2005

A study of the effects of Probait on Chuditch, Dasyurus Geoffroii, within the Julimar Conservation Park with notes on the general ecology

Melissa York
Edith Cowan University

USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

A Study of the Effects of Probait on Chuditch, *Dasyurus geoffroii*, within the Julimar Conservation Park with notes on the general ecology.

By Melissa York

Thesis Submitted in Partial Fulfillment of the Requirements for the Award of Bachelor of Science (Biological Science) with Honours.

Faculty of Computing, Health and Science
School of Natural Sciences
Edith Cowan University

Submitted: 4th November 2005

Declaration

I certify that this thesis does not to the best of my knowledge and belief:

(i) Incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;

(ii) Contain any material previously published or written by another person except where due reference is made in text; or

(iii) Contain any defamatory material

Signature. [redacted]

Date ....16/01/06...

Acknowledgements

Firstly I would like to thank my three supervisors, Dr Alan Needham (Edith Cowan University, Dr Keith Morris (Department of Conservation and Land Management) and Mr Brent Johnson (Department of Conservation and Land Management). I thank Dr Alan Needham for his guidance, time, patience and support throughout the year. I thank both Dr Keith Morris and Mr Brent Johnson for providing a topic for my honours project, but most of all their time, patience, guidance, support and for sharing their wealth of knowledge and years of experience with me.

I would also like to thank all of the CALM members and volunteers for the many aspects of help they provided in the field. I thank you for sharing your experiences with me and helping in the all important data collection. I am also grateful to Quinton Burnham (the only other honours student) and all the other postgraduate students and staff for their encouragement and support.

I would like to thank all my friends for keeping me happy and sane during this journey. I would like to say a special thankyou to Dean Butler for his love, understanding and support. Finally, my family deserves a special thankyou for their encouragement and support. I would like to thank my father, David York, sisters Tara York and Felicity Loftus and my brother-in-law Simon Loftus for their time and patience in proof reading my many drafts and my mother, Elizabeth York for her constant belief in my potential.

I could not have completed my honours thesis without the help of all of these people. I would like thank all of you from the bottom of my heart.

Abstract

Broad scale fox baiting programs have been underway in Western Australia since 1996 when the Western Shield fauna recovery program commenced with the aim of recovering many fauna species that are under threat of extinction. Until recently, effective fox control for fauna recovery has been achieved with dried meat baits impregnated with the poison 1080. The Department of Conservation and Land Management (CALM) has developed more readily available and cost effective sausage meat baits, termed Probait. As bait acceptability trials in the laboratory indicated a potential risk from Probait ingestion by chuditch (*Dasyurus geoffroii*), assessment of the likely risk of operational use of Probait was undertaken.

The species showed the capability of locating and consuming Probait in the presence of natural resources within the Julimar Conservation Park study area. A total of 59% of the individuals sampled displayed bait ingestion through fluorescent banding of their facial whiskers. The consumption of Probait by chuditch did not appear to negatively impact the population. The results from the relative abundance, sex ratio, age structure and dispersal patterns appeared to be normal in comparison with some previous yearly results.

The general ecology of chuditch populations in Jarrah forest communities has not been examined in detail since before broad scale fox baiting programs. Updated information on the general ecology of the chuditch is essential to ensuring the ongoing success of the recovery program.

The diurnal refuge utilisation and requirements for chuditch displayed little change from previous studies with the exception of refuge type selection. Core activity areas were defined for 15 radio-collared animals. These were consistent with previous studies, with males displaying larger core areas then females.

Table of Contents

List of Tables

List of Figures

List of Plates

CHAPTER 1 – INTRODUCTION

Broad scale fox baiting programs have been underway in Western Australia since 1996 when the Western Shield program commenced (Wyre 2005). It is arguably the main reason behind the recovery of many populations of small to medium sized mammals including numbats, Southern Brown bandicoots, woylies and the chuditch.

Since European settlement in Australia the continent's environmental conditions have changed considerably (Burbidge and McKenzie 1989). More species of mammal have become extinct in Australia over the last 100 years than in any other country, with many more being identified as vulnerable or endangered (Burbidge and McKenzie 1989). The documented loss of 18 Australian mammal species is a disaster thought to have a number of causes (Burbidge and McKenzie 1989), including land clearing, hunting and the introduction of stock animals and other exotic species such as the fox (*Vulpes vulpes*) and the cat (*Felis catus*) (Morris *et al.*. 2003).

Surviving species have suffered declines in abundance and distribution throughout their distribution (Wilson 1999) because of these pressures. The chuditch (*Dasyurus geoffroii*) is the largest carnivorous marsupial in Western Australia. It once occupied over 70% of the continent but is now found almost exclusively in the Jarrah forests of the south-west of Western Australia (approximately 5% of it former habitat range) as a result of fox predation and competition (Orell and Morris 1994). It has become apparent that without active management and recovery programs, many of Australia's native mammals will not survive the limitations placed upon them by feral predators such as the fox and feral cat (Burbidge and McKenzie 1989).

Until recently effective fox control programs for fauna recovery have been achieved by aerial or ground baiting operations with dried meat baits impregnated with 4.5 mg of sodium monofluoroacetate (also known as the Compound 1080). Concerns that the cost of dried meat baits have doubled over the last 10 years, and the ability of the Agricultural Protection Board to supply baits in the long term have arisen in previous years. These concerns have led to the Department of Conservation and Land Management (CALM) developing a cheaper, sausage type bait (known as Probait) (Armstrong 2004).

As a part of the Australian Pesticides and Veterinary Medicines Authority (APVMA) registration process for this new bait, CALM needed to demonstrate the effectiveness of the bait in killing foxes. Marlow and Brazell (2002) and Marlow *et al.*. (2003) indicated that Probait has the ability to kill foxes effectively. Other studies investigating the acceptability of dried meat baits, Probaits and Foxoff (another commercially available fox bait) to captive non-target animals (Martin *et al.*. 2002) has identified several dasyurid species that were potentially at risk from toxic Probaits. *Dasyurus geoffroii* (chuditch) was identified as facing a medium to high potential risk from 4.5 mg dried meat baits and a medium to low potential risk from 3 mg Probaits. However, Morris *et al.*. (2003) have demonstrated that broad scale fox baiting with 4.5 mg 1080 dried meat baits has not had a detrimental impact on chuditch populations in the wild.

Martin *et al.* (2002) suggests that the laboratory trials be taken as a guide to direct field-testing of the uptake of toxic Probaits by wild populations in the presence of natural food resources. For carnivorous marsupials such as the chuditch, fox control reduces pressure from competition for food and direct predation pressures (Morris *et al.* 2003). With this in mind, the key aim of this study was to determine the effects of Probait baiting on the chuditch population in the Julimar Conservation Park. In order to investigate these effects it was necessary to determine whether:

1. wild populations of chuditch will locate and consume Probait in the presence of natural food sources.
2. Probait affects the population dynamics of the wild population by identifying the incidence of survival of individuals, measuring the relative abundance, age structure, sex ratio, number of pouch young and dispersal rates before, during and after the trial, and to determine whether
3. there is a likelihood of numerous baits being ingested daily exists.

Notes on the general ecology such as refuge utilisation and core activity areas of the forest chuditch were also collected during this study in an effort to increase and update the current knowledge regarding post fox baited populations.

CHAPTER 2 – LITERATURE REVIEW

2.1 General Classification

2.1.1 Taxonomy and relationships

The chuditch (*Dasyurus geoffroii*) was described in 1841 by John Gould from a specimen collected on the Liverpool Plains in New South Wales (Serena, Soderquist and Morris 1991). The chuditch is a member of the *Dasyuridae* family which comprises approximately 50 species of small to medium sized predatory marsupials distributed in Australia and New Guinea (Serena and Soderquist 1989b). There are three other Australian species of *Dasyurus*: *D. maculatus* (tiger quoll), which occurs in eastern Australia, *D. viverrinus* (eastern quoll), found in Tasmania and *D. hallucatus* (northern quoll) which is found in northern Australia (Strahan 1995) from the Pilbara and Kimberley to the 'Top End' of the Northern Territory and Queensland (Serena *et al.* 1991). Two others: *D. albopunctatus* and *D. spartacus* are found only in Papua New Guinea (Van Dyke 1988, as cited by Serena *et al.* 1991).

2.1.2 Current status

In 1983, the chuditch was declared a rare and endangered species in WA under the *Wildlife Conservation Act 1950* due to its drastically reduced range (Morris 1998). A considerable amount of information on the biology and requirements of chuditch in the Jarrah forest was gathered between the years of 1985 and 1988 through a wildlife management program prepared by Serena *et al.* (1991). In 1991, the chuditch was listed as an endangered species under the *Commonwealth's List of Endangered Fauna* (ANZECC 1991). The *Endangered Species Protection Act* (1992) provided CALM with the opportunity to prepare and seek funding for a chuditch Recovery Plan. The ANCA Endangered Species Program assisted financially with the preparation and implementation of the chuditch Recovery Plan (Orell and Morris 1994) which commenced in early 1992. The *Action Plan for Australiasian Marsupials and Monotremes* (1992) listed chuditch as endangered, however a review of this plan in 1996 caused the chuditch to be classed as vulnerable using the IUCN (1994) criteria (Maxwell *et al.* 1996).

2.2 Biological and Ecological Characteristics

2.2.1 Description of species

The chuditch is the largest carnivorous marsupial found within Western Australia (Orell and Morris 1994). Adult individuals are approximately the size of a six-month-old domestic cat with males and females respectively weighing on average 1.3 and 0.9 kg (Serena *et al.* 1991). The chuditch can be readily distinguished from its northern and eastern counterparts by an absence of spots on its long black tail and the presence of a first toe on its hind feet (Kennedy 1990). Other distinguishing characteristics include a white-spotted brown pelage, large round ears, a pointed muzzle, large dark eyes and a non-hopping gait (Orell and Morris 1994). The tail is approximately three quarters of the head and body length (~250 mm) with a large black brush covering the distal portion (Serena *et al.* 1991).

2.2.2 Distribution

Prior to European settlement, chuditch displayed a habitat range of approximately 70% of the Australian continent occurring in every mainland state and territory (Figure 2.1). During this time, anecdotal evidence suggests that they were widespread and relatively abundant in forest, woodland and desert habitats covering this large range (Collett 1887; Whittell 1954; Johnson and Roff 1982; Burbidge *et al.*. 1988; Stead-Richardson *et al.*. 2001). A severe decline and contraction in their range has occurred over the last 200 years with specimens last being collected from New South Wales in 1841, Victoria in 1857 and Queensland between 1887 and 1907. chuditch were last recorded in the central arid zone in the mid 1950s (Finlayson 1961). The species was still abundant in the south west of Western Australia in 1907 but had vanished from coastal areas north of Geraldton by this time (Shortridge 1909). On the Swan Coastal Plain, chuditch persisted until the 1930s.

Chuditch are now limited to the south west of Western Australia, occurring in a roughly triangular area bounded by Moora in the north, Cape Arid to the east and Cape Leeuwin to the south. This represents about 5% of its former range. The estimate of present distribution (Figure 2.2) is supported by Western Australian Museum specimens, reliable sightings and road kill records from the past 15 years. The majority of the population has survived at low densities with a patchy distribution through jarrah (*Eucalyptus marginata*) forests.

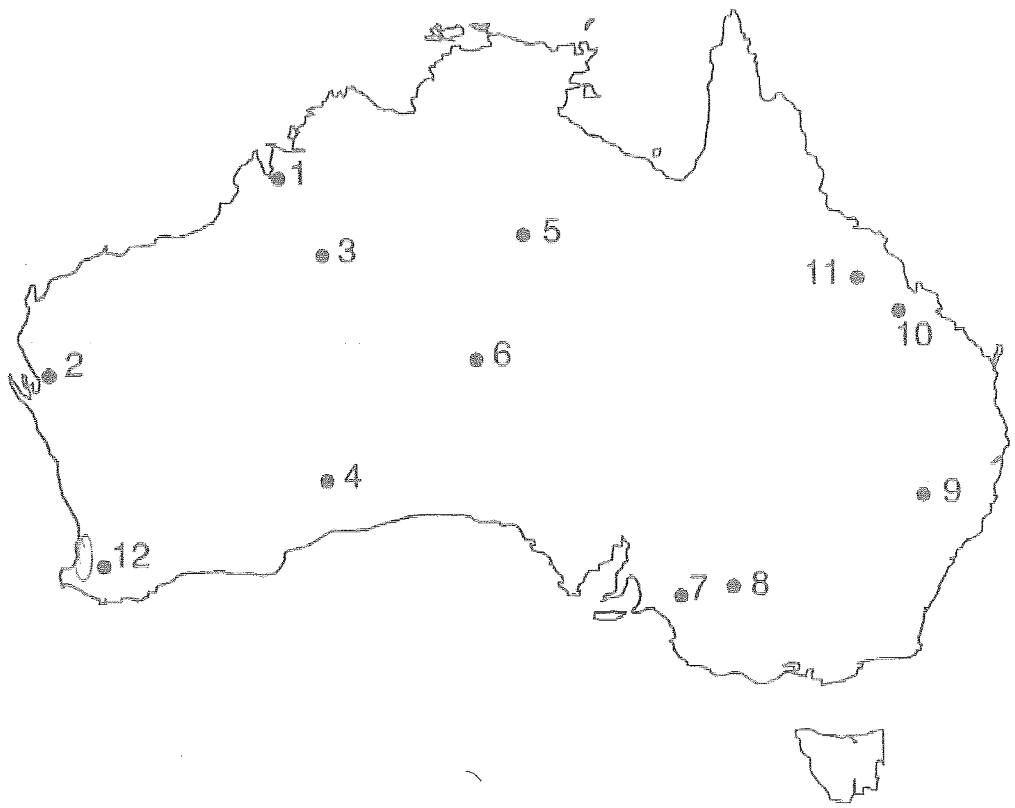

Figure 2.1: The distribution of the chuditch (*Dasyurus geoffroii*) at the time of European settlement, as documented by museum specimens.

(1 Derby, WA; 2 Shark Bay, WA; 3 Kuduarra Well, WA; 4 Rawlinna, WA; 5 Barrow Creek, NY; 6 S of Musgrave/N of Everard Ranges, SA; 7 Murray River, SA; 8 Junction of Murray/Darling Rivers, VIC; 9 Liverpool Plains, NSW; 10 Coomooboolaroo, QLD; 11 Peak Downs, QLD; 12 Arthur River, WA).

From Orell and Morris (1994), pg 2.

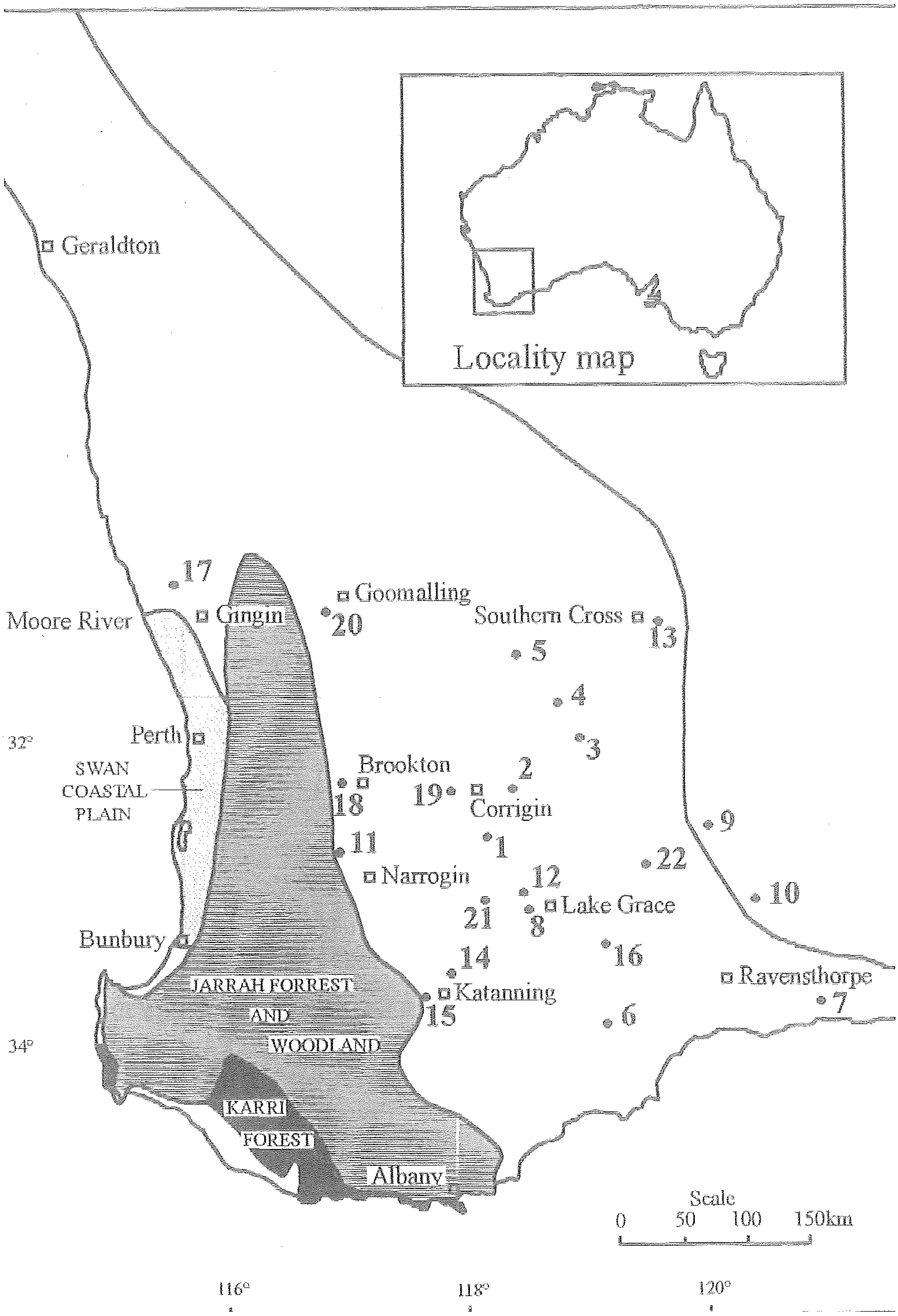

Figure 2.2: Present distribution of chuditch (*Dasyurus geoffroii*) based on museum specimens and reliable sightings and road kill records from 1975-1990.

From Orell and Morris (1994), pg 3.

There are also records of chuditch in the drier woodland and mallee shrubland in the wheatbelt (Orell and Morris 1994). In 1991 the chuditch population was estimated to be fewer than 6,000 (Serena *et al.* 1991) with Jarrah forest populations estimated between 2,500 and 4,400 based on trapping records from 1974 to 1988.

2.2.3 Habitat

The past distribution and range implies that chuditch were able to utilize a wide variety of habitats and environmental conditions associated with beaches, deserts and dry sclerophyll forests (Thomas 1906; Shortridge 1909; Burbidge *et al.* 1988). Habitat preference within the Jarrah forest does not appear to be evident, as chuditch will utilise both moist, densely vegetated, steeply sloped forest and drier, open, gently sloping forest habitats. Riparian vegetation seems to support higher densities of chuditch, possibly because food availability is more reliable and the dense undergrowth provides better shelter and cover from predation (Orell and Morris 1994).

2.2.4 Diet and feeding characteristics

Dasyurus geoffroii can consume large amounts of food in a short time frame. For example, a wild individual may consume 12% of its total body weight in the first 15 minutes of feeding and a captive individual can consume up to 43% of its body weight overnight (Soderquist and Serena 1994). Accounts from aboriginal people from the Northern Territory suggest that the diet of desert chuditch consisted of Witchetty grubs, frogs, lizards and hopping mice (Johnson and Roff 1982). The diet of Jarrah forest chuditch is predominantly insects, ranging in size from termites to large cockroaches and beetles (Johnson and Roff 1982). Forest chuditch will also consume small reptiles such as skinks and a variety of birds including the splendid fairy-wren (*Malurus splendens*) and white-breasted robin (*Eopsaltria georgiana*). Mammals included in the forest chuditch diet include mardo (*Antechinus flavipes*) and southern brown bandicoot (*Isoodon obesulus*), with freshwater crustaceans forming a small portion of its diet (Serena *et al.* 1991). They are also shown to be opportunist feeders in that they eat carrion, fruit and the red pulp from Zamia (*Macrozamia riedlei*) seeds (Hancock 1991, cited in Orell and Morris 1994).

For most of the year chuditch typically forage on the ground at night. However, during the height of the breeding season or when cold, wet weather has restricted nocturnal foraging they are known to venture out of their refuge sites during daylight hours to forage for food. They use their manipulative forepaws, sharp teeth and claws, and keen senses of sight, hearing and smell to trace and capture prey. Chuditch may also climb trees in search of food or for protection against predators but appear to be limited to small boles (12-20 cm diameter at breast height) by their imperfect ability to clasp effectively using the long hind foot and heel (Serena *et al.* 1991).

2.2.5 Reproduction and mortality

Jarrah chuditch are seasonal, promiscuous breeders (Stead-Richardson, Bradshaw, Bradshaw, and Gaikhorst 2001) with both males and females becoming sexually mature and breeding within their first year. Wild females enter oestrus, and mating occurs from late April to early July (Arnold 1976). After a gestation period of approximately 17-18 days, females give birth to 2-6 young about 5 mm in length and weighing between 9 and 15 mg (Serena *et al.* 1991). When chuditch are not reproductively active, their pouch does not fully cover the mammary area. The pouch is actually an indentation under the stomach of the animal, surrounded by a fold of skin that becomes swollen during pregnancy and extends over most of the pouch to cover and protect newborn individuals in a moist area (Serena and Soderquist 1988a). After the young are weaned the pouch regresses back its normal state. The majority of births occur in June and July (Stead-Richardson *et al.* 2001).

During the breeding season, the physical condition of the females changes (Arnold 1976). They gain weight prior to and during this period, especially around the neck. This usually occurs early in the breeding season as a means of protection from the teeth of the male. During copulation a male will generally use his teeth to grasp the female in the neck area, typically resulting in injury to the female (Stead-Richardson *et al.* 2001).

While chuditch have been known to live for 5-6 years in captivity, wild individuals normally die before their fourth year (Serena *et al.* 1991). The average lifespan of an established adult chuditch in the wild is two years (Serena and Soderquist 1988a). There are many man-made factors that contribute to chuditch mortality in the Jarrah forest, such as being hit by motor vehicles, illegal shooting near roads and injury in rabbit traps. Some of the natural causes of chuditch mortality include competition from and predation by foxes, raptors and feral or domestic cats, natural accidents (e.g. drowning) and disease (Orell and Morris 1994).

2.2.6 Juvenile development

Female chuditch deposit their litters in natal dens immediately or very soon after the young first release the teat at approximately 61 days. When first left in the den, juveniles weigh less than 15 g, still have their eyes closed and are poorly insulated by fur (Serena and Soderquist 1988a). They will not become homeothermic for another 5-6 weeks and are incapable of shivering to keep warm (Arnold 1976). At the age of about 110 days juveniles are well furred and beginning to venture outside the den sites for foraging activities (Serena and Soderquist 1988a). They are fully weaned by about 170 days of age and by early November they begin dispersing away from the natal den sites (Soderquist and Serena 2000).

2.2.7 Den and Refuge site Requirements

Many mammalian species routinely occupy dens, presumably for protection against environmental elements and predators (Serena and Soderquist 1989a). In relation to this project the term "den" refers to the resting position of the animal within the refuge site or the nursery den of females that have young deposited in the refuge site. For the purpose of this study refuge site refers to the structure (hollow log, standing tree or burrow) that chuditch shelter in during the day.

Desert chuditch occupy dens in earth burrows, hollow logs and tree limbs, and hollows in termitaria (Johnson and Roff 1982; Burbidge *et al.* 1988). In the Jarrah forest, nearly all diurnal refuge sites consist of horizontal hollow logs or earth burrows as shown by Serena and Soderquist (1989a) in a study of 360 diurnal refuge sites within the Murray River Valley, south of Dwellingup. The study found that 63% of refuge sites were earth burrows, and hollow logs or tree limbs comprised 35% of known refuge sites (Serena *et a.* 1991).

A suitable hollow log refuge site should have a diameter of at least 30 cm but preferably 50 cm; the diameter of the hollow should be between 7 and 20 cm and in most cases the location of the animal would typically be 1 m or more from the entrance (Serena *et al.* 1991). Most suitable burrows are associated with surface features such as trees, stumps, logs or rock outcrops as they offer increased protection against predation and assist in refuge construction by supplying pre-existing channels or cavities (Orell and Morris 1994). In the course of a year, an average adult female chuditch will take refuge in an estimated 66 hollow logs and 110 burrows within her home range (Orell and Morris 1994).

2.2.8 Home range

Home range is a concept of wildlife ecology that has been poorly defined despite being one of the most frequently used tools of research. Home range as defined by Burt (1943) in Jewell (1966), pg 99, as "that area traversed by the individual in its normal activities for foraging, dispersal, mating and caring for young". Information on home range obtained through radio-telemetry techniques is available for only three Australian species of dasyurid: chuditch (Serena and Soderquist 1989b); *Antechinus stuartii* and *Phascogale tapoatafa* (Soderquist 1995).

Chuditch are primarily solitary animals that occupy relatively large home ranges. Male chuditch occupy a larger home range than females, with a range of over 15 km^2 as opposed to 3-4 km^2 for females (Serena and Soderquist 1989b). A home range includes a smaller 'core area' that is usually defined by refuge sites. The core areas for males are approximately 4 km^2 and display substantial overlap with other individuals from both sexes while the core areas for females are about 0.9 km^2 and show little or no overlap with other individuals. An exception to this is that some core areas may be shared or show overlap between a mother and her adult daughter (Serena and Soderquist 1989b).

Satellite telemetry is used to determine the home range of far ranging animals such as polar bears and whales, though for shorter ranging animals such as the chuditch, radiotelemetry is used (Matthew 1996). The optimal method for calculating home range will depend on the number of animals in the study and the number of fixes obtained for each animal (Boulanger and White 1990). There are several methods including the harmonic mean method, kernel method and the minimum convex polygon method. The favoured method utilised by most literature is the minimum convex polygon method (MCP) because of its inherent simplicity (Bradshaw and Bradshaw 2002). The MCP method is a modification of a method that uses the location of the fixes to form an enclosed polygon. This method is the one that is modified in the MCP method as it results in irregular home ranges and is highly biased by the number of fixes in the data set (Matthew 1996). The MCP on the other hand uses the fixes to form the smallest possible enclosed convex polygon and is more robust than the Kernel or Harmonic mean methods when the number of fixes is low (Pavey, Goodship and Geiser 2003).

2.2.9 Fire ecology

The effect of fire ecology on chuditch populations is difficult to investigate experimentally, due to their large home ranges and low population densities throughout the forest (Serena *et al.* 1991). As a result, the effects of prescribed burning regimes and wildfires on chuditch are poorly understood (Orell and Morris 1994). chuditch may be affected by fires negatively as fires typically remove plant cover and increase vulnerability to predators. Fires may also reduce the number of invertebrate species available at various times after a fire (Abbott 1984). On the other hand, fires may benefit chuditch, by making it easier to search for food. The population consequences of fire from three sites; the Murray River valley, Perup Nature Reserve and Batalling forest block have demonstrated that chuditch are capable of surviving the present prescribed burning regimes (Serena *et al.* 1991). These are generally performed on a 5-7 year rotation and are undertaken in most of the Jarrah forest of Western Australia. The data collected from these sites have shown the ability of chuditch to utilise burnt areas for at least several months following fire (Orell and Morris 1994). Cool spring burns that result in patches of vegetation left unburnt may be preferable to chuditch populations as they do not generally consume refuge logs, and they allow invertebrate fauna to recover more quickly than do hotter fires (Orell and Morris 1994). Further research is required on the effects of fire on juvenile recruitment and abundance of dietary items in the first and second breeding season following fire (Morris *et al.* 2003).

2.2.10 Vulnerability to poisoning programs

In Western Australia, fox control is presently achieved through the distribution of dried meat baits injected with Compound 1080 (sodium monofluoroacetate) (Orell and

Morris 1994). Captive chuditch display high consumption tendencies towards the meat baits commonly used in baiting dingoes and foxes. As a result, certain factors such as the type of poison, sensitivity to Compound 1080, type of bait, amount of bait and the size and condition of the animal need to be taken into consideration when designing baiting programs that will not harm chuditch (Serena *et al.* 1991).

Compound 1080 was developed from toxins present in poison bush (*Gastrolobium* spp.), a plant that occurs naturally in northern and south-western Australia (King 1993). Marsupials in south-western Australia have a higher tolerance (per kg of body weight) to the toxic effects of Compound 1080 than have introduced species (McIlroy 1986; King, Twigg *et al.* 1989). The lethal dose, 50% (LD_{50}) of 1080 (the ingested amount that will kill half of a baited chuditch population) is approximately 7 mg/kg body weight (King *et al.* 1989). The estimated 'safe dose' (where no individuals will die) for adult chuditch is 5 mg/kg (King *et al.* 1989). Fox baiting programs implemented by CALM in Western Australia used 4.5 mg of 1080 injected into 120 g of fresh kangaroo meat bait (up until June 2002), which is then dried to 40 g before being distributed (Department of Conservation and Land Management 1996). This was later reduced to 3 mg of 1080 per 120 g of kangaroo meat (John Ashby. Pers comm. 2005). McIllroy and King (1990) have indicated that levels of 2.5 mg 1080 per bait may be able to be used in the future.

Doses of 1080 can be harmful to chuditch populations as the toxins may enter the milk of a lactating female that has eaten a sub-lethal dose and kill the pouch young. Though not demonstrated in Chudtich populations, this has been found in other species such as *Macropus eugenii* (tammar wallaby), *Trichosurus vulpecula* (Brush-tailed Possum) and *Dasyurus hallucatus* (northern quoll). Sullivan *et al.* (1979) have also shown that sub-lethal doses may cause sterility in male chuditch, as has been demonstrated in rats.

Captive feeding trials have shown that chuditch have the potential to consume all of the types of baits commonly used in predator control programs (Serena *et al.* 1991) and are therefore potentially at risk. The relative sensitivity of chuditch to 1080 may be increased by lower environmental temperatures (Oliver and King 1983). Seasonal variation in the size of chuditch will influence their vulnerability, with juveniles being the most susceptible group as they usually consume large amounts of food during the growth process. Winter is also a period of increased vulnerability due to energetic stress and low prey availability (Serena *et al.* 1991). The increase in metabolic demands associated with activity may lead to more baits being consumed by individuals than previously shown in captive trials. Thus, the values obtained for captive chuditch must be considered conservative estimates of bait consumption by wild chuditch (Serena *et al.* 1991).

2.3 Management

2.3.1 The need for management

Chuditch have a short, average life-span in wild populations. Even if the quality of the habitat is very high within their present range they are patchily distributed and occur at low densities. When considered at a local population level, they are considered highly vulnerable to extinction as result of natural environmental fluctuations, natural catastrophes or chance events (Orell and Morris 1994). The need for active management arises as a result not only because of the scarcity of the animals but also of impacts on their current forest habitats by human activities and management programs (Serena *et al.* 1991). Chuditch have survived in the Jarrah forest whilst declining elsewhere, and while no single land-use appears to constitute a threat to the survival of chuditch, the conservation of the species could be enhanced using forest management practices and accommodating chuditch habitat requirements (Orell and Morris 1994).

As defined under the *Endangered Species Protection Act* 1992 (Cwlth), it is the responsibility of CALM to manage and ensure the future survival of chuditch as a 'vulnerable' species within Western Australia. The chuditch Recovery Team was formed as a part of the active conservation of chuditch with the intention of forming and applying conservation measures and strategies that would assist the effective management of the chuditch in its natural environment (Friends of the chuditch 1996, Orell and Morris 1994).

2.3.2 Existing management measures

A management program for the chuditch has been published by CALM (Serena *et al.* 1991), with management strategies for the conservation of the chuditch. In 1994, a chuditch Recovery Plan was prepared by the chuditch Recovery Team (Orell and Morris 1994) with the key aim of downlisting the chuditch from 'endangered' to 'vulnerable' by increasing the abundance of the species within ten years of implementation of the program. The actions identified for this program by CALM were suggested by the management program published previously and included:

- habitat management;
- research into the effects of the fox on native fauna, including research into fox baiting programs;
- population and habitat monitoring;
- research to determine distribution and habitat requirements of the chuditch in wheatbelt and semi-arid areas;
- captive breeding;
- translocation.

Due to a revision of The Action Plan for Australasian Marsupials and Monotremes, the chuditch was listed as 'Vulnerable' in 1996 using IUCN (1994) criteria (Morris 1998). It is now the aim of the team to have the chuditch listed as 'lower risk' (Conservation Dependant), meeting the criteria of increased abundance, occupy an area above 20, 000 km^2 and to have one self-sustaining population established outside its present range. Under the ICUN rules for moving tax from higher threat catergories to lower threat categories, the lower threat category must have been met for five years before the change can be made. While chuditch have met these criteria since 2001, they can not be categorised as "lower risk" until 2006 (Morris and Johnson 1997).

2.4 Conservation Actions

2.4.1 Habitat management

To ensure the continued survival of the chuditch, availability of adequate refuge sites such as hollow logs and burrows within the jarrah forest need to be assessed and maintained (Serena *et al.* 1991). In forests that have been previously logged on long rotations, there should be greater numbers of logs on the ground that can be utilised by chuditch populations. Forest that has been previously logged on short rotations may require the use of artificially produced refuge sites for utilisation by chuditch (Orell and Morris 1994).

Road kills by motorists travelling through or along the forested areas are a major source of chuditch mortality, as is the clearing of habitat (Orell and Morris 1994). The use of warning signs and speed restrictions may limit the number of chuditch deaths attributed to traffic and clearing practices within forested areas will be discouraged by CALM to protect the remaining habitat for utilisation by chuditch. Other practices such as habitat assessment before clearing approval have become standard practice as standard fauna survey techniques used in the past have generally not been adequate in detecting chuditch (Serena *et al.* 1991).

2.4.2 Research into feral predator control

Feral predators such as the fox and the feral cat can potentially influence chuditch populations resulting in detrimental effects. These feral predators impact the population through direct competition for food and space and through predation (Department of Conservation and Land Management 1996). To control fox numbers in areas that are populated by chuditch, fox baiting programs using 1080 have been implemented. However, the impacts of these baiting programs on the chuditch requires further research with the potential of developing a fox bait with minimal harming impacts for chuditch (Morris *et al.* 2003).

2.4.3 Captive breeding

Captive breeding of chuditch has provided a source of individuals for educational purposes and also for translocation programs. As chuditch have low population densities, it is not currently a viable option to take individuals from populated areas for introduction into translocation areas as it is time consuming and may potentially create problems for the original population (Serena *et al.* 1991). Captive breeding of chuditch has been highly successful as they have a relatively high fecundity and are capable of breeding within their first year (Stead-Richardson *et al.* 2001).

2.4.4 Translocation and monitoring

Translocation in conjunction with ongoing population monitoring is the currently used method of introducing chuditch into their former ranges in an effort to counter the post-European settlement pattern (Serena *et al.* 1991). Translocations have been attempted in areas lacking resident chuditch with selection criteria for land management practices, size of area, presence of suitable habitat and the absence of high numbers of foxes and feral cats (Orell and Morris 1994). The ongoing population monitoring programs after the translocation have been vital in determining the health of the population and success of the trials.

2.4.5 Public education

The support of the public is essential to the survival of the chuditch. If the chuditch is to be conserved, the public need to understand the ongoing problems facing the chuditch and want to help in the conservation process, as programs are generally expensive in terms of staff and finance. Public education programs are utilised to inform the public of the conservation needs of the chuditch, measures being undertaken to prevent its extinction and the need of public support of both CALM and Perth Zoo programs (Serena *et al.* 1991).

2.5 Western Shield

Western Shield is one of Australia's largest, boldest and most visionary native fauna programs. It is also one of the most effective (McNamara 2004). Western Shield is a program initiated by CALM with the objective of intensifying introduced predator control, captive breeding programs and the reintroduction of native animals to their previous habitat (Weaving 1999).

The program had its beginning in scientific research in the 1970s and 1980s, which clearly established a link between predation by the European fox and the decline of small to medium sized native mammals in the south-west of Western Australia (Wyre 2004). Further research has shown that if these introduced predators can be controlled then many native species can be recovered in suitable habitats (Possingham *et al.* 2004). The implementation of the Western Shield program on a large scale relied upon a number of factors including; the use of cost effective fox baits, captive breeding, translocation and management of the threatened fauna, training of field officers, development and monitoring programs, risk management assessments and effective community education and communication (McNamara 2004).

In 1996, CALM commenced the major fox control program. It is now applied to nearly 3.4 million hectares of land, most of which is situated primarily in the south-west of Western Australia in national parks, nature reserves and State forest. The program is aimed at reducing fox numbers enough so that native fauna can survive and recover in their natural habitat (Possingham *et al.* 2004).

The Western Shield program has five major objectives. The first has been to maximise the recovery of sustainable populations of native fauna by reducing the impact of predation by foxes and feral cats. The second objective has been to develop cost efficient and effective control techniques for foxes and feral cats. The third objective has been for CALM to conduct the program in such a way as to encourage community acceptance, understanding and involvement in the program. The fourth objective is that the Western Shield makes the best use of new and existing research to enhance its recovery programs. The final objective has been to provide opportunities to develop and enhance partnerships with groups and organisations (e.g. universities) to maximise the efficiency and effectiveness of fauna recovery (Possingham *et al.* 2004).

The Program has already had significant success through the removal of three native mammals, the Woylie, Quenda and Tammar Wallaby, from the threatened species list. Many species have been recovered or re-established in their former ranges and the restoration of ecological processes has been initiated (Possingham *et al.* 2004; Wyre 2004). While a great deal is known about introduced predator control and predator/fauna interactions, continuing research is needed to refine and add to the knowledge enabling cost effective operations to be developed and improved (Wyre 2004).

2.6 Baiting Operations

2.6.1 Procuring bait material

Most Western Shield fox-control programs have preferred utilising dried meat baits (DMB) through aerial baiting techniques. Supplies of DMB for the Western Shield are purchased from the Western Australian Department of Agriculture (DAWA), the only commercial supplier within the state. The current annual DMB requirement for the Western Shield program for both aerial and ground based operations is 780 000 baits. Calm advises DAWA of its anticipated annual DMB need in advance and then submits firm orders quarterly. (Armstrong 2004).

2.6.2 Current bait supplies

Dried meat baits are manufactured manually in a slow, wasteful and unreliable method. The process is expensive and production capacity is limited. Currently the DAWA can produce 4,000 baits/week with wastage in excess of 20% (because 200 g chunks are required, only the large muscles of a kangaroo carcass can be utilised). The reliability of supply is often jeopardised by field conditions preventing the kangaroo shooters from harvesting. As there is no other viable supplier within the state, the Western Shield programs have often needed to be modified because of low supplies of kangaroo meat, creating significant threats to the effectiveness of routine baiting operations. The per-bait cost (which is the DAWA cost-price) has steadily increased (Table 1) since 1994 and with the current bait requirements, every one-cent rise increases the annual program cost by $7,800 (Armstrong 2004).

Table 2.1: Change in cost of DMB from 1994 to 2003 (excluding GST) as adapted from Armstrong 2004.

Year	Per-bait Cost	Annual Cost of 780 000 DMB
1994	$0.65	$507 000
2003	$0.96	$752 000
Increase	$0.31 (48%)	$245 000 (48%)

2.6.3 Future bait supplies

In 2002, the Agriculture Protection Board (APB; a component of DAWA) advised CALM that the Bait Production Unit (BPU) would cease to manufacture baits as of the 30 June 2002. This date has been extended to allow alternative sources to be found. In 1998/1999 with the uncertain bait-supply situation CALM decided, with the advice from the small-goods processing industry, to develop a sausage-bait (termed Probait) based on the salami manufacturing process. The advantages of using this process were that the automated process was easier and faster, larger production runs could be performed, there would be minimal wastage of kangaroo meat, improved shelf life and had a lower cost price of approximately $0.45 per bait (Armstrong 2004). The uniform shape of the Probait will also allow for improved packing efficiency, reduced transport and storage costs and automated bait-laying procedures. There would be the opportunity to supply these Probaits commercially, returning a profit to the Department, or possibly even subsidising the cost of the Western Shield (Armstrong 2004).

The impacts of Probait on non-target animals and its efficiency as fox bait are currently being tested on a captive fox population at CSIRO's laboratories in Canberra. Palatability of a toxin-free Probait and DMB to foxes were tested in the wild by Malrow and Brazell (2002) and found that there were no significant differences in palatability between the two. The palatability of Probait and DMB was also tested with the native species thought most at risk from 1080 poisoning (Armstrong 2004) with Martin *et al.* (2002) concluding that regardless of the bait type, chuditch would ingest at least some bait material putting them at a medium to low risk of ingesting either in the wild.

The development and implementation of the Western Shield Program has demonstrated considerable initiative and improvement since its beginning with achievements today being nationally significant. The opportunities for Western Shield to become more efficient lie primarily in the areas of management and bait product development. The development and adoption of the Probait product has the potential to realise significant financial benefits and operational savings (Armstrong 2004).

CHAPTER 3 – MATERIALS AND METHODS

3.1 Study Site – Julimar Conservation Park

3.1.1 Location

This research was conducted in the Julimar Conservation Park (Figure 3.1), located within the Avon region approximately 84 km north-east of Perth (Osbourne 2005). The park is a part of the Chittering vegetation system in the north-west Shire of Toodyay located within the Darling Botanical District (Figure 3.2). The park is approximately 28,500ha in size and is vested in the National Parks and Nature Conservation Authority (NPNCA) and managed by the Department of Conservation and Land Management. This system is similar to the Darling System but is more dissected. The area has a Mediterranean climate with dry warm summers and cool, wet winters with an average annual rainfall between 600mm and 800mm (Figure 3.3) (Weaving 1999).

3.1.2 History

In the early part of the last century almost half of the Julimar Conservation Park was cleared for farmland. Most of the farms however failed during the Depression in the 1930s and were abandoned. Most of the farms eventually reverted to Crown land and in 1956, the park was gazetted as State forest. There are still two privately owned farms located within the park (Department of Conservation and Land Management 1992).

Between 1950 and 1970 the forest was cleared further for sawlogs for the sawmilling and woodchipping industries. The park is no longer used for timber production. The only form of industry still operating within the park is beekeeping (Department of Conservation and Land Management 1992).

The area is now considered a Conservation Park instead of State Forest and is managed in this respect. As a State Forest the area was previously used for four wheel driving, commercial wildflower picking and firewood cutting. With the tenure change these practices were no longer permitted. CALM is dedicated to encouraging low impact activities within the park such as scenic driving, camping, nature appreciation

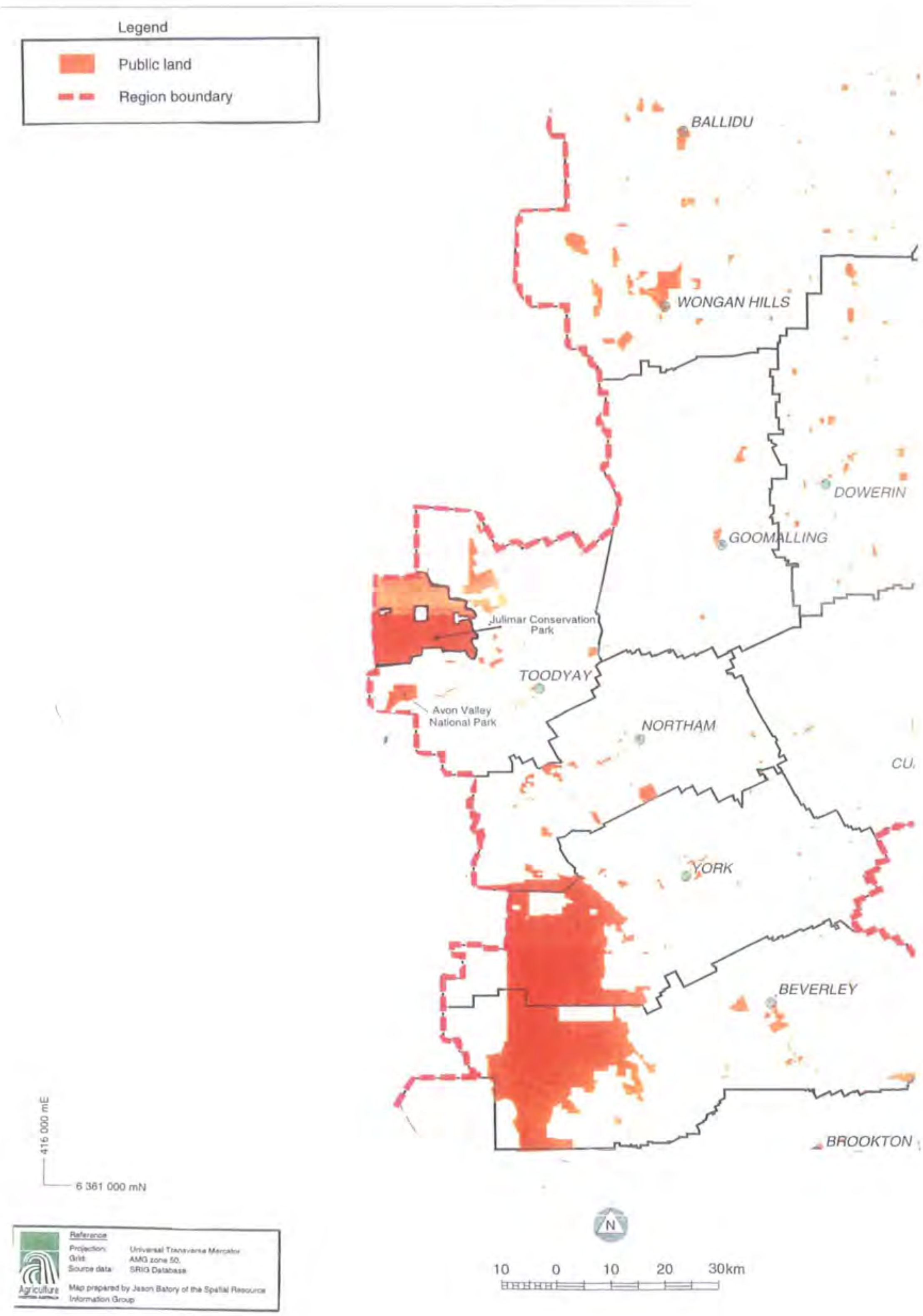

Figure 3.1: Location of the Julimar Conservation Park within the Avon and Upper Hotham Region in Western Australia as adapted from Weaving (1999), insert.

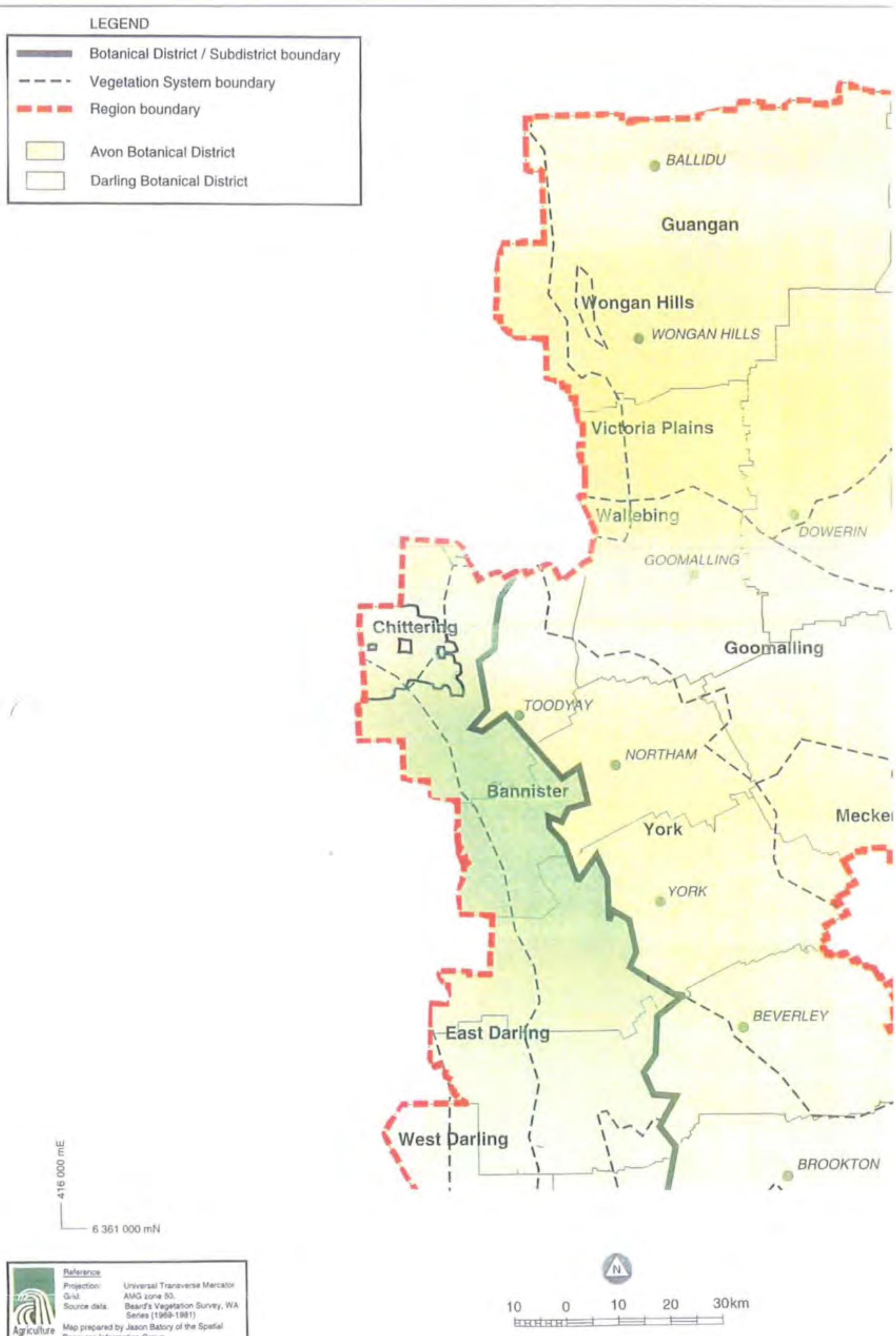

Figure 3.2: Botanical districts and Vegetation systems of the Avon and Upper Hotham Region in Western Australia as adapted from Weaving (1999), insert.

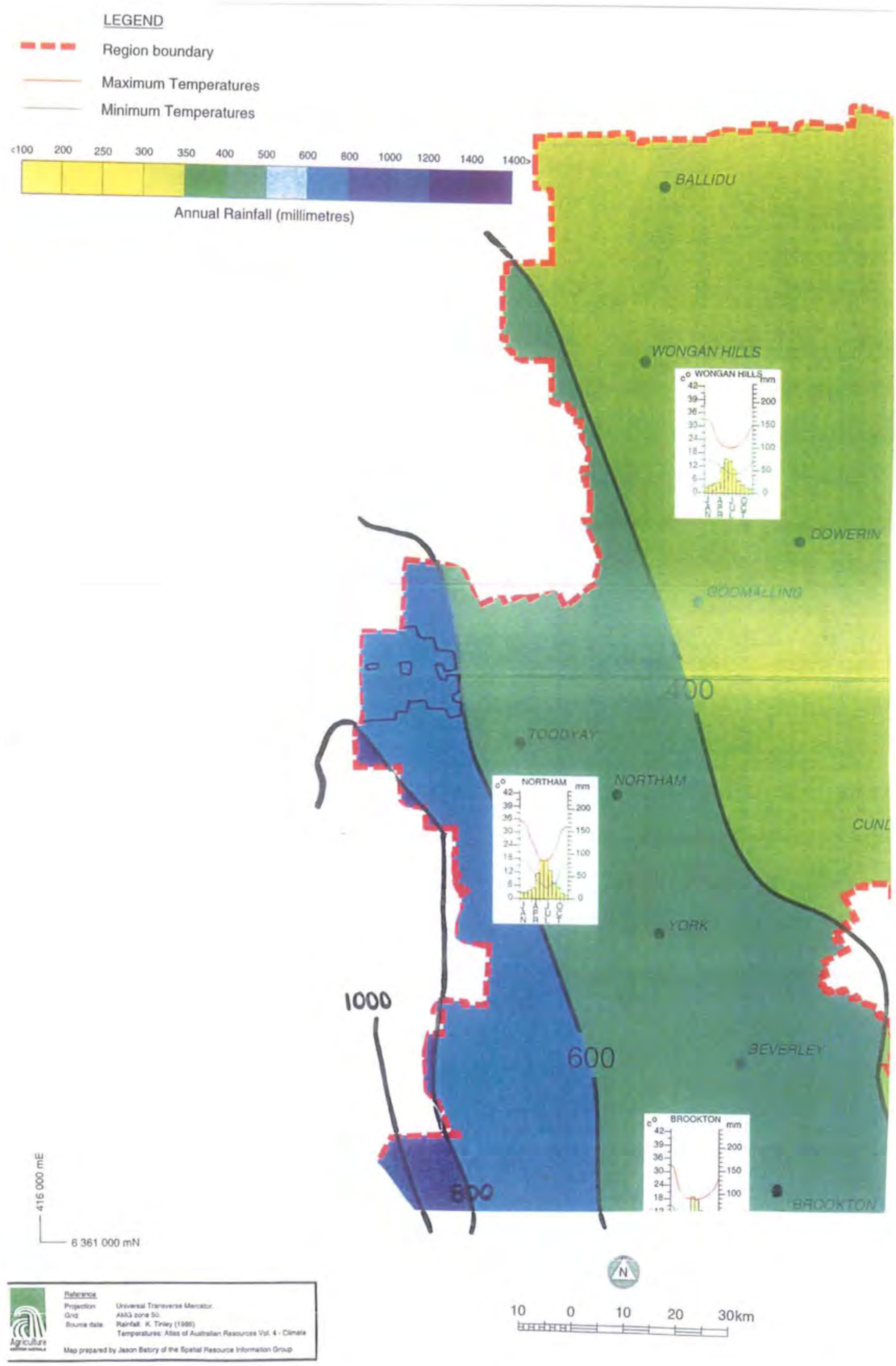

Figure 3.3: Annual Rainfall and selected annual temperatures for the Avon and Upper Hotham Region in Western Australia as adapted from Weaving (1999), insert.

and bird watching (Department of Conservation and Land Management 1992). In 1992 the park was chosen as the translocation site for the chuditch Recovery Program. chuditch were recorded in the area up until 1973 and the absence of recent records as well as the results of previous trapping records indicated that the area was still vacant before the translocation in 1992 (Orell and Morris 1994).

3.1.3 Vegetation and Fauna

The Julimar Conservation Park is made up of gently sloping hills studded with granite outcrops and dissected by steep-sided valleys. The gnarled Jarrah (*Eucalyptus marginata*), Marri (*Corymbia calophylla*) and the Wandoo tree (*Eucalyptus wandoo*) dominate the forest (Figure 3.4). The understorey, which is generally dense, consists of grasstrees (*Xanthorrhoea* spp.) and parrot bush (*Dryandra sessilis*) with paperbarks (*Melaleuca* spp.) growing along the river valleys and creek beds (Weaving 1999) (Plate 3.1, Plate 3.2).

Historical records from 1975 show approximately 43 species of mammals were present in the Avon area (Weaving 1999). Kitchener *et al.* (1980) recorded 17 local extinctions of these mammal species and identified only 12 of the 43 species as being moderately common to abundant within the area. Fauna found within the Julimar Conservation Park includes the echidna (*Tachyglossus aculeatus*), western grey kangaroo (*Macropus fuliginosus*), western brush wallaby (*Macropus irma*), southern brown bandicoot (*Isooden obesulus*) , chuditch (*Dasyurid geoffroii*), several bird species and reptiles such as bungarra (*Varanus gouldii*) and the bobtail (*Tiliqua rugosa*) (Walker 1986).

3.1.4 Selection of study site

The Park was chosen by CALM as a suitable translocation site for the chuditch before the implementation of the chuditch Recovery Program as historical records identified it as an area that was previously utilised by the chuditch. The Park is conveniently close to Perth making it easier for intense and efficient monitoring. The park is relatively large making it a valuable haven for native fauna and flora (Orell and Morris 1994). The Julimar Conservation Park was chosen as a suitable site for the Probait trial due to the success of the chuditch translocation in 1992. Annual

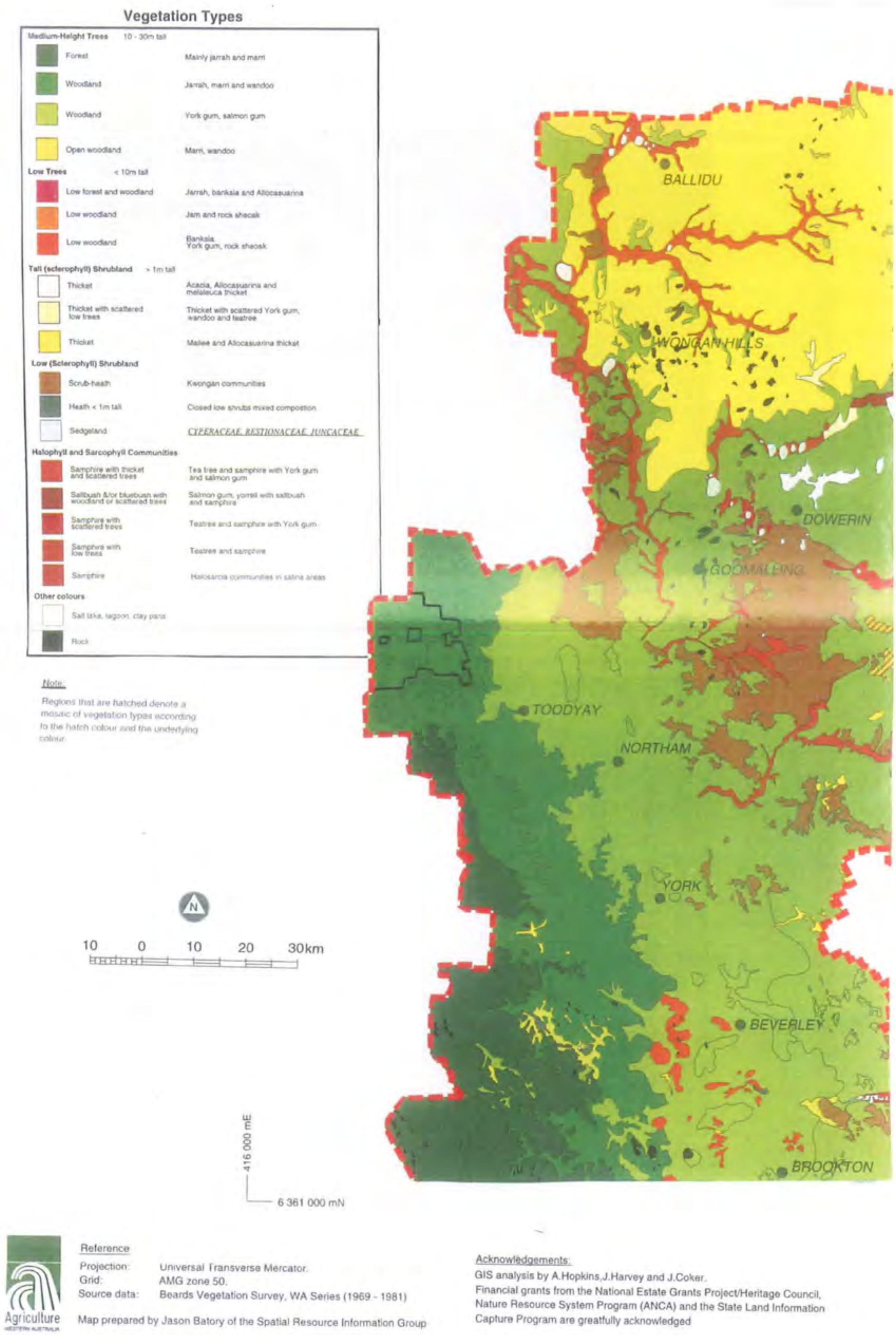

Figure 3.4: Vegetation types located in the Avon and Upper Hotham Region in Western Australia as adapted from Weaving (1999), insert.

Plate 3.1: The Marri-Jarrah-Wandoo (*Corymbia calophylla - Eucalyptus marginata – E.wandoo*) open forest with an understorey of grasstrees and parrot bush (*Xanthorrhoea* spp. and *Dryandra sessilis*) at the Julimar Conservation Park.

Plate 3.2: Vegetation of the Julimar Conservation Park with open shrubland and light/moderate litter.

monitoring sessions have shown that broad scale fox baiting has allowed the population to grow, disperse and reproduce within the baited area (Morris *et al.* 1993-1999).

3.2 Scope

For the duration of this study all other DMB programs were suspended, replaced by two aerial baitings of Probait (containing 3 mg of 1080 per bait and the non-toxic biomarker Rodamine B) along the pre-existing bait runs and following the same time frame as previous baiting regimes. These were performed on the 12th of December 2004 and the 6th of March 2005. The Rodamine B was included in the Probait to assess bait uptake as it stains the gut, mouth and scats pink and displays fluorescent bands on the whiskers after bait ingestion. The baits were dropped at a density of five baits per km^2.

Fifteen chuditch were fitted with radio collars between November 2004 and April 2005. The survival, general health, movements and refuge sites of these individuals were monitored on a weekly basis to identify any impacts resulting from the implementation of Probait.

Each month, with the exception of March, a four night trapping session (November 22-26th 2004, December 20-24th 2004, January 10-14th 2005, February 7-11th 2005, April 4-8th 2005) was conducted with the purpose of monitoring the survival and general health of the chuditch population located within the park as well as recapturing collared chuditch individuals to determine health. All of the individuals captured during these trapping sessions had facial whiskers sampled and scats checked and collected if displaying pink colouration.

All data collected during the six month study period, including any additional parameters such as pouch condition (enlarged mammary glands and pink swelling of pouch area) and litter size will be used during later analysis. The data were used to determine bait uptake by chuditch and identify the impacts the baiting trial has had on the chuditch population in the Julimar Conservation Park.

3.3 Baiting

The Probait was prepared by CALM containing 3 mg of 1080 per bait and the non-toxic biomarker Rodamine B. The dye Rodamine B has been consistently identified as an effective non- toxic marker in ecological research (Fisher 1999) and will stain oral cavity, gut, internal organs and scats with a pinkish colour or orange fluorescence under UV light (Fisher 1998) when ingested with the bait. Rhodamine B is persistent in Probaits for ~90 days and will remain in an individuals oral cavity for a few days depending on grooming activities and exposure to water (Fisher 1999). Gut passage time is rarely more than 48 hours in small to medium sized mammals enabling Rhodamine B to persist for at least that long in the gut and up to months in scats depending upon the length of time it takes for the scats to break down (Fisher 1999). Rhodamine B persists in whiskers for the life of those whiskers making the most useful systematic marking produced by Rodamine B the marking of the whiskers and claws (Fisher 1999). These show up as fluorescent bands under UV light (Fisher 1998).

The Probait was aerially distributed at a density of 5 baits per square km over the area of the Julimar Conservation Park and adjacent Commonwealth Defence property at Bindoon. The trial was performed between November 2004 and April 2005, when young born in July 2004 were dispersing from their natal home ranges and during a period of no reproductive activity (Stead-Richardson *et al.* 2001). This period during late spring was chosen to reduce any impacts, such as leaching resulting in reduced toxicity of the baits, that may be caused by high rainfall on the baits and to determine the impact of Probait on small individuals within the population. The baits were aerially deposited on the 12th of December 2004 and the 6th of March 2005.

3.4 Trapping

The Department of Conservation and Land Management maintained a chuditch monitoring program for 13 years prior to this project. As a result of the annual monitoring sessions on the chuditch population within the Julimar Conservation Park certain roads had been identified as being ideal for the placement of traps. The roads so identified for trap placement included Hewitt Rd, Biggs Rd, Cooks Rd North, Lewis Rd, Woylie Rd North, Woylie Rd South and Cooks Rd East (Figure 3.5). These roads were chosen as they are spaced widely but evenly through the park and

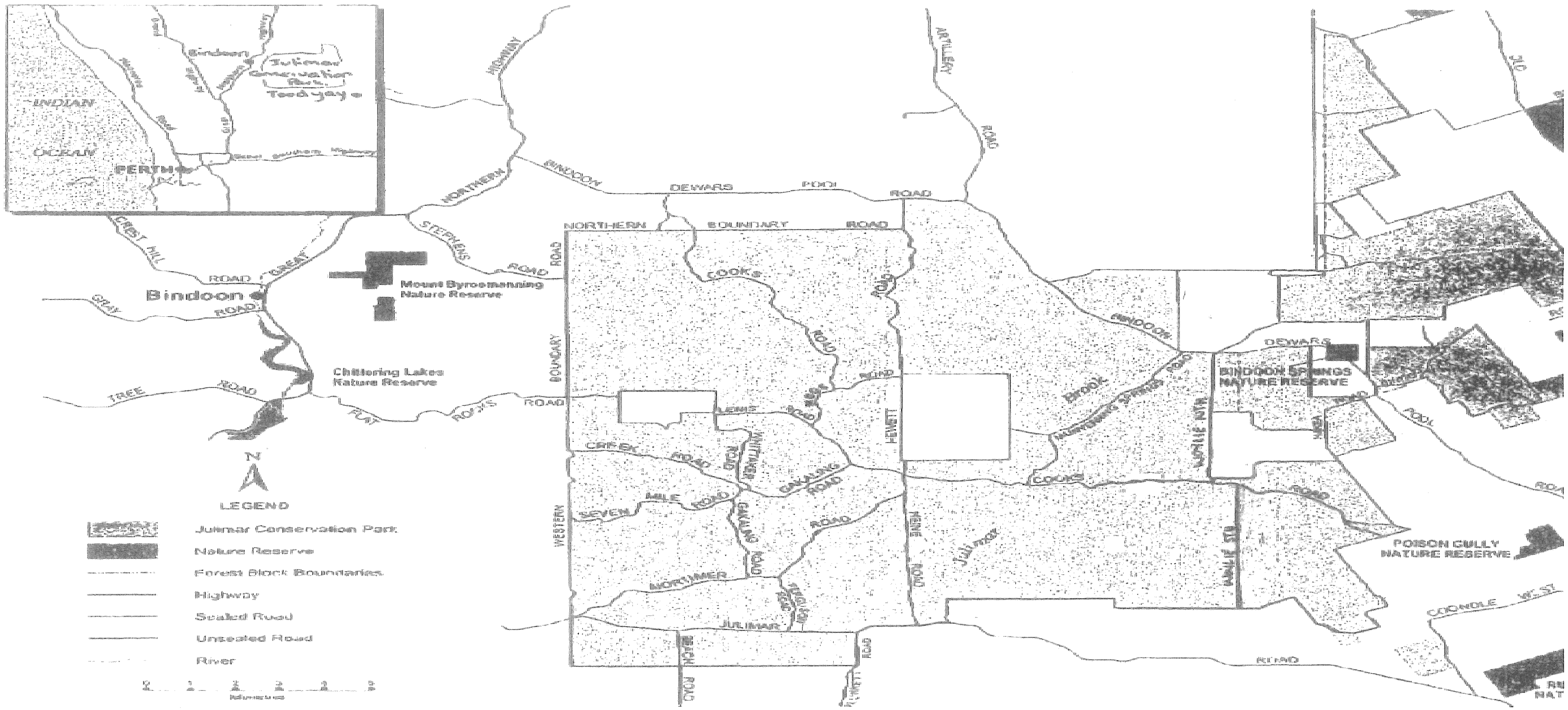

Figure 3.5: Map of the Julimar Conservation Park, showing tracks used during the Probait trial between November 2004 and April 2005, as adapted from the Department of Conservation and Land Management (1992), pg 2.

maximised the area covered by the study. chuditch "hotspots" have been identified through previous monitoring sessions (1991 to 2004), indicating which roads were more likely to result in chuditch captures (Morris *et al.* 1991-1999).

Approximately 150 Sheffield wire cage traps (22cm x 22cm x 55cm) were set 200m apart along the tracks (specified above) before and after the baiting program had commenced. The track lengths determined the number of traps set along each road with approximately 10 to 20 traps per road. All traps were set with universal bait of peanut butter, rolled oats and sardines (the standard bait utilised by CALM throughout Western Australia) (Orell and Morris 1994). The universal bait was then rolled to the size of a golf ball and attached to the bait hook at the rear of each cage. Each trap was placed in a position that ensured some protection from the sun, generally at the base of a *Xanthorrhea* or amongst the shrub foliage, with a Hessian bag encasing approximately ¾ of the cage length (Serena and Soderquist 1988b) (Plate 3.3). The traps were set at dusk and checked at dawn to ensure that the amount of time the animal spent in the cage was minimal and to reduce stress. Trapping occurred on all the specified roads over four consecutive nights with all cages being removed from the study site between trapping sessions.

Each morning the traps were checked for animal capture. Any faecal matter inside, under or surrounding the cage was collected, examined for pink colouration (noted if found to be present), labelled and stored (in a cool, dark container) for further analysis (Plate 3.4). As only the scats that were suspected of being marked (determined by presence of pink colouration) were collected the possibility of missing marked scats may have limited the accuracy of the results obtained from analysis of these samples. Collecting all scats regardless of pink colouration for analysis would have removed this limitation. After the scats were collected the traps were then reset with fresh bait for the next night of trapping.

In the event that an animal was captured, the animal was removed from the cage and placed into a black handling bag for data collection and documentation. The black handling bag was used to ensure that the animal could not see outside the bag, reducing stress placed on the animal through handling (Serena and Soderquist 1988b). The back of the vehicle was used as a secure location to collect and document data.

The ear tags (Monel #2, National Band and Tag co.) were checked to determine if the animal was new to the study or from previous monitoring studies. Ear tags are used as the standard form of identification by CALM in monitoring programs. In the event that the animal captured did not display ear tags, new ones were attached on each ear so that the animal could be identified during later trapping sessions. Tags are placed in both ears to ensure that the individual can be identified if one is lost. The individual was then recorded as new (N), recaptured (R) from previous years or re-trapped (RT) during the weekly trapping session.

The weight and sex of the individual was recorded (total weight minus the weight of the handling bag) allowing an age category to be estimated. Age was estimated from weight using categories devised with CALM assistance utilising data previously categorised using the teeth wear method (Johnson. Pers. Comm. 2005). Serena and Soderquist (1988) provided some preliminary data on the weights of juvenile chuditch and average weights for adults. These were used to approximate weight categories for this present study. Males between 0-400g were classed as juveniles, 400-900g as sub-adults and above 900g as adults. Females between 0-300g were classed as juveniles, 300-600 as sub-adults and above 600g as adults. The pes and head length of adults was measured using vernier callipers. The general health of the individual was assessed through examining coat condition, teeth condition (stained yellow) and wear, evidence of injuries and body fat. To gauge body fat, an index based on the relative thickness of fat deposited on the sides of the caudal vertebrae at the basal 4cm of the tail was used (Serena and Soderquist 1988b). Approximately 8 facial whiskers were plucked using round nose tweezers from new (N) or recaptured (R) individuals, labelled and stored for future analysis (Plate 3.5).

If the animal was identified as female, the pouch condition was noted (checked for pinkness or swelling of the pouch and enlarged mammary glands) and if pouch young were present these were counted and their body length estimated to the nearest mm.

Plate 3.3: Sheffield wire trap used during the Probait trial between November 2004 and April 2005, indicates trap placement and protection.

Plate 3.4: *Dasyurus geoffroii* scat sample displaying pink colouration (presence of Rodamine B) indicating Probait ingestion by the individual.

3.5 Radiotracking

After an animal was processed its suitability for radio collaring was assessed. Animals not suitable for radio collaring were released at the site of capture. Suitability was determined by the weight and health of the individual. A male chuditch suitable for radio collaring had a weight of approximately 1.0kg or more and a female approximately 0.8 kg or more with both displaying good health, i.e. strong teeth and few or no current injuries. The suitable individuals caught each day were transported to the Army Defence training area camp house. There were 12 radio collars available at any one time during the study. Due to death and injury of several radio collared individuals, 4 of the collars were removed and 3 were reused on new individuals bringing the total number of chuditch collared with Biotrack TW3 mortality sensing radio transmitters (Plate 3.6) between November 2004 and April 2005 to 15 (12 males and 3 females). The transmitters have a "mortality" mode which doubles the transmitted pulse rate if the animal does not move for 3 hours. The collar was fitted in such a way as to ensure the chuditch would be unable to remove it by sliding it over its head, but loose enough to reduce the chance of chafing. Once the collar was secured around the individual's neck, the identifying frequency was programmed into a hand-held receiver (Biotel RX3). The animal was then returned to a thick hessian bag where it was held until dusk before release at the original capture site.

Radio tracking to diurnal refuge sites was undertaken with the use of a modified 4 wheel drive vehicle fitted with equipment to aid in the tracking process (Plate 3.7). A Clark mast with an aerial attached to a hand-held receiver could be raised approximately 4.5 m above the car to locate the animals. The aerial remained down while the vehicle was moving between sites, and was pumped up to full height with a compressor when the car was stationary and in a suitable position.

Plate 3.5: Plucking facial whiskers from a *D.geoffroii* specimen captured during the December 2004 trapping period.

Plate 3.6: Biotrack TW3 mortality sensing radio transmitter attached to a *D.geoffroii* specimen captured during the November 2004 trapping period.

Plate 3.7: CALM vehicle fitted with radio tracking equipment used in the tracking process between November 2004 and April 2005.

The height of the mast enabled the receiver to pick up the collar transmissions from approximately 2 km away. The collar frequencies were checked every 0.5 km or until a signal was located. The hand-held receivers emitted a high pitched pulse (approximately one pulse per second) from a particular direction when a live animal fitted with a radio collar was located. The directional signal became more intense with closer proximity to the animal. Once the signal was at a 90° angle from the vehicle, the distance of the individual was then determined. A strong loud pulse indicated that the individual was at a distance of less than 0.5 km.

An individual that had been located by the vehicle equipment but was estimated to be farther than 1km away was not located by traversing the area on foot due to time limitations and the nature of the terrain. The animal was recorded as having a live signal but data on their refuge sites was not collected in this instance.

If the individual was determined to be less then 1km away, its diurnal refuge site was located by traversing the area on foot using a hand-held receiver and antenna (Plate 3.8). The tracking team would proceed on the bearing achieved from the vehicle, stopping frequently to check the bearing by rotating 360° and identifying the direction of the strongest signal. Numerous functions on the receiver could be used to clarify the signal, which becomes distorted with closer proximity to the individual. The refuge site was identified by a very strong signal from the receiver that could still be detected with the removal of the antenna. The radio collared animals had their refuge sites located as many times as possible during the trapping week and at least once a week for the rest of the month (Plate 3.9, 3.10, 3.11 and 3.12).

The diurnal refuge sites of the radio collared chuditch were located and recorded with a GPS. On several occasions the position of the radio collared animal was confirmed through visual sightings of the animals within the refuge site (Plate 3.13). Refuge types were categorised into hollow log, standing tree and burrow with many of the characteristics such as tree species, hollow diameter, length/height, diameter of refuge

Plate 3.8: Hand-held receiver and antenna used to locate radio-collared specimens and their diurnal refuge sites during the Probait trial.

Plate 3.9: A diurnal refuge site (hollow log) of a radio-collared *D.geoffroii* specimen located by Melissa York and Brent Johnson.

Plate 3.10: A diurnal refuge site (large hollow log) of a radio-collared specimen with multiple possible entrances.

Plate 3.11: A standing tree diurnal refuge site of a *D.geoffroii* specimen that was radio-collared during the Probait trial.

Plate 3.12: A diurnal refuge site (Burrow) of a radio-collared *D.geoffroii* specimen located by Melissa York and Brent Johnson during the Probait trial.

Plate 3.13: A visual sighting of a radio-collared *D.geoffroii* specimen within a hollow log diurnal refuge site.

site at bole and distance of animal from the entrance being measured (Appendix 3.1). Collar durability and general health of the animal (if visible) were also recorded. The refuge sites were examined for the presence of scats which were collected if pink in colouration.

In the event that a mortality signal was received (twice the normal pulse rate) the individual was located using the hand-held receiver and antennae and collected, labelled and stored appropriately. The cause of death was noted if it was easily determined. If it was not possible to determine the cause of death from observation, post-mortem analyses were performed in the lab. These included an autopsy and observation of the gut under UV light.

Collars were removed from 10 of the 11 individuals during the last weekly trapping session beginning on the 4th of April. All of the collared individuals were not recaptured during this session, requiring location through the radio tracking process. Once the individual was located, traps were set around the refuge site in an effort to capture it, or the animal was carefully extracted from its refuge site and taken to a secure location to remove their radio collar. Extra trapping was performed between the 20th and 22nd of April to locate radio collared individuals that were not caught during the previous trapping session. The process described above was repeated during this last session. One collar was not recovered due to loss of signal.

3.6 Data Analysis

3.6.1 Population parameters

Descriptive statistics were used to identify the relative abundance, survival of chuditch individuals, bait uptake, age structure, sex ratio, number of pouch young and dispersion rates of the chuditch population. The relative abundance was determined by calculating the trap success rates for each of the trapping sessions using the following calculation: the number of chuditch captures per day divided by the number of traps set, multiplied by 100. The trap rates for each month were then compared to see if there was a decrease after the Probaits were implemented. Trap rates from previous monitoring sessions were used as a comparison to determine if the rates dropped after the Probait trial.

The survival of chuditch that were trapped during the Probait trial was determined by counting the number of times it was re-trapped throughout the trial. Each month the individuals were classed as new, re-trapped from previous months and re-trapped from previous day. Individuals that were re-trapped from previous months were known to be alive (KTBA) through these months. If the individual was located on each specific trapping trip it was identified as KTBA at each of the trapping trips and thus, indicating survival. This method of determining survival was used on the entire population but was also used to define those that had ingested Probait.

The age structure and sex ratio of the population was defined by the percentage of the population that fit into each category. The age of the chuditch was calculated using a weight range to define the varying categories. Age structure records from previous monitoring sessions were redefined using the specified weight ranges to allow for comparability across the years. These records also supplied the sex ratio of previous populations during the breeding season, allowing comparisons to be made between results obtained pre and post Probait baiting.

The total number of pouch young present during June 2005 was compared with the total number of females present for the same time frame. These were then averaged per female and compared to previous results taken from prior monitoring sessions.

3.6.2 Whiskers and scats

Whisker and scat samples were collectively analysed with a low intensity UV light during May 2005. This technique worked suitably for the identification of Rodamine B in the scat samples but due to the dark colouration of the facial whiskers the fluorescent banding was difficult to identify. The whiskers were mounted on a slide and viewed using fluorescence microscopy. A Carlzeiss Jena Jenamed2 microscope was used with a magnification of 5x /0, 12 ∞/ -A and a UV light wavelength of 510 nm to illuminate the fluorescent bands on each of the whisker samples. The results obtained from this work were then used to identify what percentage of the trapped population had ingested Probait and whether they survived the entirety of the trail after ingesting the baits. A one-way ANOVA using the program SPSS 12.0 for Windows (2002) was used to determine any significant difference between genders, age and Probait consumption within the population.

3.6.3 Core activity area

The GPS fixes for each of the radio collared individuals were imported in the Ranges V program (Kenward and Hodder 1992) where they were analysed using the minimum convex polygon method. This determined the size of the core activity area for each of the individuals and provided the means for plotting the core activity areas and allowed comparisons and observations to be performed.

CHAPTER 4 – RESULTS

4.1 Whisker and Scat Analysis

4.1.1Probait location and consumption

During the six-month field trial from November 2004 to April 2005 a total of 54 individuals (37 male, 17 female) were trapped. Another 7 individuals (6 male, 1 female) were trapped during the annual Western Shield monitoring program in June 2005, bringing the total to 61 individuals. Approximately 73 whisker samples, comprising 8 whiskers each, were taken during the entirety of the study for analysis from 44 of the 61 individuals, with some individuals being sampled more than once during the study period. Of the 73 samples 33 (45.2%) showed fluorescent bands, an indication of the presence of Rodamine B, signifying ingestion of Probait. As some individuals had samples taken more then once, the results would be an overestimation of the actual number of individuals that ingested Probait. The number of individuals that displayed the presence of Rodamine B was 26, representing 59.1% of the individuals sampled and indicating a relatively high incidence of bait uptake (Figure 4.1).

Between the December 2004 and March 2005 baiting sessions, traps were checked for the presence of scats. Scats were only collected if the individuals were suspected of Probait ingestion. During this 4 month period 14 scats were collected, of which 6 contained Rodamine B (42.8%). All traps in April were checked for scats but none examined during this time frame displayed pink colouration. These scats were not collected as there was no indication that Probait had been ingested within the past few days.

4.1.2 Gender and age vs. Probait consumption

During the study 9 females and 17 males ingested Probait taken from their natural habitat. Of these 26 individuals, 5 were sub-adults and 21 were adults. Using a one-way ANOVA it was determined that neither the sex nor the age of an individual chuditch had an effect ($P = 0.8$ and $P = 0.909$ respectively) on consumption of Probait.

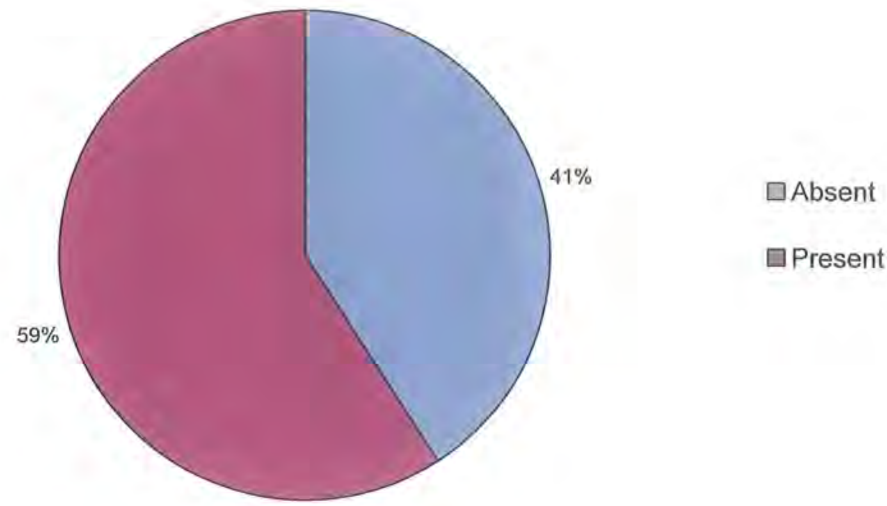

Figure 4.1: Whisker analysis of chuditch trapped during and after the Probait trial, indicating the proportional presence of Rodamine B in the 44 sampled chuditch.

4.1.3 Survival

To determine the survivorship of individuals that had ingested Probait, individuals in the study area were monitored over the six month research period from November 2004 to April 2005. Of the 26 animals that ingested Probait (as indicated by whisker analysis) 18 (69.2%) were known to be alive (KTBA) at the end of April (Figure 4.2), indicating a high incidence of survival after ingestion of Probait. The number of animals KTBA in March is low due to the cancellation of the March trapping session. Individuals recorded to be alive during this month were only those that were fitted with radio-collars. Of the 18 animals that did not display Probait ingestion 14 (77.7%) were KTBA at the end of April 2005, indicating a high incidence of survival during the baiting trial. A high incidence of survival was determined through scat analysis as 5 of the 6 individuals (83.3%) displayed pink colouration in scat samples were KTBA in April. All scats should have been collected to decrease any bias created by only selecting scats indicating suspected Probait ingestion by the animal.

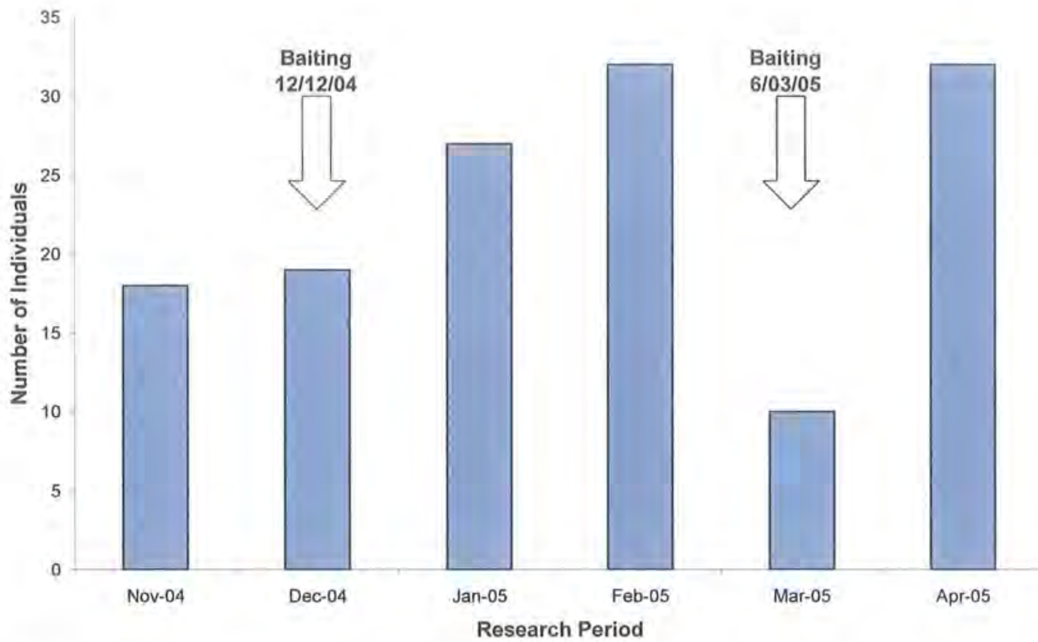

Figure 4.2: The number of individual chuditch with Rodamine Bβ **present in whisker analysis known to be alive (KTBA) during and after the Probait trial at the Julimar Conservation Park.**

4.2 Population Dynamics

4.2.1 Relative abundance

A total of 106 Chuditch, both new (48.1%) and recaptured (51.9%), were caught between November 2004 and April 2005 (Figure 4.3). There were no new individuals recorded during March as the trapping session was cancelled and only radio-collared individuals were located during this time. The greatest numbers of individuals were caught in February, including the equal highest number of new individuals. In December the lowest numbers were caught but nearly all of were new to the study area. With the inclusion of the annual June monitoring program trap results, 130 individuals (44.6% new and 55.4% recaptured) were caught between November 2004 and June 2005.

The results of the June 2005 annual monitoring program were compared to those of the previous monitoring programs of 2000 to 2004 (Figure 4.4). The number of individuals caught in June 2005 increased from the previous two years but was similar to the number of individuals caught in July 2002 and June 2000. There was a smaller number of new individuals caught during this trapping session when compared with the results of the previous 5 years as new individuals recorded between November

2004 and April 2005 were not considered to be new individuals during the June 2005 annual monitoring session.

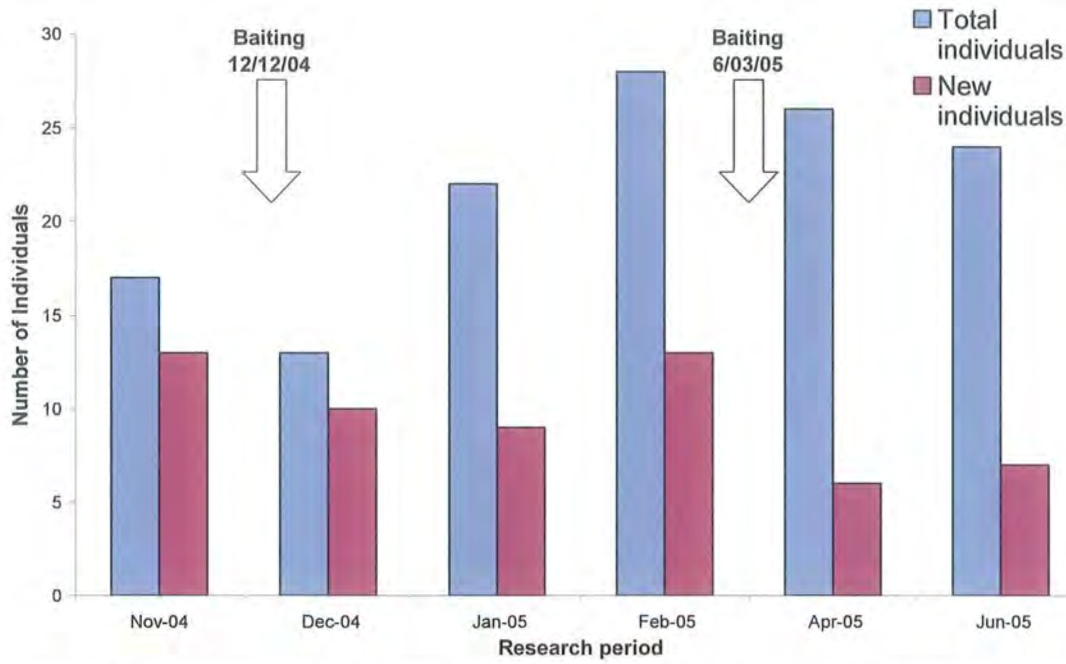

Figure 4.3: Numbers of Chuditch individuals caught during each trapping session before, during and after the Probait trials at the Julimar Conservation Park.

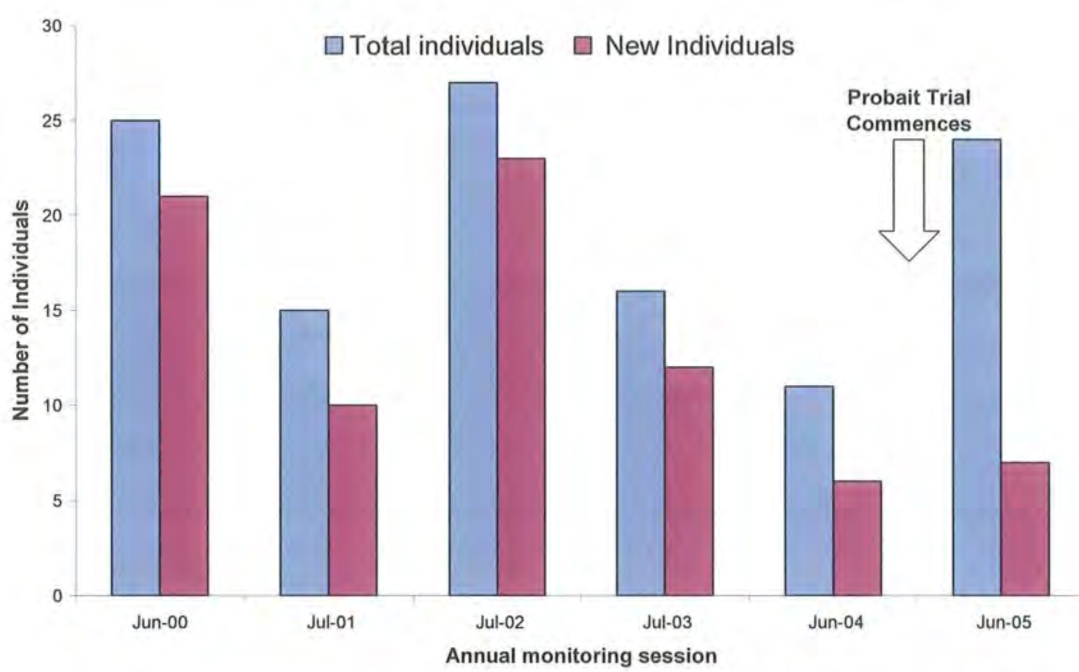

Figure 4.4: Numbers of Chuditch individuals caught during each annual monitoring session before (2000 to 2004) and after the 2005 Probait trial at the Julimar Conservation Park.

The relative abundance of Chuditch within the Julimar Conservation Park was determined by trap success (%) for each trapping session with the assumption that the study population was an open population. Trap success rates during the Probait trial are shown in Figure 4.5. They ranged between 3.4% in November 2004 and 9.1% in January 2005 peaking towards the middle of the study. No results were recorded for March 2005 as the trapping week was not undertaken because of other commitments during this time.

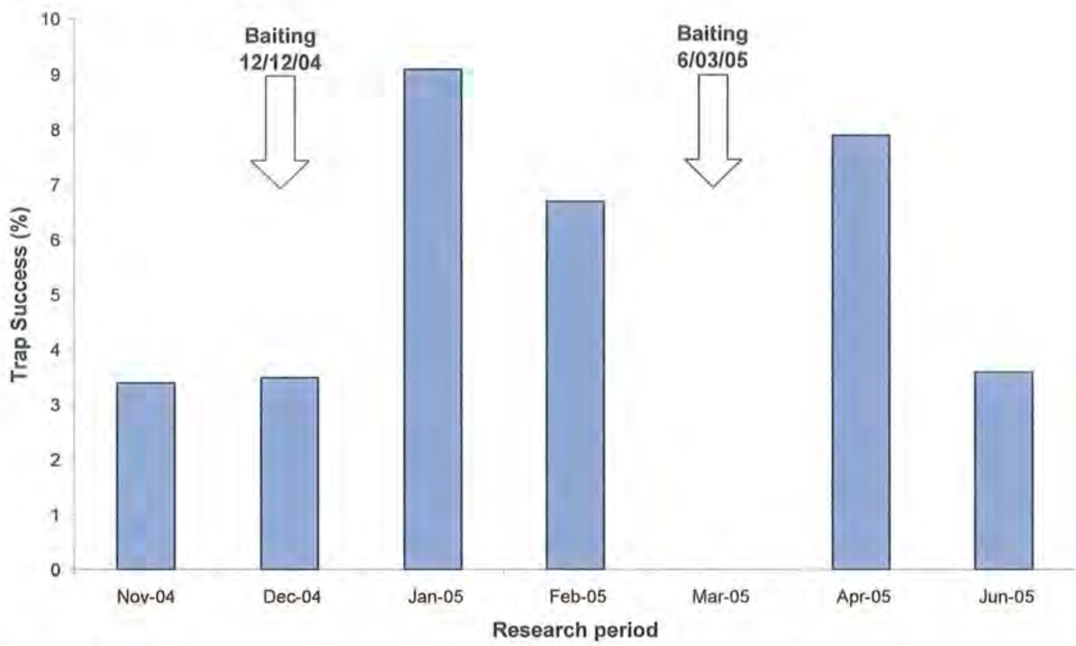

Figure 4.5: Trap success rates (%) for Chuditch caught in the Julimar Conservation Park before, during and after the Probait trial.

The trap success rates (%) from the annual monitoring sessions (2000 to 2004) before and after the 2005 Probait trial ranged between 1.3% in June 2004 and 4.3% in July 2002 (Figure 4.6). The rate for June 2005 is higher than that of the previous two years but is within the range of results shown from June 2000 to July 2002, indicating a naturally variable population abundance or a possible population recovery from previous years.

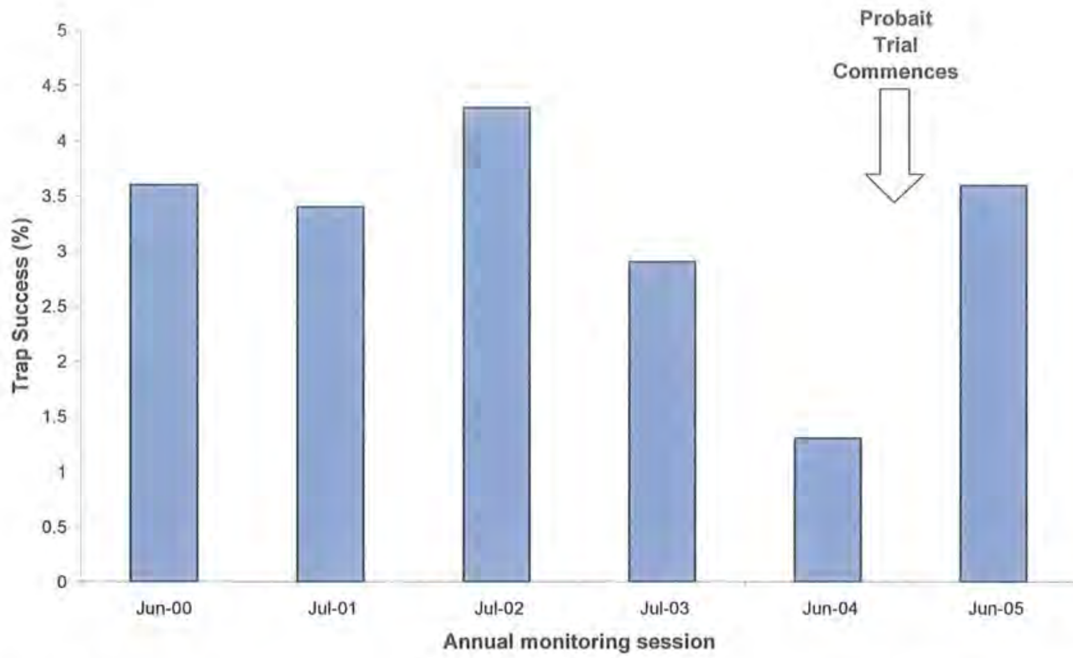

Figure 4.6: Trap success rates (%) in the Julimar Conservation Park during the annual monitoring sessions between June 2000 and June 2005.

4.2.2 Age structure

During November 2004 the age structure of the population displayed three separate divisions of juvenile (J), sub-adult (SA) and adult (A). Male adults (MA) comprised the greatest proportion of the trapped population during the month of November with similar numbers of sub-adult males and juvenile females. From December 2004 to June 2005, no juveniles were apparent in the population with only sub-adults and adults present (Figure 4.7), presumably just the juveniles growing up. During December adult males dominated the population structure followed by adult females. No juveniles were present from December onwards but the proportion of sub-adult males and females increased from the previous month. Between January 2005 and April 2005, adult males and females, with increasing numbers in the sub-adult male category, dominate the age structure of the population.

Between the 1992 and 2005 annual monitoring sessions, age structure within the population becomes more variable (Figure 4.8). Between 1993 and 1999 with the exception of 1995, adult females displayed the greatest number of individuals with all other years displaying higher numbers of adult males. Juveniles were not present during these monitoring sessions as females were either pregnant or carrying pouch young, with sub-adults occurring only in small numbers. June 2005 was the only monitoring session to record a sub-adult female.

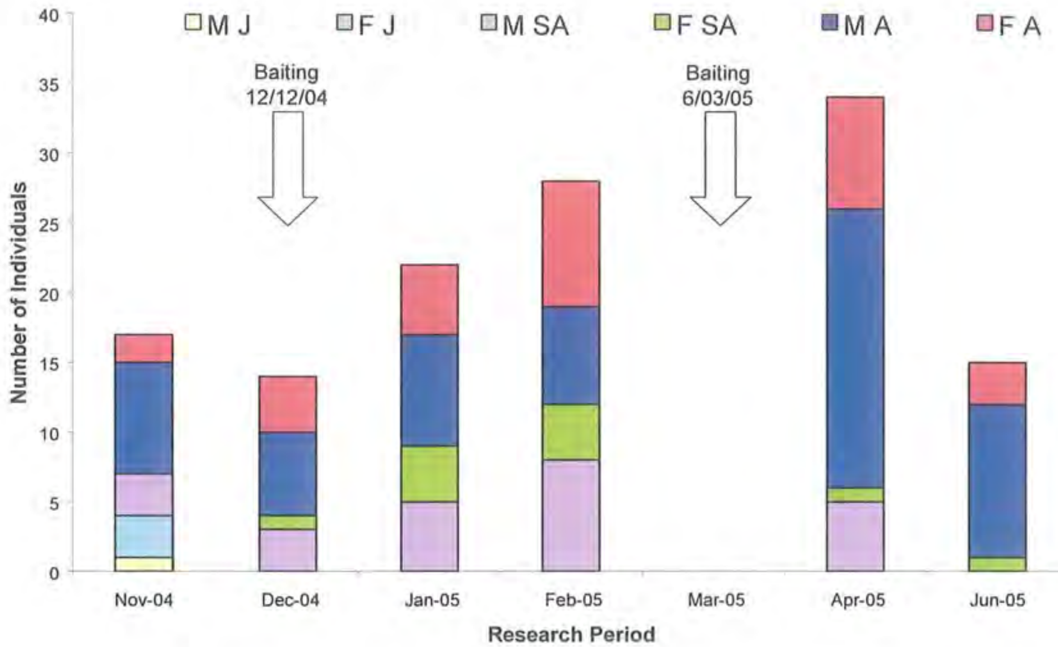

Figure 4.7: Age structure of the chuditch population before, during and after the Probait trial at the Julimar Conservation Park.

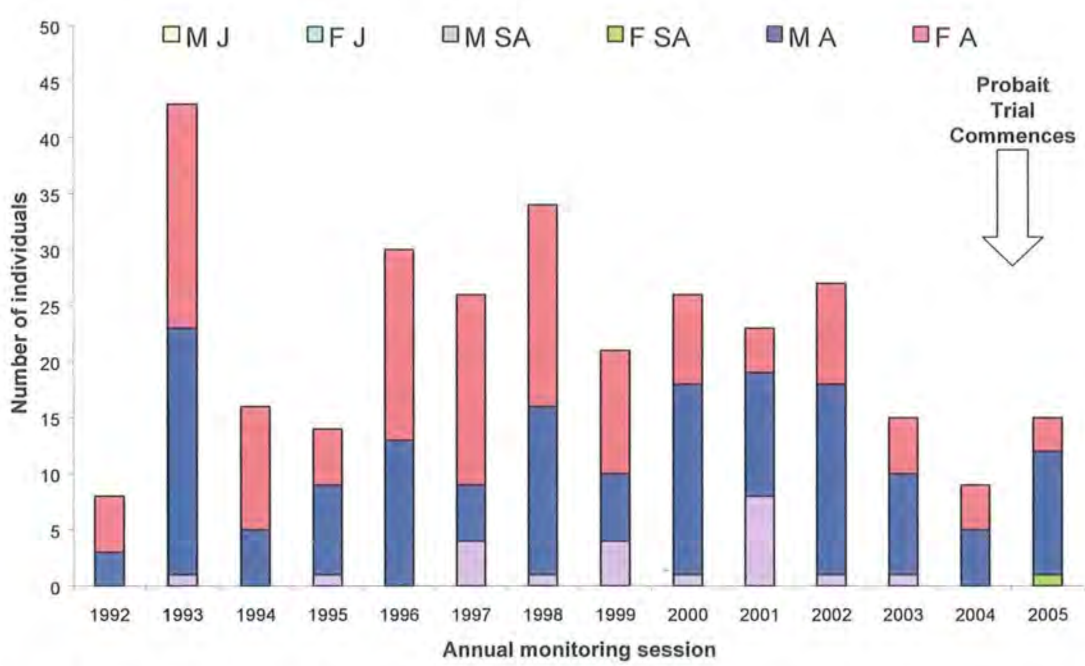

Figure 4.8: Age structure of the chuditch population in the Julimar Conservation Park between 1992 and 2005.

4.2.3 Sex ratio

During the six month research period from November 2004 to April 2005 the trapped population was mainly male dominated with a range of 58% to 79% of the individuals being male (Figure 4.9). During January females displayed the highest presence with 58% of the individuals being female.

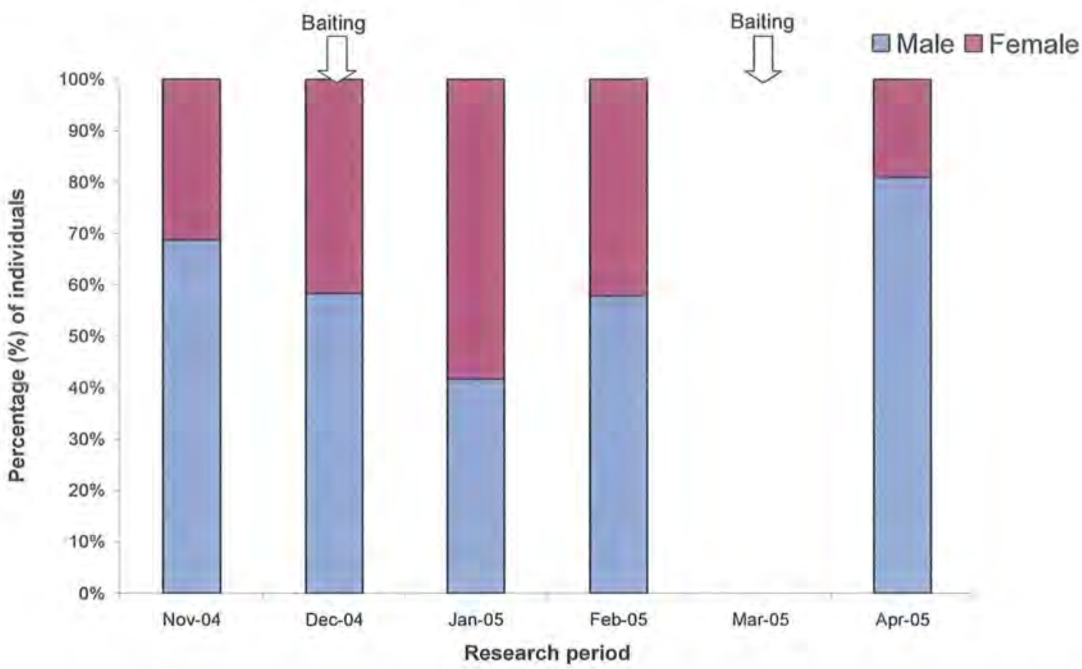

Figure 4.9: Sex ratios in the chuditch population before, during and after the Probait trial at the Julimar Conservation Park.

The sex ratio of the population varied widely between the 1992 and 2005 monitoring sessions (Figure 4.10) with the original translocated population in 1992 supporting 17 male and 12 female. In 1992, 1994 and 1996 – 1999, there was a higher percentage of females represented with a range of 51% to 68%. The population was male dominated during 1993, 1995 and 2000 – 2005 with a range of 53% to 74%. The percentage of females represented in the population was equal lowest during June 2005 and 2001 (approximately 26%).

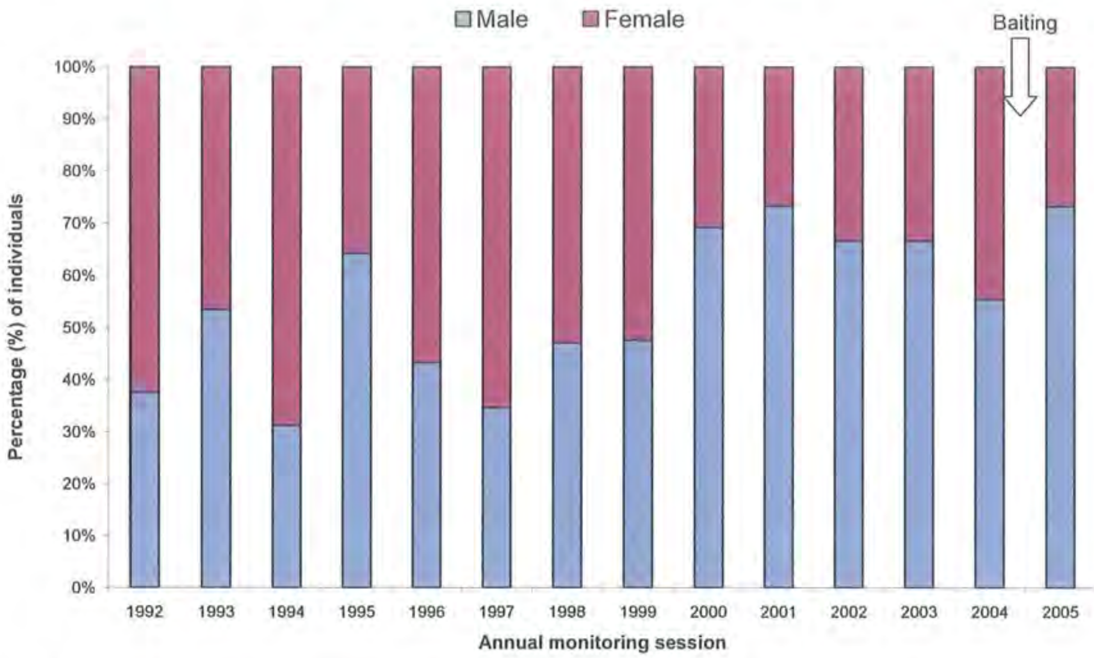

Figure 4.10: Sex ratios in the chuditch population determined from annual monitoring in the Julimar Conservation Park.

4.2.4 Fertility

The total number of pouch young recorded during the annual monitoring sessions ranges from 0 in 2004 to 101 in 1996 (Figure 4.11). Between 1996 and 2000 the number of pouch young in the population remained above 40. In the years prior to 1996 and following 2000 the number of pouch young decreased to below 30 individuals with 1992, 1993, 2004 and 2005 displaying just 4, 1, 0 and 7 pouch young respectively.

The average number of pouch young per female was highest between 1996 and 2001 with a range between 4 and 6 young (Figure 4.12). Before 1996 the average number of pouch young ranged from 1 to 2.5 per female. After 2001 there was a drop in the average to approximately 2 young per female but this increased again in 2003 to 4.2 young per female. During 2004 no pouch young were recorded and in 2005 an average of 1.75 pouch young per female was recorded.

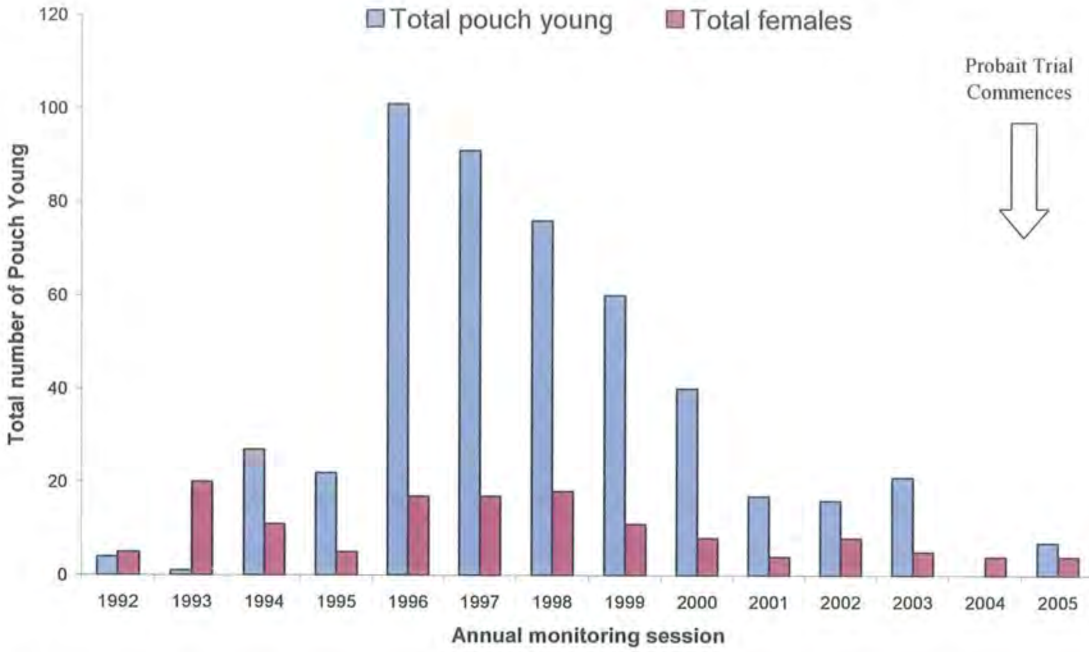

Figure 4.11: Total number of females and pouch young recorded in the Julimar Conservation Park during the annual monitoring sessions between 1992 and 2005.

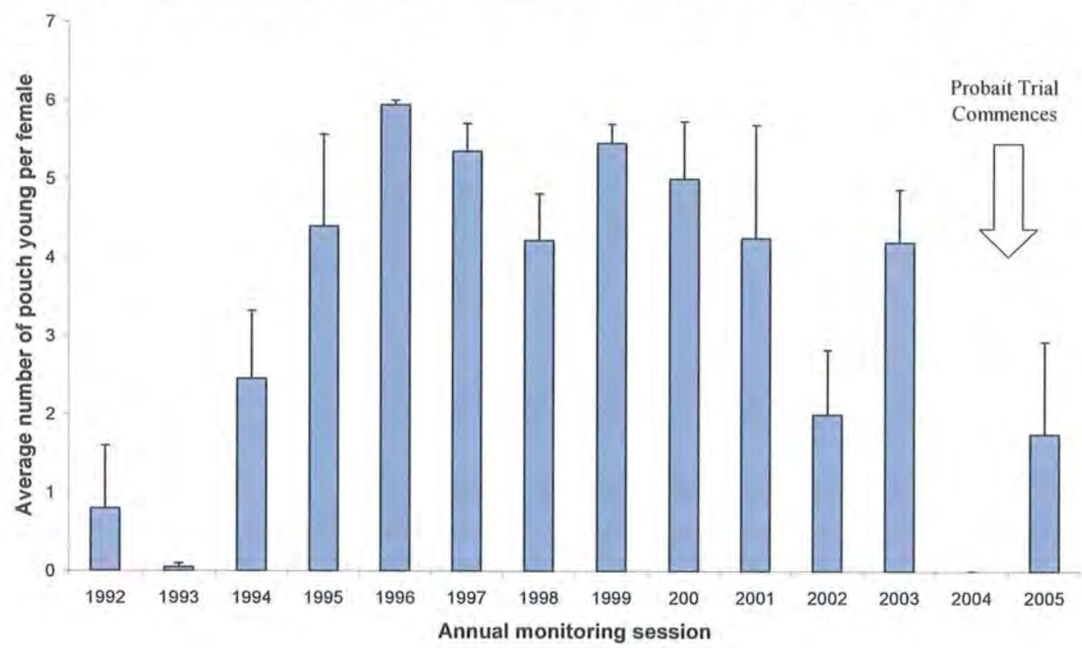

Figure 4.12: Average number of pouch young per female recorded (± Standard Error) in the Julimar Conservation Park during monitoring sessions between 1992 and 2005.

4.3 Radio collared Individuals

4.3.1 Whisker and scat analysis

Of the 15 collared individuals 14 had whiskers sampled between November 2004 and April 2005 (Figure 4.13). One individual was trapped only twice (to put the collar on and to remove it) and did not have any whiskers sampled. Four collars were removed due to death or poor health of individuals and 3 were reused on new individuals in later months of the study. The 14 individuals that had whiskers taken were sampled between 1 and 4 times depending on how often they were trapped during the study. Of those individuals 10 displayed the presence of Rodamine B through fluorescent banding of the whisker samples. Samples taken from the other 4 radio collared individuals did not display Rodamine B.

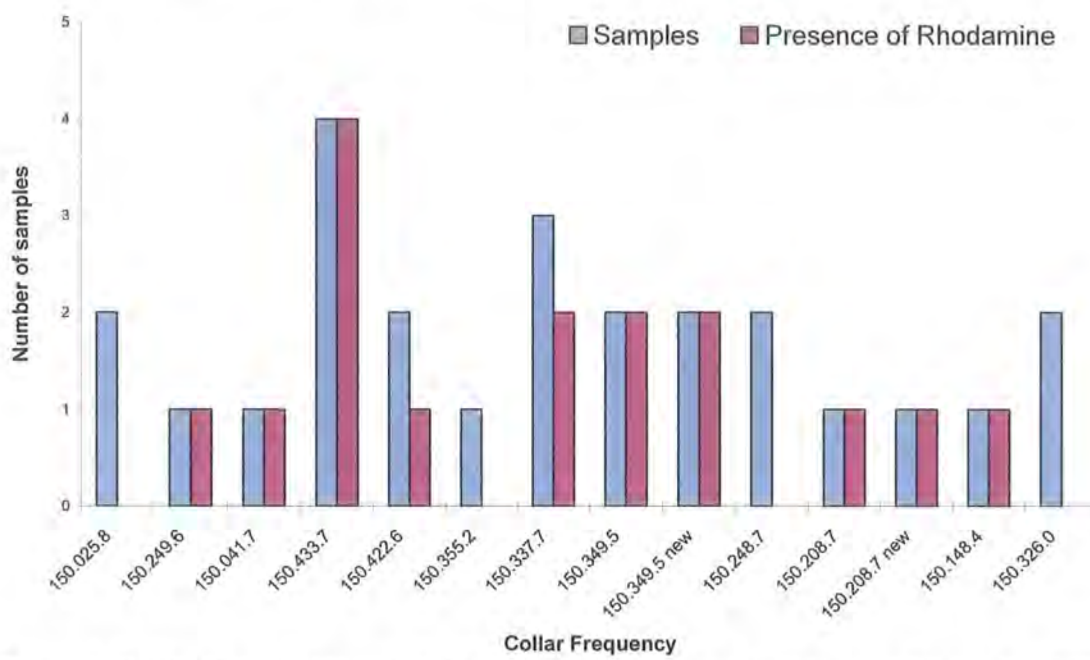

Figure 4.13: Number of times individuals had whiskers taken between November 2004 and April 2005 and the number of times Rodamine B was present in the whisker samples.

Scats were collected from 4 of the 15 radio collared individuals between November 2004 and April 2005. All of these displayed pink colouration when viewed under normal lighting conditions and fluorescence under UV lights, indicating the presence of Rodamine B. These results suggest that the individuals had ingested Probait within a few days prior to the samples being collected.

4.3.2 Survival

There were 12 radio collars available at any one time between November 2004 and April 2005. Due to death or poor health of some of the animals, some collars were removed and reused enabling 3 more animals to be radio collared at a later point in the study. The fate of the radio-collared individuals is summarised in Table 4.1. Due to predation and natural circumstances, 2 of the 15 radio collared individuals died between December 2004 and Jan 2005. Both collars were recovered but only one was suitable for reuse on a new individual. Two more collars were removed between December 2004 and February 2005 due to chafing around the neck and were reused on new individuals.

Table 4.1: Fate of radio collared individuals before, during and after the Probait trial at Julimar Conservation Park with X representing the months in which the animals were known to be alive.

Collar Frequency	Sex	Nov	12/12/2004 Bait Drop	Dec	Jan	Feb	6/03/2005 Bait Drop	Mar	Apr	Fate
150.025.8	♀			X	X	X		X	X	Ok - collar removed
150.249.6	♀			X						Dead -Predation (python)
150.041.7	♂			X	X	X		X	X	Ok -collar removed
150.433.7	♂			X	X	X		X	X	Ok -collar removed
150.422.6	♂	X			X	X		X	X	Ok -collar removed
150.355.2	♂	X			X	X		X	X	Ok -collar removed
150.337.7	♀	X		X	X	X		X	X	Ok -collar removed
150.349.5	♂	X		X						Collar removed - chafing
150.349.5new	♂			X	X	X		X	X	Ok -collar removed
150.248.7	♂	X			X	X				Collar not recovered
150.208.7	♂	X			X	X				Collar removed - chafing
150.208.7 new	♂					X		X	X	Ok -collar removed
150.148.4	♂	X			X	X		X	X	Ok -collar removed
150.326.0	♂	X		X	X					Dead - drowned
150.326.0new	♂					X		X	X	Ok -collar removed

During the first trap week in November 2004, 8 individuals were fitted with radio collars and 4 more were fitted during December 2004. Of the first 8 individuals collared in November, 4 were KTBA at the end of the study in April 2005 with 3 having their collars removed due to death or neck chafing. These collars were reused between December 2004 and February 2005. The new individuals were KTBA at the end of the study in April. Of the 4 individuals collared in December, 3 were KTBA at the end of the study in April with the other one dying due to predation and rendering the collar ineffective for future use in the study. One collar was not recovered at the end of the study due to an inability to locate the individual. It is uncertain whether the individual disappeared from the study site, died during the study or simply could not be located with the equipment.

4.3.3 Core activity area

The core activity area was determined with the use of the Rangers V program (Kenwood and Hodder 1992) using the minimum convex polygon (MCP) method. The core activity area was defined in terms of hectares but was then converted to square kilometres. The core activity area was estimated by calculating the area of the MCP encompassing all of the diurnal refuge sites located for each individual. This was calculated instead of the home range of the individuals due to the small sample size. Between 4 and 14 fixes using a global positioning system (GPS) were taken for each radio-collared animal (Appendix 4.1). The core activity areas ranged between 0.37 km^2 and 6.3 km^2 for 13 of the radio collared animals (Figure 4.14). Areas were not calculated for the remaining two collared animals due to insufficient numbers of fixes.

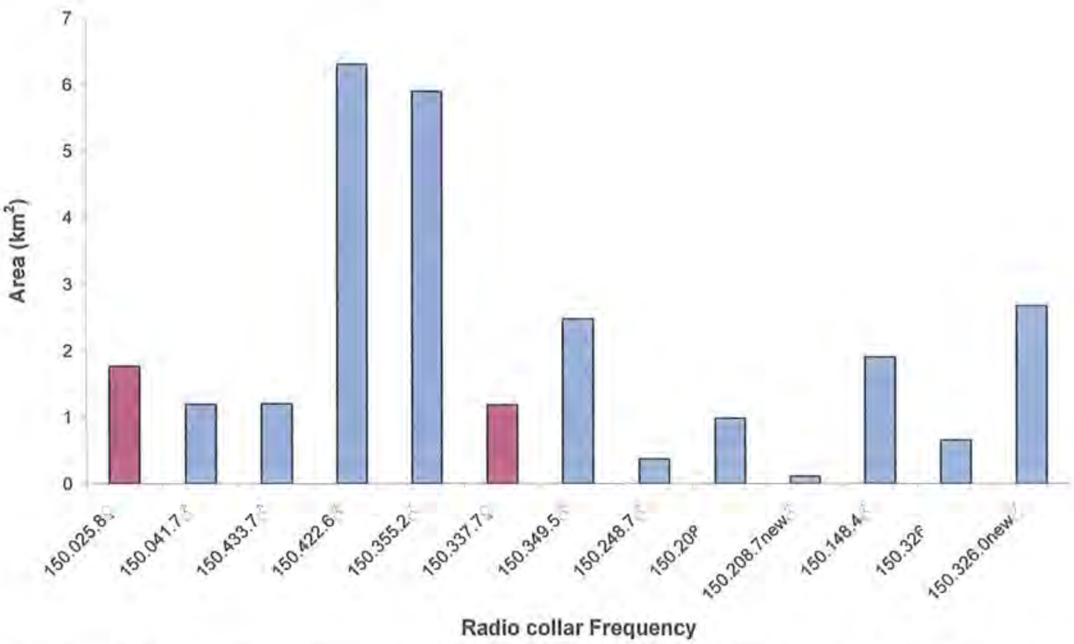

Figure 4.14: Core activity areas (km^2) of radio collared Chuditch at the Julimar Conservation Park between November 2004 and April 2005.

The areas displayed some differences between males and females with 5 of the 11 males displaying larger core activity areas than the 2 females, though sample sizes may be too small with too much overlap to rely too heavily on the previously stated conclusion. The females had a core activity area between 1.18 km^2 and 1.76 km^2 whereas the core activity areas of males ranged between 0.37 km^2 and 6.3 km^2. As Probaits were dropped at 5 per km^2 in the park, each individual with an area of more then 1 km^2 has the potential to locate and ingest at least 5 Probaits. The number of potential Probaits located and consumed by radio collared individuals is shown in Figure 4.15, ranging from 2 to 31 Probaits. This number may be an overestimate due to the overlapping nature of many of the individuals' core activity areas.

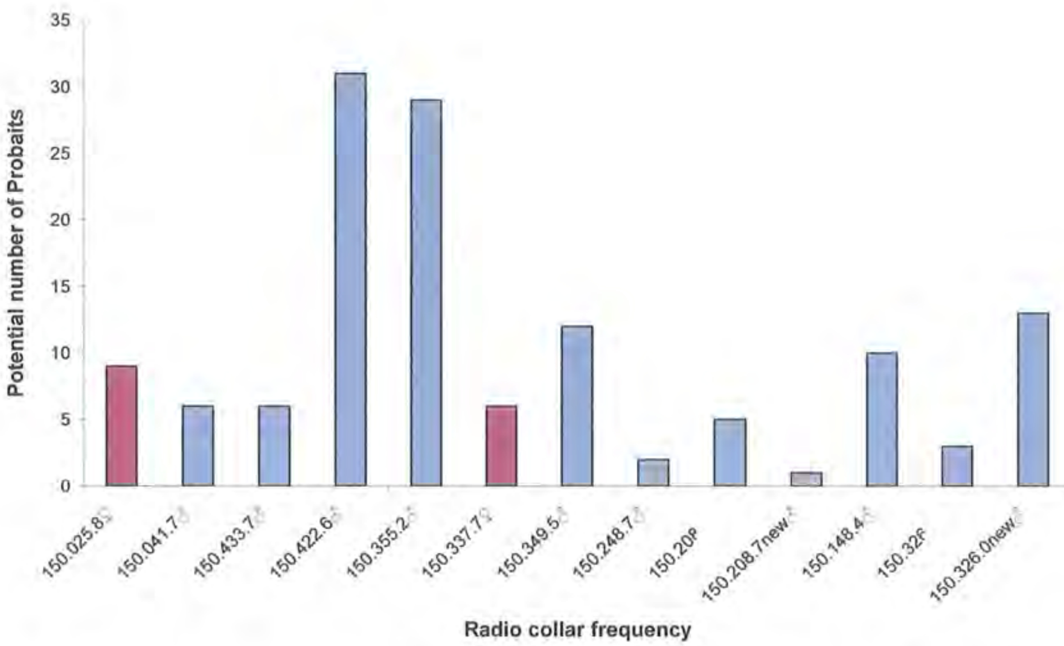

Figure 4.15: Potential number of Probaits located by radio collared individuals in the Julimar Conservation Park between November 2004 and April 2005.

Some differences were noted regarding the position of the core activity areas within the Julimar Conservation Park (Figure 4.16). Radio collared males showed an overlap of area with other males as well as females but the females did not display any overlap with other radio collared females.

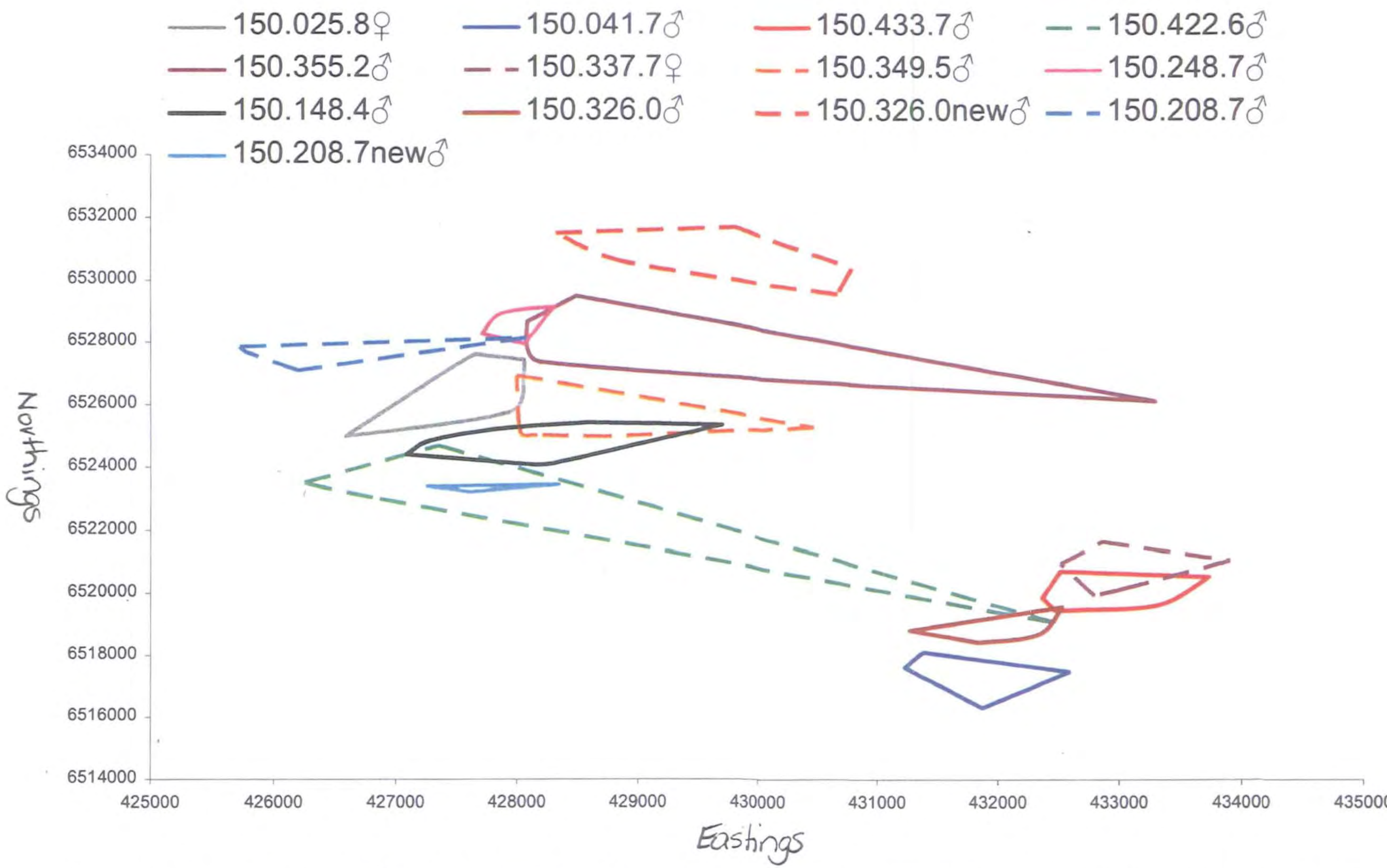

Figure 4.16: Core activity area (km^2) of 12 radio-collared Chuditch at the Julimar Conservation Park between November 2004 and April 2005, calculated using the minimum convex polygon (MCP) method.

4.3.4 Refuge utilisation

There were 79 various diurnal refuge sites located in the Julimar Conservation Park between November 2004 and April 2005 for the 15 radio collared individuals. Hollow logs made up 86% of the refuge sites. Standing trees represented 8% and 6% of the sites represented were burrows (Figure 4.17). Of these 79 refuge sites, 74 were identified as being Marri, Wandoo or Jarrah tree species. Of the total tree species, 58% were Wandoo, 26% were Jarrah and 16% were Marri (Figure 4.18). The remaining 5 refuge sites were burrows associated with particular surface features. Three burrows were associated with *Xanthorrhoea sp.*, one was characterised by a granite outcrop and the remaining burrow was identified as a rabbit warren.

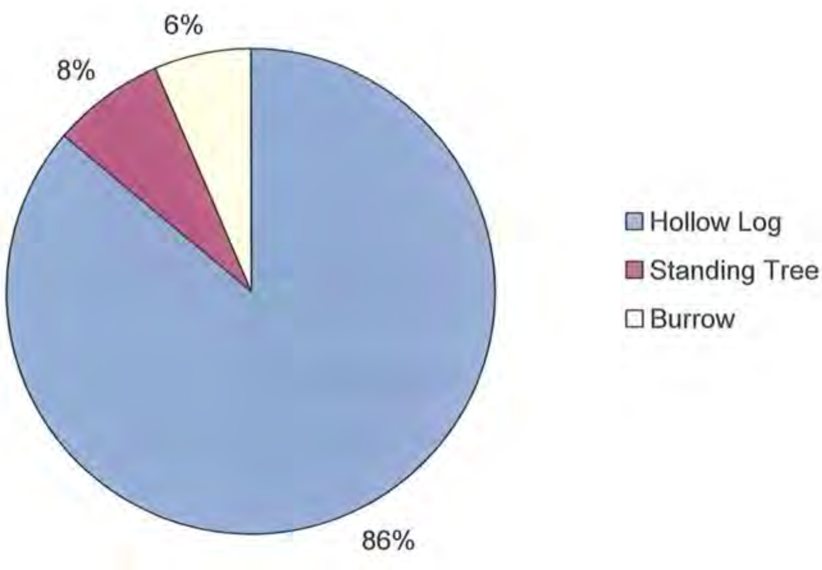

Figure 4.17: Proportional refuge type utilisation by radio collared chuditch (%) in Julimar Conservation Park between November 2004 and April 2005.

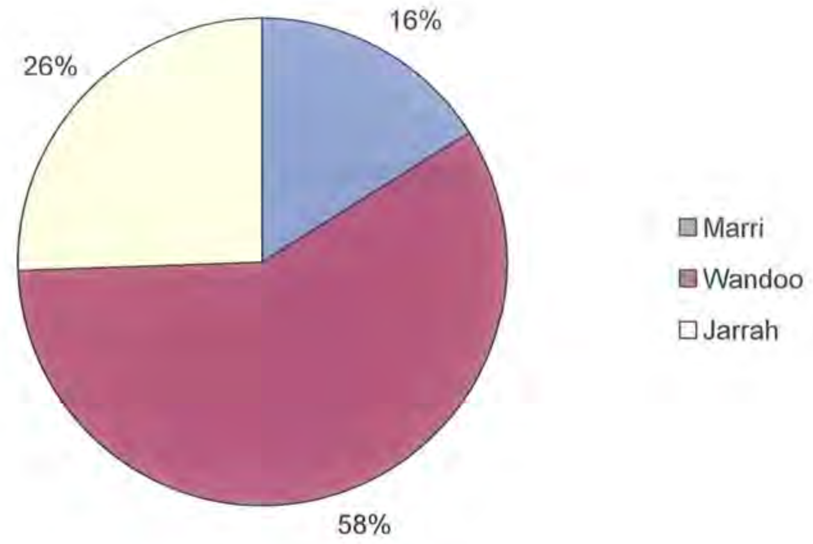

Figure 4.18: Tree species utilised by radio collared chuditch (%) in Julimar Conservation Park between November 2004 and April 2005.

The refuge log dimensions obtained through the radio-tracking period between November 2004 and April 2005 were as follows:

Length of log – The average length of the logs utilised was 9.9 ± 0.6 m (standard error) and showed a range between 2.5 m and 25 m.

Diameter of hollow – This showed a range of 8 cm to 25 cm for adult females and 8 cm to 40 cm for adult males. The average diameter of the hollow was 13.8 ± 1.9 cm for females (2 females and 10 logs). The average was 15.4 ± 1.0 cm for males (9 males and 43 logs). A one-way ANOVA displayed no significant difference ($P>0.05$) in the size of the hollow diameters as a result of the individual's gender.

Diameter of Bole at resting position – Logs utilised during the study were at least 25cm wide at the resting position of the animal but ranged to as wide as 110cm. Across all months included in the study the average bole diameter for females was 63.5 ± 7.6 cm (10 logs) and 66.6 ± 2.6 cm (52 logs) for males. Again a one-way ANOVA indicated no significant difference ($P>0.05$) between the bole diameters utilised by males and females.

Resting-entrance distance – This varied from 0.5 m to 8 m in the case of adult females and 0.5 m to 12 m in the case of adult males. On average females were found resting 1.9 ± 0.6 m from the entrance and males resting on average 2.9 ± 0.3 m from the entrance. Using a one-way ANOVA, distance from entrance to resting site did not differ significantly ($P>0.05$) between males and females.

Hollow logs were classified as resulting from a natural fall or from a cut. 88.1% of the hollow logs were the result of natural falls and 11.9% were from old or prescribed cuts. All standing trees utilised as refuge sites were alive, with 3 Wandoo, 3 Marri and no Jarrah trees being utilised. These had an average diameter at breast height of 75 ± 7.5 cm (standard error) with a range between 50 cm and 100 cm. The average height of the trees was 9.7 ± 2.3 m with a range between 5 m and 20 m.

Chapter 5 – Discussion

5.1 Whisker and Scat Analysis

5.1.1 Probait location and consumption

Previous laboratory studies have identified *Dasyurus geoffroii* (chuditch) as a potential non-target animal that is at risk from consuming harmful doses of Probait in natural environments (Martin *et al* 2002). This study confirmed that chuditch in the Julimar Conservation Park will locate and consume Probait. Martin *et al* (2002) determined the amount of 1080 theoretically ingested by captive chuditch, and the subsequent potential risk involved. It was determined that they would face a medium to low risk from Probait consumption in the wild and that the greatest risk was for the smaller individuals when they ate the smaller more concentrated baits (Martin *et al* 2002).

The Probaits used for this study contained 3mg of 1080 per bait. The biomarker Rodamine Bβ, which stains the gut, mouth and scats pink as well as marking the facial whiskers, was added to the baits to help identify the chuditch individuals that consumed baits. Of the 61 individuals that were trapped between November 2004 and June 2005, 44 had whisker samples taken after the baits were laid. 26 of the individuals sampled had whiskers that showed the presence of fluorescent banding, indicating that over half of the 44 individuals sampled had located and consumed Probait in the Julimar Conservation Park at some point during the study. Scat analysis does not indicate the amount of bait consumed by the individual, only that bait has been consumed by the individual in some unknown proportion. Scat analysis indicated that 6 out of 14 samples displayed pink colouration suggesting that 6 of the 14 chuditch sampled had ingested some portion of Probait during the study in the few days prior to scat collection; three of these were individuals that also displayed fluorescence in the facial whiskers out of the 26 that displayed Rhodamine B in the whiskers.

There was no way of determining the quantity of the baits being ingested in the wild, although captive trials with non-toxic Probaits indicated that chuditch would consume up to 8.7% of their body weight when alternative food was not available (Martin *et al.*

2002). It is probable that during one foraging session wild chuditch could consume as little as 2.9% or less of their body weight of toxic Probait in the wild due to the availability of other food sources and the possible difficulty in locating Probait (Martin *et al.* 2002). Chuditch have an approximate LD_{50} of 7.5 mg kg^{-1} for the 1080 toxin, so for a chuditch population with a weight range between 0.7 and 1.9 kg the amount of 1080 equivalent to reach the LD_{50} is between 5.3 mg and 14.3 mg which is equivalent to approximately 2 to 5 baits (Department of Conservation and Land Management 1996).

The maximum amount of 1080 possibly ingested based on the assumption that they are consuming approximately 2.9% of their body weight would be between 2.81 mg and 3.0 mg (Martin *et al.* 2002). Chuditch would have to repeat this pattern of consumption for more than 2 days in a row to obtain a lethal dose of 1080 from the Probaits as the passage time is approximately 48 hours in small to medium sized mammals (Fisher 1999). On the other hand, if they are consuming appromiately 8.7% of their body weight then the amount of 1080 possibly ingested would range between 8.4 mg and 9 mg. This is above the tolerance level for chuditch and would likely be fatal. If Probaits are not ingested continuously for several days, the toxin starts to be broken down within 30 minutes of ingestion and digested by chuditch after the first 24 hours, reducing the risk to the individual (King 1993). Sub-lethal doses are detoxified in the liver and kidneys or excreted so the poison is not accumulated in the body (King 1993). Though it is possible that chuditch may continually locate and consume Probait in the wild, the high number of individuals consuming the Probaits without fatal consequences indicates that they will not do so at a rate that would be lethal to the population.

5.1.2 Gender and age vs. Probait consumption

The Probait trial was undertaken from November 2004 to April 2005 (with data also used from the June 2005 annual monitoring session), at a time when juveniles born in June 2004 were growing and dispersing from their natal home ranges (Soderquist and Serena 2000). This time frame was chosen to ensure that pregnant females, which are under greater metabolic stress, did not consume toxic baits (Serena and Soderquist 1988) and to determine whether juveniles would locate and consume baits while dispersing from their natal home ranges. Both pregnant females and dispersing juveniles may be more likely to consume Probait due to their higher food requirements for growth and sustenance (Soderquist and Serena 2000).

Of the 44 individuals that had whiskers sampled, 16 (36.4%) were classed as sub-adults due to their low weight range (between 400 and 900g) and the rest were adults (63.6%). Ten (62.5%) of the sub-adults displayed the presence of Rodamine B, indicating Probait ingestion while 16 (57%) adults also displayed the presence of Rhodamine B. This suggests that the younger and smaller individuals as well as the older individuals in the population will locate and consume Probait while dispersing from their natal home ranges. Six of the ten sub-adults with Rhodamine B in their whiskers were KTBA in April 2005, one was eaten by a python in December 2004 and the rest were KTBA at the end of February 2005. Ten of the adults with Rhodamine B in their whiskers were KTBA in April 2005, 5 were KTBA in February 2005 and 1 was KTBA in December 2004.

5.1.3 Survival

Survival rates after ingestion of Probait during the study are vital in determining the suitability of the bait for broad scale operational use. The study showed that there was no significant difference in Probait consumption by chuditch in the Julimar Conservation Park regardless of age and gender. Survival of individuals was determined by repeated presence in the study area. The numbers of chuditch known to be alive (KTBA) ranged between 17 and 34 for the various months during the study. Of the 54 individuals trapped during the intensive part of the study 34 (62.9%) were KTBA at the end of the study, indicating a relatively high incidence of survival in a Probaited area. Individuals are lost from a population when they disperse from their home range, die as a result of natural causes, predation or as a result of competition within the population for space, food and reproductive privileges (Krebs 1999).

Of the 26 individuals that ingested Probait (as indicated by whisker and scat analysis), 18 (69.2%) were KTBA at the end of the study in April 2005, indicating a high incidence of survival while 14 of the 18 that did not show signs of Probait ingestion were KTBA in April 2005. Scat analysis also suggested a high survival rate as 5 of the 6 individuals (83.3%) that displayed pink colouration in scat samples collected prior to the March bait drop were also KTBA in April. There were two bait drops over this time, one in December 2004 and the other in March 2005. There was evidence of Probait ingestion from numerous individuals after each of these baiting sessions with many surviving baiting, suggesting that most of the individuals were capable of survival in their natural environment after ingesting Probait.

5.2 Population Dynamics

To determine whether there were detrimental impacts of Probait on the chuditch population in the Julimar Conservation Park, measurements were made of several population parameters before, during and after the Probait trial. Changes in the dynamics of a population may indicate that certain factors, such as climatic variances, natural disasters or baiting, may have affected the population (Brewer 1994). The relative abundance, age structure, sex ratio, fertility and dispersion are population parameters that were measured in this study to display the general health of the chuditch population.

The chuditch population in the Julimar Conservation Park is characterised by changes in size and composition. This is a result of new individuals being introduced into the population through births and immigration from the surrounding forest habitat at the Bindoon Army Defence Training area as well as animals leaving the population by death and emigration to surrounding forest areas (Morris *et al.* 1993-1999).

5.2.1 Relative abundance

The size of the population is potentially an important factor in determining the impact of Probait as it could be assumed that a larger population is more likely to recover from a baiting event than a smaller population (Murray and Poore 2004). The relative abundance of Chuditch within the Julimar Conservation Park was determined by trap success (%) for each trapping session with the assumption that the study population was an open population. The trap success rates before, during and after the Probait trial ranged between 3.4% and 9.1% per trapping week. The lowest trap success rate occurred in November 2004 and the highest in January 2005. Towards the end of the study in April 2005 the success rate decreased slightly and in June 2005 the rate was about equal to that of November 2004. No results were recorded for March 2005.

At the beginning of the study it was expected that trap success rates would be between 1.3% and 4.3% as previous monitoring trips had resulted in similar ranges. The lower trap rates in November 2004 were considered good based on previous results. These rates were then expected to rise during the course of the study as new individuals, dispersing young, were likely to be located within the study area (Brent Johnson. pers comm 2005). Trap rates were expected to drop towards the end of the study as more individuals moved into reproductive activities. Male and females tended to move around more frequently in search of reproductive partners towards April. The increased activity may have also increased trap success rates as they may be more likely to encounter a trap during their movements. (Stead-Richardson *et al* 2001). The trap rates for this study (3.5%) displayed similar patterns to those expected (between 3% and 4.5%), suggesting that the population was functioning similarly to previous years. Reduced trap success rates during the study would have been an indication that the population may have been limited by the Probait.

The trap success rate (%) from the annual June 2005 monitoring session increased approximately 2% from the previous year and approximately 1% from June 2003, suggesting a possible population recovery from the previous two years. If Probaits were having a detrimental impact on the population a reduction in trap success rates would be expected. As the rate increased, it is possible that Probaits do not negatively impact on the Chuditch population in Julimar Conservation Park any more than the previously used dried meat baits.

5.2.2 Age structure

To estimate the age of chuditch an index based on tooth wear is primarily used (Serena and Soderquist 1988b). For the purpose of this study the age of an individual was estimated by weight categories as the tooth wear index is difficult to distinguish without previous experience. A diverse age structure is indicative of the population's historical and ongoing reproductive success. A population that has low juvenile and sub-adult numbers may indicate a population that may no longer be reproducing due to certain limitations or as a result of high juvenile mortality. A healthy chuditch population should be able to support numerous individuals from all age categories during different periods throughout their lifecycle, indicating at certain points in the life-cycle that the population is capable of reproduction and maintaining the survival of young until adulthood (Stead-Richardson *et al.* 2001).

In November 2004 when most of the young were dispersing from the natal dens, the results displayed three distinct categories of juveniles, sub-adults and adults. By December 2004 all of the juveniles had either dispersed from the study area or gained sufficient weight to move into the sub-adult category as suggested by the shift in age structure to all sub-adults and adults. Both weight gain through healthy eating and dispersion indicating movement within and through an area are indicative of normal population parameters (Krebs 1999).

The results displayed a smaller representative of sub-adult males in the population towards the end of the study in April which were not present at all by June 2005 as would be expected based on the lifecycle patterns of the chuditch where most young have grown to maturity by this stage. All young are capable of reproduction within their first year (Stead-Richardson *et al.* 2001), so rapid growth needs to be accomplished before their first mating, especially with males who compete with one another for a female mate. The competition between males is fierce with the larger male typically winning (Brent Johnson. pers comm. 2005). Several of the sub-adults represented earlier in the study grew to adult size over the trial period with some also forced out of the study area with the beginning of the reproductive period in April. The growth of the individuals in the population from juvenile to sub-adult to adult, as shown by several females that were caught as juveniles in November 2004 and then as adults in April, suggests that food is not a limiting resource and that the implementation of Probait into the area is not restricting the growth and dispersion of the population. Further studies would indicate whether the age structure follows a similar pattern of growth and dispersal suggesting whether the population is functioning normally.

The results for the June 2005 annual monitoring session displayed one key difference to that of previous years with the presence of a sub-adult female and the absence of sub-adult males within the population. This shouldn't affect the reproductive activity within the population as all females are reproductively active during their first year, so the sub-adult female represented in June 2005 should still be capable of reproducing.

The lack of sub-adult males from the area may be the result of rapid growth in the lead up to the reproductive period or dispersion from the study area. The number of adult males in the population is approximately equal to or larger than 8 of the previous year's results, suggesting that reproduction should not be limited by the number of available males.

Due to the seasonality of breeding the results show that the population is supporting mostly adult males and females during the months of June and July, with little change between previous years and this year after the Probait trial. Future studies would need to be performed to determine the long term effects of Probait on the population but in the short term the implementation of Probait does not appear to have disturbed the age structure of the population.

5.2.3 Sex ratios

The sex ratio of a chuditch population is an indication of potential reproductive capacity, with a female dominated population the ability of the population to reproduce is higher than if the population is male dominated (Stead-Richardson *et al.* 2001). Female chuditch may mate with several males during the breeding season (Stead-Richardson *et al.* 2001) and as males have large home ranges that often overlap with several females there is the potential for one male to impregnate several females (Matthew 1996). If the population was male dominated there would be fewer females for each male to mate with, limiting the production of young within the population.

The results suggested a male dominant trend during November 2004, December 2004, February 2005 and April 2005. At the beginning of the study it was expected that more males then females would be trapped due to females remaining close to their natal dens while their young are still nesting (Soderquist and Serena 2000). As more and more young begin to leave their natal dens it was expected that females might become more readily trappable as they forage further from their natal dens and often abandon the natal den when their young are approximately 120 days old (Serena and Soderquist 1989a). The results from the January trapping week, when most of the young were approximately 184 days old, displayed more females then males being caught.

If the population was being negatively affected as a result of the implementation of Probait then it might be expected that females would be low in numbers due to their smaller size (Stead-Richardson *et al.* 2001). The first Probait drop was on the 12th of December 2004 and as the numbers of females were highest during January, it could be suggested that females were not being limited by the initial presence of Probait. The numbers of females trapped dropped later in the study between February 2005 and April 2005. The second Probait drop was performed on the 6th of March. The drop in females during April may be linked to the Probait but as they began to decrease in February, before the second baiting, it is difficult to attribute the decline to Probait. Other factors may have contributed to the decline such as the small home ranges of females (Matthew 1996). The females that were trapped earlier in the study may have been wandering on the outer edge of their home range and returned to the core area where they would not have been trapped again as the traps were placed approximately in the same positions each trapping session.

The sex ratio of the population shown by the annual monitoring session between 1992 and 2005 appears to follow cycles. The results indicated that for the first four years a variable dominance was displayed as the population was establishing within the area after being translocated into the Julimar Conservation Park in 1992 (Orell and Morris 1994). For four years in a row, the results displayed a female dominance trend, followed by four years where males became the dominant individuals. These differences may be explained by climatic conditions. In 1995 the annual rainfall for the area was above average, possibly resulting in higher productivity over the following few years. The results for the June 2005 annual monitoring session showed a male dominated population approximately equal to the results shown in 2001. The implementation of Probait as a substitute for dried meat baits does not appear to cause disproportionate mortality of one sex within the population on a short term basis.

5.2.4 Fertility

Sullivan *et al* (1979) suggest that fox baiting may lower fertility rates in chuditch populations as a result of the 1080 used. Fertility is an important factor in determining the health of a population as it indicates the populations ability to reproduce and identifies how many new individuals are being introduced into the population each year (Krebs 1999). The fertility of the population in this study was determined by the number of pouch young present in June 2005, approximately 3 months after the Probait trial. A low number of pouch young present may be indicative of a population that is being deleteriously affected by Probait as females may be in poor health due to repeated Probait ingestion resulting in sub-lethal doses. High numbers would indicate that the population is reproducing above or equal to its previous rate, regardless of the presence of Probait.

The total number of pouch young recorded during the annual monitoring sessions ranged from 101 in 1996 to 0 in 2004, indicating a large range in the reproductive ability of the population. Between 1996 and 2000 the number of pouch young in the population displayed abundances above 40 suggesting that these years were very productive for the population. A population that is thriving well in an environment might display large numbers of offspring as food and other resources are adequate to support a larger influx at any one time (Brewer 1994). The large number of offspring during this period coincided with the largest average number of pouch young per individual. If the average number of pouch young ranged from 4 to 6 it would be expected that more individuals in total were born.

In the years prior to 1996 and following 2000 the number of pouch young decreased to below 30 individuals with 1992, 1993, 2004 and 2005 displaying just 4, 1, 0 and 7 pouch young respectively. This also coincided with low average pouch young per individual (approximately 2 pouch young per female). This will also relate to the number of females present in the population. If there are more females it would be expected that more offspring could be produced. The small number of offspring supported by the population in June 2005 is actually an increase from the previous year, although with fewer females however, it would be a good idea to check later in the breeding season to see if the young are surviving. June may be too early to identify any effects of sub-lethal doses of 1080. It is also within the range of offspring born in 1992 and 1993. However, it is difficult to determine if Probait has limited the reproductive capacity of the population as the small number of pouch young could be attributed to poor productivity of the area, or even the time of year the sampling was done. Redoing the trial during the breeding season would give a better indication of the effects of Probait on pouch young and juveniles.

The results indicated that pouch young numbers in the population were low during the June 2005 trip. This is still early in the reproductive season and may not be a true indication of pouch young numbers for 2005 (Stead-Richardson *et al.* 2001). As a result the annual monitoring session for 2006 has been planned for July.

The increase in the number of pouch young from the previous year is a positive result after the Probait trial. It shows that the population has increased in abundance in this aspect even after the implementation of Probait. Future studies should be performed to determine the long term effects of Probait on the fertility of the population. Future studies may also identify if the low numbers of pouch young from the last 5 years is the result of environmental factors acting on the population.

5.2.5 Dispersion

A total of 106 Chuditch individuals were caught between November 2004 and April 2005. This included both new (48.1%) and recaptured (51.9%) individuals. With the inclusion of the annual June monitoring program trap results, 130 Chuditch individuals (44.6% new and 55.4% recaptured) were caught between November 2004 and June 2005. The number of new individuals in the population should be highest during the early part of the study between November 2004 and January 2005 when young are leaving their natal dens and beginning to disperse away from the area. It would then be expected that the number of new individuals would drop as more and more young disperse from their natal home ranges or were caught throughout the study and thus becoming recaptures (Soderquist and Serena 2000).

The results from this study support these general assumptions with the exception that the number of new individuals in the population increased during February 2005 and then dropped towards the end of the study in April 2005. A possible explanation could be that females that bred later in 2004 (Arnold 1976) and thus gave birth later may have had young that had only just left the natal den (Stead-Richardson *et al* 2001). While there are young still in the natal den, the mother will not forage far from that area (Stead-Richardson *et al* 2001) and will be less likely to be caught in traps set along or near tracks. Therefore the increase in new individuals during February could be the result of late breeding mothers and their young only just beginning to leave the den area and becoming more readily trappable during this time.

When trapping individuals it is often common to have a peak towards the middle of the trapping period and then show a decrease as more individuals disperse away from the area, die or become trap shy (Krebs 1999). The results from this study showed that the total number of individuals caught did peak towards the middle but did not decrease much towards the end of the study. This could be attributed to a low death and dispersal rate in the population.

The annual monitoring results for June 2005 appear to support this in that the total number of individuals caught is approximately twice the size of the previous year. However, the number of new individuals caught in June 2005 is relatively low in comparison as a result of the new individuals that were recorded during this time frame. Once recorded earlier in the study as new they were then not considered to be new during the June 2005 trapping session, thus reducing the total number of new individuals trapped. As a result it is difficult to say if the population is larger as a result of an influx of new individuals or as a result of fewer deaths and lower dispersion rates.

The number of individuals KTBA at the end of the study suggests that approximately 30% of the population may have dispersed from the study area. This is probably an overestimation as some would have dispersed while others may have been moving around within the area and not trapped again during the 6 month trial. The dispersion and immigration of individuals in the population does not appear to have been restricted by the implantation of Probait when compared to results obtained from previous monitoring sessions.

5.3 Radio collared Individuals

A study of 12 radio collared individuals played an important role in the 6 month Probait trial, allowing the fate of the 12 individuals to be monitored constantly over the trial. Trapping wild animals can be problematic in that individuals may be hard to relocate through the trapping process, individuals may also disappear from the study area through death and dispersal. The constant monitoring enabled the 12 individuals to be monitored on a weekly basis regardless of their movements through the study area. Observations made on the 12 collared individuals before, during and after the

Probait trial were used to help identify some of the effects of Probait on the whole population.

If it was determined that chuditch would locate and consume Probait in the wild, the potential number of Probaits ingested in one foraging session or over continuous days of foraging needed to be determined. The 12 collared individuals also enabled these estimations to be made based on their core activity areas. Refuge utilisation data was also collected in an effort to update the current knowledge on forest chuditch refuge utilisation and requirements since the implementation of broad scale fox baiting.

5.3.1 Whisker and scat analysis

Whisker samples consisting of 8 facial whiskers were taken from 14 of the 15 radio collared individuals. Scat samples were also taken from 6 of the collared individuals suspected of Probait ingestion. Rodamine B was detected in 4 of these scat samples suggesting that these 4 individuals had ingested Probait up to a couple of days before the sample was collected. Rodamine B was also detected in numerous whiskers from 10 (71%) of these individuals indicating that all 10 had ingested Probait at some point before the whiskers were sampled. Individuals were sampled anywhere between 1 and 4 times depending on the number of times they were trapped between November 2004 and April 2005. Rodamine B was detected in 4 of these individuals more than once, suggesting that they may have eaten numerous Probaits.

The radio collared individuals had core activity areas that ranged over the entire Conservation Park suggesting that Probait was located by individuals from numerous areas within the park, rather than several animals locating baits from one area. The intense study of these individuals has shown that a large proportion of the population may locate and consume Probait in the wild assuming that results from this small representative of the population can be applied to the entire population. The results are probably an underestimation of the likely impacts on chuditch individuals as the radio-collared individuals were specifically chosen because they were large and healthy. As more males than females were used during the intensive part of the study, the results were biased towards the males and may not be able to be applied to all females in the population as a result of this bias. The survival of these individuals would need to be known to display their ability to consume Probait without resulting in death.

5.3.2 Survival

There were 12 radio collars available for use at any one time during this study. The aim was to radio collar 6 males and 6 females but females of an appropriate weight were difficult to locate at the beginning of the study. Due to this difficulty only 3 females were collared with 9 males taking up the rest of the collars. One female and 1 male died between December 2004 and January 2005 as a result of predation by a python and drowning in an apiary watering tank.

The collar from the predated individual was not reused due to the unsuitability of the collar post retrieval. The collar from the drowned male was reused on another male from February 2005 to the end of the study in April 2005. Two more collars were removed from males that were suffering from neck abrasion and were reused on new males for the remainder of the study. With the exception of one male individual all collars were located and removed at the end of the study in April 2005 indicating that all 10 collared individuals survived the 6 month Probait trial. The collar that was not retrieved could not have the frequency located for several months. It is unsure if this individual died during the study, if it dispersed a significant distance from the study area that the frequency was out of range of the equipment or if the battery in the transmitter fitted to the collar failed.

The survival rate of the collared individuals was relatively high with nearly all of them known to be alive at the end of the study in April 2005. With 10 of these individuals displaying Probait ingestion and incidence of survival through the study it could be concluded that although Chuditch will locate and consume Probait in the natural environment, baiting does not appear likely to impact the population in the Julimar Conservation Park.

5.3.3 Core activity area

The core activity area (km^2) was determined with the use of the Rangers V program (Kenwood and Hodder 1992) using the minimum convex polygon (MCP) method. The core activity area was estimated by calculating the area of the MCP encompassing all of the diurnal refuge sites located for each individual (Bradshaw and Bradshaw 2002) and was calculated instead of the home range of the individuals using other methods such as the Kernel or Harmonic mean due to the small sample size (Pavey *et al.* 2003). The core activity area encompassed the areas used most frequently by individuals in their everyday activities (Samuel *et al.* 1985). Between 4 and 14 fixes using a global positioning system (GPS) were taken for each radio collared individual. The core activity areas ranged between 0.37km^2 and 6.3km^2 for 13 of the radio collared animals. Areas were not calculated for the remaining two collared animals due to insufficient numbers of fixes.

The 2 female individuals that were radio collared had a range between 1.18km^2 and 1.76km^2 whereas the males had a range between 0.37km^2 and 6.3km^2. These areas varied from previous studies in that they were larger then previous estimates for forest Chuditch (Serena and Soderquist 1989b). The Probaits were dropped at 5 per km^2 in the park so each individual with an area of more then 1km^2 had the potential to locate and consume at least 5 Probaits. The number of potential Probaits located and consumed by radio collared individuals ranged between 2 and 31 Probaits with potentially fatal implications. This number is likely an overestimation due to the overlapping nature of many of the individual's core activity areas (Matthew 1996) and the foraging nature of Chuditch (Soderquist and Serena 1994).

Male core areas overlapped extensively with those of other males as well as females. The female core areas represented in this study showed some overlap with males but were distinctly separate from other female areas. It is possible that this is a result of the areas being far away from each other to start with but results from a study performed by Serena and Soderquist in 1989 suggest that there would have been no overlap with the other female regardless of how close their areas were. Chuditch tend to forage erratically within their core areas and rarely follow straight lines (Serena *et al* 1991) so while the potential is there it would be unlikely for them to locate numerous baits by following the ones that are laid along straight transects within their core areas but it is possible that they may encounter more than one as they move about in their core area.

5.3.4 Refuge utilisation

The refuge utilisation data gathered during this study between November 2004 and April 2005 is mostly consistent with previous data collected by Serena *et al* (1991).

Within the Julimar Conservation Park, Chuditch populations were associated with relatively dry, open and gently sloping forest areas dominated by Jarrah and Marri forest and Wandoo woodland. An interesting difference between data collected by Serena *et al* (1991) and the data collected during this study is the percentage of refuge types utilised. Burrows were identified as being the dominant source for refuge sites by Serena *et al* (1991) representing 62.8% of the refuge sites. This study indicated the hollow logs were the dominant source of refuge sites (86%) with burrows representing just 6% of the refuge sites in the Park.

The difference could suggest that Chuditch in the Julimar Conservation Park preferred to rest in hollow logs rather than burrows. Other factors such as the availability of particular refuge sites may have caused these differences. The higher percentage of hollow logs being utilised as refuge sites could be attributed to a higher availability of hollow logs compared to burrows within the park. It should therefore not be assumed as a preference for hollow logs as a refuge site but simply that the greater availability of hollow logs may have contributed to these being utilised as refuge sites more frequently then burrows or standing trees.

Most of the hollow logs (approximately 58%) utilised by Chuditch as diurnal refuge sites were identified as the Wandoo species. Again this could be attributed to the greater availability of Wandoo trees as opposed to Jarrah and Marri trees within the park.

Characteristics of the refuge sites observed in this study are mainly consistent with observations from the previous study by Serena *et al* (1991). There does not appear to be much deviation in the averages of hollow diameter or the bole diameter at resting position. This study did however display a greater average distance of the animals from the nearest entrance by approximately 1m. The average distance is not very much larger than shown in previous results and may hold no important meanings other than the individuals are simply resting further in, in the refuge sites, to avoid predators.

Chapter 6 – Conclusions

As part of CALM's requirement to test the impact of Probait on wild populations of non-target animals potentially at risk, a fully operational trial using toxic baits was undertaken in the Julimar Conservation Park between November 2004 and April 2005. This study was specifically designed to determine the impacts of Probait on wild chuditch populations.

It was determined that wild populations of chuditch will both locate and consume Probaits or at least portions of the Probait in the presence of natural sources of food. The results displayed trap success rates that were comparable to previous results from the annual monitoring sessions, perhaps even higher, and did not identify any deaths relating to Probait ingestion. The incidence of survival was high with a large number of individuals that had ingested Probait known to be alive at the end of the 6 month trial. This result is particularly important, as the trial was undertaken at a time where females were underweight after spending months providing for their young, and when the smaller 2004 born animals were dispersing away from their natal home ranges and displaying rapid growth. The survival of the individuals that had ingested Probait, especially those lower weight individuals, suggests that lethal doses of Probait will not be ingested by wild populations of chuditch with the presence of natural food sources.

The results of the population parameter measurements were comparable to previous results from the annual monitoring sessions during the breeding season. This suggests that in the short term, Probait will not have a detrimental impact on the population through changes in the population composition. There may be long term impacts resulting from the broad scale use of Probait as a fox control mechanism and further studies should be undertaken to determine any impacts that may arise from the prolonged use of Probait, especially its use during the breeding months.

This study identified the possibility of wild populations of chuditch locating numerous baits daily based on their core activity areas. The potential danger in this is that the ingestion of several Probaits in a short period of time will result in a lethal dose for the individual. The results showed that chuditch could potentially ingest up to 31 baits successively based on the size of their core activity area. Though none of the collared individuals died as a result of Probait ingestion, they were mostly large healthy males and the results were considered to be an underestimation of the potential impact from Probait ingestion. It was determined that these larger individuals would not ingest lethal doses. The nature of their foraging habits does not encourage the possibility of numerous bait location and consumption.

The ability of CALM to continue broad scale fox baiting programs for fauna recovery will depend on their ability to locate a cheaper and more reliable source of bait material.The results of this and other studies into the risk of using Probaits in a broad scale baiting operation on non-target dasyurids will be important in the process to obtain national registration for this alternative fox bait.

Notes on the general ecology of the forest chuditch in the Julimar Conservation Park indicate that the population is healthy, and dispersing into other areas outside of the original translocated area. The core activity areas defined in this study were consistent with studies performed prior to broad scale fox baiting programs. The areas obtained in a study, post-broad scale fox baiting in Batalling were somewhat smaller than the results obtained during this study. As this study was relatively short, with small numbers of fixes used to determine the core activity areas, a longer study might display more reliable results and a comparison could be remade between the two studies.

The refuge utilisation of wild populations of chuditch displayed only one major difference to previous studies in that more hollow logs were used as sources of refuge sites. These results may signify a change in the composition of Jarrah forest habitats in terms of vegetation and landscape or just a difference between northern jarrah and southern jarrah but further studies are required to be more certain of the causes for the change in refuge site sources. The 6 month study period between November 2004 and April 2005 was a relatively short time and only highlighted refuge use through summer. Winter refuge sites might differ from summer sites, and should be included in future studies to give a complete understanding of refuge utilisation through the whole year.

References

Abbott, I. (1984). Changes in the abundance and activity of certain soil and litter fauna in the Jarrah forest of Western Australia after a moderate intensity fire. Australian Journal of Soil Research **22**, 463-469.

ANZECC (1991). List of Endangered vertebrate fauna. ANCA, Canberra.

Armstrong, R. (2003). Baiting operations: Western Shield review - February 2003. Conservation Science Western Australia **5**(2), 31-50.

Arnold, J. M. (1976). Growth and bioenergetics of the chuditch, *Dasyurus geoffroii*. Thesis (Ph.D.), University of Western Australia, Perth, Australia.

Bailey, C. (1996). Western Shield – bringing wildlife back from the brink of extinction. [Brochure]. Department of Conservation and Land Management, WA.

Boulanger, J. G., and White, G. C. (1990). A comparison of home range estimators using Monte Carlo simulation. Journal of Wildlife Management **54**(2), 310-315.

Bradshaw, S. D., and Bradshaw, F. J. (2002). Short-term movements and habitat use of the marsupial honey possum (Tarsipes rostratus). The Zoological Society of London **258**, pp 343-348.

Brewer, R. (1994). The science of ecology. 2nd ed. Saunders College Publishing. USA.

Burbidge, A. A., Johnson, K. A., Fuller, P. J., and Southgate, R. I. (1988). Aboriginal knowledge of the mammals of the central deserts of Australia. Australian Wildlife Research **15**, 9-39.

Burbidge, A. and McKenzie, N. (1989). Patterns in modern decline of Western Australia's vertebrate fauna: causes and conservation implications. Biological Conservation **50**, pp. 143-198

Burt, W. H. (1943). Territoriality and home range concepts as applied to mammals. Journal of Mammalogy **24**, pp 352-364

Collett, R. (1887). On a collection of mammals from central and northern Queensland. Zoologischen Jahrbuchen. Zeitschrift fur Systematik Geographie und Biologie der Thiere. Gustav Frischer, Jena.

Department of Conservation and Land Management. (1992). The conservation of our threatened species in Julimar Conservation Park (Pamphlet). Pp 1-6.

Department of Conservation and Land Management. (1996). CALM fox control manual. Section 2: preparing and implementing a 1080 fox control program. Como W.A.

Finlayson, H. H. (1961). On central Australian Mammals. IV. The distribution and status of central Australian species. Records of the South Australian Museum 41, 141-191.

Fisher, P. (1998). Rodamine BB as a marker for the assessment of non-toxic bait uptake by animals – Bait marker project 1995-1997. Department of Natural Resources and Environment. Victoria, Australia.

Fisher, P. (1999). Review of using Rodamine BB as a marker for wildlife studies. Wildlife Society Bulletin **27**(2): 318-329.

Friends of the chuditch (Inc.) (1996). The chuditch chat. Friends of the chuditch (Inc.), Balingup. Pp 1-8.

Hancock, C. (1991). A report on the distribution, seasonal occurrence and diet of the chuditch (*Dasyurus geoffroii*). Student report, Murdoch University, WA.

IUCN (1994). IUCN Red List Categories. IUCN Species Survival Commission, Gland, Switzerland.

Jewell, P. A. (1966). The concept of home range in mammals. In: Play, Exploration and Territory in Mammals. (Eds. P.A. Jewell and Caroline Loizos). Pp. 85-109. Symposia of the Zoological Society of London No. **18**. (Academic Press: London).

Johnson, B., and Morris, K. (1998). chuditch recovery team – annual report 1998. Department of Conservation and Land Management, Western Australian Wildlife Research. WA.

Johnson, B., and Morris, K. (1999). chuditch recovery team – annual report 1999. Department of Conservation and Land Management, Western Australian Wildlife Research. WA.

Johnson, K. A., and Roff, A. D. (1982). The Western Quoll, *Dasyurus geoffroii* (Dasyuridae, Marsupialia) in the Northern Territory: historical records from vulnerable sources. In: M. Archer (Ed). Carnivorous Marsupials, pp. 221-226. Royal Zoological Society of New South Wales, Mosman.

Kennedy, M. (1990) Australia's endangered species: the extinction dilemma. Brookvale, N.S.W, Simon and Schuster Australia.).

Kenwood, R.E. and Hodder, K.H. (1992). Ranges V – an analysis system for biological location data. Wareham, U.K.: Institute of Terrestrial Ecology.

King, D. R. (1993). 1080 and Australian Fauna. Agriculture Protection Board. Perth, WA. 27p.

King, D. R., Twigg, L. E. and Gardner, J. L. (1989). Tolerance to Sodium Monofluoroacetate in Dasyurids from Western Australia. Australian Wildlife Research **16**: 131-140.

Kitchener, D. J., Chapman, A., Muir, B. G. and Palmer, M. (1980). The conservation value for mammals of reserves in the Western Australian Wheatbelt. Biological Conservation. **18**. pp 179-202.

Krebs, C. J. (1999). Ecological methodology, 2nd ed. Addison-Wesley Educational Publishers, Inc. USA and Canada.

Marlow, N., and Brazell, R. (2002). Comparing the palatability of Probaits and dried meat baits. Unpublished report, Department of Conservation and Land Management, WA.

Marlow, N., Brazell, R., and Williams, A. (2003). Draft report on Probait field longevity trials. Unpublished report, Department of Conservation and Land Management, WA.

Martin, G. R., Twigg, L. E., Marlow, N. J., Kirkpatrick, W. E., King, D. R. and Gaikhorst, G. (2002). The acceptability of three types of predator baits to captive non-target animals. Wildlife Research **29**(5): 489-502.

Matthew, H. (1996). An investigation into the Effect of management strategies on the home range of chuditch, *Dasyurus geoffroii*, Thesis (Honours), Curtin University, Natural Resource Management, WA.

Maxwell, S., Burbidge, A. A., and Morris, K. (1996). The action plan for Australian Marsupials and Monotremes. IUCN. SSC Australasian Marsupial and Monotreme Specialist Group. Unpublished report to ANCA Endangered Species Unit, Canberra.

McIlroy, J. C. (1986). The sensitivity of Australian animals to 1080 poison IX. Comparisons between major groups of animals, and the potential danger non-target species face from 1080 poisoning campaigns. Australian Wildlife Research **13**: 39-48.

McIlroy, J. C. and King, D. R. (1990). Appropriate amounts of 1080 poison in baits to control foxes, *Vulpes vulpes*. Australian Wildlife Research **17**: 11-13.

McNamara, K. (2004). Foreword - Western Shield review. Conservation Science Western Australia **5**(2): 1.

Morris, K. (1996). chuditch recovery team – annual report 1996. Department of Conservation and Land Management, Western Australian Wildlife Research. WA.

Morris, K. (1998) A review of the conservation status of the chuditch, *Dasyurus geoffroii* (Marsupialia: Dasyuridae) using IUCN criteria. – Draft. Department of Conservation and Land Management, WA, 4 p.

Morris, K., and Johnson, B. (1997). chuditch recovery team – annual report 1997. Department of Conservation and Land Management, Western Australian Wildlife Research. WA.

Morris, K., and Orell, P. (1993). chuditch recovery team – annual report 1993. Department of Conservation and Land Management, Western Australian Wildlife Research. WA.

Morris, K., and Orell, P. (1994). chuditch recovery team – annual report 1994. Department of Conservation and Land Management, Western Australian Wildlife Research. WA.

Morris, K., and Orell, P. (1995). chuditch recovery team – annual report 1995. Department of Conservation and Land Management, Western Australian Wildlife Research. WA.

Morris, K., Johnson, B., Orell, P., Gaikhorst, G., Wayne, A. and Moro, D. (2003). Recovery of the threatened chuditch (*Dasyurus geoffroii*): A case study. In: Predators with pouches: the biology of carnivorous marsupials. C. D. a. M. A. Menna Jones, CSIRO, Collingwood. pp. 435-451

Murray, A. J. and Poore, R. N. (2004). Potential impact of aerial baiting for wild dogs on a population of spotted-tailed quolls (Dasyurus maculatus). Wildlife Research **31**(6), 639-644.

Oliver, A. J. and King, D. R. (1983). The influence of ambient temperatures on the susceptibility of mice, guinea-pigs and possums to Compound 1080. Australian Wildlife Research **10,** 297-301.

Orell, P. and Morris, K. (1994). chuditch recovery plan, 1992-2001. Department of Conservation and Land Management, Western Australia, Wildlife Management Program 13. 25p.

Osbourne, B. (2005). WALKGPS: Julimar walk (walk #26). Internet URL: http://www.walkgps.com/Julimar%20Walk.htm. (Last updated23rd June 2005).

Pavey, C. R., Goodship, N., and Geiser, F. (2003). Home range and spatial organisation of rock-dwelling carnivorous marsupial, Pseudantechinus macdonnellunsis. Wildlife Research. **30**, pp. 135-142.

Possingham, H., Jarman, P. and Kearns, A. (2004). Independant review of Western Shield - February 2003. Conservation Science Western Australia **5**(2), 2-18.

Samuel, M. D., Pierce, D. J., and Garton, E. O. (1985). Identifying areas of concentrated use within the home range. Journal of Animal Ecology 54, pp 711-719.

Serena, M. and Soderquist, T. R. (1988a). Growth and development of pouch young of wild and captive *Dasyurus geoffroii* (Marsupialia: Dasyuridae). Australian Journal of Zoology **36,** 533-543.

Serena, M. and Soderquist, T. R. (1988b). Field techniques for working with chuditch (*Dasyurus geoffroii*). Department of Conservation and Land Management, Western Australia, 8p.

Serena, M. and Soderquist, T. R. (1989a). Nursery dens of *Dasyurus geoffroii* (Marsupialia: Dasyuridae) with notes on nest building behaviour. Australian Mammalogy **12,** 35-36.

Serena, M. and Soderquist, T. R. (1989b). Spatial organisation of a riparian population of the carnivorous marsupial *Dasyurus geoffroii.* Journal of Zoology **219**, 373-383.

Serena, M., Soderquist, T. R. and Morris, K. (1991). The chuditch: *Dasyurus geoffroii.* Department of Conservation and Land Management, Western Australia, Wildlife Management Program 7. 32p.

Shortridge, G. C. (1909). An account of the geographical distribution of the marsupials and monotremes of southwest Australia having special reference to the specimens collected during the Balston expedition of 1904-1907. Proceedings of the Zoological Society of London **55**, 803-848.

Soderquist, T. R. (1995). Spatial organisation of the arboreal carnivorous marsupial Phascogale tapoatafa. Journal of Zoology (London). **237**, pp 385-398.

Soderquist, T. R. and Serena, M. (1994). Dietary niche of the western quoll, *Dasyurus geoffroii*, in the jarrah forest of Western Australia. Australian Mammalogy **17**, 133-136.

Soderquist, T. R. and Serena, M. (2000). Juvenile behaviour and dispersal of chuditch (*Dasyurus geoffroii*) (Marsupialia: Dasyuridae). Australian Journal of Zoology **48**(5), 551-560.

Stead-Richardson, E. J., Bradshaw, S. D., Bradshaw, F. J. and Gaikhorst, G. (2001). Monitoring the oestrous cycle of the chuditch (*Dasyurus geoffroii*) (Marsupialia: Dasyuridae): non-invasive analysis of faecal oestradiol-17 beta. Australian Journal of Zoology **49**(2), 183-193.

Strahan, R. (1995). The Mammals of Australia. (Reed Books: Chatswood).

Sullivan, J. L., Smith, F. A., and Garman, R. H. (1979). Effects of fluoroacetate on the testis of the rat. Journal of Reproduction and Fertility **56**, pp 201-207.

Thomas, O. (1906). On mammals collected in south-west Australia for Mr. W.E. Balston. Proceedings of the Zoological Society of London **1906**, pp 468-478.

Van Dyck, S. (1988). The bronze quoll, Dasyurus spartacus (Marsupialia: Dasyuridae), a new species from the savannahs, of Papua New Guinea. Australian Mammology **11**, pp. 145-156.

Walker, M. (1986). The Avon Valley: The Naturalists' View. Toodyay Naturalists' Club, Toodyay, WA.

Weaving, S. (1999). Avon and Upper Hotman Region, Natural Resource Atlas. Spatial Resource Information Group, Agriculture, Western Australia.

Whittell, H. M. (1954). John Gilbert's notebook on marsupials. Western Australian Naturalist **4**, 104-114.

Wilson, B. A. and Friend, G. R. (1999). Responses of Australian mammals to disturbance factors. Australian Mammology **21**(1), 87-105.

Wyre, G. (2004). Management of the Western Shield program: Western Shield review - February 2003. Conservation Science Western Australia **5**(2), 20-30.

Appendix 3.1 – Example of Refuge data sheet

FRQ = 150.248.7 | **ID = Mu1224/Mu1225** | **Male** | **Weight = 1430g** | **Release Point = Hw 9**

Date	Time	Location Easting	Northing	Position in Landscape	Vegetation Cover	Upper Stratum	Mid Stratum	Lower Stratum
10/12/2004	7:50 AM	427707	6528266		10-30	Jarrah/Marri	Dryandra/Xanth	Open Shrub
4/01/2005	4:50 PM	427708	6528260	Top of Rise		Jarrah	Dryandra/Xanth	Open Shrub
21/01/2005	12:50 PM	427999	6528742		2-10	Jarrah/Marri/Wandoo	Dryandra	Open Shrub
27/01/2005	11:40 AM	428055	6527926	Flat	2-10	Wandoo	Dryandra	Open Shrub
8/02/2005	5:00 PM	427867	6528914		2-10	Wandoo	Dryandra/Xanth	
17/02/2005	3:40 PM	427708	6528064	Valley	10-30	Jarrah	Dryandra/Xanth	Open Shrub

Litter	Refuge Type	Refuge Characteristics Species	Dead	Alive	Vertical	Leaning	Cut	Natural Fall	Height (m)
Light	Hollow Log	Marri						X	
Light	Hollow Log	Marri						X	
Light/Mod	Hollow Log	Jarrah						X	
Light	Hollow Log	Wandoo						X	
Mod	Hollow Log	Wandoo						X	
Mod	Hollow Log	Marri						X	

Dbh (cm)	Length (m)	Diameter (cm)	# Hollows	Height to Lowest Hollow (m)	Hollow Diameter 1 (cm)	Hollow Diameter 2 (cm)	Location of Hollows	Location of animal	# Entrances
	15	75	2		12	8	Crown/Butt	2.5m from Butt	
	12	70	2		15	10	Butt/Crown	Middle	
	12	85	2		20	50	Mid/Top	1.5m from Butt	
	8	50	1		10		Crown	2.5 from Hollow	
	7	70	1		20		Butt	3m from Butt	
	7	50	2		13		Butt	0.5m from Butt	

Appendix 4.1 – GPS locations for radio-collared chuditch

Frequency	Date	Eastings	Northings
150.349.5	24/11/2004	432327	6521016
150.349.5	25/11/2004	432347	6522421
150.349.5New	4/01/2005	428161	6525008
150.349.5New	21/01/2005	430626	6524967
150.349.5New	27/01/2005	428754	6525968
150.349.5New	28/01/2005	430459	6525272
150.349.5New	8/02/2005	428537	6525754
150.349.5New	10/02/2005	428754	6524967
150.349.5New	17/02/2005	428151	6526370
150.349.5New	4/03/2005	430042	6525344
150.349.5New	11/03/2005	427990	6526920
150.349.5New	17/03/2005	428846	6525227
150.349.5New	11/01/2005	428242	6525903
150.349.5New	13/01/2005	428254	6525702
150.349.5New	14/01/2005	428253	6525515
150.349.5New	5/04/2005	428025	6525083
150.248.7	24/11/2004	428079	6528757
150.248.7	10/12/2004	427707	6528266
150.248.7	5/01/2005	427708	6528260
150.248.7	21/01/2005	427999	6528742
150.248.7	27/01/2005	428055	6527926
150.248.7	8/02/2005	427867	6528914
150.248.7	11/01/2005	428139	6529025
150.248.7	12/01/2005	427998	6528475
150.248.7	13/01/2005	427915	6528299
150.248.7	9/02/2005	428297	6529133
150.208.7	24/11/2004	428074	6528121
150.208.7	10/12/2004	426342	6527504
150.208.7	4/01/2005	426195	6527085
150.208.7	11/01/2005	425759	6527689
150.208.7	21/01/2005	425717	6527838
150.208.7	17/02/2005	427257	6523387
150.208.7	23/03/2005	427524	6523292
150.208.7	31/03/2005	428336	6523436
150.208.7	5/04/2005	427608	6523199
150.148.4	24/11/2004	427284	6524843
150.148.4	25/11/2004	428109	6524092
150.148.4	9/12/2004	428323	6524371
150.148.4	16/12/2004	427088	6524415
150.148.4	5/01/2005	427935	6524438
150.148.4	11/01/2005	428341	6524385
150.148.4	12/01/2005	428341	6524385
150.148.4	21/01/2005	427838	6525216
150.148.4	9/02/2005	428178	6525011
150.148.4	17/03/2005	428588	6525418
150.148.4	23/03/2005	428300	6524128
150.148.4	5/04/2005	428085	6525183
150.148.4	20/04/2005	429691	6525349
150.148.4	21/04/2005	429691	6525349
150.326.0	25/11/2004	432520	6519563
150.326.0	4/01/2005	431262	6518815
150.326.0	5/01/2005	432324	6518677
150.326.0	22/12/2005	431830	6518428
150.326.0New	3/03/2005	430654	6529545
150.326.0New	23/03/2005	428905	6530552
150.326.0New	31/03/2005	428316	6531490
150.326.0New	6/04/2005	429795	6531675
150.326.0New	20/04/2005	430776	6530387

Frequency	Date	Eastings	Northings
150.025.8	13/01/2005	426580	6524979
150.025.8	27/01/2005	427939	6525757
150.025.8	27/01/2005	427401	6527033
150.025.8	17/02/2005	427651	6527607
150.025.8	11/03/2005	428049	6526914
150.025.8	7/04/2005	427266	6526259
150.025.8	8/02/2005	428052	6527428
150.025.8	17/03/2005	427997	6527151
150.041.7	5/01/2005	431381	6518095
150.041.7	13/01/2005	431222	6517605
150.041.7	14/01/2005	431336	6517986
150.041.7	21/01/2005	431577	6517514
150.041.7	9/02/2005	431614	6517835
150.041.7	3/03/2005	432579	6517459
150.041.7	31/03/2005	431867	6516294
150.041.7	10/02/2005	431703	6517731
150.433.7	4/01/2005	432665	6519623
150.433.7	28/01/2005	433324	6519639
150.433.7	10/02/2005	433719	6520526
150.433.7	17/03/2005	432730	6519486
150.433.7	31/03/2005	432356	6519867
150.433.7	12/01/2005	432549	6520290
150.433.7	14/01/2005	432594	6520090
150.433.7	17/03/2005	432461	6519460
150.433.7	10/02/2005	432504	6520712
150.433.7	7/04/2005	432461	6519460
150.422.6	26/11/2004	427011	6523422
150.422.6	16/12/2004	426966	6523357
150.422.6	5/01/2005	428170	6523384
150.422.6	21/01/2005	426247	6523505
150.422.6	27/01/2005	427295	6523320
150.422.6	8/02/2005	426804	6523034
150.422.6	11/03/2005	426414	6523344
150.422.6	31/03/2005	427347	6524674
150.422.6	13/01/2005	428093	6523446
150.422.6	6/04/2005	432453	6519075
150.355.2	10/12/2004	428187	6527349
150.355.2	7/01/2005	433280	6526108
150.355.2	10/01/2005	428252	6527795
150.355.2	28/01/2005	428832	6528453
150.355.2	8/02/2005	428338	6527459
150.355.2	31/03/2005	428252	6527798
150.355.2		428482	6529469
150.355.2	6/04/2005	428080	6528650
150.355.2	17/03/2005	428163	6527684
150.337.7	9/12/2004	433646	6522035
150.337.7	10/12/2004	432740	6521080
150.337.7	31/12/2004	433369	6520922
150.337.7	5/01/2005	432785	6519936
150.337.7	27/01/2005	433043	6520180
150.337.7	17/02/2005	432721	6520836
150.337.7	17/03/2005	432762	6521397
150.337.7	23/03/2005	433891	6521047
150.337.7	22/12/2004	433478	6521013
150.337.7	11/01/2005	432507	6520950
150.337.7	12/01/2005	432611	6521102
150.337.7	13/01/2005	432710	6521289
150.337.7	14/01/2005	432850	6521643
150.337.7	8/04/2005	432710	6520862