Porolak, Gabriel (2008) ***Home range of the Huon tree kangaroo, Dendrolagus matschiei, in cloud forest on the Huon peninsula, Papua New Guinea.*** **Masters (Research) Thesis, James Cook University.**

Home range of the Huon tree kangaroo, *Dendrolagus matschiei*, in cloud forest on the Huon peninsula, Papua New Guinea.

Thesis submitted by
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in November 2008

For the degree of Masters of Science
in the School of Marine & Tropical Biology
James Cook University

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ABSTRACT

Tree kangaroos (Marsupialia: Macropodidae, *Dendrolagus*) are some of Australasia's least known mammals. Basic questions concerning the population and conservation status of many species remain unanswered. However, there is sufficient anecdotal evidence of population decline and local extinctions to designate tree kangaroos as New Guinea's most endangered mammal group. Tree kangaroo home ranges were sampled at one site in Papua New Guinea (Wasaunon). Radio telemetry analyses were used to estimate home range sizes, which were estimated to be 81.8 ± 28.8 ha for males and 80.8 ± 20.3 ha for female Huon tree kangaroos (*Dendrolagus matschiei*). Food plants species for Huon tree kangaroos (*D. matschiei*), were collected at Wasaunon with the aid of landowners, and later identified by botanists in Papua New Guinea and Australia. The collections support Australian data that tree kangaroos are browsers, with the largest proportion of their diet coming from leaves and shoots from a wide variety of plants from at least 18 families for the Huon tree kangaroos, and at least 40 families from a previous study conducted in the same region (Dendawang) approximately 35km southeast of Wasaunon. Landowners from different areas of the region were in agreement that tree kangaroos prefer eating leaves and stems of plants, with fruits and flowers comprising a relatively minor proportion of the animals' diets. Additional information on tree kangaroo biology and conservation status was obtained through the use of informal landowner interviews. Interviews did not produce quantifiable results, but they did give some insights into tree kangaroo food plant species and human utilisation. The responses indicated that over 70 species of food plants were being utilized by the Huon tree kangaroos, *D. matschiei*, at Wasaunon, and an additional 91 species from Dendawang.

CHAPTER 1 Introduction

Tree kangaroos (*Dendrolagus spp.*) are endemic to the tropical rainforests of Australia and New Guinea, and are both iconic of the rainforests and an integral component of their biodiversity. Unfortunately, most species of tree kangaroos have come under increasing threat and their populations are declining (Flannery et al 1996).

Tree kangaroos are the only macropods that are adapted for arboreal life (Martin 2005[a]). Although rock wallabies (*Petrogale spp.*) can climb small trees (Ganslosser 1980; Eldridge 1994), they are not as efficient climbers as the tree kangaroos (Ganslosser 1981). The genus *Dendrolagus* is endemic to New Guinea and far north-east Queensland (Flannery et al 1996; Newell 1999[a;] Martin 2005[a]). Currently, ten species of tree kangaroos are recognized, of which eight are found on the island of New Guinea and the remaining two in Australia's Wet Tropics (Flannery et al 1996; Martin 2005[a]). Of the eight species found in New Guinea, four are recognized sub-species within the species *Dendrolagus dorianus*, three in *D. goodfellowi* and one in *D. inustus* (Table 1.), resulting in fourteen recognized types of tree kangaroo in New Guinea (Flannery 1995).

In the wild, tree kangaroos feed on a variety of forest leaves and herbs (Procter-Gray 1984; Newell 1999[c]) and although carnivory has not been observed in the field, captive tree kangaroos have been observed consuming meat (Flannery 1995). Tree kangaroos range in size from approximately 8 kg adult body mass (*D. lumholtzi*) to about 11-15 kg adult body mass (*D. inustus*) (Flannery et al 1996).

Tree kangaroos face a high degree of threat in the wild, largely due to habitat loss in Australia (Newell 1999[b]) and to over-hunting and habitat loss in New Guinea (Betz 1997[a]). The ancestors of the indigenous people of the Huon Peninsula of Morobe Province in Papua New Guinea have been hunting the Huon tree kangaroo (*D. matschiei*) for centuries. However, in more recent times, and with increased habitat loss, the population has declined dramatically (landowners pers. com) (Betz 1997[b]). All New Guinea tree kangaroos are currently classified as endangered by the IUCN (IUCN 2004) and some species are likely to be at immediate risk of extinction, such as the Dingiso (*D. scottae*), which is said to be one of the rarest animals on earth (Flannery et al 1996).

The overall context of this study is the need to protect both the Huon tree kangaroo (*D. matschiei*) from extinction, and also to conserve its fast disappearing environment. In order to conserve this endangered species, it is very important to understand its ecology, particularly its population density, habitat utilization, and movement/activity patterns. To actively manage and conserve a population it is necessary to estimate how many individuals are present in a particular area (population density), how they use their habitat (habitat selection), how they move about in that area (home range, movement/activity patterns), as well as to assess their current conservation status.

Culturally, tree kangaroos are an important resource to the indigenous people of New Guinea. Therefore, the results of this project will be used to inform the local people of the Huon Peninsula. The results will also assist in the efforts to sustainably manage the Huon tree kangaroo population in the wild. Furthermore, home range data from this study will assist Papua New Guinea's National Government, the Department of Conservation and Environment (DEC), in prioritizing and focusing their conservation efforts.

1.1 TREE KANGAROO PHYLOGENY

Tree kangaroos belong to a radiation of the genus *Dendrolagus* within the Macropodidae or kangaroos (Groves 1982). While their origin within the kangaroos is still unclear, it seems likely that their closest sister group is the genus *Petrogale* (rock wallabies; Figure 1.1.) (Groves 1982; Flannery et al 1996; Martin 2005[a]). The sparse fossil evidence provides little insight into the evolutionary history and the geographical origin of tree kangaroos, or into the selective pressures which may have resulted in their arboreal habitat (Flannery et al 1996;

Martin 2005[a]). However, molecular techniques have been valuable to the study of tree kangaroo phylogeny. Immunological comparisons of the protein albumin showed that the rock wallaby (*Petrogale inornata*) and Lumholtz's tree kangaroo (*D. lumholtzi*) were closely related (Figure 1.1) (Baverstock et al 1989). This technique also linked the *Dendrolagus sp.* with the *Thylogale sp.* (pademelons) and suggests that they diverged 2.7-4.7 million years ago (Baverstock et. al 1989). DNA hybridization studies also support the link between pademelons (*Thylogale sp.*), tree kangaroos (*Dendrolagus sp.*) and rock wallabies (*Petrogale sp.*) (Kirsch 1995; Kirsch 1997). These studies suggest a time for divergence from other kangaroos of around eight million years ago and a split of the tree kangaroos and rock wallabies from the pademelons about 500,000 years later (Campeau-Peloquin 2001). Martin (2005) proposed that tree kangaroos arose from rock wallaby stock in response to the invasion of nutritious malesian plants from south-east Asia, which fostered the emergence of arboreal wallabies. The ancestral tree kangaroos then dispersed throughout the malesian forest, and eventually invaded and speciated in the montane rainforest (Martin 2005[a]).

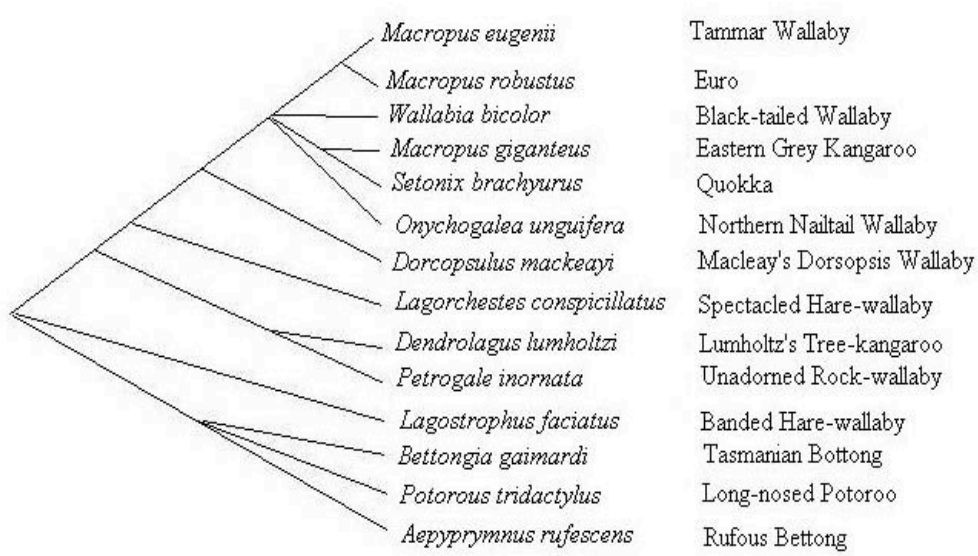


Figure 1.1 Phylogeny of the Macropods (modified from (Baverstock et. al 1989).

Knowledge of successful adaptations gives us a better understanding of past life and environments. Thus, fossils provide us with a “picture” of not only past fauna and flora but also the type of environments they occupied (Breithaupt 1992).

A fragmented fossilized premolar tooth dating back 4-4.5 million years, extracted from the Hunter Valley in New South Wales, was assigned to a tree kangaroo because of the small buccal cusps on the tooth, which are found only in the *Dendrolagus spp.* (Figure 1.2) (Flannery 1992). This tree kangaroo belonged to a savannah woodland fauna, which seemed inconsistent with the existence of tree kangaroos, due to the fact that extant species are confined to rainforests. However, recent observations of *D. bennetianus* in riparian vegetation within sclerophyll woodland, well away from rainforest, question that assumption (Martin pers comm.). The Hunter valley tooth closely resembled another from four million year-old deposits in Hamilton, western Victoria. The Hamilton tooth, however, came from a rainforest faunal assemblage, including fossils of the Rat Kangaroo (*Hypsiprymnodon sp.*), Pademelons (*Thylogale sp.*) and the New Forest Wallaby (*Dorcopsis sp.*) (Flannery 1992). Fossil pollen from Hamilton confirmed that the area was covered in temperate rainforest four million years ago (Barlow 1988).

Even though the tooth is the oldest known fossil, it could not be identified as a tree kangaroo fossil until the discovery of ankle and tibia bones, which came from deposits in the Wellington caves of central New South Wales.

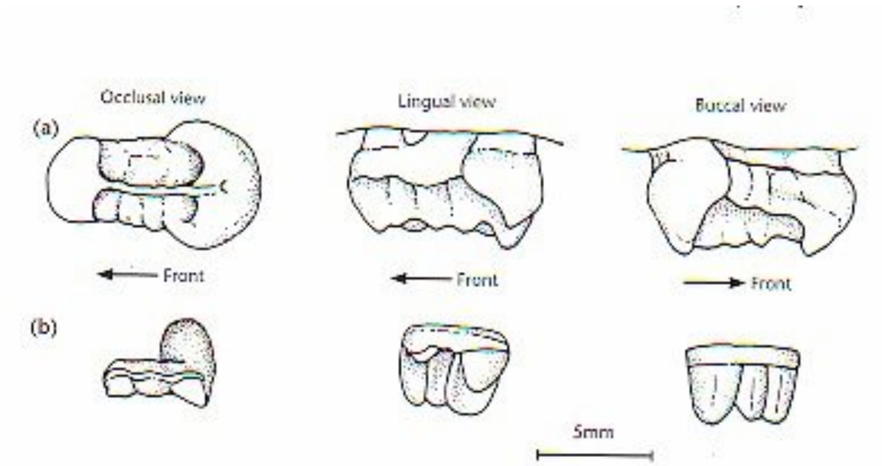


Figure 1.2 Comparison of the premolar (P3) structure of the Bennett's tree kangaroo (a) and the fossilized tooth found in Hamilton (b). Note the similarity in the buccal cusps of the Bennett's P3 (a) to the fossilized tooth (b) (Flannery 1992).

The bones most clearly related to an arboreal kangaroo were ankle bones (calcaneum and astragalus) that extracted from the Wellington caves of central New South Wales and date back to two million years ago (Flannery T. F. and Archer 1984). The fossilized ankle bones show distinctive morphological features (i.e. the shape and orientation of the facets on the astragalus), which allow rotation of the hind foot as well as the turning of the sole of the foot inwards, thus clearly linking it to a tree kangaroo (Flannery et al 1996). Identification and analysis of the tibia suggested that the animal weighed between 30-40kg and was thus larger than any of the extant forms. The tibia also suggested that the animal was not as specialized for arboreal life as any extant *Dendrolagus* forms. As a result, it was classified under a new genus, *Bohra* rather than *Dendrolagus* (Flannery et al 1996).

More recent tree kangaroo fossils come from the highlands of New Guinea and date back to 40,000 years ago. Fossils from Nombe rock shelter (a refuge for hunting parties) in Chimbu Province, Papua New Guinea, were identified as *D. goodfellowi buergersi, D. dorianus notatus* and a third was thought to be the extinct *D. noibano*, believed to be a larger form of *D. dorianus* (Flannery 1983). Other groups of fossils from Volgelkop Peninsula, West Papua, were estimated to be from the late Pleistocene (between 10,000 – 100,000 years old) and identified as *D. inustus* and *D. goodfellowi* (Aplin 1993).

1.2 TREE KANGAROO MORPHOLOGY

Terrestrial kangaroos (Figure 1.3a) differ morphologically from tree kangaroos (Figure 1.3b) in four major areas; forepaw, hind foot, tail, and ears. Terrestrial kangaroos have lighter forelimbs to aid in bipedal locomotion and also use their forelimbs for feeding and fighting. In contrast, tree kangaroos have a more muscular forelimb used specifically for climbing (Iwanuik 1998). Another distinction of the two is their claws; terrestrial kangaroos have claws, but they are small; tree kangaroos, however, have extremely well developed claws with a greater curvature than terrestrial kangaroos (Figure 1.4) (Iwanuik 1998). Indeed, tree kangaroo claws are more similar to the claws of other arboreal marsupials such as the koala and ringtail possum. Tree kangaroos are the only members of the kangaroo family known to possess the ability to rotate their hind foot, i.e. they can turn the sole of their foot inwards (Figure 1.5).

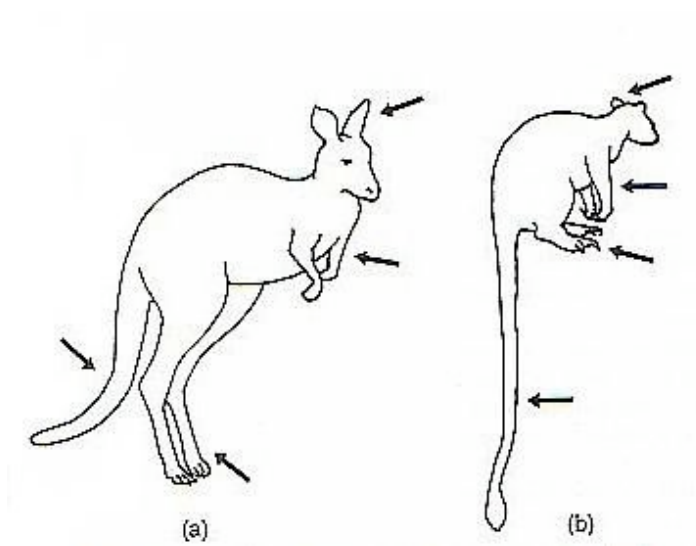


Figure 1.3 Anatomical differences between terrestrial kangaroos (a) and tree kangaroos (b) (Martin 2005[a]). Note the difference in tail length, hind legs, fore-foot and ears between a terrestrial kangaroo (a) and a tree kangaroo (b).

Figure 1.4 Tree kangaroo forepaw showing the curvature of claws (Martin 2005[a]).

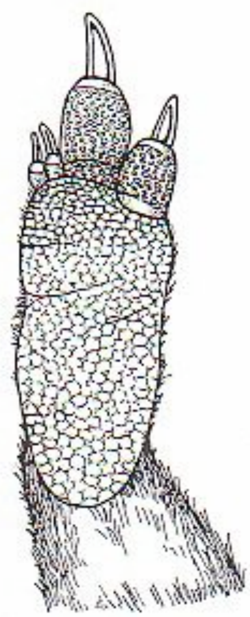


Figure 1.5 Tree kangaroo hind-foot showing claws and protuberant tuberculated pads (Martin 2005[a]).

Like terrestrial kangaroos, tree kangaroos move by hopping and retain the general form of the enlarged hind limbs of their terrestrial ancestors. The hind-foot of tree kangaroos can be distinguished from terrestrial kangaroos by the short, broad and long curved claws on each digit (Figure 1.5). Another distinct feature is the relative foot length (lower limb); essentially the foot is shorter in contrast to terrestrial kangaroos (Figure 1.3).

Unlike terrestrial kangaroos, the pads on the hind-foot of tree kangaroos are not divided into parts. Rather, they form a single, large and protuberant tuberculation on the distal portion of the foot (Figure 1.5). This feature (protuberant tuberculation) distinguishes the tree kangaroos from the terrestrial kangaroos because it enhances their grip for climbing (Bishop 1997).

Tree kangaroos are classed into two groups: the long-footed and the short-footed. The long-footed group consist of *D. inustus, D. bennettianus* and *D. Lumholtzi* (only the latter is found in New Guinea); the short-footed group consists of *D. matschiei, D. goodfellowi, D. ursinus, D. spadix,* and *D. dorianus* (Figure 1.6).

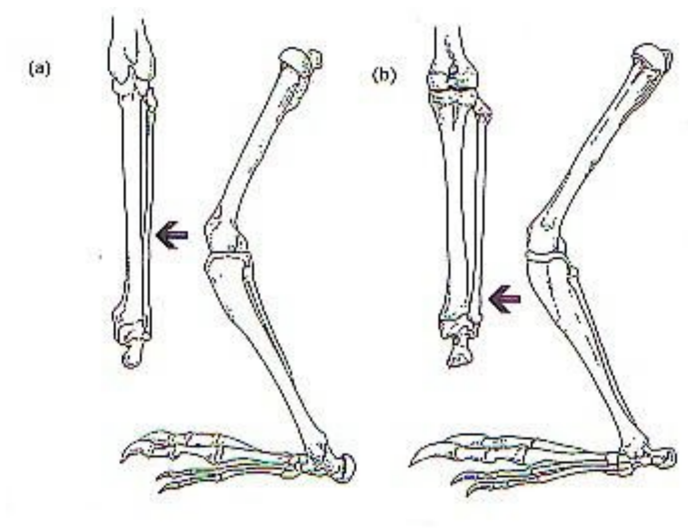


Figure 1.6 Differences between short-footed (a) and long-footed (b) tree kangaroos (Martin 2005[a]). Note the difference in the space between the tibia and the femur (arrow) which allows easy manoeuvrability for climbing in the short-footed (a), whereas the wider space in the long-footed provides support for enhanced hopping (b).

Short-footed tree kangaroos are considered to be more derived, and have greater climbing manoeuvrability. The long-footed group tends to move by hopping and is less efficient in moving about in trees. They can walk but do so less often than the short-footed species. The ability to move the hind limbs independently was lost when kangaroos learned to hop and only tree kangaroos have retained this ability (Gressitt 1992).

The tree kangaroo's tail also differs from that of a terrestrial kangaroo, being long in relation to its body size and less bulky and muscular. Terrestrial kangaroos use their tails for support while standing and hopping. The muscular tail of terrestrial kangaroos (Figure 1.2a) plays an important role in the mechanics of hopping because it counters the rotational thrust generated by the hind limbs, particularly when the animal is travelling at great speeds. Tree kangaroos do not possess such muscular tails because they hop at a gentler pace (Figure 1.2b) (Groves 1982). Tree kangaroos generally use their tails mostly for climbing. When climbing small branches tree kangaroos stretch out their tails to counterbalance the weight of their upper body (Groves 1982). Tail lengths in tree kangaroos probably reflect the amount of time spent in the canopy (i.e. the shorter the tail, the more time spent on the ground) (Martin 2005[a]).

1.3 TREE KANGAROO DISTRIBUTION AND BIOGEOGRAPHY

Tree kangaroos are entirely restricted to the island of New Guinea and the Wet Tropics region of northeast Queensland. Two members of the long-footed group inhabit lowland rainforest (*D.bennettianus and D.inustus*). The majority of the short-footed group inhabits higher elevations. However, *D. spadix* extends to the lowlands.

The highest diversity of tree kangaroos occurs in the Torricelli Range in Papua New Guinea with three attitudinally separated species. The Tenkile, *D. scottae,* occurs at altitudes over 1500m, the Golden Mantle, *D. goodfellowi pulcherrimus* from 900-1500m, and Finsch's tree kangaroo, *D. inustus finschi* occurs below 900m. Habitat types vary along this altitudinal gradient and these different habitat types support the three kinds of tree kangaroos that exist along that altitudinal gradient (Table 1.1).

Table 1.1 Tree Kangaroo Species of the World (Flannery 1995).

Common Name	Scientific Name	Area Found
Doria's Tree Kangaroo	*Dendrolagus d. dorianus*	SE-NG
	D. dorianus notatus	Central Highlands
	D. dorianus stellarum	Sandaun Province
	D. dorianus mayri	Irian Jaya Vogelkop Peninsula
Golden Mantle Tree Kangaroo	*D. goodfellowi pulcherrimus*	Torricelli Sepik
Goodfellow's Tree Kangaroo	*D. goodfellowi goodfellowi*	Sandaun Province
Timboyok	*D.goodfellowi buergersi*	Sandaun Province
Grizzled Tree Kangaroo	*D. inustus inustus* *D. inustus finschi*	- Vogelkop, Fak fak Peninsula, Wewak and North coast PNG. - Torricelli
Huon or Matschie's Tree Kangaroo	*D. matschiei*	Huon Peninsula
Tenkile or Scott's Tree Kangaroo	*D. scottae*	Torricelli Sepik
Fiwo	*D. scottae* subsp. Indet	Torricelli Sepik
Lowlands Tree Kangaroo	*D. spadix*	Gulf, Southern and Chimbu – PNG
Vogelkop Tree Kangaroo	*D. ursinus*	Irian Jaya
Dingiso	*D. mbaiso.*	Irian Jaya
Lumholtz's Tree Kangaroo	*D. lumholtzi*	Atherton tablelands QLD
Bennett's Tree Kangaroo	*D. bennettianus*	Carbine tablelands to Cook town - QLD

Biogeographically, tree kangaroo distributions tend to have a high level of co-occurrence between individual species and this is evident both in Australia and New Guinea (Appendix 1).

In far western New Guinea two other species co-exist; the grizzled (*D. inustus inustus*) and the Vogelkop (*D. ursinus*) tree kangaroos. *D. dorianus stellarum* and *D. mbaiso* are usually found in the western part of New Guinea's central mountains. In the central mountains of Papua New Guinea, *D. dorianus notatus,* and *D. goodfellowi burgersi* co-occur. In the southeastern part of Papua New Guinea, *D. dorianus dorianus* and *D. goodfellowi goodfellowi* co-exist. In the northeastern part of the country, the Matschie's (*D. matschiei*) tree kangaroo is endemic to the Huon Peninsula of Morobe Province and is the only species found there. Australian tree kangaroos, *D. lumholtzi* and *D. bennettianus*, slightly overlap in the main Coast Ranges and to the southeast of Mt. Windsor (Appendix 1).

1.4 TREE KANGAROO CONSERVATION

1.4.1 Current Status

All tree kangaroo species are considered to be threatened (IUCN 2004). The Australian species, *D. bennettianus* and *D. lumholtzi*, are considered rare, but at relatively low risk of extinction in the short term (Newell 1999[a]) because large areas of their habitat are protected within Australia's Wet Tropics World Heritage Area. In contrast, five of the New Guinea species are considered vulnerable, endangered or critically endangered (IUCN 2004) (Table 1.2), and the other three species cannot be considered secure as too little is known to determine their conservation status (IUCN 2004). Sub-species of tree kangaroos are not considered by the IUCN Red-List and, therefore, little is known about their conservation status. However, Table 1.2 also includes a list of subspecies categorized by Tim Flannery in 1996.

The current status of these tree kangaroos reflects human impacts such as loss of habitat, road deaths and predation by dogs, diseases and hunting (Newell 1999[a]). The Australian species (*D. lumholtzi* and *D. bennettianus*) are not so adversely affected by hunting. However, loss of habitat, road kills and predation by domestic or feral dogs are a major threat (Newell 1999[a]). In contrast, the New Guinean species are severely threatened by hunting but are presently unaffected by loss of habitat (Betz 2001). Nevertheless, this situation is rapidly changing due to population growth (Population Reference Bureau 2006). The conservation of New Guinea tree kangaroo habitat is an effective measure towards protecting tree kangaroos from future extinction.

Table 1.2 The IUCN Red List of Threatened Tree Kangaroo Species of the World (IUCN 2004) and modified from Flannery (Flannery 1996).

Common Name	Scientific Name	Status
Australian Species		
Bennett's tree kangaroo	*Dendrolagus bennettianus*	Lower risk/near threatened
Lumholtz's' tree kangaroo	*Dendrolagus lumholtzi*	Lower risk/near threatened
New Guinea Species		
Doria's tree kangaroo	*Dendrolagus d. dorianus*	VU/Unknown
Seri's tree kangaroo	*Dendrolagus dorianus stellarum*	VU
Ifola	*Dendrolagus dorianus notatus*	EN
Mayr's tree kangaroo	*Dendrolagus dorianus mayri*	Unknown
Goodfellow's tree kangaroo	*Dendrolagus goodfellowi goodfellowi*	EN/Unknown
Timboyok	*Dendrolagus goodfellowi buergersi*	EN
Golden-mantled tree kangaroo	*Dendrolagus goodfellowi pulcherrimus*	CR
Grizzled tree kangaroo	*Dendrolagus inustus inustus*	DD/Unknown
Finsch's tree kangaroo	*Dendrolagus inustus finschi*	VU
Huon tree kangaroo	*Dendrolagus matschiei*	EN
Dingiso	*Dendrolagus mbaiso*	VU
Scott's tree kangaroo - Tenkile	*Dendrolagus scottae*	CR
Fiwo	*Dendrolagus scottae* subsp. Indet.	VU
Lowland tree kangaroo	*Dendrolagus spadix*	DD/Unknown
Vogelkop tree kangaroo	*Dendrolagus ursinus*	DD/Unknown

Vulnerable (VU) – when animals are not critically endangered or endangered but still face a high risk of extinction. *Endangered (EN)* – species that are not critically endangered but face a very high risk of extinction. *Data Deficient (DD)* – when there is not enough information to carry out assessment of the risk of extinction based on the distribution and population status of the target species. In addition, the biology of the target species may not be well known. However, data on abundance and distribution is unknown. This category is neither under threat nor lower risk. *Critically Endangered (CR)* – animals are critically endangered when a high risk of extinction is experienced in the wild.

1.5 CONSERVATION OF AUSTRALIAN TREE KANGAROOS

All species of tree kangaroos either have been, or are currently, affected by hunting (Hutchins 1990). Lumholtz's and Bennett's tree kangaroo were historically affected by hunting (Lumholtz 1888; Cairn 1890; Le Souef 1894) and Martin (2005) suggests that recent and current distribution of Bennett's tree kangaroo reflects an expansion from refuge habitats following the recent cessation of human hunting. More recently, tree kangaroos were also affected by the loss of their habitat for agricultural clearing (Unwin 1988).

1.5.1 Loss of Habitat

Before European colonization, the Atherton and Evelyn Tablelands of far north Queensland were covered with a matrix rainforest and wet eucalypt forest. These forests have been extensively altered by logging and clearing for agriculture. Lumholtz's tree kangaroo, *D. lumholtzi*, reaches its highest densities on complex mesophyll vine thicket Type 5b (Tracey 1975) on basalt soil (Newell 1999[a;] Kanowski 2001). This forest type supports red cedar (*Toona australis*), which was selectively logged during the 1860s. However, it was clearing for agriculture that almost destroyed the 5b forest type in the 1920s (Graham 1995) and less than 5% of its original extent remains today, and so it is listed as an endangered ecosystem (Graham 1995). Logging activities led to the proclamation of the Wet Tropics World Heritage Area (WTWHA) in 1988 (Australian Government: Department of the Environment and Heritage 2006). However, the WTWHA protects only 17.5% of the remaining 5% of 5b forest, which is one of the preferred habitats for Lumholtz's tree kangaroo (Newell 1999[a]). Threats to the rainforest persist in the form of increased agricultural clearing and the development of rural home sites, which encroach on tree kangaroo habitat. These threats are expected to increase with projected growth of the human population of the area (Betz 1997[a;] Population Reference Bureau 2006) and the conservation of the Lumholtz's tree kangaroo habitat looks in jeopardy (Braithwaite 1996).

Although there have been major concerns about the conservation of the Lumholtz's tree kangaroo, several studies suggest that is not immediately threatened with extinction (Procter-

Gray 1990; Newell 1999[a;] Coombes 2005). Despite extensive alteration and fragmentation of the forest, Lumholtz's tree kangaroos can be found in small fragments of remnant habitat and corridors of a variety of forest types (Pahl 1988; Laurance 1989; Laurance 1990; Kanowski 2001; Coombes 2005). Furthermore, the density of *D. lumholtzi* does not seem to have been influenced by selective logging (Laurance 1996). This offers some optimism for the future of *D. lumholtzi,* which, however, must be tempered with concern about the possible, but currently unknown, long term effects of isolation and fragmentation. Bennett's tree kangaroo, *D. bennettianus*, is more poorly known, but given that there is less human alteration of rainforests within its range, and much of its potential range is protected, it is likely that its status is no worse than that of *D. lumholtzi* (Martin 1996; Newell 1999[c]). The challenge now is for the wildlife management agencies to halt the decline of species believed to be rare to avoid them becoming endangered and eventually extinct.

1.5.2 Road Deaths

The Atherton Tablelands of northeast Australia are covered in a vast network of roads that run through tree kangaroo habitat. The numbers of road-kills are yet to be determined. However, anecdotal reports indicate many of these animals die on the roads of the Atherton Tablelands (Kanowski 2001; Martin 2005[a]). Most tree kangaroo road-kills are juveniles and sub-adult males (Newell 1999[a]) because juveniles and males travel more frequently than females; a trait they share with terrestrial macropods (Coulson 1997). There is no effective way of stopping these deaths. However, there are certain approaches that can be used to minimize the number of road-kills (CRC 2006). Tunnels under roads were used for pygmy possums (*Burramys parvus*) to avoid unnecessary road-kills (Mansergh 1989). Effective techniques are yet to be investigated for tree kangaroos (Newell 1999[a]).

1.5.3 Predation

There are many mammalian and non-mammalian predators that will prey on tree kangaroos. Dingoes are a common predator in Australian forests that prey on tree kangaroos (Newell 1999[a]). In the highly fragmented forests of the Atherton Tablelands, domestic and feral dogs are also a major predator of tree kangaroos (Newell 1999[a]). The amethystine python (*Morelia amethistina*) also attacks tree kangaroos (Martin 1995[a]). While no longer a significant threat, humans were also once a predator of tree kangaroos in Australia, and Martin (1992) suggests that until recently human predation pressure suppressed densities quite substantially, or limited tree kangaroos to small inaccessible, or "tambu" areas protected from hunting by tradition. Similar concepts are also present in New Guinea. However the native people of Irian Jaya regard *D. mbaiso* as their ancestor and were not allowed to hunt it (Flannery et al 1996).

1.5.4 Diseases

Currently, little is known of the role diseases may play in tree kangaroo populations (Newell 1999[a]). However, lung tissues of Lumholtz's tree kangaroos are regularly infested by cysts of *Toxoplasma gondii*, which is transferred between animals through oocysts in cat faeces (George 1982) and can be lethal (Barker 1988). Tree kangaroos spend some of their time on the ground while foraging for food and are most likely to be infected there.

1.6 CONSERVAITON OF NEW GUINEA TREE KANGAROOS

It is clear that threats to tree kangaroos are quite different in Australia and New Guinea. New Guinea tree kangaroos face a greater threat from hunting than from loss of habitat (Betz 2001). Traditional hunting is an important means of sustenance in the entire country of Papua New Guinea (PNG) as well as in other remote communities in Irian Jaya (Newell 1999[a]). Most New Guinean communities live off forest meat and, like other hunters and gatherers, use parts of the animal for traditional purposes, such as body decorations for performing traditional dances (Flannery 1996) and trading for money or other necessities like food or clothing (Pernetta 1986). Previous studies of wild meat consumption in the Crater Mountain Wildlife Management Area in the Highlands of Papua New Guinea yielded an estimated daily intake of 23g per person (Mack and West 2005), which was similar to results obtained two decades ago (22g per person) (Hide 1984). These results predict that the daily intake of wild meat will increase in the next decade.

However, as human populations increase, forests that were once pristine are now exposed to greater hunting pressure (Flannery 1998). As a consequence, wild tree kangaroo populations have declined dramatically over the past century. Evidence of this is reflected in *D. scottae*, which is currently found in only a small area in the Torricelli Mountains of PNG and is now considered the most endangered tree kangaroo species (Flannery 1990). Another species, *D. mbaiso*, has also declined in numbers over recent years as a result of increased human population as well as increased numbers of hunting dogs (Flannery 1995). However, although this species was recently discovered, the deficiency in data is unable to support the trends in population. The Huon tree kangaroo (*D. matschiei*) is yet another of the New Guinea tree kangaroo species that has shown a drastic decline in numbers (Stirling 1991).

Conservation of New Guinea tree kangaroos has been seen as a key priority in the conservation of New Guinea's rainforest fauna by a number of international conservation agencies (CI 2000; WWF 2002; TKCP 2006). Despite different threats, conservation and management of New Guinea tree kangaroos can only be achieved if the Australian government sets a good conservation example with Australian tree kangaroos (Newell 1999[a]). If Australia is incapable of implementing effective conservation and management strategies for tree kangaroos then it would be impossible for New Guinea to implement proper conservation/management strategies.

Papua New Guinea is still a developing country and, since its independence in 1975, has tended to imitate foreign policies. The Papua New Guinean government relies heavily on aid and policies from Australia. Therefore, in order for conservation to work in Papua New Guinea it has to work first in Australia. Papua New Guinea does have a Conservation Areas Act (1978) but it has never been used since it was endorsed by the PNG government almost three decades ago. PNG does not have the ministerial infrastructure to implement this act and thus conservation measures require a lot of assistance not only from the Australian government conservation authorities but other conservation agencies, such as World Wide Fund (WWF), Conservation International (CI) and Wildlife Conservation Society (WCS). A good example of this is shown by the Tree Kangaroo Conservation Program (TKCP), which is currently working with American conservation agencies (CI, and other American zoos) to help enact the Conservation Act (1978) of Papua New Guinea which has been dormant for the last three decades.

Given the severity of threat faced by tree kangaroos both in Australia and New Guinea, it is difficult to see how the position of tree kangaroos can improve (Martin 2005[a]) without action by government authorities and non-government organisations in collaboration with the community. The Australian government has already accorded a high level of protection to tree kangaroos, and some areas of habitat. However, in New Guinea, even though tree kangaroos are afforded protection at the national level (Fauna Protection and Control Act 1976), such is not the case at the local level. This makes local efforts in conservation and research particularly important in convincing the national government to focus more at the local level.

1.7 METHODS OF CONSERVATION

1.7.1 Captive Breeding and Research

Conservation of tree kangaroos requires a multi-pronged approach, but more precise knowledge of the threats faced by tree kangaroos is necessary before any effective conservation methods can be constructed. The priority is to increase the population of endangered species in the wild and this can be achieved in some circumstances by captive breeding. Captive breeding is currently seen as one way of increasing the endangered tree kangaroo population (Steenberg 1990). Although this has never been successfully proven, zoos in the United States and Australia have been able to encourage tree kangaroos to breed, but not for the purpose of re-introduction back into the wild (Dabek pers. com). The concept of breeding tree kangaroos in captivity started in the mid-eighteen hundreds (Owen 1852) with the breeding of *D. inustus inustus* and has continued right up to the rearing of *D. matschiei* in the late 1980s (Mullet 1993). Realistically, such programs are capable of producing a reasonable sized population, if conducted under optimum conditions. However, animals raised in captivity are normally unable to survive in the wild (Kleiman 1989). Although captive breeding programs may not be able to develop wild population numbers, they may be a good means to extend research on tree kangaroos. Studies of captive animals can lead to a better understanding of particular aspects of their biology in both captivity and the wild. Knowledge of the reproductive cycle is essential in order to maximise mating and to determine when to introduce males to females (George 1990; Steenberg 1990; Dabek 1991; Dabek 1994). It also assists in understanding the life-history and fecundity of tree kangaroos for population viability assessment (Hutchins et al 1991). So, information about reproduction can be gained in captive breeding programs and this information is useful both for enhancing these captive programs and as a database to help develop models to conserve wild populations.

A greater knowledge of social behaviour may also help increase the declining stocks of endangered tree kangaroos. Social behavioural studies conducted on captive tree kangaroos show that they are solitary, and that males are polygynous and territorial with home ranges encompassing areas of 2-3 females (Newell 1999[c]). Observations of Huon tree kangaroos in captivity found males to be more social than females (George 1982; Hutchins 1991) and also that successful reproduction occurred when females were isolated from other females.

1.8 CONSERVATION AND RESEARCH IN THE FIELD

The Huon tree kangaroo is endemic to the Huon Peninsula but has declined in numbers in the last generation (Betz 1997[a]) and therefore has a very high risk of becoming extinct in the future. The government of Papua New Guinea has endorsed laws (Fauna Protection and Control Act 1976) to protect tree kangaroos. However, based on personal observations, those laws are not generally enforced at the local level. The native people of the Huon Peninsula traditionally hunted the Huon tree kangaroo and continue to value this practice. Thus, in order to protect this animal from extinction it is vital that the local people of the Huon Peninsula understand both the importance and the value of the Huon tree kangaroo in their community as well as how they can practically preserve this species.

Scientific research plays a crucial part in the conservation of declining populations, and so an understanding of the ecology of the declining population is necessary to develop means to conserve their habitat. Home range, habitat selection and movement patterns are important aspects in the ecology of animals. These aspects are very important in designating areas for conservation and, in addition, an understanding of how these animals interact with their environment will help to develop proper management strategies for their protection (Wong 2004.).

The tree kangaroo conservation program (TKCP) is one of the programs aimed at conserving the Huon tree kangaroo habitat in the YUS Local Level Government (YUS LLG) (Appendix 2) region of the Huon Peninsula (TKCP 2002). The objective of the program is to establish a conservation area of at least 60,000 hectares of land (Appendix 3) through a co-operative and voluntary program. Establishing the conservation area is linked with community-based actions, including conservation awareness programs, education, community health and scientific research (TKCP 2005). Conservation outreach and education are two areas of the program that educate the native people of the YUS LLG region to understand how and why the conservation of the Huon tree kangaroo is important and why they should value conservation. The TKCP reaches out to the people through conservation awareness meetings with the landowners and uses the school curriculum to teach conservation in schools around YUS.

Scientific research was carried out to acquire data needed to convince both the people of YUS as well the national government of Papua New Guinea that the Huon tree kangaroo population is really under threat and that its habitat needs to be protected. In the last decade, the TKCP has conducted research on the density, food plants, indigenous knowledge, cultural significance and the conservation status of the Huon tree kangaroo (Betz 2001). With this background knowledge, research can now focus on other neglected aspects of the ecology such as home range, habitat selection and movement patterns.

This study is aimed at studying how large an area (home range) an individual animal needs to survive, including other individuals it interacts with. The results will indicate how large an area should be conserved as tree kangaroo habitat. Secondly, the study will focus on the type of habitat (habitat selection) needed for Huon tree kangaroos to survive, because habitat preference will influence the choice of area designated for conservation. Thirdly, the study will look at how these animals move within their area (movement patterns). Documenting these movement patterns is very important in understanding how tree kangaroos utilize their area, and so will aid conservation organisations in determining which areas are to be designated for conservation.

1.9 HOME RANGE AND RADIO TRACKING

Home range was first defined as an "area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt 1943). This concept has been redefined by several authors (Burt 1943; Mohr 1947; Jewell 1966; Baker 1978; Hansteen 1997). Their criticism was based on the unclear term "normal" and the lack of a temporal component (White 1990). Revised definitions of home range were later used to specify a time frame (Morris 1988; Hansteen 1997). To date, there has been no generally accepted, revised definition, although it is accepted that "home range" is not an indivisible entity, but rather a concept that, in practice, depends on the technique used to measure it (Morris 1988). More recent definitions employ increased computing power to define range as a probability function, thus defining home range as the extent of an area with a defined probability of occurrence of an animal during a specific time period (Kenward 2001).

Simply defining the area an individual traverses has limited biological value and may lead to the development of various measures of intensity of use of parts of the range including "centre of activity" (Hayne 1949). The identification and estimation of such "activity areas" within the home range have received much attention (Samuel 1985; Samuel 1988; Hodder 1998). Recently the term "core area" (Hodder 1998) has replaced the original "centre of activity" (Hayne 1949). Following these definitions a variety of estimators have been developed to quantify home range, and various analytical techniques have been accepted (Kenward 1987; Harris et al 1990; White 1990). Common techniques have been compared and contrasted by several authors (Van Winkle 1975; Macdonald 1980; Jaremovic 1987; Worton 1987; Worton 1989; Boulanger 1990; Kenward 1992; Worton 1995; Seaman 1996; Seaman 1999).

Home range estimators are used to address a variety of research questions, such as the calculation of home range size (Burt 1943), home range shape and structure (Kenward 1992), movement or site fidelity as defined by temporal change in home range position (Phillips 1998), establishments of management boundaries (Edge 1986), resource availability (Johnson 1980), and animal interactions (dynamic interaction) (Macdonald 1980; Doncaster 1990). Nevertheless, it is clear that there is no single appropriate measure of home range, but the term depends on the experimental system and the types of questions posed.

Movements of individual animals are summarised over a specified time period to describe an animal's pattern of space use or home range. Home ranges are measured in a number of ways; bounded area or polygons (Mohr 1966), probability areas as ellipses (Jennrich 1969), and non-parametric probability contours (Worton 1989). Space use has also been described in terms of grid densities (Siniff 1965) or non-parametric density surfaces (Dixon 1980; Anderson 1982; Worton 1989). In sampling, two components have a strong bearing on the measurement of space use and home range size: the number of radio-marked animals and the number of locations collected per animal.

Previous studies have shown that tree kangaroos are solitary animals and are usually territorial (Procter-Gray 1985). Procter-Gray (1985) found that adult females (*D. lumholtzi*) had an average area of 1.8 ± 0.4 ha, while a male had an average area of 4.4 ha. Newell

(1999) showed a similar trend in his study of the Lumholtz's tree kangaroos, *D. lumholtzi*, with female areas of 0.689 ha and males areas of 1.952 ha. In contrast, Martin (1992) discovered that the Bennett's tree kangaroo covered slightly larger areas than the Lumholtz's tree kangaroos. Males had areas of 19.4 to 29.8 ha and females had areas of 5.5 to 9.5 ha. So far not much is known about the home ranges of New Guinean species; to date only one animal (*D. matschiei*) was recorded with an area of 25 ha (Flannery et al 1996).

1.10 MOVEMENT AND ACTIVITY PATTERNS

1.10.1 Site Fidelity

Home range estimators can be used to measure site fidelity in two ways. The first method is to compare the overlap of home range from a single animal between two or more time periods (Static Interaction) (Kernohan 1994; Phillips 1998). The second method requires comparing home range estimates from a single animal to random home range estimates based on random walk paths (Dynamic Interaction) (Munger 1984; Danielson 1987; Palomares 1994).

The analysis of animal movements includes a range of tools designed to assess site fidelity. The quantification of an animal's movement often ignores the temporal aspects of animal behaviour by showing the spatial arrangement of location points without regard for the sequence in which the locations were recorded (Kenward 2001). Analysis of site fidelity deals with the temporal dynamics of animal behaviour and focuses on three types of movements; (1) migration, (2) dispersal, and (3) localized movement (Millspaugh 2001). Migration is a round-trip movement of individuals between two or more areas, whereas dispersal is a one-way movement of individuals from their natal site. Localized movement is the daily movement of individuals within a home range (White 1990).

Apart from absolute spatial requirements such as that measured as home range, the way that tree kangaroos use that range is important. This includes the spatial distribution of activity, for example core use areas and the way they relate to habitat (Aebischer 1993), because these can be used to define important features of the habitat as well as the temporal distribution. As with other arboreal folivores, tree kangaroos are less active than other kangaroos (McNab 1988). Lumholtz's tree kangaroos (*D. lumholtzi*) were thought to be mostly nocturnal but can be active around dawn and dusk (Procter-Gray 1985; Newell 1999[b]), although Coombes (2005) noted substantial amounts of movement during daylight hours. On the other hand, Bennett's tree kangaroos (*D. bennettianus*) are largely nocturnal and feed around dusk (Martin 1992). Limited information on activity patterns is available on New Guinean tree kangaroos. However, they are thought to be either crepuscular or diurnal (Fisher and Austad 1992; Flannery et al 1996).

Nocturnal behavior in New Guinea tree kangaroos was correlated with hunting pressures and was exhibited near human populations by both *D. goodfellowi buergersi* and *D. matschiei* (Flannery et al 1996; Betz 1997[a;] Betz 2001). This nocturnal behavior in *D. matschiei* was also observed by William Betz in the wild in 2004. Landowner interviews (Betz 1997[a]) suggested that *D. matschiei* can be either crepuscular or diurnal. Most of the landowners (53 out of 62), suggested that *D. matschiei* was diurnal. However, other areas of the Huon Peninsula suggested otherwise, for example the Kabwum people to the eastern part of the Huon Peninsula suggested *D. matschiei* to be nocturnal.

This study will focus on localized movements of the Huon tree kangaroo. Studying localized movements gives an indication of how the animal utilizes its area, which will relate directly to how conservation efforts can focus on establishing a suitably sized range to enable maximum usage of that particular area.

1.11 HABITAT USE

Animal species usually attempt to select resources that best meet their requirements and consequently maximize their fitness (Manly 2002). The use of resources compared to resource availability is a form of resource selection (Manly 2002) and the resources used disproportionately to availability are selective. Resource selection occurs in a hierarchical fashion and thus determines the location of an animal's home range. The "first order selection" is defined as the selection of physical or geographical range, the "second order" determines the home range of an individual or social group and the "third order" pertains to various habitat components within the home range, such as feeding sites (Johnson 1980). Territorialism may also influence the location of an animal's home range (Aebischer 1993) with respect to the overall study area. Habitat patches differ in their suitability for each animal species (Kozakiewicz 1995). Therefore, each habitat is classified as optimal, suboptimal, marginal or non-inhabitable for its species requirements (Kozakiewicz 1995). However, it is important to know that suboptimal habitats also provide useable habitats, because they usually contain 80% of the resources found in optimal habitats (Munks 1996).

Another good measure of habitat suitability is the reproductive success of species (Krebs 1985). Reproduction cannot occur without safe nesting sites, because food, water sources, shelters and predators all affect habitat suitability (Pople 1989; Kozakiewicz 1995). Habitat suitability is generally reflected by population density. However, the quality of the habitat is not assessed by population density alone (Van Horne 1983), because habitat quality reflects population density.

According to Betz (2001), a total of 91 plant species, were identified as food plants used by the Huon tree kangaroo (*D. matschiei*). This however, leaves a gap between other types of habitats found on the Huon Peninsula, because his results were based on one particular area (Dendawang) and not on the entire area of the Huon Peninsula. Consequently, this study as well as other future studies will be able to minimize this gap by sampling other areas of the Huon Peninsula to ensure that all food plant species are identified in different habitats along the altitudinal gradient on the Huon Peninsula.

The method used in Betz (2001) was also used in this study in the identification of food plant species used by *D. matschiei*. However, a further investigation was carried out on tree preferences of the Huon tree kangaroo. The investigation involved identifying the intensity of usage, and why particular tree species were preferred over others.

1.12 DENSITY

The methods of estimating population sizes have been extensively studied over the past 25 years (Jolly 1969; Robinette 1974; Burnham 1980; Clark 1986; Pollock 1987; Norton-Griffiths 1988; Buckland 1993; Campbell 1995). However, the results show that the methods of estimating population sizes have not been able to cover aspects such as habitat quality, which influences home range estimates (Edwards 1981; White 1989; Bergstedt 1990; Buckland 1992; Pojar 1995). The inability to cover habitat aspects in estimating population sizes is particularly common in the tropics where less research has been done compared to temperate ecosystems. Yet, the tropics have a greater diversity of mammal species, which are hunted and threatened with extinction and are in particular need of study (Caro 1998).

The most widely used means to survey populations of large and medium-sized mammals is by aerial surveys (Norton-Griffiths 1978). However this method has a number of limitations; for example the inability to spot animals while flying over thick tree canopy (Barnes 1995). In such circumstances ground survey methods are used (Stearns 1969), including strip transects (Lamprey 1963), drive counts (Runyoro 1995) and dropping counts (Barnes 1991) for larger mammals, and dung pellets (Koster 1988; Komers 1997), leaf nest (FitzGibbon 1994) and track counts (Koster 1988; Prins 1989) for smaller mammals.

In radiotelemetry studies, the estimation of population density can be approached in two ways; (1) radio collars can act as primary markers for the Lincoln Index estimates of population size within a given area, and (2) radio tagged animals can also be used to correct density estimates from grid trapping and visual surveys (Kenward 2001).

1.13 SUMMARY AND PROPOSAL

Despite recent advances in understanding of Australian tree kangaroos (Martin 1992; Newell 1999c; Coombes 2005), knowledge of the biology and ecology of New Guinea tree kangaroos still remains rudimentary. Currently there are ten tree kangaroo species recognized worldwide, with an additional seven sub-species (Table 1.1). The conservation status of the group has attracted a lot of attention over the past decade. All tree kangaroo species are considered threatened (IUCN 2004). Of the eight New Guinean tree kangaroo species, one is critically endangered (*D. scottae*), two are endangered (*D. matschiei* and *D. goodfellowi*), two are vulnerable (*D. dorianus* and *D. mbaiso*) and three have insufficient data to determine status (*D. inustus, D. spadix* and *D. ursinus*), although it is most likely that they, too, are at risk.

The endangered Huon tree kangaroo (*D. matschiei*) is endemic to the Huon Peninsula of Morobe Province in Papua New Guinea and restricted to relatively high altitudes (Flannery 1996). Its small geographic range and endangered status make active conservation efforts in the wild, such as protection in conservation areas, vital to the medium to long term future of this species. As part of evaluation of the optimum conservation strategy for *D. matschiei*, it is important to have more extensive data on their biology and ecology in the wild, especially space and habitat requirements.

1.13.1 Home Range

The current knowledge of home range, habitat use and behavior in tree kangaroos is based on the two Australian species (*D. lumholtzi* and *D. bennettianus*) (Procter-Gray 1985; Martin 1992; Newell 1999[c]) and no research has been published on the New Guinean species, with the exception of home range results from a single individual of *D. matschiei* in 1991 (Stirling 1991). Consequently, the understanding of home range, habitat use and behavior remains rudimentary for the Huon tree kangaroo (*D. matschiei*), and indeed all New Guinea tree kangaroo species.

Both GPS and regular VHF transmitters were attached to wild Huon tree kangaroos (*D. matschiei*), and tracked on a daily basis. Daily locations of each animal were recorded and used for home range analysis. Use of both GPS loggers and VHF transmitters will be able to allow a comparison of the relative advantages of these technologies in determining movement and habitat use within the rugged and inaccessible terrain that forms the habitat of the Huon tree kangaroo.

1.13.2 Density

From previous studies, density of the Huon tree kangaroo (*D. matschiei*) was estimated at one animal per hectare (Betz 2001). This is similar to Lumholtz's tree kangaroo (*D. lumholtzi*) of North Queensland with an average and exclusive home range of 0.8 ha/animal (Newell 1999[b]). Home ranges of both of these species were slightly denser than that of Bennett's tree kangaroo (*D. bennettianus*), which was estimated to be 0.3 ha/animal (Martin 1993). Currently Betz (2001) is the only source of information on *D. matschiei* density and was estimated from a 16 hectare area of the Huon Peninsula (Keweng 1 Village - Dendawang & Sibidak). There are no density estimates or other types of ecological information from other parts of the Huon Peninsula, an area with substantial variation in forest and habitat types (Betz 1997[a;] Forest Research Institute 2004). So it is unlikely that Betz (2001) provides a complete understanding of the density and habitat use by *D. matschiei*. This study, based at Wasaunon, provides a point of comparison with density estimates from Betz (2001). Density estimates in Wasaunon (Appendix 3.) will be calculated using the "Lincoln Index" (Southwood 1978) with the sighting of collared animals constituting recaptures.

1.13.3 Habitat Use and Tree Preference

Landowner accounts from Betz (2001) suggested that the Huon tree kangaroo fed on a wide variety of plant species. This is similar to other generalist folivores such as howler monkeys (Crockett and Eisenberg 1987). Betz (2001) identifies 91 plant species that were used by the Huon tree kangaroo with a further 70 specimens from Maimafu in the Eastern Highlands Province of Papua New Guinea used by the Doria's tree kangaroo (*D. dorianus notatus*) (Betz 1997[a]). However, this broad use of many plant species was not the case in other areas of the Huon Peninsula. For example, the Kabwum people to the eastern part of the Huon Peninsula suggested that only seven plant species were used by *D. matschiei* (Betz 1997[a]).

Resource availability (Burt 1943), habitat types (Mitchell 1990) and habitat quality (Melzer 1995) can influence home range and density. Consequently, there is a strong possibility that tree kangaroos in other areas of the Huon Peninsula may vary in home range or density. Home range and density are interrelated (Ostfield 1995), so an understanding of Huon tree kangaroo spatial and habitat requirements are very important in the management and the development of conservation areas for this species. By understanding the spatial and habitat requirements of a particular species, we can then identify particular areas of the habitat that would have the potential to provide the required resources needed for the species to survive.

This study will identify important resources and features of habitat in two ways. Food plant species used by the Huon tree kangaroo will be identified, firstly, through ethnobiological knowledge based on interviews with traditional hunters and landowners, and secondly, by comparing habitat features within the preferred and less-preferred portions of the home range of tree kangaroos. Daily animal locations will include observations of the species of tree utilized by the focal individual as well as characteristics of the habitat. Comparison of habitat within foci of activity with that in sparsely used parts of the home range will allow determination of the importance of specific habitat features in shaping home range and identify crucial habitat features.

1.13.4 Movement and Activity Patterns

An understanding of activity and movement patterns is essential in conservation, at least partly because it helps us understand behavioral flexibility in tree kangaroos, and how they may respond to hunting pressure. Given that there is a dispute regarding tree kangaroo activity patterns amongst landowners in different areas on the Huon Peninsula, the use of radiotelemetry to study animal movement/displacement would be an excellent alternative to landowner interviews. The use of radiotelemetry can be used to monitor the daily displacement of *D. matschiei* and consequently produce a better understanding of activity patterns in *D. matschiei*.

CHAPTER 2 Habitat and Food plants of the Huon tree kangaroo, *Dendrolagus matschiei*

2.1 INTRODUCTION

The Huon tree kangaroo (*Dendrolagus matschiei*), also known as the Matschie's tree kangaroo, belongs to the family Macropodidae which includes about 55 species of kangaroos, wallabies and their relatives. The genus *Dendrolagus*, includes around 10 species of tree kangaroos. This species lives on the Huon Peninsula in the north eastern Morobe province of Papua New Guinea. Under the IUCN classification, the Huon tree-kangaroo is endangered (IUCN 2004). Huon tree kangaroos live in mountainous rainforests at elevations of between 1000 and 3300 m (Flannery 1995). Huon tree kangaroos are generalist folivores and feed on a wide variety of plant species such as leaves, fruits and mosses (Betz 2001).

This section of the study seeks to investigate the plant species composition of the study area (Wasaunon) and further identify food plant species used by the Huon tree kangaroo using ethno-biological data. This data is helpful in understanding the variety of food plant species used by the Huon tree kangaroos, and can also be useful in future research of food plant species by investigating the occurrences of these plant species at different elevations and different habitat types.

2.2 STUDY SITE

2.2.1 Location

This study was conducted at an area known to local landowners as Wasaunon, part of the land pledged as a conservation area by the ToBai Clan of Toweth village in the Ward 1 area of Yopno Uruwa and Som Local Level Government Area (YUS LLG) of Kabwum District in Morobe Province, Papua New Guinea (Figure 2.1). Wasaunon is contiguous with other forested areas within the pledged conservation area.

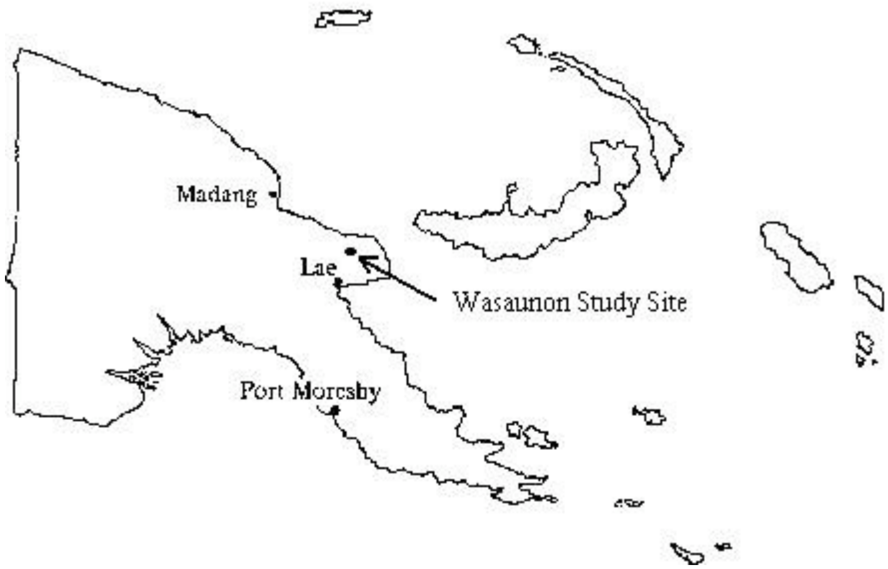


Figure 2.1 Map of the Huon Peninsula showing the location of the study site in the Kabwum District of Morobe Province.

Wasaunon is located towards the north coast of the Huon peninsula, Papua New Guinea within the Sarawaget Range (146° 54’ 52.90” South, 6° 5’ 31.68” East), a rugged and poorly accessible mountain range with peaks up to 4000 in altitude. It is approximately 80 km northeast of Papua New Guinea’s second largest city, Lae, at altitudes of around 3000 meters above sea level. There is currently no road access into the YUS LLG, so access to the site was by light aircraft to an airstrip associated with the village of Yawan at 1400m, followed by a 1 - 2 day walk to Wasaunon. Wasaunon is approximately 9.8km northwest of the Yawan village and 5 km SSE from Hameligan village. Wasaunon was extensively hunted during the 1960s up until the early 90s, when hunting ceased due to reports of missing relatives that never returned after a hunting trip to the area. Wasaunon has not been hunted since then and has proven to be very reliable in providing satisfactory numbers of tree kangaroos for this study.

2.2.2 Climate

Climatic records of Wasaunon were collected starting from March 2004 and ended in November 2007. The climatic records collected shows that rainfall is approximately 1920 mm per annum (p.a.). Rainfall is spread out throughout the year, with the wettest season occurring between April through to August and the driest season from September to March (Figure 2.2). Wasaunon has a minimum annual temperature of 11°C and a maximum of 13°C (Figure 2.3).

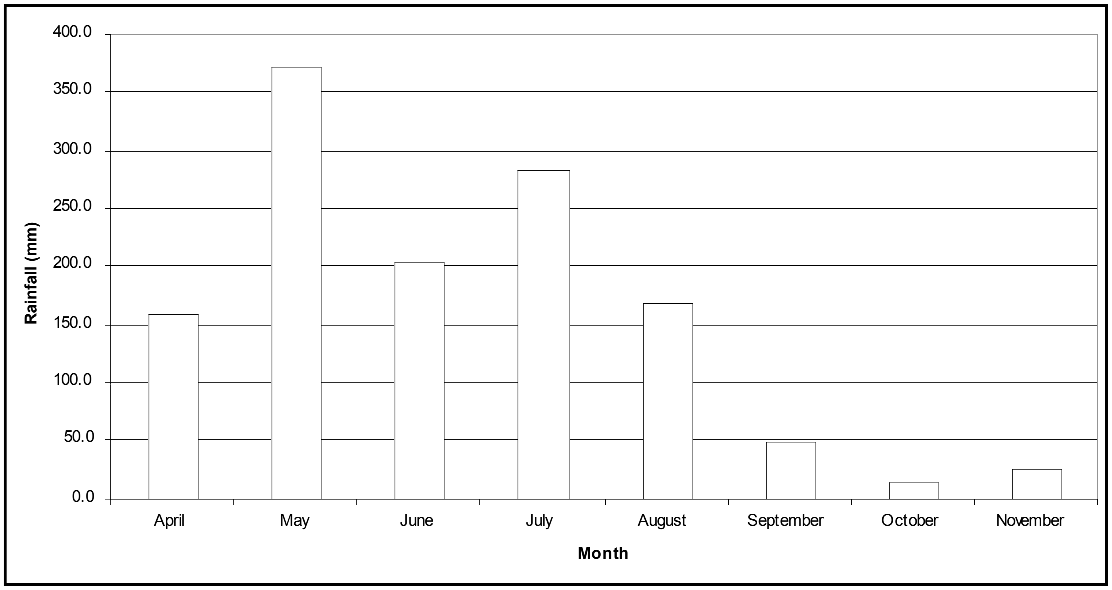


Figure 2.2 at Wasaunon between 2004 and 2007.

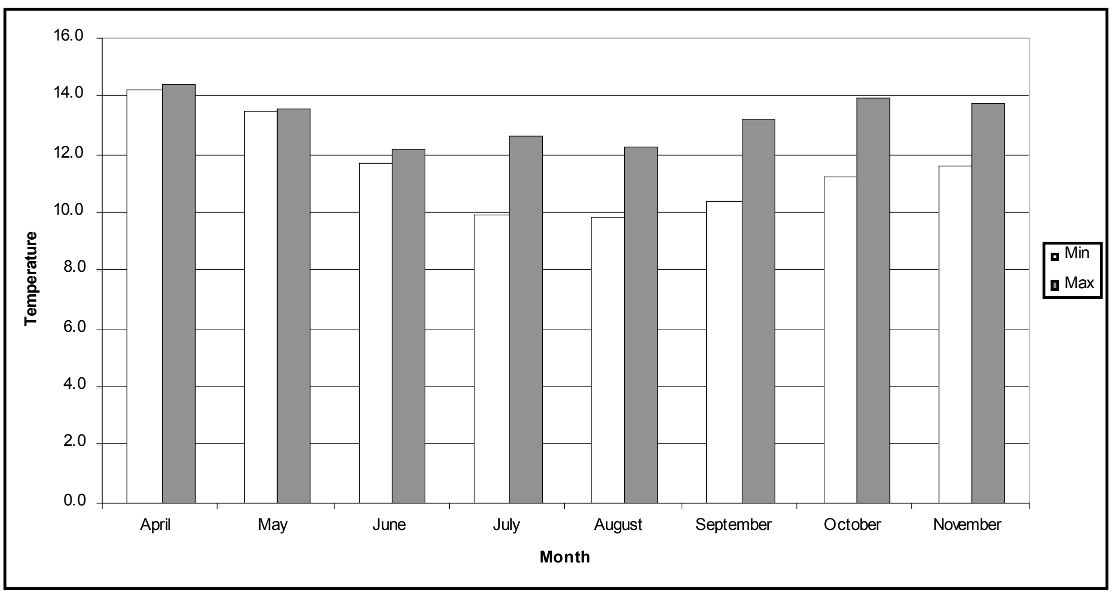


Figure 2.3 Temperature at Wasaunon between 2004 and 2007.

2.2.3 Forest Composition

The locality of Wasaunon is around 3900 hectares of lower montane forest with a canopy dominated by *Dacrydium nidilum* (FRI 2004), from altitudes of 2400m to 3100m above sea level. The forest structure at Wasaunon is described as a thin canopy with even heights, small-crowned and containing prominent under stories. Almost all forest floors at Wasaunon are covered by various species of moss and lichens and lianas are not common at this altitude. Tree ferns of the species *Dicksonia hieronymi* and *Cyathea hornei* are dominant at the lower canopy, whilst ground ferns (*Dennstaedtia magnifica, Dennstaedtia aff. Penicillifera, Hypolepis bamleriana*, *Histiopteris aff. Estipulata* and *Marattia costulisora*) dominate the ground level (Appendix 4).

Three habitat sub-types were chosen along the altitudinal gradient at Wasaunon and plots were set-up to measure tree species composition. The vegetation survey consisted of 20 circular subplots, which were set-up at three different altitudes along the altitudinal gradient (Kotom River 2400m, 8 plots; Songann forest 2700m, 3 plots; Wasaunon 3100m, 8 plots and one at Dendawang 2400m). In each plot, eight canopy trees were randomly chosen at each compass direction (Figure 2.4) and the distance from centre, height, diameter, coordinates and species of individual trees were recorded, resulting in a total of 32 trees with the center tree as number 33. All plant species within each plot were then identified starting from the upper canopy right down to the herbs on the forest floor. Dominant plant species were recorded starting at the upper canopy, mid canopy, lower canopy and the forest floor (Appendix 4). Tree kangaroos were tracked only at the higher two elevations (2700m and 3100m). Therefore, only the plots at these two altitudes were used to summarize tree species composition of areas (Table 2.1).

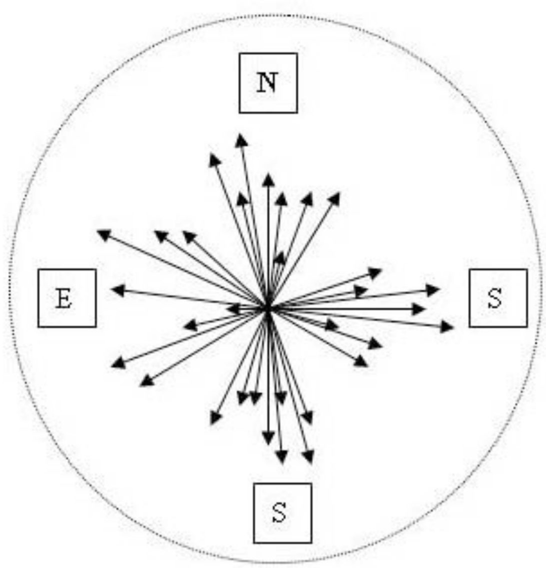
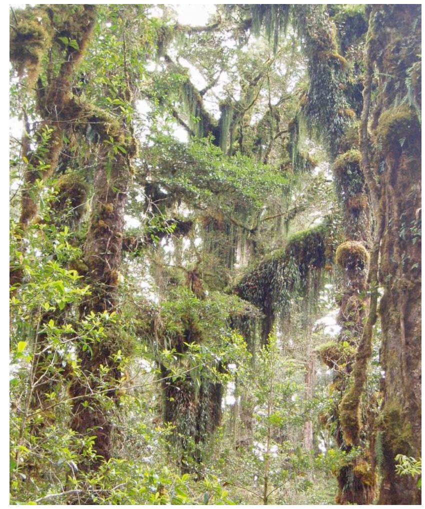


Figure 2.4 The 32-Tree Method showing layout of subplots at Wasaunon and Songann forests.

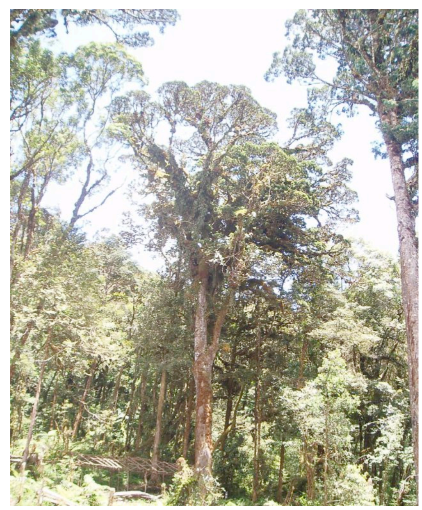
The forest canopy at 2700m is dominated by *Nothofagus starkenborghii, Elaeocarpus altigenus* and *Podocarpus crassigemmiss* (Figure 2.5). In contrast, the forest composition at Wasaunon mainly consists of *Decaspermum forbesii, Quintinia ledermannii, Dacrydium nidulum, Saurauia capitulata* and *Libocedrus papuana* (Figure 2.5). The forest floor at both altitudes is entirely covered with spongy mosses and herbs such as *Elatostema papuana, E. blechnoides, E. mongiense, Pilea cuneata* and *P. effuse*. Tree ferns such as *Dicksonia hieronymi* and *Cyathea hornei* dominate the lower canopy while ground ferns, *Dennstaedtia magnifica D. penicillifera Hypolepis bamleriana Marattia costulisora* and *Histiopteris aff. Estipulata* dominate the ground (Table 2.1, Appendix 4).

A.



B.

C.



D.

Figure 2.5 ***Nothofagus*** **Forest at 2, 700m (A – forest floor and B –** ***Nothofagus*** **tree) and Lower Montane Forest at Wasaunon (3, 100m) (C – forest floor and D –** ***Decrydium nidulum*****).**

Table 2.1 Plant species composition at Wasaunon and Songann forests.

Plant Species		Proportion (%)
Acronychia murina		1.52
Ardisia sp. (canopy tree, fruit axilary)		0.61
Dacrydium nidulum		10.61
Decaspermum forbesii		10.30
Dryadodaphne crassa		0.30
Elaeocarpus altigenus		1.52
Elaeocarpus polydactylus		0.61
Endiandra fragrans		0.61
Eurya tigang		2.12
Helicia odorata		0.91
Ilex archboldiana		0.61
Levieria squarrosa		2.12
Libocedrus papuana		5.76
Nothofagus starkenborghii		26.36
Podocarpus crassigemmiss		4.85
Polyosma forbesii		0.30
Prunus glomerata		0.61
Prunus grisea var. microphylla		2.12
Quintinia ledermannii		10.61
Saurauia capitulata		8.79
Schuurmansia elegans		0.91
Sphenostemon papuanum		1.52
Symplocos cochinchinensis var. leptophylla		1.82
Syzygium alatum		3.03
Timonius longitubus		1.21
Zanthoxylum conspersipunctatum		0.30
	Total	100

2.3 TREE KANGAROO DIET

New Guinea's tree kangaroos (Marsupialia: Macropodidae, *Dendrolagus* spp.) are perhaps the island's most threatened mammal group. Basic knowledge of their natural history, which is critical to their conservation, is lacking (Beehler 1991). One area of ignorance is feeding ecology. Tree kangaroos have dentition that is suited for a browsing feeding style, and the ten known species possess gut morphologies that show varying levels of adaptation to a mostly folivorous diet (Sanson 1989; Flannery et al 1996). Previous research has shown that Australian tree kangaroos eat a wide variety of plant species (Flannery et al 1996; Coombes 2005; Tree Kangaroo and Mammal Group 2000). The diet of New Guinea tree kangaroos is believed to be similarly diverse, but data to support this are lacking. There has been no concerted effort to determine the full range of New Guinea tree kangaroo diets (Flannery et al 1996). This is due in part to the extreme difficulty of directly observing the animals in the wild. However, traditional New Guinea cultures have been shown to possess extensive knowledge about native wildlife and its natural history (Flannery 1998; Diamond 1999). Traditional knowledge can contribute to scientific understanding (Bulmer 1982; Hill 1982), but biologists often fail to use these indigenous biological databanks.

2.4 DETERMINING THE DIET OF THE HUON TREE KANGAROO

In Betz's initial effort to document New Guinea tree kangaroo diets knowledgeable landowners, typically older experienced hunters, were asked to identify food plants for the Huon tree kangaroo (Betz 1997[a]). The wild diets of *D. matschiei* are almost completely unknown with only limited data recorded for *D. matschiei* and none for any other New Guinean tree kangaroo species (Flannery et al 1996). While the native plant lists are anecdotal, they provide a useful starting point for future research using more direct methods.

In this study a similar approach was taken. Landowners from the village of Toweth and Worin (Yopno Uruwa Som (YUS) Local Level Government Area, Morobe Provinve, Papua New Guinea) assisted in identifying and collecting Huon tree kangaroo (*D. matschiei*) food plants at the Wasaunon field site (S.6° 5' 31.682" E. 146° 54' 52.904", altitude 3000 m).

Collections (general plant collections) were made in an altitude range from 2300 to 3100 m in June and July of 2004 (Appendix 4).

Plants were identified and gathered by older landowners with extensive tree kangaroo hunting experience, and a full grasp of traditional botanical and zoological knowledge. For some of the specimens, landowners provided information on which portions of the plant were consumed by *D. matschiei*. The specimens were later identified to genus and species level at the Forest Research Institute (FRI) in Lae by Australian botanist Rigel Jensen and FRI para-botanist Fazang Kaigube and his assistants. A key element in the collecting method used at Wasaunon was to allow the landowners to walk in the forest and identify the plants themselves. The high quality of these informal, discovery based methods has been noted by other ethnobiological researchers in New Guinea (Diamond 1999).

2.4.1 Field Observation

Field observations of tree use by 15 radio-collared tree kangaroos in this study (Chapter 4) at Wasaunon resulted in the identification of a total of 30 canopy tree species, of which 29 were identified to species level. Over 50% of tree use was from a single tree species, *Dacrydium nidulum*, and the next most used species, *Prunus sp*, with only 7% of observations, while 6% of observations were on the ground (Table 2.2). These species were used more frequently than would be expected and were selected randomly in proportion to their relative abundance in the forest. Conversely, 29 other tree species present were used less frequently than expected. Huon tree kangaroos also apparently favored particular individual trees within some of the preferred tree species such as *Syzygium alatum*, *Libocedrus papuana* and *Decaspermum forbesii* (Table 2.2).

Table 2.2 Proportions of observations of radio-collared, Huon tree kangaroos according to canopy tree species and the abundance of those tree species in the forest.

Tree Species	% Sighted	% of Occurrence
Dacrydium nidulum	48.47	51.71
Prunus sp	12.3	7.2
Ground	0.74	6.37
Syzygium alatum	4.44	5.22
Decaspermum forbesii	6.75	4.89
Libocedrus papuana	3.33	4.89
Saurauia capitulata	6.29	3.69
Nothofagus	1.39	2.4
Podocarpus crassigemmiss	1.85	1.94
Unknown	3.05	1.90
Quintinia ledermannii	3.05	1.75
Timonius longitubus	1.02	1.48
Eleaocarpus	0.74	1.25
Macaranga trichanthera	1.57	0.97
Achronychia murina	1.3	0.83
Euodia sp	0.28	0.6
Endiandra fragrans	0.65	0.55
Bidens pilosa	0	0.37
Levieria squarrosa	0.46	0.37
Schuurmansia elegens	0.37	0.37
Sphenostemon papuanum	0.28	0.23
Phyllocladus hypophyllus	0.19	0.18
Polyosma sp	0.37	0.18
Symplocos sp	0.28	0.14
Acronychia pullei	0.09	0.09
Eurya sp	0.19	0.09
Helicia sp	0.19	0.09
Melicope perpicunervia	0.09	0.09
Repanea leucantha	0.19	0.09
Psychotria sp	0.09	0.05

Over 70 specimens of tree kangaroo food plants were collected at the Wasaunon site. A further 209 plants were obtained at Wasaunon alone. Table 2.3 provides a list of food plant species identified by the Toweth and Worin landowners; general plant species collections were also identified both inside and outside of Wasaunon (Appendix 4).

Table 2.3 Food plant species of the Huon tree kangaroo, *Dendrolagus matschiei*, as identified by Toweth and Worin landowners.

No.	Type	Family	Genus species	Local Name	Portion eaten
1	Creeper	Rosaceae	*Rubus ledermannii #*	Dirong 1	shoots/leaves
2	Creeper	Rosaceae	*Rubus laeteviridis**	Dirong 2	shoots/leaves
3	Creeper	Rosaceae	*Rubus dicilinis var. diclinis**	Dirong 3	shoots/leaves
4	Creeper	Rosaceae	*Rubus arcboldianus**	Dirong 4	shoots/leaves
5	Creeper	Rosaceae	*Rubus lorentzianus**	Dirong 5	shoots/leaves
6	Creeper	Rosaceae	*Rubus papuana*	Dirong 6	shoots/leaves
7	creeper	Rosaceae	*Solanum aff. Arffractum**	Dirong 7	shoots/leaves
8	fern	Cyatheaceae	*Cyathea sp. (white, large) **	Ami white	shoots/leaves
9	fern	Cyatheaceae	*Cyathea sp. (ami, brown)**	Ami brown	shoots/leaves
10	fern	Cyatheaceae	*Cyathea sp. (ami, blues)**	Ami blue	shoots/leaves
11	fern	Cyatheaceae	*Cyathea sp. (kamingdek)**	Kamingdek gomon	shoots/leaves
12	fern	Dennstaedtiaceae	*Dennstaedtia magnifica**	Engeng tatac 1	shoots/leaves
13	fern	Dennstaedtiaceae	*Dennstaedtia penicillifera**	Engeng tatac 2	shoots/leaves
14	fern	Dennstaedtiaceae	*Hypolepis bamlerianum**		shoots/leaves
15	fern	Dennstaedtiaceae	*Microlepia sp.**	Engeng tatac 3	shoots/leaves
16	fern	Dennstaedtiaceae	*Histiopteris aff. Estipulata**		shoots/leaves
17	fern	Dicksoniaceae	*Dicksonia hieronymi #*	Ami gomon	shoots/leaves
18	fern	Dicksoniaceae	*Dicksonia sp.**	Ami	shoots/leaves
19	fern	Marattiaceae	*Marrattia costulisora**	Durem 1	shoots/leaves/stem
20	fern	Marattiaceae	*Marrattia werneri #*	Durem 2	shoots/leaves/stem
21	fern	Pteridaceae	*Pteris tripartite**	Togoguyang	shoots/leaves
22	herb	Apiaceae	*Hydrocotle javanica**	Gerogero	shoots/leaves
23	herb	Polygonaceae	*Polygonum**	Mutmut 1 (small lf)	shoots/leaves
24	herb	Polygonaceae	*Polygonum #*	Mutmut 2 (small lf)	shoots/leaves
25	herb	Urticaceae	*Pilea cuneata**	Daunding 1	shoots/leaves/stem
26	herb	Urticaceae	*Pilea effusa**	Daunding 2	shoots/leaves/stem
27	herb	Urticaceae	*Pilea papuana**	Daunding 3	shoots/leaves/stem
28	herb	Urticaceae	*Pilea sp.**	Daunding 4	shoots/leaves/stem
29	herb	Urticaceae	*Elatostema blechnoides**	Guram 1	shoots/leaves/stem
30	herb	Urticaceae	*Elatostema mongiense**	Guram 2	shoots/leaves/stem
31	herb	Urticaceae	*Debregeasia**		shoots/leaves
32	herb	Urticaceae	*Elatostema*	Tamberem 1	shoots/leaves/stem

			*cf.novoguineensis**	(brd.lf)	
33	herb	Urticaceae	*Elatostema sp.(medium lf)**	Goiyac	shoots/leaves/stem
34	herb	Urticaceae	*Larpotea decumana #*	Ut	shoots/young leaves
35	herb	Urticaceae	*Procris frutescens #*		shoots/young leaves
36	herb	Urticaceae	*Dendrocnide sp.#*	Utut	shoots/young leaves
37	shrub	Araliaceae	*Harmsiopanax ingens var. ingens #*	Makim	shoots/leaves
38	shrub	Gesneriaceae	*Cyrtandra sp.**	Bokbok 1	shoots/young leaves
39	shrub	Gesneriaceae	*Cyrtandra schurmanniana #*	Bokbok 2	shoots/young leaves
40	shrub	Gesneriaceae	*Cyrtandra sp.(clipping)**	Bokbok 3	shoots/young leaves
41	shrub	Grossulariaceae	*Carpodetus arboreus #*	Tamtam	shoots/young leaves
42	shrub	Monimiaceae	*Tetrasynandra sp. **		shoots/young leaves
43	shrub	Piperaceae	*Piper bolanicum**	Kowok	shoots/young leaves
44	shrub	Piperaceae	*Piper subbullatum #*	Kumbukumbu	shoots/young leaves
45	shrub	Piperaceae	*Piper sp.**	Magorom	shoots/young leaves
46	shrub	Rubiaceae	*Psychotria #*	Bokbok	shoots/young leaves
47	shrub	Urticaceae	*Cypholophus kerewensis**	Ititit 1	shoots/leaves/stem
48	shrub	Urticaceae	*Cypholophus macrocephalus**	Ititit 2	shoots/leaves/stem
49	shrub	Urticaceae	*Cypholophus sp.#*	Ititit 3	shoots/leaves/stem
50	shrub	Urticaceae	*Pipturus angenteus #*	Utang	shoots/leaves
51	shrub	Winteraceae	*Drimys piperita H.K.f.ent.heteromera**	Sumbiri	shoots/leaves
52	shrub	Winteraceae	*Bubbia sylvestris (Bubbia 1)**	Yamsi 1	shoots/leaves
53	shrub	Winteraceae	*Bubbia calothyrsa (Bubbia 2)**	Yamsi 2	shoots/leaves
54	tree	Actinidiaceae	*Saurauia capitulata**	Tomtom	shoots/leaves
55	tree	Actinidiaceae	*Saurauia cf. conferta**	Gundemot	shoots/leaves
56	tree	Actinidiaceae	*Saurauia fimbriata**	Igot	shoots/leaves
57	tree	Monimiaceae	*Kibara sp.**		shoots/leaves
58	tree	Monimiaceae	*Levieria squarrosa**		shoots/leaves
59	tree	Ochnaceae	*Schuurmansia elegens**	Handot 1	shoots/leaves
60	tree	Ochnaceae	*Schuurmansia heningsii #*	Handot 2	shoots/leaves
61	tree	Rubiaceae	*Timonius longitubus**	Dandukdanduk	shoots/leaves/stem/bark & wood
62	tree	Rutaceae	*Acronychia murina**	Egek 1	shoots/leaves
63	tree	Rutaceae	*Euodia = Acronychia pullei #*	Egek 2	shoots/leaves
64	tree	Rutaceae	*Acronychia sp.(brd.lf)**	Egek 3	shoots/leaves
65	tree	Rutaceae	*Zanthoxylon conspersipunctatum #*	Dinom	shoots/leaves

66	tree	Rutaceae	*Melicope perpicunervia*	Egek	shoots/leaves
67	tree	Urticaceae	*Dendrocnide sp.**	Dingnak	shoots/leaves
68	vine	Araliaceae	*Schefflera setulosa**	Nemok	shoots/leaves
69	vine	Araliaceae	*Harmsiopanax ingens**	Usim	shoots/leaves
70	vine	Ericaceae	*Dimorphanthera dekockii var. chlorocarpa**	Yaromyarom	shoots/leaves

** = Found in both Wasaunon and Dendawang; # = Found in Wasaunon only.*

The Toweth and Worin landowners that assisted in the plant collections believe that the Huon tree kangaroo ate a wide variety of plants from several families. They are partial to ferns from several families, climbing vines, (*Schefflera setulosa*, Araliaceae), various herbs (Urticaceae) especially species from genus *Elatostema*, peppers (Piperaceae), vines and shrubs from *Rubus* (Rosaceae), and trees from *Timonius* (Rubiaceae). The Toweth and Worin landowners also identified bark and hard wood of the *Timonius longitubus* (Rubiaceae) as an important component of the Huon tree kangaroo diet. The Toweth and Worin landowners stated that the diet of the Huon tree kangaroo is primarily composed of shoots, young stems and young leaves. The animals were also observed eating some sort of soil however this was not considered to be an important part of their diet.

2.5 DISCUSSION

In terms of plant part preferences (shoots, young leaves and stems) the diet of the Huon tree kangaroo (*Dendrolagus matschiei*) is not very different to the published accounts of the diets of the Lumholtz's tree kangaroo, *D. lumholtzi* (Coombes 2005; Newell 1999; Proctar-Gray 1985). However, the Toweth and Worin landowners stressed that Huon tree kangaroos preferred immature portions of the stems and leaves. The mature plants or plant parts were primarily herbaceous species, and not mature leaves and other parts from trees or shrubs. Consumption of mature leaves, especially mature tree leaves, was not a major part of the Huon tree kangaroo diet. This contrasts with the Australian Lumholtz's tree kangaroo whose observed diet consists of more than 80% mature leaves (Procter-Gray 1985). With its emphasis on immature and young foliage, *D. matschiei*'s dietary choices more closely resemble that of other folivores such as the mantled howler monkey (*Aloutta palliata*), which has a diet composed of 19% mature leaves and 44% new leaves (Glander 1977).

Some of the difference Lumholtz's and Huon tree kangaroo diets may reflect plant secondary metabolites from food species at Wasaunon. Three families, Balsaminaceae, Pandanaceae, and Rubiaceae, typically possess leaves which contain calcium oxalate, a known skin and mouth irritant. Tree kangaroos are said to consume all portions of the Balsaminaceae, but only the fruit and immature portions of leaves of Pandanaceae, and only immature leaves of Rubiaceae (Watson 1992). Limited data are available on wild tree kangaroo diets in New Guinea. The only available data recorded on Huon tree kangaroo diet come from Dendawang, which is situated south of Kumbul village in the Yopno region of YUS local level government area (YUS LLG). Wasaunon and Dendawang, the locality for Betz's (1997) study, are at different altitudes (3000m *vs.* 2400m) on the Huon Peninsula, and are thus home to different plant communities. Nevertheless, the tree kangaroo food plant lists from Wasaunon and the Dendawang field sites show some similarities at the family level, with 17 shared families and 19 shared genera (Table 2.4). Some of the differences between the localities may be partially due to incomplete identification. Food plants which *D. matschiei* in Wasaunon share with Dendawang include ferns (such as Dennstaedtiaceae), and vines and shrubs from the pepper (Piperaceae) family. They also share the herbaceous *Impatiens hawkeri* (Balsaminaceae) that grows in moist areas of the forest and on stream banks, and the large *Marratia* spp. (Marratiaceae) terrestrial ferns, that are a prominent constituent of the understory of mid-montane forests. When comparing the food plant species identified in Wasaunon and Dendawang, a few similarities emerged and revealed, that the consumption of *Timonius* (Rubiaceae), *Piper* (Piperaceae), terrestrial ferns such as genus (Dennstaedtiaceae and Marratiaceae), and *Elatostema* (Urticaceae) were common bet ween the two sites (Table 2.4).

Table 2.4 Shared Families and Genera of *Dendrolagus matschiei*, food plant species between Wasaunon and Dendawang.

Shared Family	**Shared Genus**
Actinidiaceae	*Saurauia*
Apiaceae	
Balsaminaceae	*Impatiens*
Dennstaedtiaceae	*Histiopteris*
Dryopteridaceae	*Dicksonia*
Ericaceae	*Dimorphathera*
Gesneriaceae	*Cyrtandra*
Urticaceae	*Elatostema* and *Cypholophus*
Rosaceae	*Rubus*
Rubiaceae	*Timonius* and *Psychotria*
Polygonaceae	*Polygonum*
Piperaceae	*Piper*
Marattiaceae	*Marattia*
Monimiaceae	*Leveria* and *Kibara*
Pteridaceae	*Pteris*
Podocarpaceae	*Podocarpus*
Solanaceae	*Solanum*

However, there are some differences in the food plant lists from Wasaunon and Dendawang. The most obvious is the identification of orchids (Orchidaceae) as important tree kangaroo food plants by Dendawang landowners but not by the Toweth and Worin landowners, or indeed by any previous studies on any tree kangaroo species (Coombes 2005; Flannery et al 1996; Proctar-Gray 1985; Tree Kangaroo and Mammal Group 2000). Orchidaceae is the largest plant family in New Guinea, with over 3000 known species, and orchids account for much of the plant diversity in epiphyte-rich montane forests such as the ones found at Wasaunon and Dendawang (Mittermeier 1997). There is no doubt that *D. matschiei* are capable of eating Orchidaceae – landowners from other parts of the Huon, such as the Yopno people, have also stated that *D. matschiei* eat orchids (Betz 1997[a]).

Another important tree kangaroo food plant family identified was Urticaceae (*Elatostema sp.*). Although Urticaceae are not as large a family as Orchidaceae they are equally prominent, especially in the forest under-story (Table 2.3). Like orchids they are typically low in toxins (Opler 1975), which may make them more attractive to tree kangaroos (Watson 1992).

It is important to stress that the plant lists and the plant part proportions of tree kangaroo diets from Wasaunon and Dendawang are not very different at all. It is likely that the composition of tree kangaroo diets may vary with location, soil type and altitude in conjunction with changes in the resource base, and plant collections will need to be made at a variety of locations to capture the full spectrum of tree kangaroo diets (per. com. Toweth landowners). For example, when Betz (1997), visited *D. matschiei* habitat at 2000-2500m with landowners from Kotet and Towet villages in 1995 (approximately 7 km southwest of Wasaunon), he was shown ten tree kangaroo food plant species that were on the Dendawang list, and ten that were not (Betz 1997[a]). Invariably the plants that were not shared with the Dendawang list were species not found at Dendawang, as confirmed by accompanying Dendawang landowners. The Kotet landowners said that *D. matschiei* consumes the fruit of a fig (Moraceae), which the Dendawang landowners stated does not occur on their land. On another occasion Towet landowners showed the author *Tom* trees, identified as *Carpodetus* spp., Saxifragaceae, which is part of the Huon tree kangaroo diet. The accompanying Dendawang landowner was certain that the species does not occur at Dendawang, and was unsure whether it was found at lower altitude forests down valley from that site.

The identification of a fig as a tree kangaroo food plant by Kotet and not by Dendawang landowners is interesting because it suggests that the relative proportions of plant parts in *D. matschiei* diets may not be fixed. Huon tree kangaroo has a wide altitude range (1500-3300 m), from lower montane forests to tree-line, and different populations live in different habitats with different vegetative resources. It is the only tree kangaroo that occurs on the Huon Peninsula, and thus occupies a wider ecological niche than most New Guinea tree kangaroos, which typically share their mountain ranges with one or two other species (Flannery et al 1996). For example, most of the PNG Central Cordillera is occupied by two species: *D. goodfellowi* and *D. dorianus*. *Dendrolagus goodfellowi* occurs at lower altitudes and *D. dorianus* at higher with a limited sympatric zone. Wild *D. goodfellowi* are known to consume figs, while *D. dorianus* may prefer ferns and leaves to fruit (Flannery 1995). It seems possible that *D. matschiei* at lower altitudes may show a more *goodfellowi*-like diet (consume a higher proportion of fruit), in conjunction with the greater fruit resources found in lower elevation forests, while high altitude *D. matschiei* would have a more folivorous diet.

This folivorous behavior in tree kangaroos is also found in other mammals such as the Howler monkeys (*Alouatta sp.*), possums (*Psuedochirops sp.*) and koalas (*Phascolarctos sp.*). Possums and koalas are generally referred to as specialist folivores rather than generalists (Hindell 1985; Hume 1999; Jones 2006). In contrast, Howler monkeys are capable of adapting to changes in the availability of resources present in their habitat. For example, in the presence of few fig trees Howler monkeys had a strong tendency towards folivory and in the presences of many fig trees, frugivory was dominant (Serio-silva 2002). Other studies have shown that Howler monkeys have the capacity to feed from many different plant species and have the ability to adapt to plant species available in different habitats (Bicca-Marques 1994; Crockett 1998; Asensio 2007). Additionally, Howler monkeys are said to cover large distances everyday (443m/day) because they are very selective in their feeding (Milton 1980; Cristo'Bal-azkarate 2007). This suggests that howler monkeys consume a wider variety of food items in order to meet their daily nutritional requirements and therefore posses a similar feeding behavior to tree kangaroos.

2.6 CONCLUSION

Literature on New Guinea tree kangaroo diets in the wild is very limited, thus the comparisons of food plant species between different habitat types can be problematic. The information on food plant species of the Huon tree kangaroo from the Wasaunon and Dendawang landowners agree with the previous Australian data that tree kangaroos prefer to eat many species of plants, with leaves and stems being the primary constituents of the diet. This is typical of the more generalist arboreal folivores (Montgomery 1978), and is probably related to the need for the animals to deal with the high levels of secondary compounds commonly found in leaves and stems of tropical plants. According to Toweth and Worin landowners Huon tree kangaroos concentrate on young leaves and stems which are typically less toxic and more nutritious (Hladik 1975; Coley 1983). A similar approach is also observed in other arboreal folivores such as mantled howler monkeys (*Aloutta palliata*) (Milton 1980).

The plant lists from the Wasaunon and Dendawang are not complete and further collecting is necessary. However, even once the full list from these two sites is known, there will still be a need for collections from other areas on the Huon Peninsula in order to approximate the complete plant menu for the Huon tree kangaroo diet. It would not be surprising if *D. matschiei* eat hundreds of species across its range. It is also possible that the composition of tree kangaroo diets varies in conjunction with altitudinal or habitat based resource variation, especially for species like *D. matschiei* that occupy a wide ecological niche. For example, fruit such as figs may form a greater proportion of *D. matschiei* diets at lower altitudes, while comprising a very small proportion or none of the diet at higher altitudes.

The large number of plant species eaten by New Guinea tree kangaroos and their preference for young or immature plants and plant parts suggests that they are well adapted to the frequent ecosystem disturbances that affect New Guinea's habitats (Johns 1986; Hovius 1998). The regrowth from these disturbances would probably be lower in toxins, contain more nutrients than mature plants, and thus be more suitable for tree kangaroos (Hladik 1975; Whitmore 1998). One likely conclusion from this possible flexibility is that habitat change and alteration due to natural (landslides, fires, etc) and human (selective logging) agents are probably not as great a threat to the Huon tree kangaroo as overhunting.

CHAPTER 3 Home Ranges and Activity Patterns of the Huon Tree Kangaroo in Papua New Guinea.

3.1 INTRODUCTION

The Huon tree kangaroo (*Dendrolagus matschiei*) is one of ten tree kangaroo species currently recognized in the world. Eight species are endemic to New Guinea and two are endemic to Australia (Martin 2005). Huon tree kangaroos (*D. matschiei*) are native to the Huon Peninsula in Morobe Province, PNG, with a limited distribution of 0.95/ha (Betz 1997[b]). All New Guinean tree kangaroo species are considered to be endangered (IUCN 2004) due to small and restricted ranges, specialized diet and habitat requirements (although many of these requirements are unknown or poorly known) (Betz 1997[a]).

Despite being considered endangered, Huon tree kangaroos along with New Guinea's seven other tree kangaroo species are poorly studied in contrast to the two species of Australian tree kangaroo (Martin 1992; Flannery 1996). There is currently no information available on habitat requirements, home range or activity patterns of any New Guinean tree kangaroo species. Long-term conservation of Huon tree kangaroos (*D. matschiei*) requires better understanding of ecological characteristics such as home range size, seasonal shifts in range, core areas, and dispersal rates and patterns. Knowledge of the home range and habitat use can provide information about diet and ecology that allow the development of ecological-based management strategies for wildlife (White 2002). This ecological knowledge combined with mapping techniques (gap analysis) can be used to ensure that representative habitat and ecosystems are present within an existing or proposed protected area or management zones (Scott and Caicco 1993).

Range sizes and habitat use are better known in the two species of Australian tree kangaroos. Lumholtz's tree kangaroo, *D. lumholtzi*, which is restricted to the Atherton and Evelyn Tablelands of north-east Australia's wet tropical rainforests, has been the subject of studies of home range (Newell 1999[c;] Coombes 2005), diet and behaviour (Procter-Gray 1984; Coombes 2005). Lumholtz's tree kangaroos have small home ranges, ranging from 0.69 ha (Newell

1999[b]) to 2.1 ha (Coombes 2005). Female *D. lumholtzi* are relatively solitary and maintain discrete home ranges independent of other females (Coombes 2005) with only minor overlap at the margins of other females (Newell 1999[c]). Newell (1999) found that females occupied smaller ranges (0.69 ha) than males (1.95 ha), while the females in Coombes' (2005) study had ranges as large as those of the males (2.1 ha average). Male *D. lumholtzi* maintained a home range independent of other males (Newell 1999[b;] Coombes 2005) but have a greater tendency to overlap with adjacent males as well as with several females. Bennett's tree kangaroos occupy a slightly larger home range compared to the Lumholtz's tree kangaroo, male *D. bennettianus* 3.8-6.4 ha and female *D. bennettianus* 3.7-5.5 ha (Procter-Gray 1985). Male and female *D. bennettianus* have exclusive home ranges, and while males remain solitary, females often share their home range with their offspring. Field studies of the Bennett's tree kangaroo suggest that male home range size is more related to body size, age and vigour rather than resources, which reflects their status and the number of females they interact with. This spatial distribution suggests that females may maintain ranges based on distribution of resources defended from other females whereas male spatial distribution is determined by the need to overlap several females.

This study seeks to describe the spatial use of habitat by Huon tree kangaroos (*D. matschiei*), focusing on estimating home range size as well as spatial distribution of male and females. The information obtained from this study will be used to support the development of effective management strategies to conserve populations of Huon and other tree kangaroos in the wild. Tree kangaroos are an important component of New Guinea's endemic marsupial fauna with special significance for indigenous land-owners (Mack 2005) and have an important role as flagship species for motivating the public and decision-makers to ensure that Papua New Guinea's ecosystems are protected and well managed.

3.2 METHODS

This study was conducted between March 2004 and November 2007 in an upper montane forest at a locality known as Wasaunon in the Sarawaget Ranges on the north coast of the

Huon Peninsula, Papua New Guinea (146° 54' 52.90" South, 6° 5' 31.68" East). The study area is about 984 ha in extent within a large tract (60,000 ha) of relatively undisturbed forest at an altitude of 3000m above sea level, with an average rainfall of approximately 2500mm p.a., and an average minimum temperature of 5°C and annual average maximum temperature of 30°C. The wettest season occurs from July through to August and the driest season from September to December, although rain is relatively evenly distributed throughout the year. The site supports an upper montane forest dominated by *Dacrydium, Decaspermum, Syzygium,* and *Dicksonia* (Jensen 2005).

Huon tree kangaroos (*D. matschiei*) were located for the study by a team of 6-8 local hunters searching visually within the vicinity of one kilometre of the camp. After sighting a tree kangaroo, the hunters used a traditional method to live-capture the animal. The undergrowth within a radius of approximately 10m around the tree in which the tree kangaroo was sitting was rapidly cleared and the cut vegetation was piled around the perimeter to create a temporary barrier known in the local language as an "*im*" (pronounced "eem"). One hunter then climbed the tree and proceeded to encourage the tree kangaroo to jump to the ground where it was hand-captured by the base of the tail, within the "*im*". The captured tree kangaroo was then quickly placed into a hessian bag, which helped to calm the animal while it was transported back to the camp. The capture process took approximately 15-20 minutes once the animal had been sighted and generally occurred in the early hours of the day (8am – 12pm).

Tree kangaroos were sedated for measurements and handling, either by inhalation of anesthetic (Isoflurane:Oxygen 0.5% - 1.5% to effect) or Telazol (I.M. 2 mg/kg). Animals were then weighed, measured (body length, tail length, skull width/length), and fitted with a radio transmitter mounted on a collar (MOD-205 VHF Transmitter; Telonics Inc. USA). Animals were fitted with PIT tags (AVID Microchip Company, CA, USA) implanted subcutaneously and suprascapularly. Animals were then kept under observation for a period of at least four hours. When they had sufficiently recovered they were released at the point of capture.

Animals were radio-located daily for six months using a hand-held radio receiver (AVM – LA12-Q receiver, AVM Instrument Company, CA, USA) with a three-element Yagi antenna. Locations were confirmed visually where possible (54% of locations were confirmed visually) and the position recorded using GPS (Garmin 12CX, Garmin International Inc, KS, USA or GeoExplorer^R 3, Trimble Navigation Ltd CA, USA).

The home range area for each individual was calculated according to three different methods: Harmonic mean (HM), Kernel (KM) and Minimum Convex Polygon (MCP), using Ranges VI software (Kenward 1996). The probabilistic methods (HM, KM) were included to provide some information about the distribution of activity within the ranges (i.e. cores) and the MCP method was included to provide comparisons with other studies. The number of locations required to adequately define home range were determined by the incremental area analysis function of Ranges VI and showed that between 80 to 110 locations were needed in this study (Figure 3.1). Individuals with less than 80 locations were discarded from further analyses; one animal was not included in the analysis, possessing only 70 locations.

Grid size was estimated through visual analysis of contour plots which showed minimal cluster between individual contours, in which case the default (40mx40m) cell size in Ranges6 was appropriate for this study/analyses. The smoothing factor is a variable that modulates the density estimated by a kernel function to vary the tightness with which contours conform to locations (Kenward 2001). This variable was determined by identifying a point in the kernel analysis where contours showed conformity towards the locations (smoothing factor = 40 in this study).

Home range cores were determined at the isopleths where the incremental change in home range size was minimized. The Harmonic cores defined in this way, were at 45% and 70% (Figure 3.2), while the kernel cores were at 50% and 75% (Figure 3.3). In both cases the 90% isopleths were used to define the entire range because it avoided undue emphasis on outliers that caused rapid increase in incremental change of area at isopleths above 90% (Figures 3.2, 3.3; (Kenward 2001)). These isopleths have been used to define the home ranges in the results. Results for the 95% isopleth have also been included, as well as 50% isopleth HM and 70% isopleth KM results, for comparison with other studies which commonly report 50, 70 and 95% isopleths.

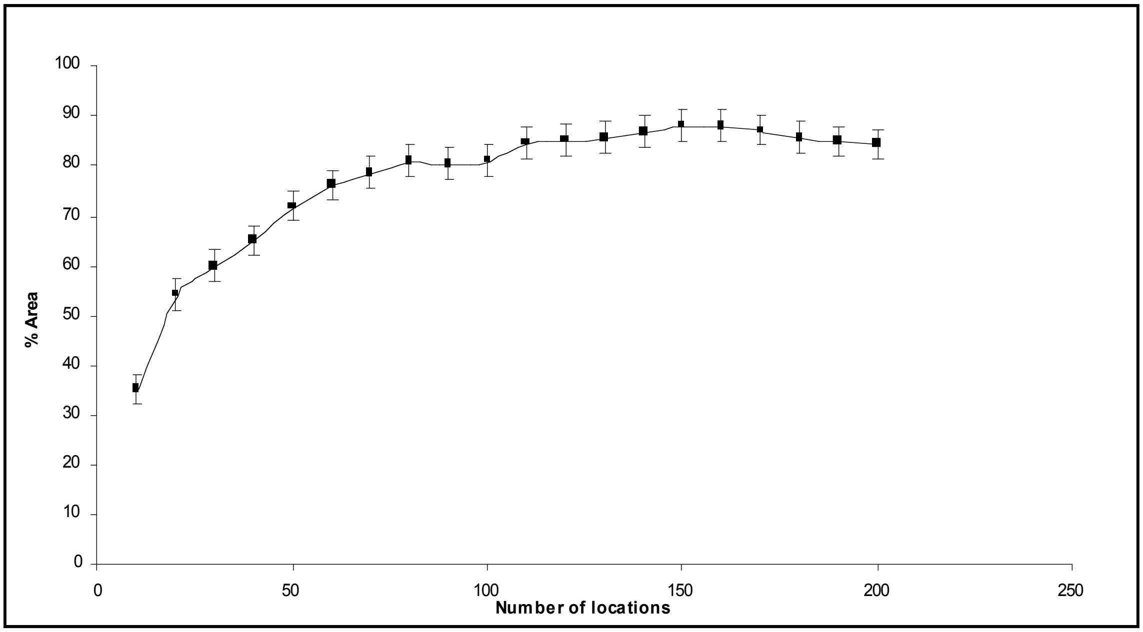


Figure 3.1 The incremental increase in home range size, calculated at the 90% Harmonic mean isopleth, as the number of locations included in the analysis increases (mean ± SE; *n* = 15).

The proportional incremental change in home range area moving out from the centre of activity by increments of 5% isopleths (means ± standard error; n = 15). Core areas corresponded to minima on the curve and the 90% isopleth was taken to represent the entire range without strong effects of outliers that increased the incremental changes at more inclusive isopleths (i.e. 95% and 100%).

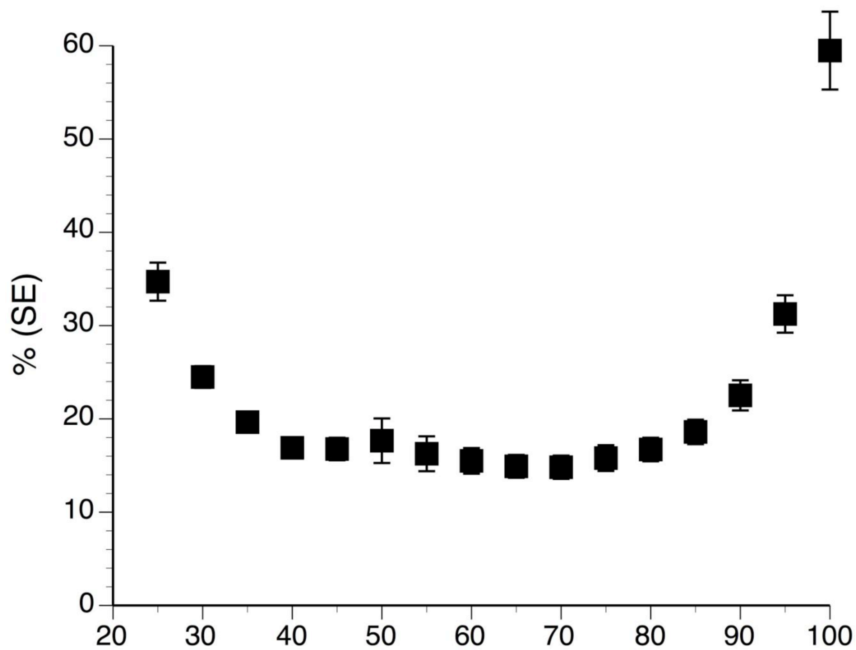


Figure 3.2 Areas calculated using the Harmonic mean algorithm with cores at 45% and 70% isopleths.

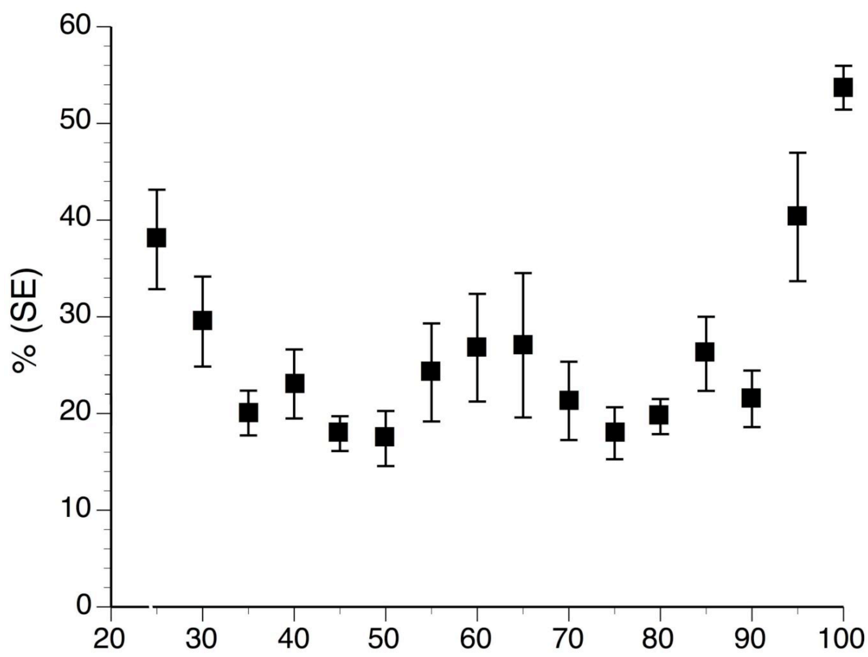


Figure 3.3 Areas calculated using the Kernel algorithm with cores at 50% and 75% isopleths.

Overlap between home ranges of neighboring individuals was calculated using the Ranges VI software, at core area isopleths of 45% and 70% for harmonic mean, 50% and 75% for kernel and 90% isopleth for both methods. Overlap was only calculated for pairs of individuals that were known, or strongly suspected to have contiguous, or closely contiguous without an intervening animal, ranges. Home range sizes of males and females were compared using Student's *t-test* (Fowler 1998).

3.3 RESULTS

Huon tree kangaroos (*D. matschiei*) had large home ranges, averaging 81.3 ± 16.9 ha (SEM, n = 15, 90% HM isopleth; Table 3.1) that overlapped extensively (>50% at 90% HM isopleth) with their neighbours (Table 3.2). There was no statistical difference between the home range size of males and females at any core of any of the three calculation algorithms used in this study.

Despite the extensive overlap at the level of the entire range (90% isopleth), at the level of the smaller core (45% HM, 50% KM) there was little (average of 5-10%) overlap between adjacent females or adjacent males. At the core (45% HM or 50% KM) female Huon tree kangaroos had relatively exclusive ranges, overlapped by male Huon tree kangaroos that tended to overlap several females.

Table 3.1 Home Range areas (ha) for adult male and female Huon tree kangaroos (D. matschiei) in upper montane forest at Wasaunon on Papua New Guinea's Huon Peninsula (mean ± SEM).

		45%	**50%**	**70%**	**75%**	**90%**	**95%**
Males (*n* = 7)	HM	21.7 ± 7.0	25 ± 8.1	38.6 ± 13.1	50.5 ± 17.6	81.8 ± 28.3	103.2 ± 35.1
mean ± se	Kernel	13.5 ± 4.6	16.1± 5.8	27.6 ± 9.5	40.1 ± 13.8	72.4 ± 24.7	99 ± 32.3
	MCP						120.4 ± 38.6
Females (*n* = 8)	HM	20.4 ± 5.1	23.4 ± 5.9	34.7 ± 8.9	46.9 ± 11.8	80.8 ± 20.3	108.7 ± 27.5
mean ± se	Kernel	10.2 ± 1.7	11.8 ± 2.0	24.5 ± 6.8	33.9 ± 9.1	65.5 ± 17.2	95.9 ± 28.0
	MCP						156.5 ± 37.6
Overall Mean							
(*n* = 15)	HM	20.9 ± 4.1	24.2 ± 4.8	36.6 ± 7.5	48.6 ± 9.9	81.3 ± 16.5	106.2 ± 21.2
	Kernel	11.7 ± 2.3	13.8 ± 2.9	25.9 ± 5.5	36.8 ± 7.8	68.7 ± 14.2	97.4 ± 20.5
	MCP						139.6 ± 26.5

Core areas were similar in both the harmonic mean and the kernel. With the harmonic mean, core areas occurred at the 45% and the 65% isopleths (Figure 3.2). On the other hand, the kernel core areas occurred at 50% and 75% isopleths (Figure 3.3).

Table 3.2 Area of overlap between adjacent Huon tree kangaroos (*D. matschiei*) in upper montane forest at Wasaunon on Papua New Guinea's Huon Peninsula (mean ± SEM).

	Area (ha)				
	45% HM	50% Ker	65% HM	75% Ker	90% HM
Females (*n*=3)	2.03 ± 1.83	0.98 ± 0.98	8.06 ± 5.91	6.95 ± 4.93	46.19 ± 17.08
Males (*n*=7)	1.09 ± 0.71	0.53 ± 0.22	5.50 ± 1.99	7.85 ± 2.08	40.56 ± 8.10
Males & females (*n*=5)	4.17 ± 1.82	2.26 ± 0.89	12.52 ± 4.01	14.77 ± 4.11	58.20 ± 10.98

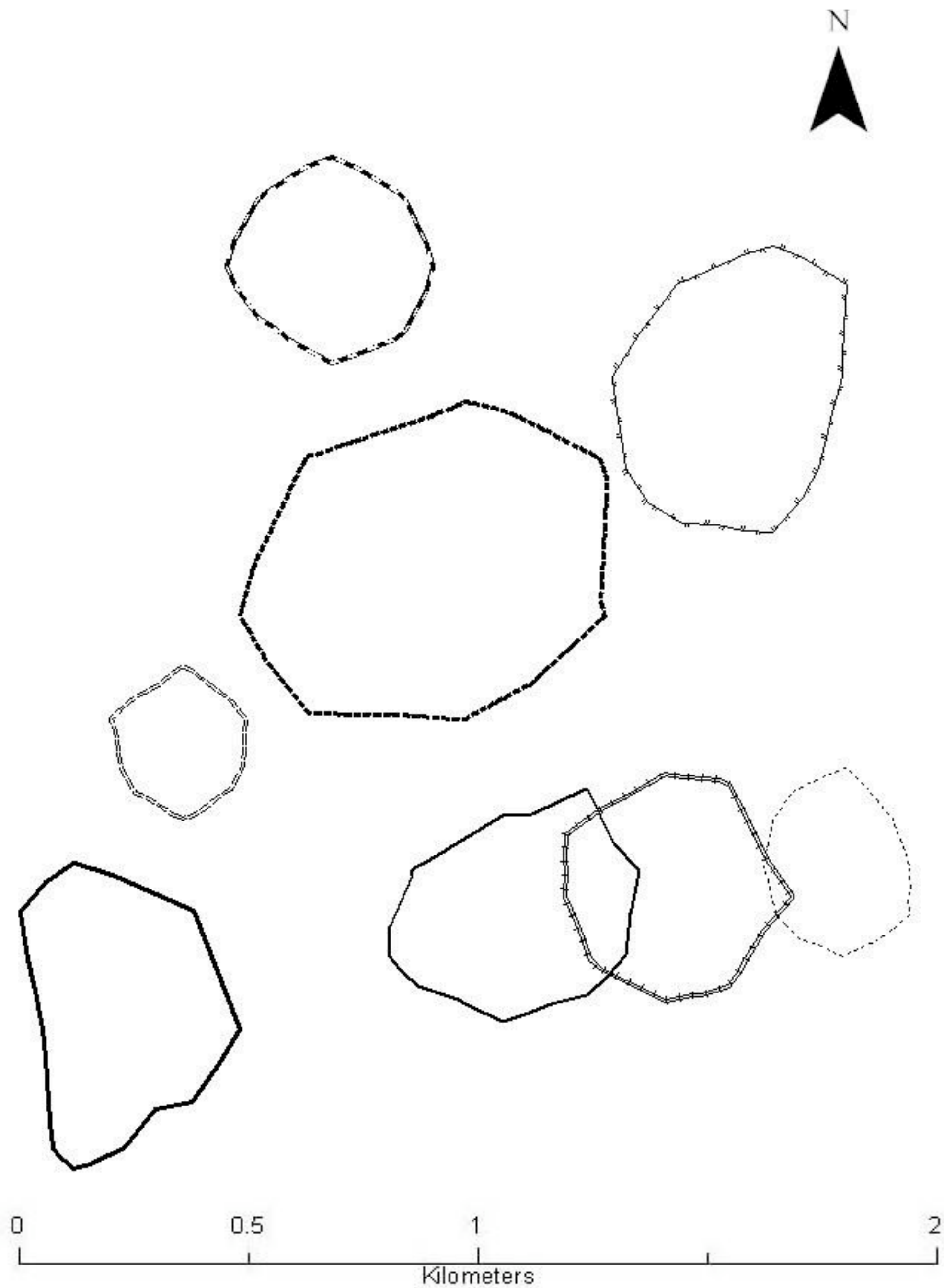


Figure 3.4 Core areas depicting small home ranges with minimal overlap between female *D. matschiei* at 45% Harmonic mean.

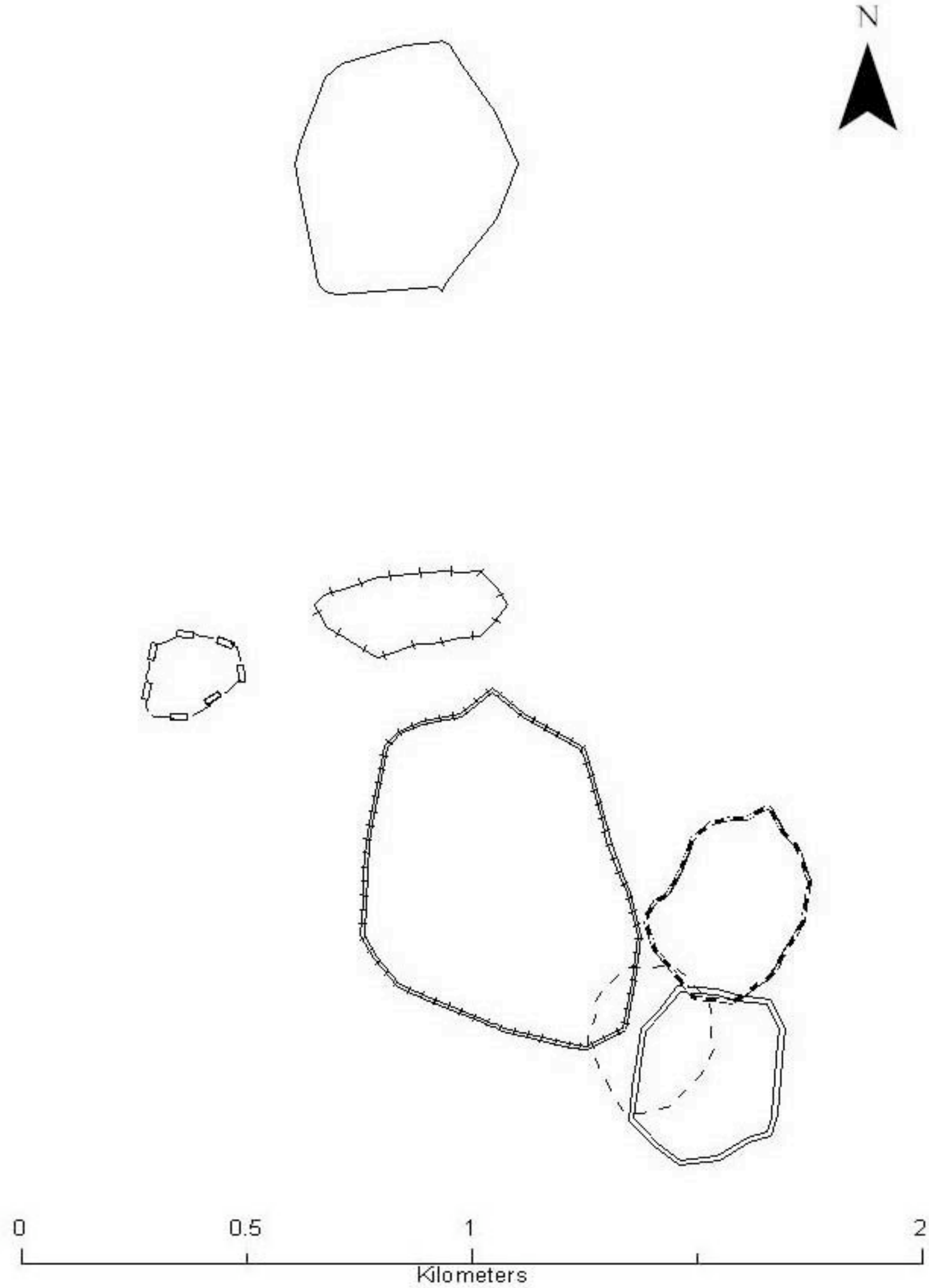


Figure 3.5 Core areas showing exclusive home ranges with some overlap between male *D. matschiei* at 45% Harmonic mean.

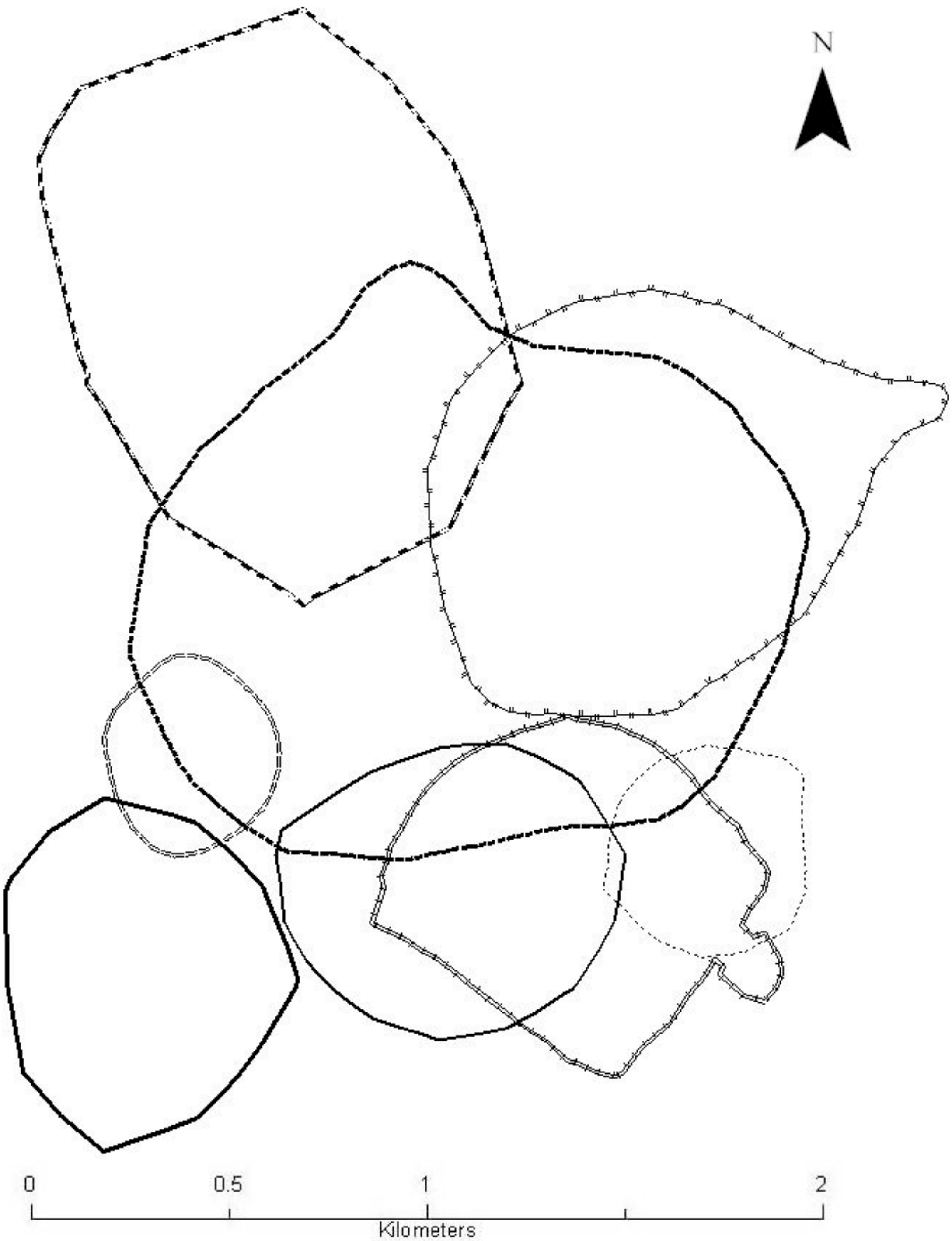


Figure 3.6 Female home ranges of the Huon tree kangaroo on the Huon Peninsula in Papua New Guinea (90% HM).

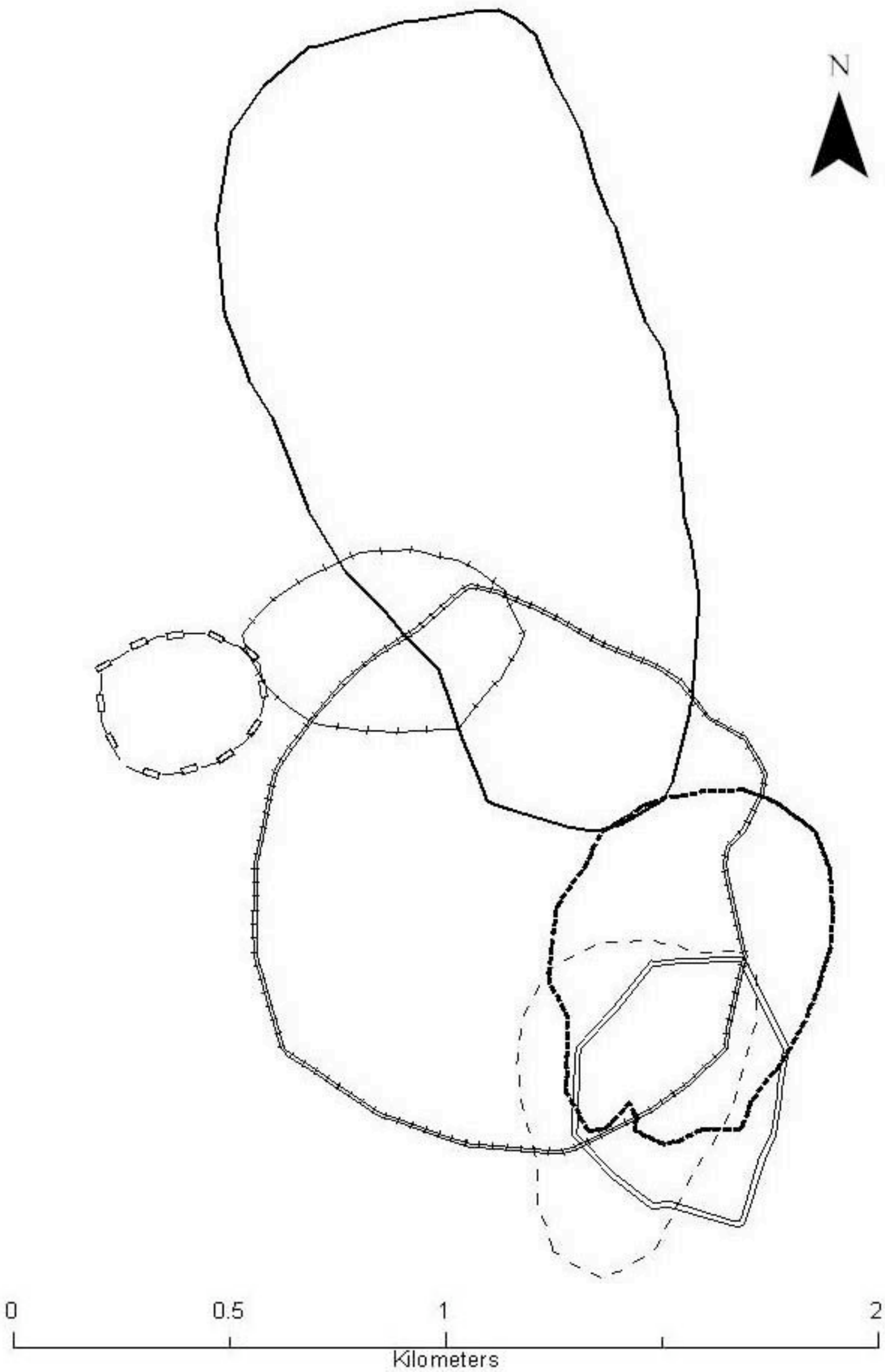


Figure 3.7 Male home ranges of the Huon tree kangaroo on the Huon Peninsula in Papua New Guinea (90% HM).

3.4 DISCUSSION

This study provides the first information on the movements and home range size of any New Guinean tree kangaroo species, substantially expanding our understanding that has previously been restricted to a few studies of Australian tree kangaroos (Procter-Gray 1985; Martin 1992; Newell 1999[c;] Coombes 2005). The tree kangaroos in this study had the largest home range size recorded for any tree kangaroo species (81.8 ± 28.3 ha; 90% HM), which was between 40 and 100 times larger than ranges measured for the similar sized Lumholtz's tree kangaroo (Table 3.1; (Newell 1999[b;] Coombes 2005). Male and female Huon tree kangaroos also ranged over similar areas, in contrast with Newell's (1999) study of *D. lumholtzi*, where males had substantially larger ranges than females. Understanding this large variation in home range between tree kangaroo species is particularly important to understanding the space use and habitat requirements for conservation of tree kangaroos. In this study we have reported results using a variety of calculation techniques (Harmonic mean, Kernel and Minimum Convex Polygon) to maximize the potential for comparability with past and future studies. However, given that the pattern of results is very similar between the Harmonic mean and Kernel techniques, we will largely discuss the results of the harmonic mean algorithm, as the most commonly used technique in the literature.

There are three effects that may explain the large variation between the home range of the Huon tree kangaroo and its Australian congeners; habitat fragmentation effects, altitude and its effects on productivity, and effects of past hunting. Habitat fragmentation is widely regarded as a major threat to the persistence of wildlife populations (Rolstad 1991; Fahrig 1994; Wiens 1995). Hhowever, little is known about mechanisms underlying population responses to fragmentation (Wiens 1993; Diffendorfer 1995; Ims 1995). The studies of *D. lumholtzi* were conducted in strongly fragmented habitat, whereas this study was conducted in largely intact primary rainforest. Clearing of forest vegetation for agriculture or settlements results in a reduction of available habitat and, more particularly, in the fragmentation of habitat (Forman 1995). Habitat fragmentation or shape determines the distribution of resources in the environment (Ims 1995), which in turn largely determines spatial distribution of individuals within it (Emlen 1977; Slobodchikoff 1984). For example, brush-tailed phascogales (*Phascogale tapoatafa*) and squirrel gliders (*Petaurus norfolcensis*) in roadside habitats (fragmented forest) had substantially smaller home ranges compared to individuals in continuous forest (van der Ree 2001; van der Ree 2003), possibly associated with a higher density of large trees and higher habitat quality in small fragmented areas. The roadside was protected within an agriculture landscape of relatively high nutrient soils (van der Ree 2001), whereas the continuous forest had not initially been cleared as it was less suitable for agriculture. The author (van der Ree 2001, 2003) interpreted the smaller range size of females in the fragmented habitat as indicating higher habitat quality of these fragments because habitat quality and environmental productivity are major determinants of home range size (Lindstedt 1986) and female home range reflect resource availability (Clutton-Brock 1978; Ims 1987). Habitat fragmentation can also alter social distributions. The distribution of male and female mammals within a habitat affects the mating patterns of populations (Clutton-Brock 1978; Clutton-Brock 1989). Therefore, habitat fragmentation has the potential to influence the social and mating systems of a population (Yahner 1997) by influencing the spatial distribution of individuals (Davies 1991).

Secondly, the large home range size of the Huon tree kangaroo may be due to effects of altitude on habitat productivity and plant diversity. Plant species richness and diversity decreases with increasing altitude along an altitudinal gradient (Rannie 1986), and the accompanying decrease in average temperature slows plant growth (Went 1953). This could result in lower productivity of the high altitude (3000m) Huon tree kangaroo habitat in this study compared to studies of the Lumholtz's tree kangaroo conducted at 700m altitude. The low productivity of high altitude habitat may force the Huon tree kangaroo to maintain large home ranges to include sufficient resources for maintenance and reproduction.

Assume that an animal utilizes a minimum area that can sustain its energetic requirements. Consider an animal of energetic requirements R (kcal $\cdot$ day^{-1}) and the environment provides utilizable energy at a rate P (kcals $\cdot$ day^{-1} $\cdot$ unit area^{-1}). The simplest expression for home range (*H*) thus becomes $H = R/P$ (Lieth 1975). From this equation, it can be noted that within a trophic class, animals in habitats of high productivity will have a smaller home range than animals in habitats of lower productivity. Thus, an animal living in a habitat of low productivity will have a larger home range than that predicted by the generalized relationship between home range and body weight (the bigger the animal the larger the home range (McNab 1963)). Home range size is directly related to the productivity variables such as latitude and precipitation (Rosenzweig 1968) and an overview of the productivity of the biosphere also indicates these variables to be most appropriate (Lieth 1975). Consequently, if increasing latitude is associated with decreasing primary productivity, we would expect home range size of a given species to increase with latitude.

Lastly, although the current study was conducted in a conservation area and where current hunting is low, hunting is an important customary practice for rural men in Papua New Guinea (Dwyer 1984; Dwyer 1991), and the effects over many years of past hunting have influenced the population distribution. In comparison, hunting has not been an important influence on tree kangaroos in Australia for a much longer period. Hunting of wildlife for human consumption has been identified as both a conservation and human livelihood issue (Bennett 2002; Brown 2003; Milner-Gullard 2003) because it can lead to a decline in population of the target species (Bennett 2000; Peres 2000a; Peres 2000b; Steadman 2002). Hunting is especially problematic in the humid tropics, where the low biological production of large bodied animals frequently cannot meet the hunting pressure (Robinson 2000). Hunting could have direct and indirect effects on density and range size of tree kangaroos. Hunting could have reduced the density of *D. matschiei* below the carrying capacity of the habitat. This low density might allow individuals to maintain larger home ranges because of low numbers of territorial interactions with their neighbors, leading to a dynamic adjustment between reduced densities and increased ranges size. Hunting can also affect the behavior of prey animals, influencing them to maintain lower densities to avoid predators and hunters (Mack 2005).

Field studies conducted on the Bennett's tree kangaroo by Roger Martin suggest that Bennett's tree kangaroos were once restricted to "*taboo*" sites (Mt Finnigan) located on traditional Aboriginal land on Shipton's Flat in far northeast Queensland. This was attributed to no hunting practices on sacred land where Aboriginals believed their ancestors originated. This has changed over the past few decades and Bennett's tree kangaroos are now commonly found in the lowlands due to low levels of hunting since the war.

3.4.1 Core Areas and Overlap

Unlike *D. lumholtzi* whose females are effectively solitary and maintain exclusive ranges with little overlap from neighboring females at the 90% HM isopleths ((Newell 1999[b]), ranges of female *D. matschiei* overlap extensively with their neighbours (Table 3.2). However, female *D. matschiei* do maintain an exclusive, solitary core (45% HM, 50% KM) within their range (Figures 3.4, 3.5). Identifying the core area provides an important theoretical framework for describing selected areas that contain resting sites, shelter, and reliable food sources for these tree kangaroos (Burt 1943; Kaufmann 1962). In this study, we used a numerical procedure to determine core areas that made no assumptions about the likely cores, but rather defined cores as the isopleths where the incremental increase in range size was minimized. The core areas we describe were defined by the way that individual tree kangaroos structured their activity within their range, as relative concentrations of activity; and, therefore, have greater ecological significance compared to studies that use an *a priori* statistical definition, and commonly define the "core" as either 50% or 70% (White 1990; Kenward 2001). Within the core of activity, males overlapped extensively with females but relatively little with other males. The approach used in this study to define the core home range was similar to that used by Coombes (2005) who also found similar exclusive core areas at 55% and 75% HM for both males and females, in contrast to this study where male core areas overlapped with several females on a ratio of 1:3 (males:female). In Newell's (1999) study, female ranges were exclusive (90% HM), but males overlapped several females. In *D. matschiei*, male distribution is influenced by female distribution as in *D. lumholtzi* (Procter-Gray 1985; Pritto 2002; Coombes 2004; Hoset et al 2007).

The identification of core area is essential in the estimation of population density in mammals (Forsyth 1973; Clutton-Brock 1978; Harestad 1979; Benson 2006) and the exclusive core area of females identified is important because it helps to identify social spacing between individual tree kangaroos (i.e. how much space each animal requires in that particular habitat) (Wilson 1975). Alternatively, core areas can also identify resources availability, because home range and resource abundance have an inverse relationship (Harestad 1979). In this case, when an animal has a home range twice the size of another, it is because resources per unit area are proportionally lower (Brown 1964) so larger home ranges would reflect lower resource densities (Davies 1978) possibly due to the effects of altitude on productivity (Rannie 1986). Either way, female density is particularly important in conservation biology because it is females that determine the reproductive rate of the population (Wolff 1997). From the exclusive core area of 20.4 ha (45% HM; Table 3.1), we can provide the first estimate of female density for *D. matschiei*, one female per 20-21 hectares in this habitat (Say 2004). From this density, the population of females within the 76000 ha pledged for conservation on the Huon Peninsula in Papua New Guinea could be calculated at approximately 3700. However, we need to look at this figure carefully. A simple extrapolation of this sort from the current study assumes that all the land pledged for conservation is suitable tree kangaroo habitat, and the density equal across that area. If the carrying capacity of the habitat for tree kangaroos is strongly affected by productivity, driven by an altitudinal gradient of temperature, as discussed above, much of the pledged area is at lower altitude and could have higher densities of tree kangaroos. If, on the other hand, the density of tree kangaroos at the Wasaunon study site was depressed by the impacts of past hunting, as discussed above, then much of the pledged area is closer to the villages and likely to have sustained higher hunting pressure in the past, with consequent lower density (Mack 2005). Clearly, although we can now make the first estimates of tree kangaroo population in the pledged conservation area, understanding the value of that estimate depends on understanding the variation in quality of the habitat and consequent variation in density of tree kangaroos across the landscape.

Neighbouring tree kangaroos overlapped each other extensively at the level of the entire range (90% HM Figure 3.7). This is important because it clearly signifies that in this study, *D. matschiei* did not have exclusive home ranges outside the inner cores. This finding differs from studies conducted on the Australian Lumholtz's tree kangaroo which show that females have exclusive home ranges, while males overlap with each other as well as with several other females (90% HM) (Newell 1999[c]). This apparent tolerance of overlap with adjacent females could be associated with small dispersal distances in females that would lead to high degrees of relatedness in adjacent females (Johnson 1986), so the tolerated neighbors may be sisters or mother and daughter. Coombes (2005) suggested that possibility for one pair of females in her study. Alternatively, *D. matschiei* may not be as solitary a species as *D. lumholtzi*, even though they do maintain an exclusive range core. Lastly, the two tree kangaroo species may be equally solitary, but range size and overlap may interact in a complex way with density. Mammals frequently put up with large amounts of overlap in the areas they use (Fleharty 1973; Mares 1976; Metzgar 1979) as well as the periphery area of their home range, territories and core areas (Wittenberger 1981). In this scenario the low density *D. matschiei* of this study have low numbers of territorial encounters with their neighbours and so are tolerant of overlap, whereas the high density populations of *D. lumholtzi* studied by Newell (1999) and Coombes (2005) have large numbers of interactions with their neighbours that promote more intense territorial defense and thus not only smaller ranges, but also lower tolerance of overlap. Consequently, if this were true, and either altitude or hunting pressure have contributed to the large ranges seen in this study, then we might expect that either in lower altitude habitat, or with recovery of population after cessation of hunting, the pattern of smaller, but exclusive ranges seen in *D. lumholtzi* would apply also to *D. matschie*

3.4.2 Comparison with other folivores

Large variation in home range size was found between the Huon tree kangaroo and the Lumholtz's tree kangaroo, but also substantial variation in the home ranges reported for other arboreal folivorous mammals (Table 3.3). A number of factors are known to influence home range including: habitat, social organization, ecology, temperature, rate of productivity and body mass (Troy 1993). Body mass particularly is thought to determine home range size due to the absolutely great requirements as size increases (McNab 1963; Milton 1976; Harestad 1979; Lindstedt et al 1986; White 2002). This relationship is broadly evident among the arboreal folivores, with larger ranges in larger animals (Table 3.3), but does not explain the difference between the tree kangaroo species which all have similar body sizes. For example, *D. lumholtzi* generally has a similar body size compared to *D. matschiei* (Table 3.3). However, show a large variation in home range size. The common brushtail possum (*Trichosurus vulpecula*) is another example showing similar body size to the Green ringtail possum (*Psuedochirops archeri*) and yet show a large variation in home range size. This clearly suggests that body size is not a major factor in determining tree kangaroo home range size. Therefore, other factors must play an important role, such as dietary energy content, latitude, altitude, temperature and rainfall (Mueller 2001). Additionally factors such as age and vigour can also be taken into consideration, however, vigour is difficult to quantify and measure scientifically (Martin 1996).

3.4.3 Implications for Conservation

The prediction of small populations has become a key issue in ecology and conservation biology. Experimental studies have shown population size and habitat area to be strong predictors of extinction and vulnerability (Terborgh 1980; Berger 1990). This study provides a reference point for population density and range size that can be used in assessing the value of specific management actions (Jackson 1996). The availability of resources to conservation programs are limited and data on endangered species are inadequate or unavailable. Therefore, there is a critical need for general rules for predicting minimum reserve size and the minimum viable size of wildlife populations (Lacy 1992). Because executive decisions are frequently made without time or data, general yet scientifically reliable estimates of minimum viable population (MVP) sizes and habitat areas are essential (Pressey 1993). This study has contributed to the study of *D. matschiei* by providing the first estimates of population density, population size and habitat area required by an individual New Guinea tree kangaroo. We have also identified likely mechanisms for variations in the density of tree kangaroos. The prediction affects of those mechanisms, changes in range size and density over altitudinal gradient or over time in response to cessation of habitat fragmentation and hunting, can be experimentally tested and used in developing management strategies for this species.

Table 3.3 Comparison of home range sizes of Matschie's tree kangaroo with other arboreal folivores.

Species	*Body Mass (Kg)*	*Method*	*Home Range (ha) (mean ± sd)*
Dendrolagus matschiei	6.23 – 7.0	90% HM[1]	M 81.8 ± 28.3
			F 80.8 ± 20.3
		MCP[1]	M 120.4 ± 38.6
			F 156.5 ± 37.6
		90% Kernel[1]	M 72.4± 24.7
			F 65.5 ± 17.2
D. lumholtzi	4.8 – 7.8	90% HM[2]	M 2.1 ± 0.7
			F 2.1 ± 0.8
		MCP[2]	M 3.1 ± 0.7
			F 5.3 ± 2.8
	6.0 – 7.5	90% HM[3]	M 0.689 ± 0.4
			F 1.952 ± 0.68
		MCP[3]	M 2.80 ± 0.65
			F 1.06 ± 0.56
	7.0 – 9.0	MCP[4]	M 4.4
			F 1.2-2.6
D. bennettianus	10.5 – 13.5	95% HM[5]	M 3.8-29.8
			F 3.7-9.8
		MCP[5]	M 6.4-40.0
			F 5.5-8.3
Phascolarctos cinereus (Koala)	8.5 – 12.0	90% HM[6]	M 1.7 ± 1.0
			F 1.2 ± 0.7
		95% Kernel[7]	M 34.4 ± 11.8
			F 15.0 ± 29.4
Hemibelideus lemuroids (Lemuroid ringtail possum)	0.8 – 1.1	MCP[8]	0.6 ± 0.1
Trichosurus vulpecula (Common brushtail possum)	1.8 – 2.6	95% HM[9]	13.7 ± 5.5
Alouatta palliate (Howler Monkey)	3.0 – 9.0	MCP[10]	9.9
Psuedochirops archeri (Green ringtail possum)	1-1.5	MCP[11]	0.222 ± 0.043
		HM[11]	0.047 ± 0.009

This study[1], (Coombes 2005)[2], (Newell 1999[c])[3], (Procter-Gray 1985)[4], (Martin 1992)[5], (Mitchell 1990)[6], (White 1999)[7], (Wilson 2000)[8], (Scrivener 2000)[9], (Glander 1981)[10], (Krockenberger In Prep.)[11].

CHAPTER 4 Dispersal of a juvenile male Huon Tree Kangaroo, *Dendrolagus matschiei* in a continuous forest.

4.1 INTRODUCTION

The Huon tree kangaroo (*Dendrolagus matschiei*) is one of the ten tree kangaroo species found in the world, eight in New Guinea and two in Australia. Like its Australian congeners, the Huon tree kangaroo is also folivorous, making it one of New Guinea's largest arboreal folivores (Flannery 1992). The Huon tree kangaroo (*D. matschiei*) along with New Guinea's seven other tree kangaroo species are poorly studied in contrast to the Lumholtz's tree kangaroo (*Dendrolagus lumholtzi*) and the Bennett's tree kangaroo (*Dendrolagus bennettianus*) in Australia, and little is known of its ecology other than aspects of its home range (Porolak *et al*. in prep) and diet (Porolak 2008). The Huon tree kangaroo (*D. matschiei*) is endemic to the Huon Peninsula in Morobe Province, thus limiting its distribution to only a small area of Papua New Guinea (Flannery 1995). Due to its rarity and geographical location, the Huon tree kangaroo is isolated from the rest of the world and consequently difficult to study, but sufficient data exists for it to be considered as endangered by the *International Union for Conservation of Nature* (IUCN 2004).

Tree kangaroo populations are subject to a number of serious threatening processes (IUCN 2004). Hunting is a major contributing factor in the decline of Huon tree kangaroo populations, as well as other *Dendrolagus* species in Papua New Guinea (Flannery 1998; Betz 2001; Mack and West 2005; Martin 2005). Until now habitat loss or degradation due to human activity has not been considered a serious threat to New Guinean tree kangaroos, but the rate and scale of forest degradation in New Guinea has accelerated sharply, with 83% of the forest predicted to be cleared or degraded by the year 2021 (Sherman 2008), so habitat loss is an emerging threat to tree kangaroo populations. Conserving tree kangaroos in the face of the threats of hunting and particularly habitat destruction requires a better understanding of their ecology.

Dispersal of mammals is an important component of population studies (Johnson 1991; Beier 1995; Cowan 1997; Gompper 1998). Dispersal is regarded as the movements of individuals from their point of origin to where they reproduce (Howard 1960), as long as the place of reproduction is not an exploratory movement or extension of home range boundaries (Lidicker 1975). Dispersal differs from migration – mass directional movement of large numbers of a species from one location to another (Begon 1996). Dispersal plays an important role in the maintenance and regulation of existing population and in establishments of new populations (Sharp 1997). Long-term persistence of tree kangaroo populations will depend on dispersal of individuals throughout their habitat (Kanowski 2002). Currently no information is available on the dispersal of tree kangaroos, except for one field observation, which documented dispersal patterns of a juvenile male Bennett's tree kangaroo (*D. bennettianus*) on Shipton's Flat, Cape York in far northeast Queensland (Martin 1996). Currently there is no published information available on dispersal patterns of any New Guinean tree kangaroo species. Understanding dispersal in tree kangaroos is important to planning conservation areas, helping us to determine the physical size of areas required as well as the possible patterns of gene flow within tree kangaroo populations.

This note documents dispersal of a juvenile male Huon tree kangaroo tracked as a part of the study of home range and movement of tree kangaroos at a high altitude study site on the Huon peninsula, PNG (Porolak *et al* in prep). The juvenile male that forms the focus of this study was radio-collared as a young-at-foot when it was captured along with its mother in 2005, and then tracked until the completion of this study in November 2007. The techniques used to capture, collar, track and define home range follow those of Porolak *et al* in prep.

4.2 RESULTS

In 2006, Joey who later became Joel started displaying evidence of dispersal by slowly moving away from its point of origin or natal location. By the end of 2006 Joel had established a totally independent home range away from its original home range (Figure 4.1).

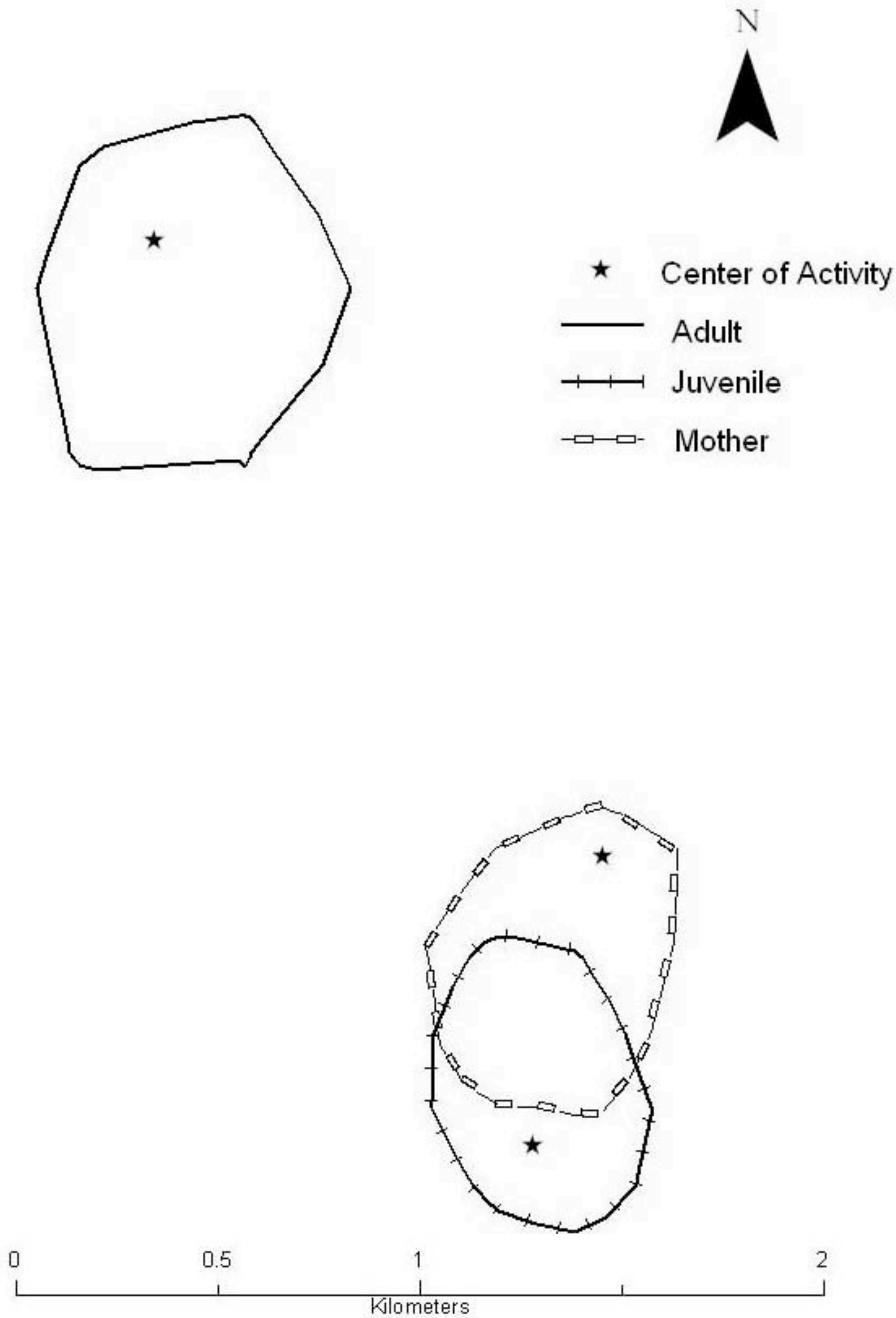


Figure 4.1 Dispersal shown in a single sub-adult male *D. matschiei* on the Huon Peninsula in Papua New Guinea (45% HM isopleths).

The juvenile male Huon tree kangaroo was approximately 15 months old in April 2005, when tracking commenced at Wasaunon on the Huon Peninsula of Papua New Guinea. During the first three weeks of tracking he was found within his mother's home range, never actually in the same tree as the mother, but within 30-50 meters from the mother. By the end of August, the juvenile started moving further from its mother and was regularly found in new locations. After the second week of September, the juvenile started showing signs of fidelity to its own extension in area and maintained that new area for the remaining two months of tracking. This established the area designated as the juvenile home range, locations from April to November 2005, which overlapped extensively with his mother's range, but his centre of activity was displaced nearly 600m from his mother's centre of activity (Table 4.1).

Table 4.1 Mean displacements between a juvenile male *D. matschiei* and its mother over a period of two years (2005-2006).

	Distance (m)
Mother to juvenile	593.10
Mother to adult	1522.33
Juvenile to adult	1954.38

The second tracking season started in June 2006. At the age of was 2 years, 3 months the young male proved initially difficult to track because he was moving a lot. The animal was very difficult to track during July 2006 because it was not only found on the ground but also moving during attempts to locate him. He was eventually sighted in August approximately 2km (Table 4.1) from his natal location and began to be found in that vicinity regularly during August 2006. At the end of September, the animal was sighted approximately 30m from two unmonitored females, and seven days later it was again sighted in the same tree with one of the monitored female, who was collared in 2006. There were no major movements or excursions in the animal's new location from September to November 2006 whilst the animal showed signs of site fidelity and maintained its new home range, locations from June to

November 2006 designated as the adult range, with a centre of activity over 1500 m from his mother's range.

4.3 DISCUSSION

This study originated as a larger study of home range size and habitat use of free-ranging Huon tree kangaroos (*D. matschiei*). However, sufficient data became available on dispersal in one juvenile male *D. matschiei* to provide the first documentation of dispersal in any of the New Guinean tree kangaroo species.

The available data contained the movements of the young male over a two year period and found that the young male *D. matschiei* initially dispersed a short distance, made several exploratory movements and returned to its natal location. He dispersed before the age of three years and most (90%) of the dispersal occurred between 23 and 28 months of age and was confined to the months between February and July 2006. The distance between the natal area and the place of settlement of dispersing male ranged from 0.5km to 2km (Table 4.1).

From the literature there are three major mechanisms for the dispersal of juvenile animals (Greenwood 1980; Dobson 1982; Johnson 1986; Johnson 1987). These are competition for mates, competition for resources and the avoidance of inbreeding, which occurs as a result of sex-biased dispersal found in a number of species (Clutton-Brock 1989; Veltman 1990; Johnson 1991). Male-biased dispersal occurs in mammals with polygynous mating systems (Greenwood 1980; Greenwood 1983) because intra-sexual competition is more intense among young males than females (Trivers 1972). Young males are more likely to disperse in search of better mating opportunities or are forced to disperse by aggressive dominant males. This supports the observation made on dispersal by juvenile males in Bennett's tree kangaroo in far northeast Queensland, where young males at the ages of 14-18 months were constantly found on the ground covering large distances (Martin 1996). The increase in sexual behaviour and social pressure in koalas were suggested as contributing factors towards the dispersal of koalas (Martin 1985; Ramsay 1999), to ensure better mating/breeding opportunities and avoid aggression from dominant males (Mitchell 1990[a;] Mitchell 1990[b]).

The information gathered from this study supports previous studies that social behaviour is highly likely to be a contributing factor towards the dispersal of young male *D. matschiei,* and although dispersal also occurs in females the effect of the mechanisms would differ from the males (Dobson 1979).

Observations of the forest at Wasaunon suggest that, resources (food plant species) were abundant throughout the study site and therefore the competition for resources is not a major contributing factor in the dispersal of young tree kangaroos. It is highly likely that, the competition for mating partners or aggression from dominant males would be the most likely factors contributing to the dispersal of sub-adult tree kangaroos. In this case, the dispersal behaviour shown by Joel is consistent with the free-ranging Bennett's tree kangaroos in Australia (Martin 1996), which were observed to engage in battles over territory. Although no territorial fights between adult Huon tree kangaroos were observed in the field, evidence of territorial fights were present in one of the adult males which had a torn nostril and missing one ear. This strongly suggests that young male tree kangaroos do compete with aggressive dominant males for territory and access to females. While the information obtained by this study is similar in some respects to dispersal patterns displayed in other mammals (Metzgar 1979; Dique 2003), there are a number of notable differences. Compared to other folivores such as, koalas and Bennett's tree kangaroos, *D. matschiei* has a smaller displacement distance (Table 4.1). Koalas have large displacement distances with a dispersal range of 0.3 to 10.6km (Dique 2003). Bennett's tree kangaroos have a slightly lower dispersal range (2 to 5km) (Martin 1996), but still higher in comparison with the Huon tree kangaroos.

The large variation in dispersal distances may be attributed to the density of animal populations in the each study site. Previous studies have shown that high population densities results in a decrease in home range size (Erlinge 1990; Kjellander 2004; Glessner 2005). The Huon tree kangaroo population is likely to be under the carrying the capacity due to severe hunting practices in Papua New Guinea (Flannery 1998; Mack and West 2005; Martin 2005) and therefore would not have to disperse great distances in order to establish a new home range. In contrast, koalas and Bennett's tree kangaroos are not subjected to hunting pressures would consequently have higher densities thus resulting in dispersing greater distances in order to establish new home ranges.

From the data presented here, together with the review of data from other studies of mammal dispersal patterns, we would suggest that young male tree kangaroos disperse from their natal location prior to breeding as a result of the social behaviour and mating systems as well as other factors such competition for resources.

CHAPTER 5 General Conclusions

5.1 INTRODUCTION

Previous knowledge of *D. matschiei* ecology and habitat use was limited except for one population study on *D. matschiei* on the Huon Peninsula of Papua New Guinea (Betz 1997[a]; Betz 1997[b]; Betz 2001). Current knowledge indicates that *D. matschiei* occurs on the Huon Peninsula of Papua New Guinea from altitudes of 1000m to 3100m above sea level. *D. matschiei* have relatively large home ranges with a small degree of overlap occurring at their core areas. *D. matschiei* are threatened by severe hunting, and habitat loss is increasingly becoming a threat (Sherman 2008).

This study investigated home range sizes and habitat use of *D. matschiei* on the Huon Peninsula of Papua New Guinea in order to improve our understanding of the ecology and biology of *D. matschiei*. To be able to conserve this species from extinction, it is essential to gather information on spatial use and habitat use which included nutritional requirements (food plants species). This study was able to provide information on home range size and food plant species. However, data on food plant species was only based on ethno-biological knowledge from the local people of the ToBai and Opmat Clans of the Uruwa valley in YUS LLG region on the Huon Peninsula in Papua New Guinea. A study confirming the traditional knowledge is being carried out currently.

Studies on the Lumholtz's tree kangaroo in Australia suggest that they are generalist folivores but showed no preferences to tree species (Newell 1999[b]; Coombes 2005). This is strongly supported by this study, which also suggests that *D. matschiei* are generalist folivores, however *D. matschiei* show that they have a preference over tree species (85% of sightings on *Decrydium nidulum*).

5.2 HOME RANGE

This study is the first to take on home range analyses on *D. matschiei* as well as on any of the other New Guinean tree kangaroo species. This initial approach in investigating spatial use has given us an idea on the distribution of the Huon tree kangaroo populations in the wild. The distribution of individual home ranges has shown that, female home range sizes are small with minimal overlap at core edges. The identification of the core area is essential in the estimation of population density in mammals (Clutton-Brock 1978; Harestad 1979). Females determine the reproductive rate of a population (Wolff 1997) therefore by identifying core areas of females, we may be able to provide the first estimates of female *D. matschiei* densities (Say 2004).

There are three major factors that may have an impact on the home range size of *D. matschiei* and they include: hunting practices, loss of habitat and possibly the effects of altitude on productivity. Hunting practices, a traditional practice in New Guinea, has over the past three decades put a lot of pressure on the wild Huon tree kangaroo population by isolating the population to uninhibited parts of the forest. This may influence the current home range size resulting in larger home ranges due to wild populations being under the carrying capacity (Begon 1986). Loss of habitat however is not a major threat but is increasing becoming a threat and could also have a detrimental effect to tree kangaroo habitat as well as their home range size, by forcing wild populations to establish smaller home range sizes due to lack of resources and space. The altitudinal effect on productivity is another factor that may affect the home range size of the Huon tree kangaroo, because low productivity would mean less plant diversity forcing the Huon tree kangaroo to maintain large home ranges in order to satisfy their nutritional requirements.

5.3 FOOD PLANTS

One of the objectives of this thesis (Chapter 2) was to understand habitat selection in wild populations of the Huon tree kangaroo (*D. matschiei*), at Wasaunon on the Huon Peninsula in Papua New Guinea. This was achieved through the identification of food plant species that were eaten by *D. matschiei* and identified by the local hunters with great hunting skills and knowledgeable on wild tree kangaroo behavior. Betz (2001) also embarked on the quest to identify food plant species that were used by the Huon tree kangaroo in Dendawang (2400m abl), approximately 34km west of Wasaunon. Betz's study identified over 100 food plant species however, only 91 plants were identified. This study is a replication of Betz's study however; it was conducted at a different altitude and on a different site (Wasaunon – 3000m asl).

Both studies indicated that different plant species occurred at both sites and showed a difference in food preferences between the two sites (74 species in Dendawang and 53 species at Wasaunon). Studies conducted on diets of the two Australian species (*D. lumholtzi* and *D. bennettianus*) (Procter-Gray 1985; Martin 1996; Newell 1999[b;] Coombes 2005), suggest a arboreal folivorous diet. This study strongly supports these previous studies with a combination of 161 food plant species found between the two study sites that were used by the Huon tree kangaroo. Although anecdotal, ethnobiological knowledge on tree kangaroo food plants provides support for this investigation. Experienced hunters from Toweth and Worin as well as from other parts of the Huon Peninsula stated that *D. matschiei* has a wide and varied diet consisting of plants from several families (generalists). Toweth and Worin villagers also confirmed that tree kangaroos exhibited an arboreal folivorous trait, by not only eating a wide variety of food plants, but also do not consume large amounts of any particular species.

5.4 CONSERVATION IMPLICATIONS

Hunting pressures can rapidly reduce tree kangaroo populations to levels that would require much larger forested areas for the animals to persist (Redford 1992). Protecting and managing such large areas would be difficult because of the divided nature of land ownership in the Huon Peninsula, and PNG in general (Holzknecht 1994). *D. matschiei*'s vulnerability to hunting pressure, and the pattern of land ownership in its range suggests that a potential method of ensuring the species' survival would be to establish a network of relatively small "no hunting" zones. These reserves would need to be fully protected with no hunting or other resource extraction allowed. Landowners would only demarcate part of their land, and the intervening forests would be maintained as hunting/subsistence use areas for human populations and as corridors for genetic interchange for tree kangaroos (and other wildlife). This method of establishing a network of small reserves has been observed in other traditional societies and has been shown to be an effective method for conserving wildlife while allowing sustainable hunting (Joshi 1991). This strategy is particularly effective when reserves are numerous and well distributed throughout the habitat. This allows mixing of populations to occur and maximizes populations outside of the reserves.

Hunting outside the reserves does not need to be discouraged but perhaps does need to be moderated, preferably by local government laws. This is particularly important for dealing with individuals or clans that trespass on other clan's lands. Indeed this is one of the prime reasons given by landowners for supporting formal conservation efforts.

In order for the clan-based conservation strategy to be successful, workers will need to identify landowners and clans that have a sincere interest in conservation, and intensive efforts will need to be made to engage them. Landowners and clans that are not interested in conservation should not be pressured to participate, although they may join later. 'Engaging' clans will require using an effective strategy of facilitating local economic and social development, while a conservation ethos is inculcated in landowners that they will adopt and will outlast the conservation project's lifetime. This will take time and an *isi isi* (slow) approach will be necessary (Ellis 1997; Orsak 1999).

A secondary rationale for conservation will be the concept of clan conservation area or areas as wildlife and resource banks that will guarantee that future generation will be able to obtain the same wildlife and plant resources as their parents. Finally, the establishment of conservation areas will be presented as being an integral part of broader efforts to improve landowner livelihoods through sustainable developments in agriculture, education, health, etc. It is hoped that conservation projects can help foster, and in turn benefit from, improved regional cooperation, especially if larger inter-clan landowner groups are formed to manage conservation areas. Once formed, the same groups could conceivably work together to accomplish other development objectives in the area.

Successful conservation of *D. matschiei* will benefit other species as well. The network of small clan-based reserves may not be sufficiently large and/or contiguous to guarantee protection to reproductively self-sustaining populations of nomadic/highly mobile species or those with large habitat requirements, such as the New Guinea Harpy Eagle (*Harpyopsis novaeguineae*). However, they should be sufficient to protect much of the resident fauna, including New Guinea conservation priorities such as the long beaked echidna (*Zaglossus bruijni*), and Huon Peninsula endemics such as the Huon Astrapia Bird of Paradise (*Astrapia rothschildi*) and the Spangled Honeyeater (*Melipotes ater*). The example of clans protecting mid to upper montane habitats containing tree kangaroos may serve to inspire other Huon Peninsula landowners at lower altitudes to conserve areas which contain their own endemic 'flagship' species, such as the Emperor Bird of Paradise (*Paradisaea guilielmi*) or the Wahnes' Parotia Bird of Paradise (*Parotia wahnesi*).

Paramount to the success of any conservation project in PNG is the realization that landowners must feel that they are in control of the process. Initially this may not fully be the case, but as they become familiar with conservation arguments they must be encouraged to not merely tolerate, but to take leadership roles in projects that are taking place on their lands. They alone must determine what areas of land that will be set aside for protection, and they must assume responsibility for maintaining the protected status of the lands that they set aside.

FUTURE RESEARCH

Future research should focus on conducting home range studies in different habitat types along the altitudinal gradient of YUS LLG, to compare home ranges size at different altitudes and if there are differences, then further investigations can lead into questions such as:

1. Why is there a difference (if there is) in home range size at different altitudinal range?
    a. Is habitat loss, hunting pressure and the effects of altitude on productivity an influential factor in home range size?

Chapter 2 listed and discussed New Guinea landowner identified food plants for *D. matschiei*. Although descriptive and anecdotal, these lists represent the first extensive food plant information ever gathered for the Huon tree kangaroos. Future research could aim to finish recording landowner knowledge at both existing as well as new sites, confirm landowner statements through direct observation of wild tree kangaroos. Suggested future research should include:

- Further plant collections at Wasaunon and lower altitudes sites to gather the complete tree kangaroo food plant menu for those areas.
- Working with landowners from other clans or villages to collect tree kangaroo food plant at new sites, especially at different altitudes and/or different forest types to begin to document full diversity of food plants.
- Determine tree kangaroo diets by analysis of plant fragments in tree kangaroo faeces.
- Nutritional and chemical analysis of tree kangaroo food plants, especially favoured plants such as *Dicksonia* spp. (Dicksoniaceae), *Schefflera setulosa* (Araliaceae), *Timonius longitubus (*Rubiaceae), and *Bubbia sylvestris* (Winteraceae).
- Direct observation of the feeding behaviour of radio-collared tree kangaroos as a cross-check to the landowner plant lists.

CHAPTER 6 References

6.1 CHAPTER 1 REFERENCES

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APPENDICES

APPPENDIX 1: Distribution Maps of Tree Kangaroos – modified from (Flannery 1996).

Australian Species

Distribution of *D. bennettianus* (green) and *D. lumholtzi* (orange)

New Guinea Species

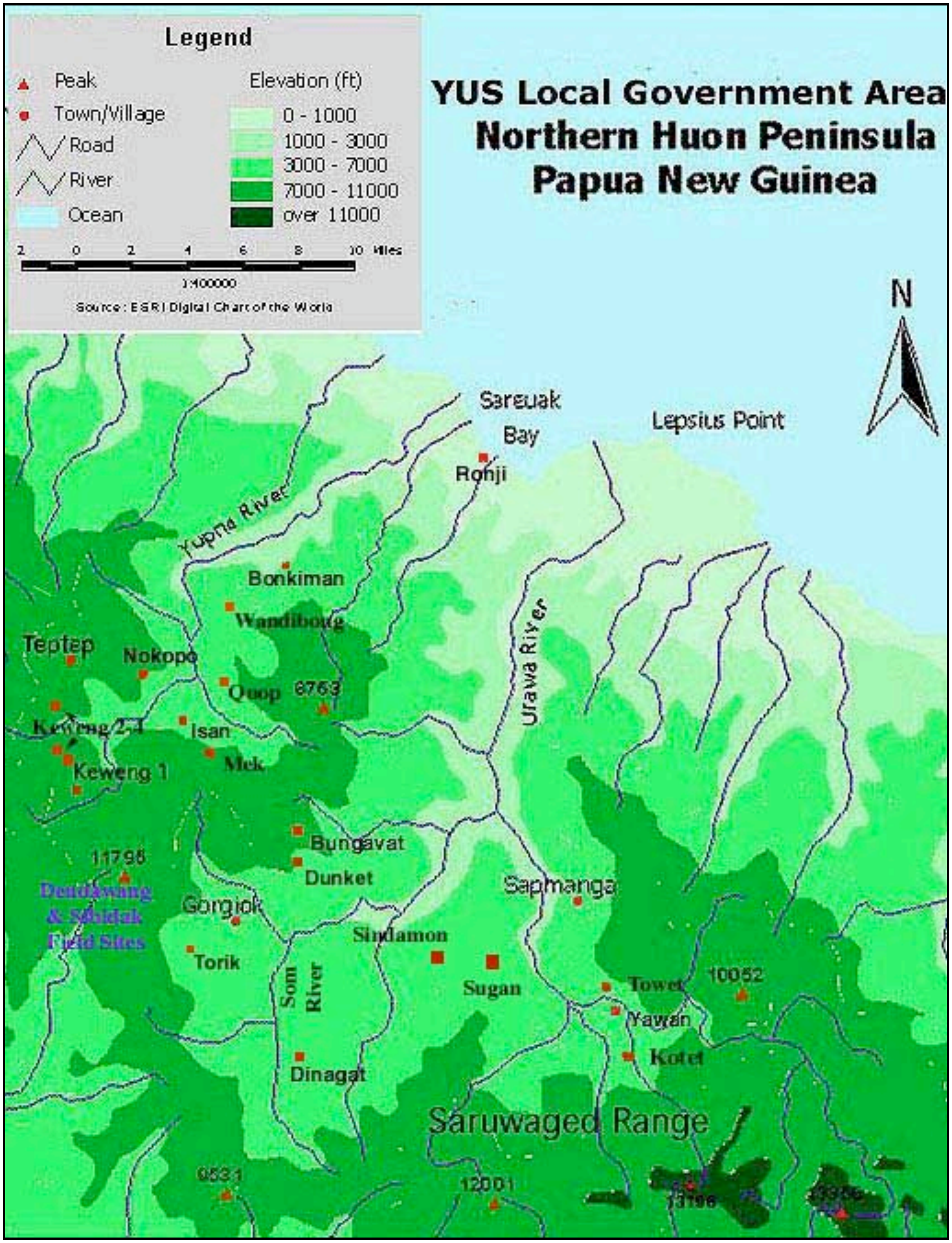
Distribution of *D. spadix* (orange) and *D. matschiei* (purple). Note the two purple dots on New Britain and Umboi Island are due to anthropogenic introductions.

Distribution of *D. dorianus mayri* (Wondiwoi Peninsula), *D. dorianus stellarum* (pink), *D. dorianus notatus* (orange) and *D. dorianus dorianus* (green).

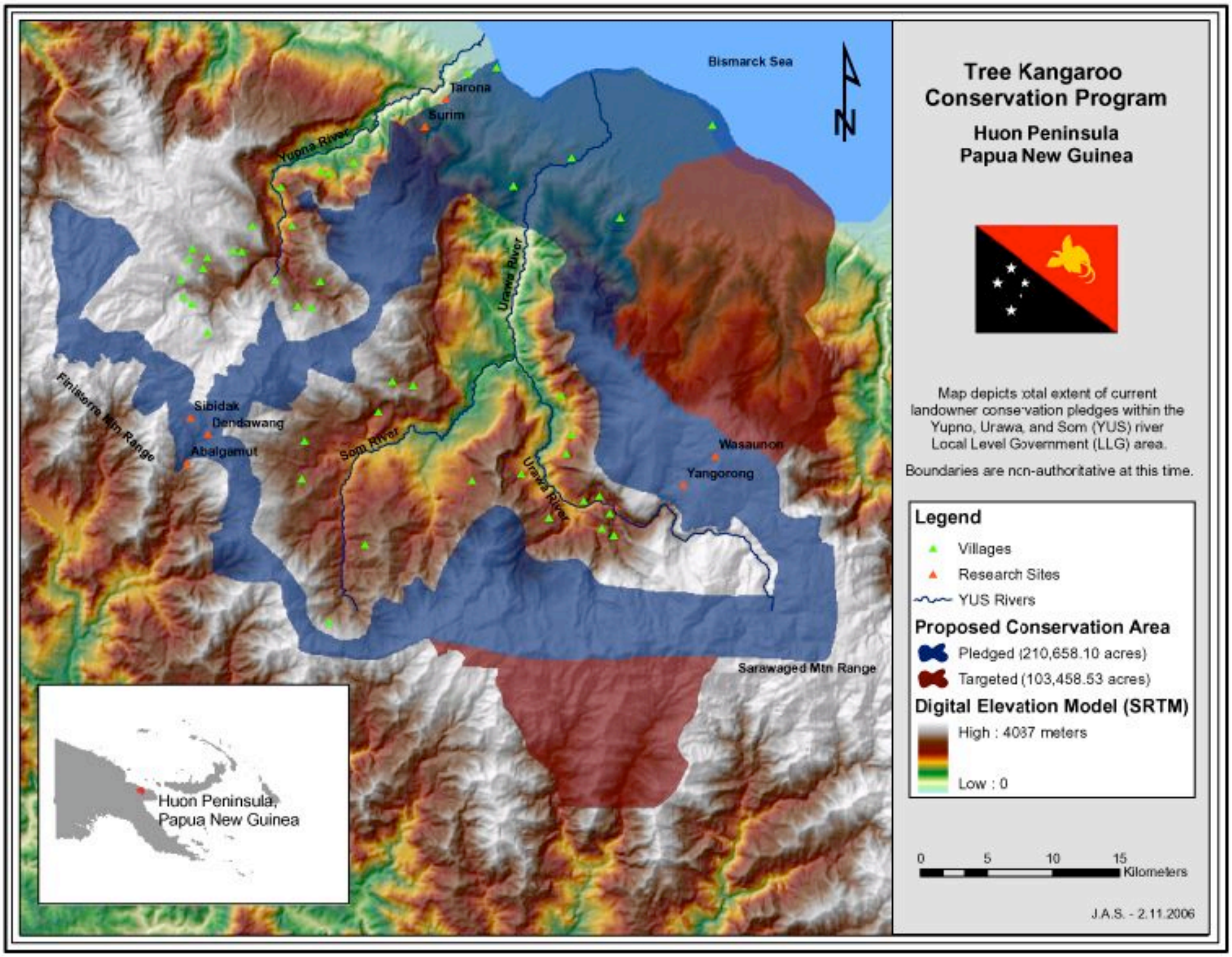
Distribution of *D. ursinus* (green), *D. mbaiso* (purple), *D. scottae* subsp. (Mt Menewa), and *D. scottae* (Torricelli Mountains).

Distribution of *D. goodfellowi pulcherrimus* (Torricelli Mountains and Mt. Sapu), *D. goodfellowi buergersi* (orange), and *D. goodfellowi goodfellowi* (green)

APPPENDIX 2: Map of the YUS Local Level Government Region of the Huon Peninsula in Morobe Province, Papua New Guinea (Jim Pugh 2001).



APPPENDIX 3: Map of the Proposed YUS Conservation Area on the Huon Peninsula of Morobe Province, Papua New Guinea (Jim Pugh 2001).



APPENDIX 4: Food Plant Species of Huon Tree Kangaroos and General Plant Collections of Wasaunon Field Site.

Table 3.1: Dominant plant species at upper canopy, mid canopy and lower canopy and ground level at Wasaunon.

Upper canopy
Quintinia ledermannii
Syzygium alatum
Dacrydium nidulum
Decaspermum forbesii
Podocarpus crassigemmiss
Libocedrus papuana
Zanthoxylon conspersipunctatum
Prunus glomerata
Prunus grisea var. microphylla
Endiandra fragrans
Astronia atroviridis
Mid-canopy
Levieria squarrosa
Bubbia calothyrsa
Rapanea sp.
Sphenostemon papuanum
Macaranga trichanthera
Saurauia capitulata
Symplocos cochinchinensis var. ssp. leptophylla
Lower canopy
Drimys piperita-coriacea
Piper bolannicum
Amaracarpus sp.
Vaccinium sp.
Bubbia sylvestris
Cypholophus kerewensis
Cypholophus macrocephalus
Dicksonia hieronymi
Cyathea hornei
Cyathea sp.
Forest floor
Elatostema papuana
Elatostema blechnoides

Pilea cuneata

Pilea effusa

Elatostema mongiense

Dennstaedtia magnifica

Dennstaedtia aff. Penicillifera

Dennstaedtia sp.

Hypolepis bamleriana

Histiopteris aff. Estipulata

Marattia costulisora

Vines

Aeschynanthus sp. (Gesneriaceae)

Cissus sp.

Cayratia sp. (Vitaceae)

Dimorphanthera sp. (Ericaceae)

Table 3.4 General plant collection made inside the study area (Wasaunon).

No.	Family	Scientific name	Local name
1	Actinidiaceae	*Saurauia fimbriata*	Igot 1
2	Ulmaceae	*Prasponia*	Alan
3	Dicksoniaceae	*Dicksonia sp.*	Ami
4	Cyatheaceae	*Cyathea*	Ami blue
5	Cyatheaceae	*Cyathea*	Ami brown
6	Dicksoniaceae	*Dicksonia hieronymi*	Ami gomon
7	Cyatheaceae	*Cyathea pruinosa*	Ami white
8	Fabaceae	*Mucuna*	Bambumon
9	Rubiaceae	*Mussaenda*	Bangam
10	Rubiaceae	*Weinlandia paniculata*	Bangindo
11			Biguyang
12	Poaceae	*Bamboo sp. 2*	Bilum
13	Rubiaceae	*Myrmecodia sp.*	Bimbim
14	Araliaceae	*Polycias*	Bitatang
15	Malvaceae	*Sida*	unknown
16	Rubiaceae	*Psychotria*	Bokbok
17	Gesneriaceae	*Cyrtandra sp.*	Bokbok 1
18	Gesneriaceae	*Cyrtandra schurmanniana*	Bokbok 2
19	Gesneriaceae	*Cyrtandra sp. (clipping)*	Bokbok 3
20	Moraceae	*Artocarpus cf.communis*	Bon

21	Moraceae	*Ficus sp.*	Borup
22	Phyllocladaceae	*Phyllocladus hypophyllus*	Bugaring
23	Pandanaceae	*Pandanus sp.*	Bum
24	Begoniaceae	*Begonia*	Dadac
25	Araliaceae	*Osmoxylon*	Dagung
26	Lauraceae	*Neolitsea*	Damgo
27	Rubiaceae	*Timonius longitubus*	Dandukdanduk
28	Ulmaceae	*Trema orientalis*	Dang
29	Urticaceae	*Pilea cuneata*	Daunding 1
30	Urticaceae	*Pilea effusa*	Daunding 2
31	Urticaceae	*Pilea papuana*	Daunding 3
32	Urticaceae	*Pilea sp.*	Daunding 4
33	Moraceae	*Ficus sp.*	Dingap
34	Urticaceae	*Dendrocnide sp.*	Dingnak
35	Euphorbiaceae	*Breynia sp.*	Dingomenmen
36	Rutaceae	*Zanthoxylon conspersipunctatum*	Dinom
37	Rosaceae	*Rubus ledermannii*	Dirong 1
38	Rosaceae	*Rubus laeteviridis*	Dirong 2
39	Rosaceae	*Rubus arcboldianus*	Dirong 3
40	Rosaceae	*Rubus lorentzianus*	Dirong 4
41	Rosaceae	*Rubus papuana*	Dirong 5
42	Rosaceae	*Rubus dicilinis var.dicilinis*	Dirong 6
43	Rosaceae	*Solanum aff.arffractum*	Dirong 7
44			Dirongit
45	Lauraceae	*Beilschmedia sp.*	Dirot
46	Ericaceae	*Vaccinium sp.*	Dogomong
47	Araliaceae	*Schefflera sp. (red flower)*	Dowetnoporo
48	Cyatheaceae	*Cyathea sp.*	Dum
49	Dennstaedtiaceae	*Didymochlaena truncatula*	Dungu
50	Marattiaceae	*Marattia costilusora*	Durem 1
51	Marattiaceae	*Marattia werneri*	Durem 2
52	Rutaceae	*Melicope perpicunervia*	Egek
53	Rutaceae	*Euodia = Acronychia pullei*	Egek 1
54	Rutaceae	*Acronychia murina*	Egek 2
55	Rutaceae	*Acronychia sp.*	Egek 3
56	Dennstaedtiaceae	*Dennstaedtia magnifica*	Engeng tata 1
57	Dennstaedtiaceae	*Dennstaedtia penicillifera*	Engeng tata 2

58	Amaryllidaceae	*Crinum*	Facmot
59	Zingiberaceae	*Alpinia sp.*	Fifit
60	Apiaceae		Fitnumfitnum
61	Aquifoliaceae	*Ilex*	Fotom
62	Zingiberaceae	*Alpinia pulcher*	Garem
63	Poaceae	*Imperata cylindrica*	Gam
64			Gambeng
65	Lauraceae	*Litsea guppyii*	Gat
66	Euphorbiaceae	*Homalanthus novoguineensis*	Gau
67			Gayuk
68	Podocarpaceae	*Podocarpus crassigemmiss*	Gang
69	Apiaceae	*Hydrocotle javanica*	Gerogero
70	Arecaceae	*Areca macrocarpa*	Giosinon
71	Myrsinaceae	*Rapanea leucantha*	Going 1
72	Myrsinaceae	*Rapanea sp.*	Going 2
73	Urticaceae	*Elatostema (sml.lf)*	Goiyac
74	Cucurbitaceae	*Cucurbita sp.*	Gongo
75	Moraceae	*Ficus cf.stenocarpa*	Gorogoro
76	Euphorbiaceae	*Macaranga trichanthera*	Gorom 1
77	Euphorbiaceae	*Macaranga inermis*	Gorom 2
78	Piperaceae	*Piper sp.*	Gowong
79	Poaceae	*Coix*	Gumbarong
80			Gundemot
81	Actinidiaceae	*Saurauia conferta*	Gundemot
82	Rubiaceae	*Amaracarpus montis - wilhelmi*	Gunhung 1
83	Rubiaceae	*Amaracarpus aff.clemensae*	Gunhung 2
84	Urticaceae	*Elatostema blechnoides*	Guram 1
85	Urticaceae	*Elatostema mongiense*	Guram 2
86	Gunneraceae	*Gunnera macrophylla*	Guyang
87	Ochnaceae	*Schuurmansia elegens*	Handot 1
88	Ochnaceae	*Schuurmansis heningsii*	Handot 2
89	Piperaceae	*Piper radatzii*	Hodot boyom
90	Agavaceae	*Cordyline sp.*	Hondot
91	Melastomataceae	*Astronia atroviridis*	Ibaiba
92	Urticaceae	*Cypholophus kerewensis*	Itititit 1
93	Urticaceae	*Cypholophus macrocephalus*	Itititit 2
94	Urticaceae	*Cypholophus sp.*	Itititit 3

95	Actinidiaceae	*Saurauia pluricularis*	Igot 2
96	Dennstaedtiaceae	*Pteridium aquilinum*	Ilup
97	Piperaceae	*Piper*	Kaip
98	Cyatheaceae	*Cyathea*	Kamingdek gomon
99	Cupressaceae	*Dacrydium nidulum*	Katimot
100	Cyatheaceae	*Cyathea*	Katirom
101	Cyatheaceae	*Cyathea sp.*	Katirom
102	Poaceae	*Bamboo sp. 1*	Katnang
103	Rubiaceae	*Timonius sp.*	Kec
104	Fagaceae	*Nothofagus*	Korockkorock
105	Zingiberaceae	*Riedelia*	Korombing
106			Kotkot
107	Piperaceae	*Piper bolanicum*	Kowok
108	Sapindaceae	*Dodonea angustifolia*	Koyoc
109	Elaeocarpaceae	*Elaeocarpus sayeri var.altigenus*	Koyo 1
110	Elaeocarpaceae	*Elaeocarpus polydactylus*	Koyo 2
111	Elaeocarpaceae	*Elaeocarpus sp.*	Koyo 3
112	Myrtaceae	*Syzygium malaccanse*	Kugec
113	Solanaceae	*Solanum sp.*	Kuku
114	Piperaceae	*Piper*	Kumbukumbu
115		*Pteris sp.*	Kungam
116	Araliaceae	*Harmsiopanax ingens*	Makim
117	Piperaceae	*Piper*	Magorom
118	Poaceae	*Panicum*	Mamkowung
119	Euphorbiaceae	*Macaranga aleurites*	Mijong
120	Smilaceae	*Smilax*	Mindimundi
121	Euphorbiaceae	*Euphorbia sp.*	Miyak
122	Piperaceae	*Piper*	Mogum
123	Poaceae	*Brachneria*	Momong
124	Polygonaceae	*Polygonum*	Mutmut 1
125	Polygonaceae	*Polygonum*	Mutmut 2
126	Araliaceae	*Schefflera setulosa*	Nemok
127	Myrtaceae	*Syzygium alatum*	Nim
128	Psilotaceae	*Psilotum*	Ocya
129	Pandanaceae	*Pandanus*	Omop
130	Rubiaceae	*Canthium sp.*	Ondu
131	Thelypteridaceae	*Sphaerostephanos unitus*	Ote

132	Ericaceae	*Rhododendron*	Rongorongo
133	Euphorbiaceae	*Phyllanthus sp.*	Sanginn
134	Rutaceae	*Euodia sp. (purple & pinkish flower)*	Sinbitnon
135	Symplocaceae	*Symplocos cochinchinensis ssp.leptophylla*	unknown
136	Moraceae	*Ficus adenosperma*	Sogum
137	Cupressaceae	*Libocedrus papuana*	Sombe
138	Poaceae	*Digitaria sp.*	Sombom
139	Apocynaceae	*Cerbera floribunda*	Sombong
140	Myrtaceae	*Decaspermum forbesii*	Songomong
141	Araliaceae	*Polycias 2*	Soroc
142	Winteraceae	*Drimys piperita H.K.f.ent.heteromera*	Sumbiri
143	Fabaceae	*Erythrina*	Sundeng
144	Poaceae		Sundic
145	Araliaceae	*Schefflera sp. (red flower)*	Sunsun
146	Poaceae	*Sachrum sp.*	Tagam
147	Urticaceae	*Elatostema cf.novoguineensis*	Tamberem
148	Pithosporaceae	*Pithosporum sp.*	Tamtam
149	Asteraceae	*Bidens pilosa*	Tapmantapman
150	Euphorbiaceae	*Glochidion*	Tendong
151	Pteridaceae	*Pteris tripartita*	Togonguyang
152	Convolvulaceae	*Ipomea (vine) purple flower*	Toim
153	Actinidiaceae	*Saurauia capitulata*	Tomtom
154	Bixaceae	*Bixa*	Ufoc
155	Orchidaceae	*Spathoglothis (purple flower)*	Umbam
156	Anacardiaceae	*Rhus taitensis*	Up
157	Moraceae	*Ficus damalopsis*	Upit
158	Moraceae	*Ficus copiosa*	Usac
159	Araliaceae	*Harmsiopanax ingens var.ingens*	Usim
160	Poaceae	*Poaceae*	Usimusim
161	Urticaceae	*Larpotea decumana*	Ut
162	Urticaceae	*Pitturus argenteus*	Utang
163	Urticaceae	*Debregeasia*	Utangutang
164	Urticaceae	*Dendroncnide sp.*	Utut
165	Proteaceae	*Macademia*	Walnat
166	Casuarnaceae	*Casuarina sp.*	Wam
167			Waum

168	Anacardiaceae	*Mangifera minor*	Wonin
169	Aspleniaceae	*Asplenium sp.*	Yagon
170	Ericaceae	*Dimorphanthera deckockii var.chlorocarpa*	Yaromyarom 1
171	Ericaceae	*Dimorphanthera amplifolia*	Yaromyarom 2
172		*Cyclosorus*	Yamyam
173	Dennstaedtiaceae	*Dennstaedtia sp.*	Yetgunotawa
174	Asclepiadaceae	*Hoya*	Yifofoc
175	Dennstaedtiaceae	*Dennstaedtia sp.*	Yitgunotawa
176	Rosaceae	*Prunus grisea var.microphylla*	Yorip 1
177	Rosaceae	*Prunus glomerata*	Yorip 2
178	Oleaceae	*Chionanthus sp.*	Yu

Table 3.5 General collections made outside of the study area (Wasaunon).

No.	Family	Genus species
1	Actinidiaceae	*Saurauia capitulata*
2	Actinidiaceae	*Saurauia fimbriata*
3	Actinidiaceae	*Saurauia pluricularis*
4	Apiaceae	*Trachymene adenodes*
5	Apiaceae	*Hydrocotle javanica*
6	Apocynaceae	*Alstonia glabriflora*
7	Aquifoliaceae	*Sphenostemon papuanum*
8	Aquifoliaceae	*Ilex archboldiana*
9	Araceae	*Rhphidophora*
10	Araliaceae	*Schefflera setulosa*
11	Araliaceae	*Harmsiopanax ingens*
12	Araliaceae	*Harmsiopanax ingens var.ingens*
13	Aspleniaceae	*Diplora sp.*
14	Aspleniaceae	*Asplenium cuneata*
15	Aspleniaceae	*Asplenium (droopin lf)*
16	Aspleniaceae	*Asplenium (terrestrial)*
17	Asteraceae 1	*Olearia platyphylla var.platyphylla*
18	Asteraceae 2	*Papuacalia glossophylla*
19	Begoniaceae	*Begonia sp.*

20	Blechnaceae	*Blechnum sp.*
21	Boraginaceae	*Cynoglossum sp.*
22	Chloranthaceae	*Ascarina philippinensis*
23	Chloranthaceae	*Ascarina subsessilis*
24	Cunoniaceae	*Caldcluvia rufa*
25	Cunoniaceae	*Caldcluvia nymanii*
26	Cupressaceae	*Dacrydium nidulum*
27	Cupressaceae	*Libocedrus papuana*
28	Cyatheaceae	*Cyathea sp. 1*
29	Cyatheaceae	*Cyathea sp. 2*
30	Cyatheaceae	*Cyathea sp. 3*
31	Cyatheaceae	*Cyathea sp. 4*
32	Cyatheaceae	*Cyathea sp. 5*
33	Cyatheaceae	*Cyathea pruinosa*
34	Cyperaceae	*Cyperus = Carex brunnea*
35	Davalliaceae	*Humata neoguineensis*
36	Dennstaedtiaceae	*Dennstaedtia magnifica*
37	Dennstaedtiaceae	*Dennstaedtia penicillifera*
38	Dennstaedtiaceae	*Didymochlaena truncatula*
39	Dennstaedtiaceae	*Lindsaea sp.*
40	Dennstaedtiaceae	*Hypolepis bamlerianum*
41	Dennstaedtiaceae	*Microlepia sp.*
42	Dennstaedtiaceae	*Lycopodium cf.volubile*
43	Dennstaedtiaceae	*Lycopodium phlegmaria*
44	Dennstaedtiaceae	*Histiopteris aff.Estipulata*
45	Dicksoniaceae	*Dicksonia hieronymi*
46	Dicksoniaceae	*Dicksonia sp.*
47	Elaeocarpaceae	*Elaeocarpus sayeri var.altigenus*
48	Elaeocarpaceae	*Elaeocarpus polydactylus*
49	Elaeocarpaceae	*Elaeocarpus sp.*
50	Ericaceae	*Dimorphanthera dekockii var.chlorocarpa*
51	Ericaceae	*Dimorphanthera amplifolia*
52	Ericaceae	*Gaultheria nundula*
53	Ericaceae	*Rhododendron superbum*
54	Ericaceae	*Syphelia suaveolens*
55	Euphorbiaceae	*Macaranga trichanthera*
56	Euphorbiaceae	*Macaranga inermis*

57	Euphorbiaceae	*Claoxylon coriaceo - lanatum*
58	Euphorbiaceae	*Endospermum medullosum*
59	Fagaceae	*Nothofagus starkenborgii*
60	Flacourtiaceae	*Casearia sp.*
61	Gesneriaceae	*Cyrtandra sp.*
62	Gesneriaceae	*Cyrtandra schurmanniana*
63	Gesneriaceae	*Cyrtandra sp. (clipping)*
64	Gesneriaceae	*Aeschyanthus leptocaldus*
65	Gesneriaceae	*Aeschyanthus pachyanthus*
66	Gleicheniaceae	*Stricherus erectus*
67	Gleicheniaceae	*Gleichenia sp.*
68	Grammitidaceae	*Ctenopteris undosa*
69	Grammitidaceae	*Ctenopteris 2*
70	Grammitidaceae	*Ctenopteris 3*
71	Grammitidaceae	*Grammitis sp.*
72	Grammitidaceae	*Prosaptia sp.*
73	Grossulariaceae	*Polyosma integrifolia*
74	Grossulariaceae	*Polyosma forbesii*
75	Grossulariaceae	*Polyosma cestroides*
76	Gunneraceae	*Gunnera macrophylla*
77	Hymenophyllaceae	*Hymenophyllum sp.*
78	Hymenophyllaceae	*Crepidomanes = Hymenophyllum polyanthus*
79	Hymenophyllaceae	*Hymenophyllum kurzii*
80	Hymenophyllaceae	*Hymenophyllum rubellum (growing on dead rocks)*
81	Juncaceae	*Juncus effusus*
82	Lauraceae	*Endiandra fragrans*
83	Lauraceae	*Cinnamomum ledermannii*
84	Lauraceae	*Cryptocarya xylophylla*
85	Lauraceae	*Cryptocarya sp.*
86	Loganiaceae	*Fagraea bodenii*
87	Loranthaceae	*Amyema sp. (parasite plant)*
88	Loranthaceae	*Decasinia hollrungii*
89	Marattiaceae	*Marattia costulisora*
90	Marattiaceae	*Marattia werneri*
91	Melastomataceae	*Astronia atroviridis*
92	Melastomataceae	*Medinilla sp.*

93	Monimiaceae	*Tetrasynadra sp.*
94	Monimiaceae	*Kibara sp.*
95	Monimiaceae	*Palmeria arfakiana*
96	Monimiaceae	*Dryadodaphne crassa*
97	Moraceae	*Streblus europhyllus*
98	Moraceae	*Ficus wasa*
99	Myrsinaceae	*Rapanea leucantha*
100	Myrsinaceae	*Rapanea sp.*
101	Myrsinaceae	*Maesa haplobotrys*
102	Myrtaceae	*Decaspermum forbesii*
103	Myrtaceae	*Syzygium alatum*
104	Orchidaceae	*Epiblastus chimbuensis*
105	Ochnaceae	*Schuurmansia elegens*
106	Ochnaceae	*Schuurmansia heningsii*
107	Onagraceae	*Epilobium detznerianum*
108	Ophioglossaceae	*Ophioglossum pendulum*
109	Orchidaceae	*Epiblastus auriculata*
110	Orchidaceae	*Dendrobium masarangense*
111	Orchidaceae	*Dendrobium engae*
112	Orchidaceae	*Glossorhyncha sp. 1*
113	Orchidaceae	*Vanda sp.*
114	Orchidaceae	*Bulbophyllum rhodolencum*
115	Orchidaceae	*Glossorhyncha sp. 2*
116	Orchidaceae	*Epiblastus chimbuensis*
117	Orchidaceae	*Epiblastus auriculatus*
118	Orchidaceae	*Glossorhyncha sp. 3*
119	Orchidaceae	*Mediocalcar agathodae*
120	Orchidaceae	*Dendrobium acutisepalum*
121	Orchidaceae	*Dendrobium ameniacum*
122	Orchidaceae	*Phreatia gangapensis*
123	Orchidaceae	*Bulbophyllum discolor*
124	Orchidaceae	*Glomera sp.*
125	Orchidaceae	*Dendrobium sp.*
126	Orchidaceae	*Bulbophyllum brachypetalum*
127	Orchidaceae	*Bulbophyllum mischobulbon*
128	Orchidaceae	*Bulbophyllum savalense*
129	Orchidaceae	*Glomera flamula*

130	Orchidaceae	*Epiblastus sp.*
131	Orchidaceae	*Ceratosphylla subcoerulea*
132	Pandanaceae	*Pandanus sp.*
133	Phyllocladaceae	*Phyllocladus hypophylus*
134	Piperaceae	*Piper bolanicum (kowok)*
135	Piperaceae	*Piper subbullatum (Kumbukumbu)*
136	Piperaceae	*Piper sp. 1*
137	Piperaceae	*Piper sp. 2*
138	Piperaceae	*Piper radatzii*
139	Piperaceae	*Piper (next to kunai)*
140	Poaceae	*Poaceae*
141	Poaceae	*Imperata cylindrica*
142	Poaceae	*Brachneria sp.*
143	Poaceae	*Deschampsia sp.*
144	Podocarpaceae	*Podocarpus crassigemmiss*
145	Polygonaceae	*Polygonum runcinatum (sml.lf)*
146	Polygonaceae	*Polygonum chinensis (brd.lf)*
147	Polypodiaceae	*Antrophyum sp.*
148	Polypodiaceae	*Polypodiaceae 1 = Belvisia novoguineesis*
149	Polypodiaceae	*Polypodiaceae 2 = Belvisia revolute*
150	Polypodiaceae	*Loxogramme subselliguae*
151	Polypodiaceae	*Vittaria cf.longifolia*
152	Polypodiaceae	*Vittaria elongata*
153	Polypodiaceae	*Crypsinus albidosquamatus*
154	Proteaceae	*Helicia odorata*
155	Rosaceae	*Rubus ledermannii*
156	Rosaceae	*Rubus laeteviridis*
157	Rosaceae	*Rubus arcboldianus*
158	Rosaceae	*Rubus lorentzianus*
159	Rosaceae	*Rubus papuana*
160	Rosaceae	*Rubus dicilinis var.dicilinic*
161	Rosaceae	*Solanum aff.arffractum*
162	Rosaceae	*Prunus grisea var.microphylla*
163	Rosaceae	*Prunus glomerata*
164	Rubiaceae	*Timonius longitubus*
165	Rubiaceae	*Amaracarpus montis - wilhelmi*
166	Rubiaceae	*Amaracarpus aff.clemensae*

167	Rubiaceae	*Psychotria sp.*
168	Rutaceae	*Euodia = Acronychia pullei*
169	Rutaceae	*Acronychia murina*
170	Rutaceae	*Acronychia sp.*
171	Rutaceae	*Zanthoxylon conspersipunctatum*
172	Rutaceae	*Melicope perpicunervia*
173	Sabiaceae	*Meliosma pinnata ssp.humilis*
174	Santalaceae	*Cladomyza cuneata*
175	Sapindaceae	*Lepisanthes sp.*
176	Saxifragaceae	*Quintinia epiphytica (climber vine)*
177	Saxifragaceae	*Quintinia ledermannii*
178	Staphyllaceae	*Turpinia pentandra*
179	Symplocaceae	*Symplocos cochinchinensis ssp.leptophylla*
180	Theaceae	*Eurya tigang*
181	Urticaceae	*Pilea cuneata*
182	Urticaceae	*Pilea effusa*
183	Urticaceae	*Pilea papuana*
184	Urticaceae	*Pilea sp.*
185	Urticaceae	*Elatostema blechnoides*
186	Urticaceae	*Elatostema mongiense*
187	Urticaceae	*Cypholophus kerewensis*
188	Urticaceae	*Cypholophus macrocephalus*
189	Urticaceae	*Cypholophus sp. 3*
190	Urticaceae	*Debregeasia sp.*
191	Urticaceae	*Dendrocnide sp.*
192	Urticaceae	*Elatostema cf.novoguineesis*
193	Urticaceae	*Elatostema sp. (sml.lf)*
194	Urticaceae	*Larpotea decumana*
195	Urticaceae	*Dendrocnide sp.*
196	Urticaceae	*Pipturus argenteus*
197	Urticaceae	*Procris frutescens*
198	Vitaceae	*Cayratia sp.*
199	Winteraceae	*Drimys piperita H.K.f.ent.heteromera*
200	Zingiberaceae	*Riedelia*
201	Zingiberaceae	*Alpinia pulcher*
202	Pteridaceae	*Pteris tripartita*
203	Gleicheniaceae	*Stricherus erectus*

204	Osmundaceae	*Leptopteris alpina*
205	Orchidaceae	*Agrostophyllum graminifolia*
206	Orchidaceae	*Glossorhyncha grandiflora*
207	Orchidaceae	*Phreatia longicaulis*
208	Orchidaceae	*Dendrobium habbemense*