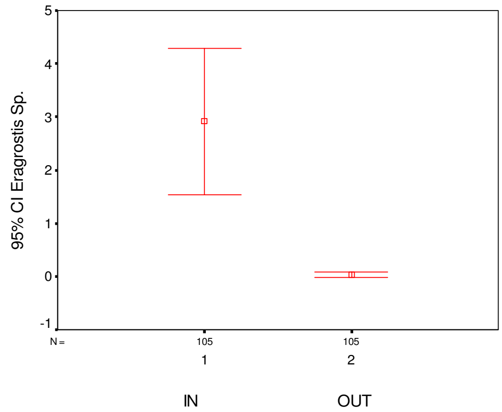
Several grasses surveyed in the baseline habitat mapping at ####### Dam were found to occur inside the area where the finches were recorded to be foraging more often than outside and vice-versa, allowing us to infer preference or avoidance of these species. A total of 13 grasses differed signifcantly in their abundance between 'within' and 'outside' their immediate area of foraging (Table 3.2). The species that were recorded inside the foraging area of the finch more often than outside and were preferred grasses include *Alloteropsis cimicina, Bothriochlora decipiens, Chloris* species*, Eragrostis* spp.*, Setaria apiculata* and *Sporobolus* caroli. The species that were recorded outside the foraging area more often than inside and were grass species that were avoided by the finch include *Aristida* spp.*, Bothriochloa pertusa,* and *Heterpogon* contortus.

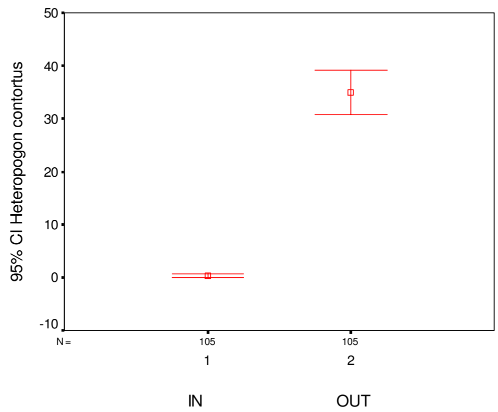
Table 3.2. A Mann-Whitney U test was used to determine the *p* values for each grass and descriptive statistics was used to generate the mean and standard error for ####### Dam. The table shows the mean number of the grass specie's occurring inside the foraging range and the mean number occurring outside the foraging range. A * represents a significant result, the significant results are further illustrated with error bar graphs in figure 6.

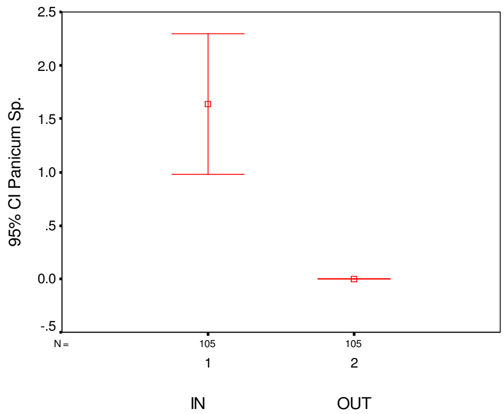
Grass Species	IN	OUT	*P*
Alloteropsis cimicina	0.19 ± 0.64	0 ± 0	0.02*
Alloteropsis semialata	0 ± 0	0 ± 0	1.00
Aristida spp.	0 ± 0	1.25 ± 0.59	0.01*
Bothriochloa decipiens	1.12 ± 0.29	0.13 ± 0.07	0.01*
Bothriochloa pertusa	7.16 ± 0.88	10.5 ± 1.59	0.50
Cymbopogon ambiguus	0 ± 0	0 ± 0	1.00
Chloris gayana	0 ± 0	0 ± 0	1.00
Chloris spp.	27.83 ± 1.77	1.96 ± 0.49	0.00*
Eragrostis spp.	2.91 ± 0.7	0.03 ± 0.03	0.00*
Eriachne armatii	0 ± 0	0 ± 0	1.00
Heteropogon contortus	0.06 ± 0.04	6.99 ± 0.36	0.00*
Melanis repens	0 ± 0	0 ± 0	1.00
Panicum spp.	1.64 ± 0.33	0 ± 0	0.00*
Setaria apiculata	6.22 ± 1.43	1.22 ± 0.44	0.00*
Sporobolus caroli	1.45 ± 0.37	0 ± 0	0.00*
Sporobolus diandrus	0 ± 0	0 ± 0	1.00
Stylosanthes spp.	0.44 ± 0.19	0.51 ± 0.19	0.01*
Themeda triandra	0.45 ± 0.12	4.57 ± 0.59	0.00*
Urochloa mosambicensis	2.23 ± 0.38	0.46 ± 0.12	0.01*
Weeds	0 ± 0	0.18 ± 0.24	0.00*

Some species of grass at ####### Dam were obviously preferred by the finch and others were clearly avoided. One particular grass that was strongly preferred was *Chloris* spp., where the mean number of seed heads occurring inside the foraging area of the finch being 27.83 (Figure 3.19d). Other grasses that were preferred but not as strongly included *Panicum* spp*., Setaria apiculata* and *Urochloa mosambicensis*, the mean number of seed heads for these species were 1.64, 6.22 and 2.23 respectively (Figure 3.19g,h,l). Two particular grass species that were strongly avoided by the finch include *Heteropogon contortus* and *Themeda triandra* with 6.99 and 4.57 mean number of seed heads respectively, occurring outside the foraging area of the finch (Figure 3.19f,k). Other forage that was less intensely avoided was *Aristida* spp*., Stylosanthes* spp*.,* and weeds with 1.25, 0.51 and 0.18 mean number of seed heads respectively, occurring outside the foraging area (Figure 3.19b,j,m).




95% CI Eragrostis Sp.
5
4
3
2
1
0
-1
N =
105
105
1
2
IN
OUT
e)


95% CI Heteropogon contortus
50
40
30
20
10
0
-10
N =
105
105
1
2
IN
OUT
f)


95% CI Panicum Sp.
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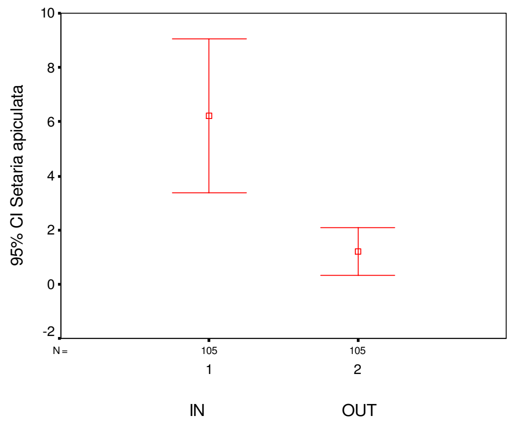
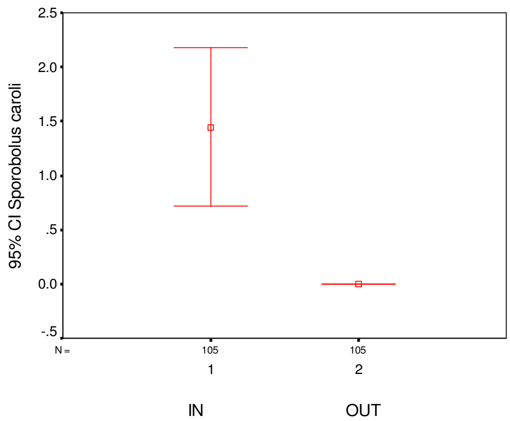
1.0
.5
0.0
-.5
N =
105
105
1
2
IN
OUT
g)


95% CI Setaria apiculata
10
8
6
4
2
0
-2
N =
105
105
1
2
IN
OUT
h)


95% CI Sporobolus caroli
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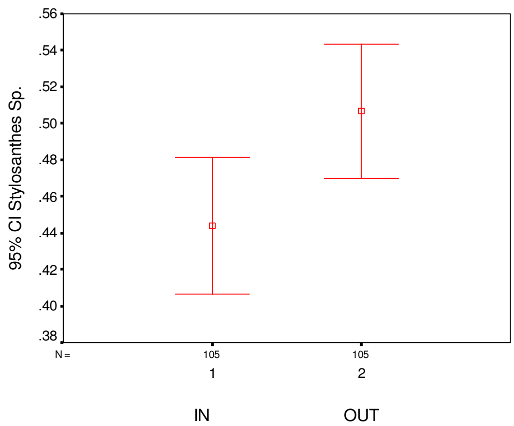
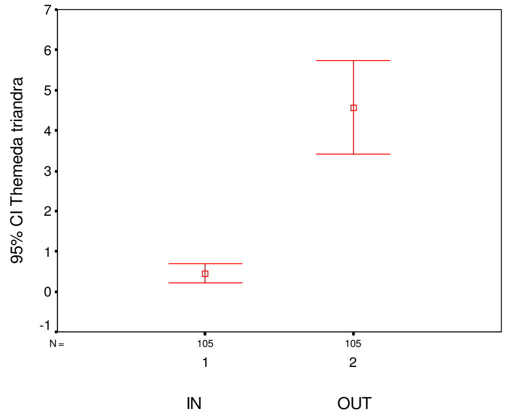
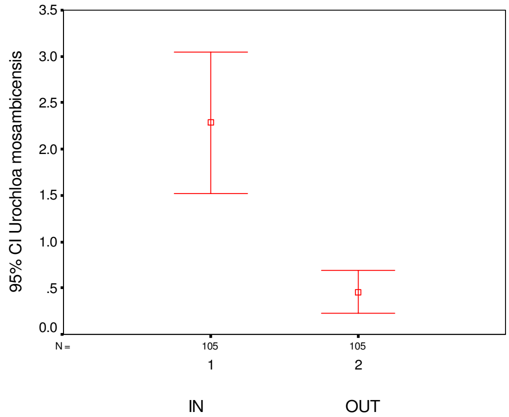
2.0
1.5
1.0
.5
0.0
-.5
N =
105
105
1
2
IN
OUT
i)

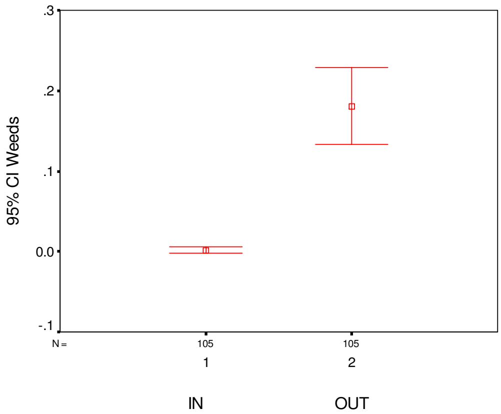

95% CI Stylosanthes Sp.
.56
.54
.52
.50
.48
.46
.44
.42
.40
.38
N =
105
105
1
2
IN
OUT
j)



k)



l)



m)

Figure 3.19. Error bar charts illustrate the comparison of grass species occurring inside and outside the observed foraging area of the Black-throated finch. **a), c), d), e), g), h), i), l)** These error bar graphs show that these grass and weed species and occur more often inside the foraging area of the finch then outside. **b), f), j), k), m)** These error bar graphs show that these grass species occur more often outside the foraging area of the finch than inside. Confidence interval between bars is 95%.

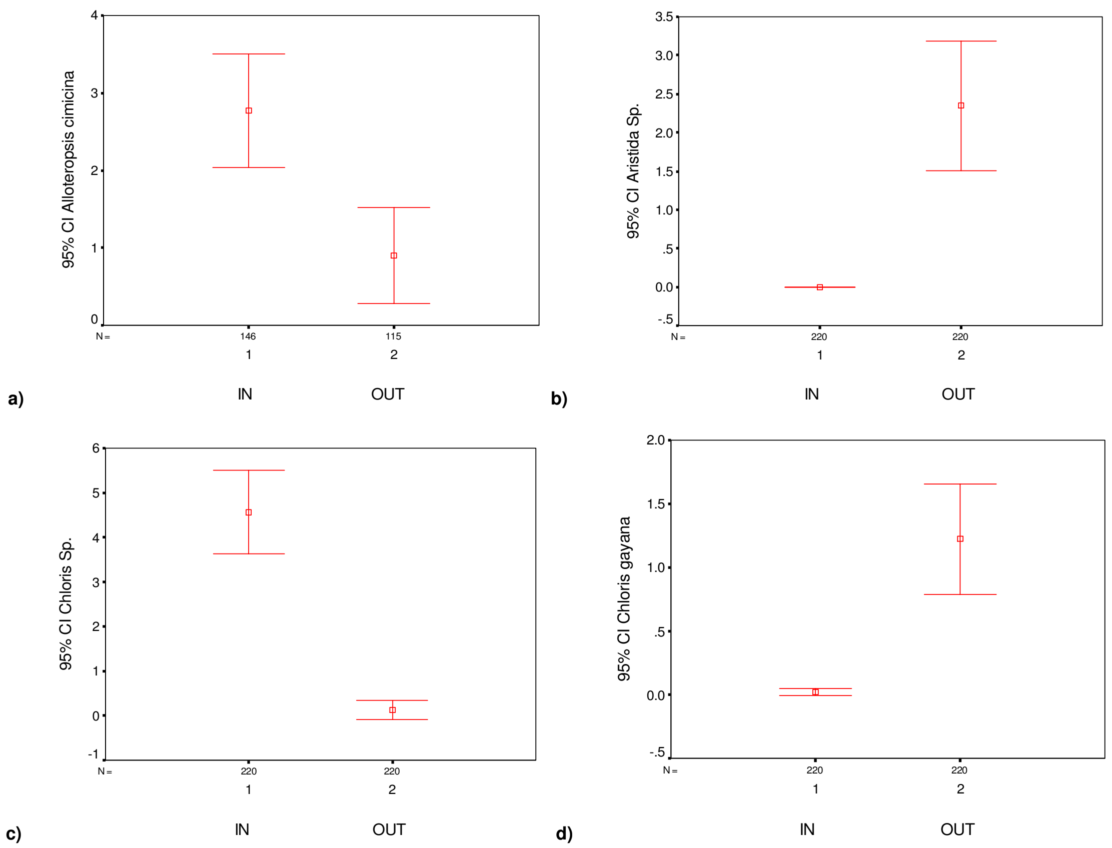
************* Creek**

Several grasses surveyed in the baseline habitat mapping were found to occur inside the area where the finches were recorded to be foraging more often than outside and vice-versa. A total of 11 grasses were found to have significant results, this included being recorded inside more often than out and outside more often than inside the foraging area of the finch (Table 3.3). The grasses that were preferred by the finch include *Alloteropsis cimicina, Chloris* spp., *Eragrostis* spp., *Panicum species, Stylosanthes* spp. and *Urochloa mosambicensis*. The grass species that the finches avoided included *Aristida species, Chloris gayana, Heteropogon contortus, Melanis repens* and weeds.

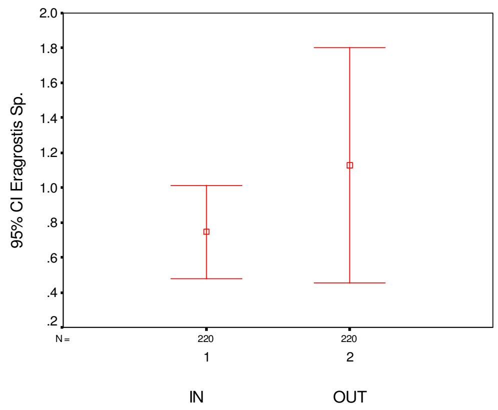
Table 3.3. A Mann-Whitney U test was used to determine the *p* values for each grass and descriptive statistics was used to generate the mean and standard error for ********* Creek. The table shows the mean number of the grass specie's occurring inside the foraging range and the mean number occurring outside the foraging range. A * represents a significant result, the significant results are further illustrated with error bar graphs in figure 6.

Grass Species	IN	OUT	*P*
Alloteropsis cimicina	1.95 ± 0.26	0.17 ± 0.05	0.00*
Alloteropsis semialata	0 ± 0	0 ± 0	1.00
Aristida spp.	0.83 ± 0.19	1.17 ± 0.22	0.00*
Bothriochloa decipiens	0.01 ± 0.00	0.01 ± 0.00	0.32
Bothriochloa pertusa	1.52 ± 0.22	0.83 ± 0.15	0.16
Cymbopogon ambiguus	0 ± 0	0 ± 0	1.00
Chloris gayana	0.50 ± 0.11	0.62 ± 0.11	0.00*
Chloris spp.	2.35 ± 0.27	0.48 ± 0.10	0.00*
Eragrostis spp.	0.94 ± 0.18	0.68 ± 0.17	0.00*
Eriachne armatii	0.40 ± 0.12	0.20 ± 0.10	0.84
Heteropogon contortus	0.15 ± 0.06	2.44 ± 0.31	0.00*
Melanis repens	0.01 ± 0.07	0.34 ± 0.07	0.00*
Panicum spp.	0.28 ± 0.06	0.05 ± 0.02	0.00*
Setaria apiculata	0 ± 0	0 ± 0	1.00
Sporobolus caroli	0 ± 0	0 ± 0	1.00
Sporobolus diandrus	0 ± 0	0 ± 0	1.00
Stylosanthes spp.	0.75 ± 0.21	0.50 ± 0.14	0.00*
Themeda triandra	0 ± 0	0 ± 0	1.00
Urochloa mosambicensis	0.65 ± 0.13	0.10 ± 0.42	0.01*
Weeds	0 ± 0	0.11 ± 0.02	0.00*

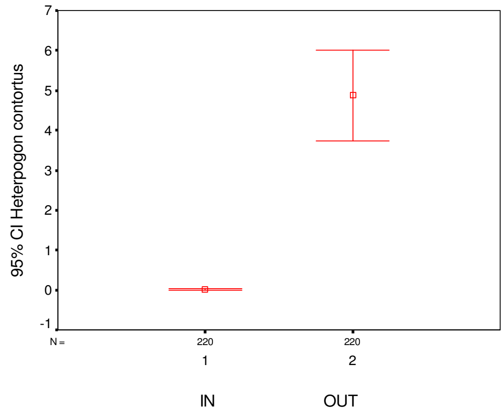
********* Creek followed a similar trend to ####### Dam where there were some species of grass that were obviously preferred and avoided. However, grasses and other forage were not as strongly preferred or avoided as they were at ####### Dam. Two grasses that were most preferred at ********* Creek was *Chloris* spp. and *Alloteropsis cimicina* with 2.35 and 1.95 mean number of seed heads occurring inside the foraging area of the finch (Figure 3.20d,a). The legume *Stylosanthes* spp. was mildly preferred at the site with 0.75 mean number of seed heads occurring where the finches were found to forage (Figure 3.20i). *Aristida* spp. and *Heteropogon contortus* were also avoided at this site with 1.17 and 2.44 mean number of seed heads occurring outside the foraging area of the bird (Figure 3.20b,f).



e)


95% CI Eragrostis Sp.
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
N =
220
220
1
2
IN
OUT

f)


95% CI Heterpogon contortus
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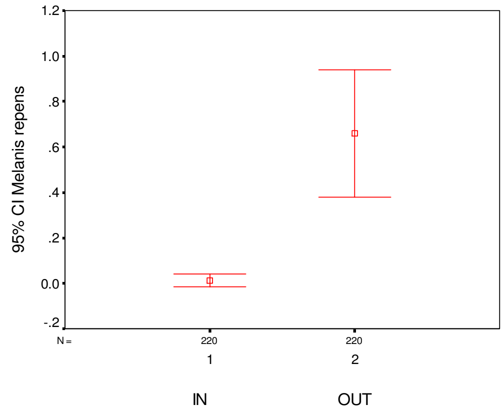
6
5
4
3
2
1
0
-1
N =
220
220
1
2
IN
OUT

g)


95% CI Melanis repens
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1.0
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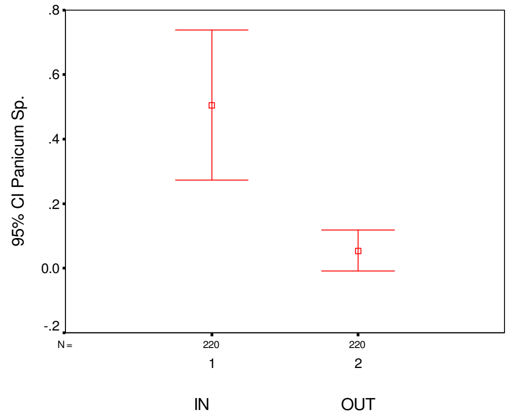
.6
.4
.2
0.0
-.2
N =
220
220
1
2
IN
OUT

h)


95% CI Panicum Sp.
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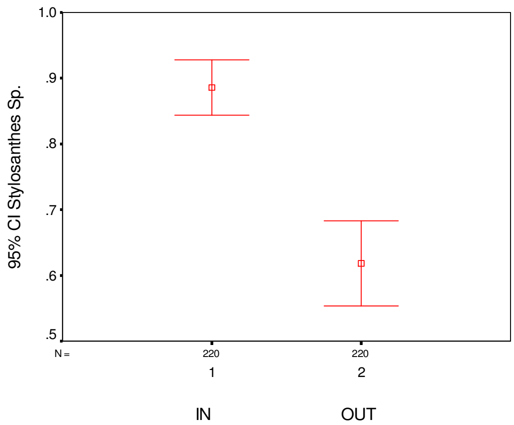
.6
.4
.2
0.0
-.2
N =
220
220
1
2
IN
OUT

i)


95% CI Stylosanthes Sp.
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.7
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N =
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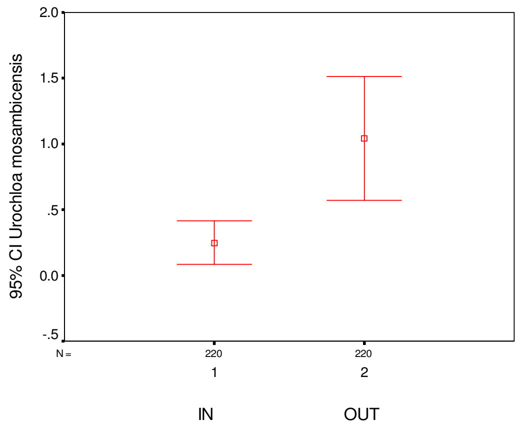
220
1
2
IN
OUT

j)


95% CI Urochloa mosambicensis
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N =
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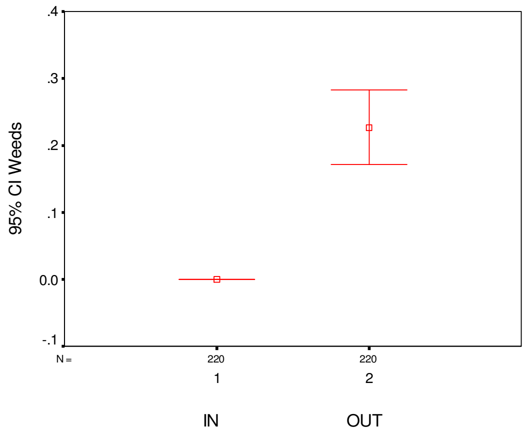
220
1
2
IN
OUT



k)

Figure 3.20. Error bar charts illustrate the comparison of grass species occurring inside and outside the observed foraging area of the Black-throated finch. **a), c), e), h), i), j).** These error bar graphs show that these grass species occur more often inside the foraging area of the finch then outside. **b), d), f), g), k).** These error bar graphs show that these grass species occur more often outside the foraging area of the finch than inside. Confidence interval between bars is 95%.

Chapter 4: Discussion

Activity Budget

In the present study, Black-throated finches were observed to spend the longest duration of their day during breeding season foraging also. Black-throated finch chicks had fledged by the time first observations began but were still dependent on the parents for food and thus remained tied to the nest. Since the parents were still supporting the chicks with food, they would have to continue to consume enough food/energy to not only maintain themselves but their chicks as well. Mitchell's (1996) study on the Black-throated finch found that finches foraged for up to 64.8% of observation time. A study undertaken on the New Zealand Mohua *Mohoua ochrocephala* by Oppel and Bevan (2004) investigating habitat use and foraging behaviour found that breeding Mohua spent a little more than half their time foraging and another quarter of their time scanning for food. A study by Bugoni *et al.* (2005) found similar results for Common terns in Southern Brazil. Bugoni *et al*. found that Common turns spent from 46-64% of daylight hours away from the nest foraging. An independent study by Frank and Becker (1992) found evidence to support Bugoni *et al*.'s find whilst observing body mass and nest reliefs in Common terns exposed to different feeding conditions. This study revealed that these terns spent an estimated 31% of daylight time feeding. Mehlum, Gabrielsen and Nagy (1993) studied the energy expenditure by Black guillemots *Cepphus grille* during chick-rearing and found that guillemots consumed 61% of their body mass per day during chick rearing. Although, Black-throated finches have a different diet and breeding biology they would also use a significant percentage of their body weight during chick provision. This supports the change in foraging behaviour during the non-breeding season when finches mainly forage in the early morning and late afternoon to such long foraging durations during the breeding season (Zann, 1976).

Foraging Distance and Effort

Black-throated finches spent all of their time within a very short distance from their nesting sites or mean centre as for the colony at ********* Creek during breeding season, although they were capable of moving much farther. The main proportion of their day was spent foraging close to the nest, in short bouts. Foraging tended to occur more often at particular foraging locations that were visited repeatedly over the six week period of observation. Other patches were exploited, however longer time was spent foraging at patches they'd visited before; this may suggest that these patches contained more abundant, high quality seed. Black-throated finches show a strong similarity in breeding ecology to the Western long-billed corella *Cacatua pastinator* in many ways. A study by Smith and Moore (1992) on the patterns of movement in the Western long-billed corella in the Western Australia found that all partners of this corella species tend to stay together during their daily movements during breeding season. The pair was found to be the basic unit of the Black-throated finch with partners rarely more than a metre away during breeding season (Zann, 1976). The nest tree is the focus of the corella's activities and foraging trips were usually at foraging sites nearest to the nest. Breeding Tree sparrows *Passer montanus* also remains attached to the natal area, seldom flying more than 300m to forage (Field & Anderson, 2004). Another study on the foraging ecology of the Tree swallow found similar results in which breeding Tree swallows forage within 100-200m of their nest (McCarty & Winkler, 1999). Black-throated finches also seldom flew far from the nest for foraging, rarely traveling more than 350m away from the nesting site. Black-throated finches like Tree sparrows remain relatively sedentary during breeding season, moving only small distances to forage even know they are capable of moving much larger distances. Optimal foraging theory predicts that food patches with the highest energy rewards should be selected by finches (MacArthur & Pianka, 1966). Diet is linked to foraging efficiency, so depending on the quality or attributes of the patch will decipher how long a bird or finch remains foraging in the one area. Mitchell (1996) found that each foraging bout for the Black-throated finch lasted for a consistent duration of the time of day it began. The food abundance for the time of this study according to Mitchell was within a period of Medium to Low food abundance. During this time foraging bouts were instigated by finches when land on the ground within a patch and terminated when flying from the patch to perform another activity. Foraging at times of medium to low food abundance would mean that finches would have to increase foraging effort and duration in order to their daily demands (Schluter, 1980). Schulter's (1980) study on the seed and patch selection by Galapagos finches recorded similar durations of foraging to this study. Foraging intervals for the Galapagos finches typically varied from 20-300 seconds. Black-throated finch foraging durations were recorded to mainly occur between 20-300 seconds also.

Colonial Living

Although the time spent foraging as a group was not recorded it was noted that the three pairs of finches at ####### dam foraged together the majority of the time. It was observed that if one pair flew away or to another patch the remaining finches would follow shortly after, this was also thru for the colony at ********* Creek. Pairs as a unit tended to lead the colony to the next foraging site. Zann (1976) observed that Black-throated finches were highly social and that most activities occurred within the nesting area. Zann also observed that when foraging members of a flock moved at the same time in the same direction. This same observation was made during this study and has also been noted for other similar species such as the Gouldian finch (Dostrine *et al.*, 2001). Colonial living is thought to provide advantages in located foraging sites by providing the opportunity to reduce searching costs. Therefore, the more birds in a colony the more information there will be about food location (Barta & Giraldeau, 2001). The presence of a colony of birds at a foraging site also indicates the availability and quality of food (Bayer, 1982). Black-throated finches were found to repeatedly return to a number of patches throughout this study; this may indicate that food was readily available and that these particular sites contained quality foraging material. The short foraging bouts also suggest that these particular foraging sites that were revisited contained abundant and quality food. The optimal foraging theory supports this as animals will feed at sites with abundant good quality food for a short space of time as they can acquire energy faster, whereas animals will spend more time at foraging sites with low abundance and poor quality fodder in order to gain the same amount of energy (MacArthur and Pianka, 1966).

Diet

Several grasses were found to occur in greater abundance within the foraging area of the Black-throated finch than outside; indicating that some grasses may be of more importance to foraging and survival. *Urochloa mosambicensis* and *Alloteropsis semialata* appeared to be preferred by the Black-throated finch. *Urochloa mosambicensis* was found to be abundant in foraging areas of the finch. Mitchell (1996) found that *U.mosambicensis* dominated the diet of the Black-throated finch in his study.

Mitchell also suggest from his findings that the finch obtained the highest average energy from *U.mosambicensis* even know the seeds of this grass were found to be the least consumed. *Alloteropsis semialata* is one of the first perennial grasses in monsoonal Australia to produce seed at the start of the wet season and was one particular grass that was found to be preferred by the finch (Crowley & Garnett, 2001). The wet season triggers grasses to germinate like a blanket, emptying the entire landscape of the once fallen seeds that were sustaining seed-eating birds. This period of time is a struggle for survival where there may not be any resources for weeks, until the first seeds are produced by *A.semialata*. This species of grass produces seed far earlier than other grass species, due to rapid growth and maturation. Smaller rain events may also trigger germination, whereas other grasses may require more substantial amounts of rain to germinate (Woinarski, 2005). This grass could therefore be a key species in sustaining the Black-throated finch leading up to breeding season. *Alloteropsis* is also highly palatable to cattle and rapidly declines in abundance and lags in seed production in response to grazing pressure (Crowley & Garnett, 2001). This may result resource shortages for the Black-throated finch in times when such grasses are relied on for survival and there is an extended time until the next grass species germinates; increasing the chances of local extintion. For species of bird such as the Black-throated finch which are already restricted in range and declining, the management of key grasses such as *Alloteropsis semialata* is critical to future persistence. *Alloteropsis* has large seeds and high nutritional value and has been found by Garnett and Crowley (1999) to influence the onset and duration of the breeding season for the Golden shouldered parrot. *Alloteropsis* was observed to have mainly fallen seeds during the study of the Black-throated finch, therefore this grass species may also have a strong influence on when the breeding season of the finch begins.

Limitations of this Study

In a study that is constrained by time there is always bound to be limitations to how much data you can collect and how you can collect that data. Although, a substantial amount of data was collected at the ####### Dam site in particular, far less information was able to be collected at ********* Creek because nesting sites were unable to be located. Consequently, this study focused far more on the ####### Dam site. Information on the dynamics of such a large colony would have been useful data to collect and analyse, unfortunately given the circumstances this was unable to be done. The small number of breeding pairs at ####### Dam posed similar problems, however this site was chosen more so for reliability and consistence not volume. More pairs in a colony would have allowed greater generalisation to be made about the ecology of pairs of finches in a colony, however the difficulty would then arise with accurate identification and location of each pair. During the six week period of observation it sometimes became difficult to identify which pair was which. This could have been avoided by tagging the finches to allow ease of identification. However, although time was a constraint it was unknown whether capturing and tagging the finches whilst they were nesting and had chicks would disturb them and cause them to abandon their nests. Every study has its limitations, however this study contributes valuable information about the Black-throated finch during breeding season and therefore achieves the aims that were set and the answered the questions that this study attempted to answer.

Conservation Applications of this Study

The conservation significance of this research is that this data collection will allow better knowledge to be gained about the optimal area that is required to maintain a healthy breeding population of Black-throated finch. Although, this data alone cannot be used to determine the area required to sustain the finches during both breeding and non-breeding season, it can be used in conjunction with future studies during non-breeding season to create a full picture of the land requirements of the Black-throated finch through its entire lifecycle. This data will also assist in giving advice on the buffer zones that are necessary to safeguard finch habitat against the adverse affects of development. This could also lead to much wider benefits for instance the protection of other grassland species of bird and assist in the conservation of related species such as the Gouldian finch.

Future Research into the Black-throated Finch

Further identify areas of potential habitat for the Black-throated finch by mapping known habitat types determined from more extensive surveying of the habitat the finches are already known to occur in. And although my research will contribute to managing and protecting the finch more research still needs to be undertaken on the finch during breeding season by investigating habitat requirements in more detail – such as vegetation structure, fire, stock grazing and rainfall. Radio-tracking of the finches during non-breeding season when they are much more mobile and more difficult to track is an important research area that needs to be focused on in the future. Radio-tracking will allow more accurate identification of individual finches or pairs and allow the distance traveled to be more easily determined. This type of information could be combined with results from this study to give a much fuller picture of the ecology of the Black-throated finch. Vital research into the survivorship of juveniles is also required, in order to determine whether the current populations are increasing, stable or declining in number. The persistence of the Black-throated finch relies on research like this and such research will no doubt hold the key to the finch's recovery in the future as well.

Literature Cited

Ahrens, J.D. & Nour, T.M. (1997). *Rainfall Alleviates Drought Impact on Somali Region: A Field Visit to Jijiga Degehabur Zones of the Somali National Regional State*. United Nations Development Programme, Ethiopia.

All Maps (2007). Queensland Maps. Retrieved April 11, 2007, from Wilkins Tourist Maps Website, http://www.arta.com.au/qld.htm.

Barta, Z. & Giraldeau, L. (2001). *Breeding Colonies as Information Centers: A Reappraisal of Information-based Hypotheses Using the Producer – Scrounger Game.* Behavioural Ecology **12(1)**: 121-127.

Barrett, G; Silcocks, A; Barry, S; Cunningham, R. & Poulter, R. (2003). *The New Atlas of Australian Birds*. Royal Australasian Ornithologists Union, Melbourne.

Bayer, R.D. (1982). *How Important are Bird Colonies as Information Centers?* Auk **99**: 31-40.

Begon, M; Harper, J.L. & Townsend, C.R. (2003). *Ecology*. Blackwell Publishing Co., Melbourne.

Black-throated finch Recovery Team, Department of Environment and Conservation (NSW) and Queensland Parks and Wildlife Service. (2004). *Recovery Plan for the Black-throated finch Southern Subspecies Poephila cincta cincta.* Department of Environment and Conservation (NSW), Hurstville and Queensland Parks and Wildlife Service, Brisbane.

Blakets, M; Davies, S.J.J.F., & Reilly, P.N. (1984). *The Atlas of Australian Birds*. Royal Australasian Ornithologists Union, Melbourne.

Brown, J.S. (1988). *Patch Use as an Indicator of Habitat Preference, Predation Risk and Competition.* Behavioral Ecology and Sociology **22**: 37-47.

Brown, J.S. & Mitchell, W.A. (1989). *Diet Selection on Depletable Resources.* Oikos **54**: 33-43.

Brown, J.S. & Morgan, R.A. (1995). *Effects of Foraging Behaviour and Spatial Scale on Diet Selectivity: A Test with Fox Squirrels.* Oikos **74**: 122-136.

Bugoni, L; Cormon, T.D; Boyne, A.W. & Hays, H. (2005). *Feeding Grounds, Daily Foraging Activities, and Movements of Common Terns in Souther Brazil, Determined by Radio-telemetry.* Waterbirds **28(4)**: 468-477.

Buosi, P. (2005). *Enertrade North Queensland Gas Pipeline Black-throated finch Studies (Post Construction).* Natural Resource Assessments, Townsville.

Buosi, P. (2006). *Black-throated finch Habitat in the Townsville-Thuringowa Local Government Areas – A Predictive Model.* Natural Resources Assessments, Townsville.

Clark, C.W. & Mangel, M. (1986). *The Evolutionary Advantages of Group Foraging.* Theoretical Population Biology **30**: 45-75.

Colls, K & Whitaker, R. (1999). *The Australia Weather Book.* Child & Associates Publishing Pty Ltd, NSW, Australia.

Courtney, P.A. & Blokpoel, H. (1980). *Food and Indicators of Food Availability for Common Terns on the Lower Great Lakes.* Canadian Journal of Zoology **58**: 1318-1323

Crowley, G.M. & Garnett, S.T. (2001). *Growth, Seed Production and Effect of Defoliation in an Early Flowering Perennial Grass, Alloteropsis semialata (Poaceae), on Cape York Peninsula, Australia.* Australian Journal of Botany **49**: 735-743.

Department of Environment and Heritage (DEH). (2005). *Advice to the Minister for the Environment and Heritage from the Threatened Species Committee (TSSC) on Amendments to the List of Threatened Species Under the EPBC Act 1999.* Canberra, Australia.

Dostine, P.L. *et al.* (2001). *Seasonal Use of Savanna Landscapes by the Gouldian Finch, Erthrura gouldiae, in the Yinberrie Hills Area, Northern Territory.* Wildlife Research **28**: 445-458.

Emlen, J.M. (1966). *The Role of Time and Energy in Food Preferences*. The American Naturalist **100**: 611-617.

Field, R.H. & Anderson, G.Q.A. (2004). *Habitata Use by Breeding Tree Sparrows Passer montanus.* Ibis **146**: 60-68.

Frank, D. & Becker, P.H. (1992). *Body Mass and Nest Reliefs in Common Terns Sterna hirundo Exposed to Different Feeding Conditions*. Ardea **80**: 57-69.

Franklin, D.C. (1999). *Evidence of Disarray Amongst Granivorous Bird Assemblages in the Savannas of Northern Australia, a Region of Sparse Human Settlement.* Biological Conservation **90**: 53-68.

Garnett, S.T. (ed). (1993). *Threatened and Extinct Birds of Australia, Second Edition.* RAOU, Melbourne.

Garnett, S. & Crowley, G. (1999). *Recovery Plan for the Golden-shouldered Parrot Psephotus chrysopterygius 1999-2002.* Australian Nature Conserveration Agency, Canberra.

Garnett, S.T. & Crawley, G.M. (2000). *The Action Plan for Asutralian Birds 2000.* Environment Australia, Canberra.

Garnett, S.T. *et al.* (2005). *Habitat and Diet of the Star Finch (Neochmia ruficauda clarescens) in the Early Wet Season at Princess Charlotte Bay, Cape York Peninsula, Australia*. EMU **105**: 81-85.

Hanson, J. & Green, L. (1989). *Foraging Decisions: Patch Choice and Exploitation by Pigeons.* Animal Behviour **37**: 968-986.

Henry, M; Thomas, D.W.; Vaudry,R. & Carrier, M. (2002). *Foraging Distances and Home Range of Pregnant and Lactating Little Brown Bats (Myotis lucifugus).* Journal of Mammalogy **83(3)**: 767-774.

Hobday, D.K. (1992). *Abundance and Distribution of Pilchard and Anchovy as Prey Species for Little Penguin Eudyptula minor at Phillip Island, Victoria.* EMU **91**: 342-354.

Immelmann, K. (1962). *Beitrage zu einer vergleichenden Biologie australischer Prachtfinken (Spermestidae).* Zool. Jb. System **90**: 1-196

Iwasa, Y.M; Higashi, & Yamamura, N. (1981). *Prey Distribution as a Factor Determining the Choice of Optimal Foraging Strategy.* American Naturalist **117**: 710-723.

Keast, J.A. (1995). *Infrastructure variation in the Australian Finches.* EMU **58**: 219-246.

Kohlmann, S.G. & Risenhoover, K.L. (1998). *Effects of Resource Distribution Patch Spacing and Preharvest Information on Foraging Decisions of Northern Bobwhites.* Behavioral Ecology **9(2)**: 177-186.

Krebs, J.R; Stephens, D.W. & Sutherland, W.J. (1983). *Perspectives in Optimal Foraging.* In 'Brush, A.H. & Clark, J.A. (ed.), Perspectives in Ornithology. pp165-216. Cambridge University Press, New York.

Levins, R. (1969). *Some Demographic and Genetic Consequences of Environmental Heterogeneity for Biological Control.* Bulletin of the Entomological Society of America **15**: 237-240.

Lubin, Y & Henschel, J. (1996). *The Influence of Food Supply on Foraging Behaviour in a Desert Spider.* Oecologia **105**: 64-73.

McCarty, J.P. & Winkler, D.W. (1999). *Foraging Ecology and Diet Selectivity of Tree Swallows Feeding Nestlings.* The Condor **101(2)**: 246-254.

MacArthur, R.H. & Pianka, E.R. (1966). *On Optimal Use of a Patchy Environment.* The American Naturalist **100**: 603-609.

Martin, T.G.; Kuhnert, P.M.; Mengersen, K. & Possingham, H.P. (2005). *The Power of Expert Opinion in Ecological Models Using Bayesian Methods: Impact of Grazing on Birds.* Ecological Applications **15(1)**: 266-280.

Mehlum, F; Gabrielsen, G.W. & Nagy, K.A. (1993). *Energy Expenditure by Black Guillemots (Cepphus grylle) During Chick-Rearing.* Colonial Waterbirds **16(1)**: 45-52.

Mitchell, D. (1996). *Foraging Ecology of the Black-throated finch Poephila cincta cincta.* Master's Thesis, James Cook University, Townsville.

Negro, J.J. & Hiraldo, F. (1993). *Nest-sites Selection and Breeding Success in the Lesser Kestrel Falco naumanni.* Bird Study **40**: 115-119.

Newton, I. (1994). *The Role of Nest Sites in Limiting the Numbers of Hole-nesting Birds: A Review.* Biological Conservation **70**: 265-276.

NQ Water (2007). *Ross River Dam Upgrade Project.* Retrieved Aprill 11, 2007, from NQ Water Websites, http://www.nqwater.com.au/?page+88.

Nye, E.R. & Dickman, C.R. (2005). *Activity Budgets and Habitat Use of the Green Pygmy-goose (Nettapus pulchellus) on Dry-season Refuges in Kakadu National Park, Northern Territory*. EMU **105**: 217-222.

Oppel, S. & Beavan, M. (2004). *Habitat Use and Foraging Behaviour of Mohua (Mohua ochrocephala) in the Podocarp Forest of Ulva Island, New Zealand.* EMU **104(2)**: 235-240.

Passingham, H.P. (1989). *The Distribution and Abundance of Resources Encountered by a Forager.* The American Naturalist **133(1)**: 42-60.

Pyke, G.H; Pulliam, H.R. & Charnov, E.L. (1977), *Optimal Foraging: A Selective Review of Theory and Tests.* Quarterly Review of Biology **52**: 137-154.

Pyke, G.H. (1984). *Optimal Foraging Theory: A Critical Review.* Reviews of Ecology and Systematics **15**: 523-575.

Schluter, D. (1980). *Seed and Patch Selection by Galapagos Finches: Relation to Foraging Efficiency and Food Supply*. Ecology **63(4)**: 1106-1120.

Schluter, D. & Repasky, R.R. (1991). *Worldwide Limitation of Finch Densities by Food and Other Factors.* Ecology **72(5)**: 1763-1774.

Smith, J.N.M. & Dawkins, R. (1971). *The Hunting Behaviour of Individual Great Tits in Relation to Spatial Variations in their Food Density.* Animal Behaviour **19**: 695-706.

Smith, J.N.M. & Sweatman, H.P.A. (1974). *Food Searching Behaviour of Titmice in Patchy Environments.* Ecology **55**: 1216-1232.

Smith, G.T. & Moore, L.A. (1992). *Patterns of Movement in the Western Long-Billed Corella Caccitua pasinatior in the South-West of Western Australia.* EMU **92**:19-27.

Thomas, C.D. & Harrison, S. (1992). *Spatial Dynamics of a Patchily Distributed Butterfly Species.* Journal of Applied Ecology **61**: 437-446.

Thomas, C.D. (1994). *Extinction, Colonisation, and Metapopulations: Environmental Tracking by Rare Species.* Conservation Biology **8(2)**: 373-378.
Tidemann, S.C. (1993). *Management of a Threatened Species – the Gouldian Finch Example.* In 'Birds and their Habitats: Status and Conservation in Queensland. pp123-131. Queensland Ornithological Society, Brisbane.

Tidemann, S.C; Lawson, C; Elvish, R; Boyden, J. & Elvish, J. (1999). *Breeding Biology of the Gouldian Finch Erythrura gouldiae, an Endangered Finch of Northern Australia*. EMU **99**: 191-199.

Valone, R.J. & Brown, J.S. (1989). *Measuring Patch Assessment Abilities of Desert Granivores.* Ecology **70**: 1800-1810.

Village, A. (1993). *The Role of Nest-site Availability and Territorial Behaviour in Limiting the Breeding Density of Kestrels.* Journal of Animal Ecology **52**: 635-645.

Weavers, B.W. (1992). *Seasonal Foraging Ranges and Travels at Sea of Little Penguins Eudyptula minor, Determined by Radio-tracking.* EMU **91**: 302-317.

Woinarski, J.C.R. & Caterral, C.P. (2004). *Historical Changes in Bird Fauna at Coomooboolaroo Northeastern Australia, From the Early Years of Pastoral Settlements (1873) to 1999.* Biological Conservation **116**: 379-401.

Woinarski, J.C.Z; Williams, R.J.; Prince, C. & Rankmore, B. (2005). *Landscape Without Boundaries: Wildlife and their Environments in Northern Australia.* Wildlife Research **32**: 377-388.

Yorio, P; Quintana, F; Gatto, A; Lisinizer, N. & Suarez, N. (2004). *Foraging Patterns of Breeding Olrog's Gull at Golfo San Jorge, Argentina*. Waterbirds **27(2)**: 193-199.

Zach, R. & Falls, J.B. (1976). *Ovenbird (Aves: Parulidae) Hunting Behaviour in a Patchy Environment: An Experimental Study.* Canadian Journal of Zoology **54**: 1863-1879.

Zann, R. (1976). *Distribution, Status and Breeding of Black-throated finches Poephila cincta in Northern Queensland.* EMU **76**: 201-206.