



RURAL INDUSTRIES RESEARCH  
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# The Kangaroo Island Tammara Wallaby

**Assessing ecologically sustainable  
commercial harvesting**

**A report for the Rural Industries Research  
and Development Corporation**

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University of Adelaide

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# Foreword

The Tammar Wallaby on Kangaroo Island, South Australia, is currently managed as a vertebrate pest.

Sampled populations from culled and previously unculted properties were used to establish whether the current level of control is ecologically sustainable, and whether the population, as a whole, can sustain a commercial harvest.

This project showed that culling is having a slight effect on the Tammar Wallaby populations on the properties surveyed, and this effect is of benefit to the surviving wallabies because there is a small trend towards lower parasite burdens, higher energy reserves, faster growth rates in adults and increased fertility in males.

It is suggested that, as there are only slight effects due to culling on the properties tested, the current management level on these two properties is therefore ecologically sustainable.

This project is the first step towards writing a management plan for the Tammar Wallaby on Kangaroo Island, without which a commercial harvest cannot be established.

This report, the latest addition to our diverse range of over 250 research publications, forms part of our New Animal Products R&D program which aims to accelerate the development of viable new animal industries. This report and others, can be viewed or purchased online at [www.rirdc.gov.au](http://www.rirdc.gov.au)

**Peter Core**  
Managing Director  
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# Executive Summary

The Tammar Wallaby is a threatened native species and considered extinct on mainland South Australia. But, in 1996, Kangaroo Island farmers shot 14,000 wallabies under pest destruction permits plus an estimated 2 to 5 times that number illegally. Wildlife managers, naturally, are concerned at this high level of culling, particularly when the population size is unknown. These wallabies are seen as a resource which could provide an income to people on Kangaroo Island - not just farmers, but also other people who could be employed in adding value to wallaby products such as meat processing, tanning hides, making leather goods and marketing to tourists.

This project was established to assess the effect that culling is having on the wallaby populations, whether the current culling level is sustainable, and to assess the potential for a commercial wallaby harvest as a new animal product for farmers on Kangaroo Island.

Assumptions, based on population dynamics, were made that (a) wallaby populations on an uncultured property would be at maximum carrying capacity and that (b) this population at the higher animal density would be subject to higher stress levels and to a reduction in available feed, which in turn would have a negative effect on growth rates, energy reserves, fecundity, survival/mortality and the ability to resist diseases whilst (c) the population of wallabies on the culled property would be at less than maximum carrying capacity.

From these assumptions, 8 parameters were selected as being appropriate indicators which could be used to test the null hypothesis that culling was having no effect on the Tammar Wallaby population. These were:

- kidney fat index, adult carcass weight, and the number of juveniles surviving to become adults would be lower in uncultured populations
- mean population age of the uncultured animals would be higher
- the number of females carrying pouch young would be less in uncultured populations
- scrotal circumference would be smaller and intestinal worm burdens would be higher in uncultured populations
- the male:female ratio would be 1:1 in uncultured populations but altered in culled populations.

Four sites were established - *Brookland Park* and *Jarumble* were properties which have managed their wallaby populations for at least 20 years whilst *Tandanya* and *Leska Park* had not previously been culled. All four properties share at least one boundary with Flinders Chase National Park and have areas of dense vegetation within the property boundaries. Therefore they have a high wallaby population grazing on pastures and crops at night with the wallabies resting in the adjacent scrub during the day.

The summary for data on 469 wallabies collected for this project show that:

- Adult ages ranged from out-of-pouch juveniles at about 10 months to 13-year old females, with the oldest animals from the unculled properties. There is a small, but significant, difference in the mean ages of the 2 populations.
- There was a small non-significant difference between adult carcass weights of the 2 populations. The heavier animals tended to be from the culled properties.
- There was an unexplained male bias at most collections which was in contrast to all previous published data for Tammar Wallabies. However, the male:female ratios were not all that different between culled and unculled populations for either the adults or the pouch young.
- Kidney fat index tended to be higher in females than males, especially if the females carried pouch young. There were no significant differences between culled and unculled populations, although there was a slight trend to higher KFI on the culled properties.
- Worm counts ranged from 0 to nearly 20,000, and although the mean for the culled population was lower at 1400 than that at 2200 for the unculled population, there was no significant difference overall between the two populations.
- There was a significant difference in scrotal circumference measurements with the differences due to both younger males maturing earlier and older males having a larger scrotal circumference in the culled populations.
- There was no significant difference between populations in the number of females with pouch young or in the mean ages of the pouch young. However, 97% of females in the culled populations had their joeys in the normal January/February period, whilst only 62% of females in the unculled populations gave birth during the same period.
- Mortality rates and survival rates were almost identical for both population types.
- Regression of age on weight for pouch young showed no differences between populations.
- Adult age-related weight showed that for the same age, culled wallabies tended to be up to 0.5 kg heavier than unculled wallabies.

It appears that, generally, culling is having a slight effect on the Tammar Wallaby populations on the properties surveyed.

Putting all the parameters together, the trend indicates that both the culled and unculled populations studied are close to maximum carrying capacity on the logistic growth curve with the culled population only slightly lower towards the point of inflection.

The data suggest that culling is having a beneficial effect on the surviving wallabies on the two culled properties. There is a small trend towards lower parasite burdens, higher energy reserves, faster growth rates in adults and increased fertility in males. All of these parameters are of importance should a commercial harvest be put in place.

Research in Australia on sheep, cattle and goats show considerable improvements in liveweight gains, male and female fertility and birth rates when livestock stocking rates are reduced - which is effectively the same as culling. As the trends in the Tammar Wallaby populations are much lower than those shown with other species, it suggests to me that as there are only slight effects due to culling on the properties tested, the current management level on these two properties is ecologically sustainable

The next step in establishing a potential commercial harvest of wallabies is the population count of the whole of Kangaroo Island. There also needs to be a management plan developed and approved for the conservation, utilisation and ongoing monitoring of the wallabies. Farmers need to get together and look at various options of harvesting, processing, value-adding and marketing the produce.

An ecologically sustainable harvest of Tammar Wallabies would benefit Kangaroo Island in a number of ways. By putting a \$-value on the wallabies, farmers would be encouraged to see the wallaby as an additional resource to their farm income. Farmers may be encouraged to look at alternative farming enterprises so they increase wallaby numbers and reduce conventional farming methods. A commercial harvest would also see a reduction in illegal shooting - an important animal welfare issue. An on-going monitoring programme, as part of a management plan, would ensure that the population is not put at risk by over-harvesting. And finally, there would be an end to the sense-less waste of 20-50,000 Tammar Wallabies every year.



## **Chapter 1: Introduction**

The Tammar Wallaby population on Kangaroo Island, South Australia is currently culled (under destruction permits) as a vertebrate pest. At this point in time, the total population, as well as the effect of culling on that population, is unknown. This project seeks to establish whether the current level of control is affecting the population, whether the current control level is sustainable and, if so, whether the population can sustain a commercial harvest.

### **1.1 Ecology of the Tammar Wallaby**

The Tammar, or Kangaroo Island, Wallaby, *Macropus eugenii decres* Troughton, 1941, (Maxwell *et al.*, 1996) is one of the smaller members of the family Macropodidae. The adults range in size from 4.5 to 10 kilograms with the males averaging 7.5 kilograms and the females averaging 5.5 kilograms (Archer *et al.*, 1985; Poole *et al.*, 1992). Their fur is generally grey darkening to very dark grey-black at the extremities (paws and tail tip) with pale grey chest and belly, a rufous tinge across the shoulders and sometimes also on the lower back and flanks, and a distinctive cream cheek-stripe (Thomas, 1888). The young are usually born late January to early February and weaned in September-October of the same year. The females mate in oestrus immediately post-partum and the resulting blastocyst is held in embryonic diapause until development is triggered by the summer solstice. If a pouch young is lost prior to mid-June, then the blastocyst develops and is born 25 days later. (Tyndale-Biscoe & Renfree, 1987; Poole *et al.*, 1992).

The Tammar Wallaby is mainly nocturnal and lives in the ecotone, that is, it shelters during the day in dense scrub and comes out after dusk to feed on the grasses adjacent to the scrub (Maxwell *et al.*, 1996).

### **1.2 Historical Background**

The Tammar Wallaby was the first Australian marsupial to be seen and described by Europeans - in 1629 by Francisco Pelsaert, a navigator on the ship *Batavia* which was wrecked on Houtman's Abrolhos, Western Australia. The type specimen to be scientifically described was collected in 1803 by Nicholas Baudin from L'Ile Eugenie (St. Peter Island) South Australia, and was originally named *Kangarus eugenii* (Desmarest 1817). The Tammar has had several name changes since its original description as more information became known about the macropodidae.

### **1.3 Status of the Tammar Wallaby**

Tammar Wallabies were once common on mainland South Australia in the Mount Lofty Ranges and on both Yorke and Eyre Peninsulas; in south-western Western Australia as far north as Geraldton; as well as occurring on islands around the coast of South Australia and Western Australia (Jones, 1924; Poole *et al.*, 1991).

Land clearing for agriculture and predation by foxes (*Vulpes vulpes*) has reduced the mainland populations to nine confirmed locations in Western Australia (Maxwell, 1996). There have been reports that there may still be a remnant population on Eyre Peninsula (Aitken, 1970; Poole *et al.*, 1991) but elsewhere on the South Australian

mainland, Tammar Wallabies are now extinct in the wild. Populations of Tammar Wallabies still exist on Western Australian islands in the Houtman Abrolhos Group and the Recherche Archipelago as well as Garden Island near Freemantle (Maxwell, 1996). Populations which were reported by Matthew Flinders on South Australian islands are now extinct - these included St Peter Island (L'Ile Eugenie), St Francis Island, Thistle's Island, and Flinders Island. However, the population on Kangaroo Island has increased as a result of European-style agriculture increasing the availability of grasses and crops (Inns, 1980), particularly following the massive land clearance in the 1950's for the soldier settlement blocks, with the wallabies living in remnant scrub on the farms and along roadsides during the day and feeding on pastures and crops at night (Andrewartha and Barker, 1969). The dense vegetation in National Parks also provides daytime habitat with the wallabies coming out onto adjacent farmlands at night.

Introduced populations of Tammar Wallabies at Rotorua and Kawau Island in New Zealand are believed to be of the South Australian mainland sub-species (Poole *et al.*, 1991) on the basis of skull morphology.

#### **1.4 The Tammar Wallaby on Kangaroo Island**

In 1996, land-holders on Kangaroo Island were issued with permits to shoot over 14,000 Tammar Wallabies (NPWS, 1997 - unpublished data) as vertebrate pests. A survey of farmers indicated that the actual number of wallabies shot was in excess of 32,000 (see addendum). Until such time as a management plan for the Tammar Wallaby has been approved and implemented, wallabies cannot be commercially harvested (Maxwell, 1996) and consequently the carcasses of wallabies shot as pests are left to rot in scrubby areas away from main farm activities. A management plan cannot be developed until detailed information about the population dynamics of the Tammar Wallaby is available.

#### **1.5 Population Dynamics**

A group of individuals of the same species is called a population when they occupy the same area at the same time. The population can be described by a number of characteristics which cannot be assigned to individuals but which are affected by each individual within the population. These characteristics can include: birth rate - the percentage of births per year per female; death rate - the percentage of deaths per year; age structure - the distribution of individual's ages within the group; density - the number of individuals of the species living within a specified unit area. (Robinson and Bolen, 1984).

Population growth can be represented by the Logistic Equation which calculates the number of individuals that can be sustained within the population for a particular environment. The equation is written as follows:

$$\frac{\Delta N}{\Delta t} = r N \frac{(K - N)}{K}$$

where  $\Delta N$  is the change in number of individuals in the population,  $\Delta t$  is the change in time,  $r$  is the maximum potential growth rate,  $N$  is the number of individuals in the population, and  $K$  is the maximum carrying capacity of the

population (Teague and Decker, 1979). The equation produces a sigmoidal curve with the top of the curve being K or maximum carrying capacity and the point of inflection on the curve (at approximately half K) being referred to as the maximum sustainable yield that the population can support without the population declining (Teague and Decker, 1979; Robinson and Bolen, 1984).

Carrying capacity is the maximum number of individuals that can be sustained in a particular environment. It changes with alterations to the available food and water resources as well as in response to other factors such as the seasons, behaviour of individuals and other species sharing the same environment (Teague and Decker, 1979). For example, Robinson (1988) suggests that in Bush Rats (*Rattus fuscipes*) the early winter decreases in food availability has an effect on the survival and establishment of territory of sub-adults which is then reflected in the breeding population size the following spring.

Density dependence determines whether mortality increases or fecundity decreases within a population in order to control the population as it reaches maximum carrying capacity. If the carrying capacity is exceeded then nutrition or disease usually become the density dependant factors which cause the population to crash (Teague and Decker, 1979). Fowler (1990) found that in the Northern Fur Seal (*Callorhinus ursinus*) alterations in body weight and length, skeletal measurements, disease incidence and foraging times are all indicators of density-dependant changes within the population.

There are various ways in which increases and decreases in population numbers can be controlled and these act on birth rate and immigration (increases) and death rate and migration (decreases). One example of changes in population numbers is that which is found in populations of the Long-Haired Rat (*Rattus villosissimus*) when the population rises considerably after rainfall (which increases available food resources) (Predavec and Dickman, 1994) with the change in numbers being due to mainly immigration, and also to reproduction. However population crashes when food resources are no longer available could have been due to a number of, as yet unidentified, factors including: increased predation; a decline in the overall health of the population; or an increase in parasitism in the population (Predavec and Dickman, 1994). Predation is another example of population control and Ballard *et al* (1991) found a high mortality rate in Moose (*Alces alces*) calves in Alaska with only 39% of calves surviving to five months of age. Mortality was due mainly to predation by Brown Bears (*Ursus arctos*) within the first six weeks after birth.

Inns (1980) monitored a protected population of Tammar Wallabies in Flinders Chase National Park. However there is no recent published research about the population dynamics of the Tammar Wallaby population on Kangaroo Island in relation to the effect that culling has on the population, so by studying aspects of the demographics of populations, the carrying capacity and sustainable yield may be able to be estimated.

## **1.6 Aims and Hypotheses**

Demographics are the finer details which are used to describe a population, and they are the factors which have an effect on the population dynamics. These

characteristics include such things as age structure, growth rates, energy reserves, parasitism, disease status, sex ratios, fertility, and birth and death rates (Robinson and Bolen, 1984). There is very little published information on the demographics and population dynamics of Tammar Wallaby populations and how they differ with different levels of management and so this project seeks to establish whether population management has an effect on Tammar Wallabies on Kangaroo Island.

Three assumptions, based on population dynamics, were made. Namely:

1. that wallaby populations on an uncultured property would be at maximum carrying capacity
2. that this uncultured population at the higher animal density would be subject to higher stress levels due to a reduction in available feed, which in turn would have a negative effect on growth rates, energy reserves, fecundity, survival, mortality, and the ability to resist diseases
3. the population of wallabies on a culled property would be at less than maximum carrying capacity and therefore subject to lower stress levels.

The null hypothesis is that culling is not having any effect on the Tammar Wallaby population. This null hypothesis can be tested using a number of the different characteristics which influence population demographics and are summarised in table 1.1.

Consequently, the parameters which will be tested by this project are:

1. that the average age of an uncultured population will be older than a culled population,
2. that the annual recruitment of juveniles will be lower in the uncultured population compared with the culled population,
3. that the average body weight for animals of the same age will be lower in the uncultured population than in the culled population,
4. that the growth rates of the pouch young will be slower in the uncultured population,
5. that the energy reserves, measured as kidney fat index, of the uncultured population will be lower than the culled population,
6. that the male:female ratio in the uncultured population will be 1:1 compared with an uneven sex ratio in the culled population
7. that there will be a higher parasite burden, measured as intestinal nematodes, in the uncultured population compared with the culled population
8. that scrotal circumference, as a measurement of male fertility, will be lower in the uncultured population compared with the culled population,
9. that female fertility, measured as presence of pouch young, will be lower in the uncultured population compared with the culled population,

and are summarised in table 1.1. Each of these parameters are discussed within each relevant chapter.

The data collected during the course of this project may also be useful in determining the carrying capacity and sustainable yield levels in managed and unmanaged populations of Tammar Wallabies on Kangaroo Island.

Table 1.1: Predictions to be tested in order to accept or reject the null hypothesis that culling is having no effect on Tammar Wallaby populations.

<b>Demographic characteristic</b>	<b>Parameter to be measured</b>	<b>Culled populations</b>	<b>Unculled populations</b>
population age structure	age of the population	younger	older
annual recruitment	% juveniles	higher	lower
size of adults	body weight	higher	lower
growth rates	growth of pouch young	higher	lower
energy reserves	kidney fat index	higher	lower
male:female ratio	male:female ratio	not 1:1	1:1
parasite status	intestinal nematodes	lower	higher
fertility in males	scrotal circumference	larger	smaller
fertility in females	presence of pouch young	higher	lower

## **Chapter 2: General Methods**

### **2.1 Methods**

Five sites were initially established on five different properties - three which had been under constant wallaby management (Western River, “Brookland Park” and “Jarumble”) and two which had not previously culled the wallaby populations (“Leska Park” and “Tandanya”). All five properties share at least one boundary with a National Park as well as having suitable remnant wallaby habitat within each of the properties. Due to unforeseen circumstances, the Western River property was not available for the duration of the project and data collected in February is not generally included in results unless specified. Management programmes at “Leska Park” and “Tandanya” prohibited data collection in February, whilst “Jarumble” was too wet to collect data in July.

Wallaby carcasses were obtained from the farmers under University of Adelaide Animal Ethics Approval Number W/088/96. The wallabies were shot by the farmers under Destruction Permits obtained from the National Parks and Wildlife Service at Rocky River Headquarters. Normally the wallabies would have been shot, by rifle, in the head but for this project the wallabies were shot in the heart to ensure that the head was intact to enable aging by molar index to be carried out.

After the wallabies were shot, the carcasses were tagged on the hind leg with an individual number which corresponded with the number on each animal’s record sheet. The carcasses were then weighed to the nearest 100 grams using electronic sheep scales (Ruddweigh sheep and cattle scales). The sex of each animal was recorded. Each animal was assessed visually for general body condition and external parasites. If male, the scrotum was removed from the body and the circumference measured. If female, the pouch young was removed, euthanased with lithobarb, identified with the same number as its mother, then put aside for later measurements (weight, head length, ear length, pes length, leg length and tail length).

Initially it was planned that only 10% of carcasses would be randomly selected for further measurements. However, this was changed to ten animals (five males and five females) at each property on each visit. The selected carcass was laid on its back on a dissection tray and with either a scalpel or a razor blade the abdominal cavity was opened ventrally from the sternum to the pubic bone. The mesenteric fat was assessed visually and scored from 0 to 5 (0 = nil, 5 = exceptionally fat). The stomach was removed at the oesophagus and immediately below the pylorus. The stomach was identified with the carcass number and put aside for worm counts to be conducted the following morning. The intestines were pushed aside and the right kidney and associated peri-renal fat removed and measured for kidney fat index. If the right kidney was damaged during shooting, then the left kidney and associated fat was removed and measured - on the assumption that the two kidneys and their associated peri-renal fat were similar.

Detailed methods, specific to each characteristic being measured, appear in the appropriate chapter for that characteristic.

All data was recorded in a spreadsheet using Excel7 (Microsoft). The data from "Brookland Park" and "Jarumble" were compared for differences between the two sites, and as there was no significant difference, they were combined as the culled population. The same was applied to the data from "Leska Park" and "Tandanya", and again as there was no significant difference, they were combined as the uncultured population. Statistical analyses were carried out using Excel7 and Genstat 5 Release 3.1 (Rothamsted Experimental Station) as detailed in each of the following chapters.

## **2.2 Property descriptions**

All properties are involved with sheep farming and consequently have large areas of improved pastures but they all maintain remnant areas of native vegetation, which provides shelter for the sheep as well as habitat for the wallabies.

"Brookland Park" has been managing wallabies since the property was established by the current owner's grandparents, and has supplied live wallabies to research institutions in Canberra, Melbourne and Adelaide. The property has large areas of remnant vegetation scattered throughout the improved pasture paddocks, including several areas of revegetation which provide habitat for wallabies as well as Kangaroo Island Kangaroos (*Macropus fuliginosus fuliginosus*). "Brookland Park" shares its northern and western boundaries with Flinders Chase National Park.

"Jarumble" was purchased by the current owner four years ago and since then has had a wallaby-proof fence erected around the entire property. A pasture renovation programme is currently in place, together with some cropping of canola. Wallaby management has been fairly intense since the fence was erected. "Jarumble" is bordered on three sides by the Flinders Chase National Park.

"Leska Park" is mainly cleared for sheep grazing and cropping of oats in a pasture/oats rotation, with small areas of remnant vegetation. It shares the western boundary with Flinders Chase National Park (across the road). "Leska Park" does not carry out a culling programme on the wallabies.

"Tandanya" is a leased property which has had little management during the last few years. The front portion is cleared grazing and cropping, with an area established for irrigation during the summer months. Wallabies have not been culled on "Tandanya" for a number of years, and during the course of this project, culling occurred in a different paddock on each collection period. "Tandanya" is bordered on the western side by Flinders Chase National Park, on the eastern boundary by Kelly Hill Caves Conservation Park and the southern area is natural dense scrubland.

The property at Western River has beef cattle and sheep grazing on cleared pastures. Wallabies have been heavily culled for a number of years. Further details of this property are unavailable to ensure confidentiality.

## **Chapter 3: General Results**

A total of 469 Tammar Wallabies were shot on the five properties with the numbers varying at each site and at each visit (table 3.1). The numbers were affected mainly

by weather conditions (wind had more of an adverse effect than rain), but also by the accuracy of the rifle used and by the number of wallabies present at the time of shooting.

Table 3.1: Tammar Wallabies shot under destruction permits at five collection sites on Kangaroo Island during 1997.

Site	February	March	June	July	Total
<b>Culled sites:</b>					
• <i>Western River</i>	21	0	0	0	21
• <i>Brookland Park</i>	36	24	31	11	102
• <i>Jarumble</i>	47	32	42	0	121
subtotal:	104	56	73	11	244
<b>Unculled sites:</b>					
• <i>Leska Park</i>	0	28	29	10	67
• <i>Tandanya</i>	0	60	77	21	158
subtotal:	0	88	106	31	225
Totals:	104	144	179	42	469

The numbers of wallabies shot at any one time were approximately 1-5% of the wallabies actually seen in the paddock just prior to and during the shooting. Actual numbers were hard to establish due to the very timid nature of the wallabies, especially on the two properties where management is carried out on a regular basis causing the wallabies to become “gun-shy”. Of the 448 wallabies shot on “Brookland Park”, “Jarumble”, “Leska Park” and “Tandanya”, 305 were male and 143 were female. The breakdown of numbers of wallabies used to assess the different demographic parameters are summarised in table 3.2.

Table 3.2: Summary of age, weight, sex ratio, kidney fat index, worm count, scrotal circumference, number of pouch young and age of pouch young for Tammar Wallabies in culled (“*Brookland Park*”, “*Jarumble*”) and unculled (“*Leska Park*”, “*Tandanya*”) populations on Kangaroo Island.

	age (years)	carcass weight (kgs)	male to female ratio	KFI (%)	worm count (no.)	scrotal circumference (mm)	number of pouch young	age of pouch young (days)
<b><i>culled</i></b>								
number	220	219	148:80	74	47	143	65	66
mean	3.22	5.45		93.07	1,387	164.92	83%	81.15
min	0.87	2.40		2.82	0	60.00	0%	5.00
max	10.87	10.90		347.90	6,216	250.00	100%	190.00
sd	2.22	1.55		79.67	2,347	35.21	38%	53.92
<b><i>unculled</i></b>								
number	220	224	162:63	59	46	162	58	58
mean	4.00	5.27		83.38	2,182	154.53	92%	76.94
min	0.72	1.80		0.00	0	60.00	0%	5.00
max	13.11	8.50		282.45	19,666	200.00	100%	182.00
sd	2.73	1.55		71.17	3,524	31.11	27%	54.02
<b><i>total</i></b>								
number	440	443	305:143	133	93	305	123	124
mean	3.61	5.36		88.77	1780	159.4	87%	85.93
min	0.72	1.80		0.00	0	60.0	0%	5.00
max	13.11	10.90		347.90	19,666	250.0	100%	190.00
sd	2.51	1.55		75.89	2998	33.45	34%	53.88

## Chapter 4: Age structure

### 4.1 Introduction

Age is an important factor in describing the status of a population. It tells how long animals live for, if there has been a catastrophe which limited the survival of a particular age class, or if there is a balanced age structure from juveniles through to old adults at the end of their productive life.

The mean age of a population reflects the relative position of the population on the logistic growth curve. If a population is closer to the point of inflection, then the population has a higher percentage of juveniles because the population is increasing at a faster rate compared with a population which is closer to maximum carrying capacity and is increasing at a slower rate because the juvenile recruitment is much less (Teague and Decker, 1979; Robinson and Bolen, 1984).

The stability of the age class structure for a population is often dependant on the population's available food resources - as shown by a population of Arctic Fox (*Alopex lagopus* Linnaeus) on St. Lawrence Island. Fay and Rausch (1992) found that the age structure was stable and that the fox population was correlated with its prey population - the Northern Vole (*Microtus oeconomus* Pallas). If the vole population remained stable then there was sufficient food resources for each generation of fox cubs to survive to adulthood and consequently maintain the stable age structure of the fox population.

The age structure of a population can change on a seasonal basis during an annual cycle but remain relatively constant on a year-to-year basis, particularly in small animals which only live for one or two years. Press (1987) found that juvenile Bush Rats (*Rattus fuscipes*) born in summer/autumn, grew during the winter and become mature adults in the following spring/summer, with very few adults surviving to the second breeding season, but there was always another generation of Bush Rats to take the place of the previous generation which had died.

The percentage of animals in each age class will have an effect on the whole population. For example, Hellgren *et al* (1995) found that adult female Collared Peccaries (*Tayassu tajacu*) had higher production of young than yearling females, that is, they had larger litters. Therefore, if there was a larger percentage than normal of older females there would be more large litters born which could result in a population explosion.

Juvenile female Tammar Wallabies are sexually mature at about ten months and are mated when they leave the pouch, with the embryo held in diapause until normal development resumes after the summer solstice (Poole, 1986; Tyndale-Biscoe and Renfree, 1987). Therefore, in a healthy wallaby population, every female could be expected to produce a pouch young during late summer. However, there is little information about the age when (or if) Tammar Wallabies become less fertile and less likely to have joeys, although 14 year old females have been recorded with pouch young (Inns, 1982c; Poole *et al*, 1988). Male Tammar Wallabies do not become sexually mature until eighteen to twenty months (Inns, 1980 and 1982b) and

presumably remain sexually active for the rest of their lives, although there is little published information to support this theory. There is also little information on the longevity of Tammar Wallabies in managed wild populations, although there is evidence to suggest that in unmanaged wild populations the wallabies live to about 15 years (Inns, 1980, 1982a and 1982c; Poole *et al*, 1988).

There are a number of techniques in determining age classes for different animal species. The weight of dried eye lens has been used to age wild European Rabbits (*Oryctolagus cuniculus*) in Australia (Dudzinski and Mykutowycz, 1961) and Brown Hare (*Lepus europaeus*) populations in France (Pépin, 1987). Leader-Williams (1979) determined ages of live Reindeer (*Rangifer tarandus*) and Reindeer skulls from South Georgia, Antarctica, by using typical tooth replacement and tooth eruption patterns. However difficulties with under-aging were encountered due to influences from an environment in which the Reindeer are an introduced species. Skogland (1983) used tooth development to age Reindeer up to 2.5 years and the tooth cementum layering to age animals older than 2.5 years while Albon *et al* (1986) used tooth eruption and annual rings in the dental cementum to estimate the age of Red Deer (*Cervus elaphus*). The separation of juvenile, sub-adult and adult Bush Rats (*Rattus fuscipes*) was determined by incisor width across the two incisors in the upper jaw, with juvenile status being confirmed by the lack of mature sexual characteristics (Press, 1987). Lyne and Mort (1981) aged skulls of wild bandicoots (of the genus *Isodon*) using a combination of tooth eruption, tooth replacement and tooth wear when compared with skulls of animals of known age from a growth studies project. They were consequently able to describe a new species on the basis of dental morphology. Skulls of captive-reared and known age Bandicoots (*Perameles nasuta*) were used by Lyne (1982) to age skulls of wild Bandicoots on the basis of tooth eruption patterns. Eight subspecies of *Antechinus* were described by Davison (1986) on the basis of dental morphology, and tooth wear was the basis of determining age classes of Koalas (*Phascolarctus cinereus*) from 1.2 to 7.3 years (Gordon, 1991).

Table 4.1: Ageing techniques available for macropod species.

Species	growth tables	ageing keys	molar index	mandible growth	Reference
Agile Wallaby ( <i>M. agilis</i> )			•		Dudzinski <i>et al</i> , 1977; Newsome <i>et al</i> , 1977
Bennett's Wallaby ( <i>M. rufogriseus fruticus</i> )	•			•	Catt, 1979
Common Euro ( <i>M. robustus</i> )	•				Sadleir, 1963
Eastern Grey Kangaroo ( <i>M. giganteus</i> )		•	•		Poole <i>et al</i> , 1980; Pearse, 1981; Wood <i>et al</i> , 1981; Poole <i>et al</i> , 1982a; Wood <i>et al</i> , 1983; Poole <i>et al</i> , 1984
Eastern Wallaroo ( <i>Osphranter robustus</i> )	•		•		Kirkpatrick, 1965; Maynes, 1972
Grey Kangaroo ( <i>M. major</i> )	•		•		Kirkpatrick, 1964; Kirkpatrick, 1965
Parma Wallaby ( <i>M. parma</i> )	•		•		Maynes, 1972
Red Kangaroo ( <i>Macropus rufus</i> )	•		•		Sharman <i>et al</i> , 1964; Kirkpatrick, 1965; Kirkpatrick 1970
Red-Necked Wallaby ( <i>Wallabia rufogrisea</i> )	•		•		Kirkpatrick, 1965; Maynes, 1972
Tammar Wallaby ( <i>M. eugenii</i> )	•		•		Murphy & Smith, 1970; Inns, 1980; Inns, 1982a
Western Grey Kangaroo ( <i>M. fuliginosus fuliginosus</i> , <i>M.f. melanops</i> , <i>M.f. ocydromus</i> )		•	•		Poole <i>et al</i> , 1980; Poole <i>et al</i> , 1982b; Poole <i>et al</i> , 1984; Poole <i>et al</i> , 1985
Plain Rock-Wallaby ( <i>Petrogale penicillata</i> <i>inornata</i> )			•		Johnson, 1979
Red-Bellied Pademelon ( <i>Thylogale billardieri</i> )			•		Rose & McCartney, 1982

For marsupial young still in the pouch, it is easy to take measurements and calculate growth rates and there are tables of growth rates for a number of marsupial species (Table 4.1). Catt's (1979) method of ageing Bennett's Wallabies (*Macropus rufogriseus fruticus*) in a captive population on the basis of annual layers in the mandible was found to be not suitable for marsupials in the arid zone because irregular seasons cause variations in nutrition and therefore regular annual layers are not deposited in the teeth or the jaw (Wilson, 1975). Aging keys, using head length, ear length, foot length, leg length, arm length, tail length, sex, known age, and body weight, were developed for eastern grey kangaroos (*M. giganteus*) and western grey kangaroos (*M. fuliginosus fuliginosus*, *M. f. melanops*, *M. f. ocydromus*) for easier aging of wild animals in the field.

Generally, macropods are aged by tooth eruption in younger animals and molar progression in older animals. The progression of the molars along the jaw relative to the anterior rim of the eye orbit is measured in tenths for each molar - the molar index. The molar index for unknown age skulls is then compared with a linear regression of molar index against age of known animals (Kirkpatrick, 1964; Sharman *et al*, 1964). Linear regressions of molar index against age have been calculated for the macropod species as indicated in table 4.1.

Tammar Wallabies up to about fourteen years were aged by Inns (1980 and 1982a) using the linear relationship of molar progression against log age with the regression equation being:  $\log(\text{age in days}) = 2.0939 + 0.4067(\text{molar index})$ . Wilson (1975) used the molar index (with different regression equations), as well as annual survival rate, for red kangaroos, western and eastern grey kangaroos and wallaroos to assess the age structure of culled populations of these four species in New South Wales and concluded that, on the basis of age structure, the populations were stable. The average age and the annual survival rate of each species indicated that the red kangaroos were the least heavily culled and the grey kangaroos (both species combined) were the most heavily culled. Frequency of age class for Tammar Wallabies has been calculated for uncultured populations (Inns, 1982c; Poole *et al*, 1988) but not for culled populations, and differences between age structures of culled and uncultured populations will assist in determining the stability of the populations. However, errors can occur with ageing techniques, and Caughley (1967) suggested using annual mortality rate and life expectancy to compare populations, as these statistics are estimated from the proportion of juveniles under one year within the population rather than on the frequency of each age class, and a comparison of these statistics for culled and uncultured wallaby populations would also assist in determining the effect of culling on the Tammar Wallaby population of Kangaroo Island.

#### **4.2 Specific Methods**

The skull of each wallaby was removed and placed in a sealable plastic bag with the individual wallaby's identification number marked on the outside of the bag. The skulls were then held in cold storage until they could be cleaned. The skulls were cleaned of all flesh and brain by simmering in individual beakers of water for 2-6 hours until the flesh was able to be flushed off with running water. The skulls were then allowed to air dry, and were identified permanently with their individual number.

Skulls were aged using both molar eruption (younger animals) and molar index, as described by Inns (1980) and Sharman *et al* (1964). Age, based on the molar index, was calculated using Inns (1982a) equation of:

$$\log(\text{age in days}) = 2.0939 + 0.4067(\text{molar index}).$$

Age, based on the molar eruption, was plotted on the graph from Inns (1982a). The two sets of data were then averaged to give an age for each wallaby and this age was used for all further calculations.

The mean age of the culled and uncultured population was calculated. The age of all wallabies was compared using regression analysis in Genstat with age as the response variate and the two types of management (culled or uncultured) as the fitted terms.

All wallabies were classified into an age structure based on the year of birth, the age of the wallaby in days and the time of year when the wallaby was shot. The frequency of occurrence of age classes of the culled and uncultured populations was compared using Kruskal-Wallis one-way analysis of variance in Genstat.

The percentage of 1-2 year old wallabies (ie those born in 1996) from the two populations was compared using the  $\chi^2$  analysis.

The annual survival rate (s) of the two populations was calculated using the formula from Chapman & Robson (1960):

$$s = T/(n + T - 1)$$

where  $T = N_1 + 2N_2 + 3N_3 + \dots + kN_k + (k + 1)M$ ;  $N_1$  is the number of wallabies in the first year to be considered;  $N_k$  is the number in the oldest reliable age class;  $M$  is the total number of wallabies in the older unreliable age classes grouped together; and  $n$  is the total number of wallabies to be considered in the population. The annual survival rate for the two populations was compared using the  $\chi^2$  analysis.

The annual mortality rate (q) for the two populations was calculated using the formula of Caughley (1967):

$$q = j / n$$

where  $j$  = number of female pouch young and  $n$  = total number of female wallabies at each collection time. The unweighted mean for annual mortality rate of the culled and uncultured populations was compared using the  $\chi^2$  analysis.

The life expectancy (mean age at death) ( $e_0$ ) for the two populations was calculated using the formula of Caughley (1967):

$$e_0 = (2n - j) / 2j$$

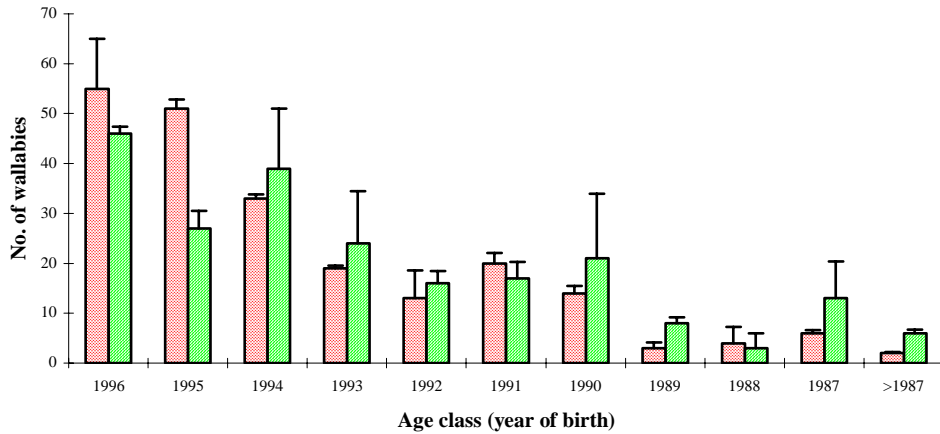
where  $j$  = number of female pouch young and  $n$  = total number of female wallabies at each collection time. The unweighted mean for life expectancy of the culled and uncultured populations was compared using the  $\chi^2$  analysis.

Measurements taken from pouch young (the head length, pes length and leg length) were plotted onto growth curves from Murphy & Smith (1970) and averaged to give an age for each of the pouch young. The mean age of the pouch young was calculated for each site at each collection period as well as for the two populations.

### **4.3 Results**

The ages of the culled population ranged from 0.87 years to 10.87 years with a mean of 3.22 years and a standard deviation of 2.22 years. The ages of the uncultured population ranged from 0.72 years to 13.11 years with a mean of 4.00 years and a standard deviation of 2.73 years. The regression analysis of age on management showed a significant effect ( $P=0.1\%$ ) due to culling with a  $V.R_{obs}$  of 10.91 and  $F_{1,436}$  of 3.84.

The frequency of age classes for the two populations is shown in figure 4.1. The Kruskal-Wallis one-way analysis of variance showed there was no significant difference between the age structures of the culled and uncultured populations ( $P = 5\%$ ) with a value of  $H = 0.2113$  with 1 degree of freedom.



**Figure 4.1:** Comparison of age class structure for Tammar Wallabies from culled (red dots) and unculted (green stripes) populations on Kangaroo Island. Standard deviations are shown as error bars.

The juvenile recruitment is also shown in figure 4.1. The culled population had 25% of the population born in 1996 whilst the unculted population had 21%. A  $\chi^2$  analysis showed there was no significant difference between the two populations with  $\chi^2 = 1.04$  with 1 degree of freedom.

The annual survival rate for the culled population was calculated as 0.767 (“Brookland Park” = 0.774, “Jarumble” = 0.763) and for the unculted population as 0.792 (“Leska Park” = 0.814, “Tandanya” = 0.773).

The estimated mortality rate and estimated life expectancy of Tammar Wallabies from the culled and unculted populations are shown in table 4.2.

Table 4.2: Estimated mortality rate and life expectancy for Tammar Wallabies from culled and unculted populations on Kangaroo Island.

Sample period	No. of female pouch young	Total females	Mortality rate	Life Expectancy
<b><i>culled</i></b>				
February	10	45	0.22	4.00
March	4	17	0.24	3.75
June	5	30	0.17	5.50
July	2	9	0.22	4.00
means:			0.21	4.31
<b><i>unculted</i></b>				
February	-	-	-	-
March	5	28	0.18	5.10
June	7	35	0.20	4.50
July	5	17	0.29	2.90
means:			0.22	4.12

Table 4.3: Ages of pouch young Tammar Wallabies from culled and unculted populations on Kangaroo Island.

Time of collection	No. of pouch young	Average age (days)
<b><i>culled:</i></b>		
February	22	16.5
March	13	54.6
June	24	125.8
July	7	141.0
mean:		81.2
<b><i>unculted:</i></b>		
February	-	-
March	20	39.2
June	26	96.2
July	12	141.8
mean:		76.9

The average age of pouch young at each collection period is shown in table 4.3, but it does not show the great range in ages at a particular collection period. In February, ages ranged from 5 to 30 days in the culled populations. In March, ages ranged from 47 to 61 days in the culled populations and from 5 to 64 days in the unculted populations. In June, the culled populations had pouch young from 102 to 148 days including one pouch young aged 49 days; whilst the unculted populations had pouch young aged between 5 days and 148 days - with 10 pouch young less than 75 days and three of those were less than 21 days old. In July, the ages ranged from 90 to 182 days for the culled populations and from 30 to 190 days for the unculted populations. This is summarised in table 4.4, which shows the months in which the pouch young were born. 97% of females in the culled populations had their pouch

young born in the normal January-February period compared with 62% of females in the unculled populations.

Table 4.4: Birth months for pouch young Tammar Wallabies from culled and unculled populations on Kangaroo Island.

Month	culled population		unculled population	
	number	%	number	%
January	41	58.6%	21	36.2%
February	27	38.6%	15	25.9%
March	0	0%	12	20.7%
April	2	2.8%	5	8.6%
May	0	0	2	3.4%
June	0	0	3	5.2%
total:	70		58	

#### **4.4 Discussion**

Culling is having an effect on the wallaby populations tested. Mean age of the culled populations is statistically lower than the unculled populations. However, none of the other age characteristics show significant effects, although they do show a trend that the unculled population is older and has a slightly higher annual survival rate than the culled population. This suggests that culling on the two properties tested is sustainable.

The slightly lower juvenile recruitment rate of the unculled population indicate that these properties have populations which have a tendency towards maximum carrying capacity than the two culled properties. Further studies with a larger sample size are required before a definitive result can be obtained.

The significant difference in birth dates of pouch young between the two populations could have been due to a number of stress-related or higher density-related factors which may have been improved by culling. This also requires further studies.

## Chapter 5: Growth and nutrition

### 5.1 Introduction

Nutrition is closely linked to carrying capacity because it is assumed that a lack of food reserves is the main limiting factor in determining the carrying capacity, and hence the population density, of a particular location. Growth can be slowed down as a result of a lack of nutrition and have an effect on the future productivity of the animal. Allden (1979) showed that nutritionally deprived lambs resulted in smaller adult ewes with reduced wool production but that under-nutrition did not affect reproduction performance in these lambs. However, maternal under-nutrition was found to affect foetal growth in Reindeer (Roine *et al*, 1982), was one of the main causes of lamb mortality in the first three weeks of life of Suffolk lambs in Mexico (Cervantes *et al*, 1986), was the major factor affecting fecundity and juvenile mortality of Banteng cattle (*Bos javanicus*) in northern Australia (Choquenot, 1993), and reduced foetal body weight of Guinea Pigs (*Cavia porcellus*) at parturition (Dwyer *et al*, 1995). Harding and Johnston (1995) suggest that maternal nutrition is vital for foetal growth and that under-nutrition affects the hormonal interactions between the mother, the foetus and the placenta to retard foetal development. Harding and Johnston (1995) also suggest that nutritional effects may affect not just the foetus but future generations as well. Maternal nutritional intake affects the size and vigour and consequently the viability of the newborn animal, with Robinson (1996) showing that under-nutrition in ewes in late pregnancy causes reduced foetal insulin and insulin growth factor 1 (IGF1) with a low sequential retardation in growth and development of the lamb.

Nutrition has an affect on growth rates, the mature size of animals, and fertility. Verme and Ozoga (1980) found that White-Tailed Deer (*Odocoileus virginianus*) fawns fed on a reduced diet grew slower, had reduced fat stores and had smaller organs than fawns fed on an ad-lib diet, but that the nutritionally deprived fawns still managed to store some fat. A correlation between reduced jaw bone length (and therefore a smaller sized animal) and increasing herd density was found in twelve Reindeer herds in Norway, indicating that adult size of Reindeer is influenced by population density which in turn influences the amount of feed available to each reindeer within its own herd (Skogland, 1983). Albon *et al* (1986) showed that fertility in Red Deer hinds was affected by body size and that small increases in body size considerably increased the probability of pregnancy. Skogland (1986) showed that an increase in population density of Reindeer causes a decrease in the size of adult females and a decrease in young born - both of which occur as a result in a reduction of food available in winter.

Seasonal feed availability may mean that adequate nutritional requirements are not met at appropriate times for growth of young animals. Grant and Temple-Smith (1983) found that young Platypuses (*Ornithorhynchus anatinus*) in the Shoalhaven River showed an initial growth spurt when they emerged from nesting burrows after weaning in mid summer through until autumn when there were high food resources but that growth became retarded during the winter months with reduced feed resources. Juvenile females then increased growth rates in the spring and reached

adult size by the following mid-summer. Juvenile males, on the other hand, did not reach adult size until later in the summer-autumn period than the juvenile females.

Nutrition plays an important role in changes of population numbers in macropods. Bayliss (1985) found that where rainfall was adequate to maintain kangaroo food supplies then the populations of Red and Western Grey Kangaroos remained stable in Kinchega National Park. In the same location, Caughley and Gunn (1993) found that as plant biomass increases then there is an increase in kangaroo numbers and conversely as plant biomass decreases there is a rapid decline in kangaroo numbers - concluding that a drought has a drastic effect on kangaroo numbers. Cairns and Grigg (1993) also found that rainfall affects kangaroo numbers. This was confirmed by McCarthy (1996) who concluded that changes in South Australian Red Kangaroo numbers are correlated with rainfall and population size and that rainfall needs to be taken into account when assessing macropods populations for harvest levels.

On Kangaroo Island, rainfall is not such a major factor in feed availability for the Tammar Wallaby as there is about 6½ months of effective annual rainfall (and 5½ months when occasional rainfall occurs) with the growing season from mid April to mid October (Inns, 1980). In late summer through until the seasonal break is the time of reducing food resources for the Tammar Wallaby - which also occurs at a time when the females are in early lactation (Tindale-Biscoe and Renfree, 1987) and are therefore drawing on body energy reserves.

There is no published work to indicate whether management of Tammar Wallaby populations (and therefore increased food resources) has an effect on growth rates of pouch young, fertility in males and females, or on mature body size.

## **5.2 Specific Methods**

The weight of adults was recorded accurate to the nearest 100g using a Ruddweigh Sheep and Cattle electronic scales and the weights of the pouch young were recorded accurate to the nearest 0.01 gram using a Sartorius PT210 portable electronic scales.

The mean weight of the culled and unculted population was calculated. The weight of all adult wallabies was compared using regression analysis in Genstat with weight as the response variate and the two types of management (culled or unculted) as the fitted terms. A second regression analysis was carried out after eliminating all wallabies less than 6.0 kilograms.

A regression analysis in Genstat was carried out to determine the effect of culling on the relationship between age and weight.

All adult wallabies were classified into a weight class structure and the frequency of occurrence of weight classes of the culled and unculted populations was compared using Kruskal-Wallis one-way analysis of variance in Genstat.

A regression curve for growth (weight over age) was calculated for the pouch young in the culled and unculted populations and compared.

### 5.3 Results

#### 5.3.1 Adults

The weights of the culled population ranged from 2.40 kilograms to 10.90 kilograms with a mean of 5.45 kilograms and a standard deviation of 1.55. The weights of the unculled population ranged from 1.80 kilograms to 8.50 kilograms with a mean of 5.27 kilograms and a standard deviation of 1.55. The regression analysis of weight on management showed no significant difference ( $P = 20.8\%$ ) between culled and unculled populations with a  $V.R._{obs}$  of 1.59 with  $F_{1,436}$  of 3.84. However, for all animals over 6.0 kilograms, the regression analysis of weight on management showed that culling is having a significant effect ( $P = 1.7\%$ ) on heavier animals ( $V.R._{obs}$  of 5.84 with  $F_{1,157}$  of 3.84).

The regression analysis of weight on age and management showed a highly significant difference ( $P < 0.1\%$ ) between culled and unculled populations with a  $V.R._{obs}$  of 204.67 with  $F_{3,434}$  of 2.65. The best model was found to be two parallel exponential curves, thus:

$$\begin{aligned} \text{weight}_{\text{culled}} &= 6.941 + (-6.959)(0.99)^{\text{age}} \\ \text{weight}_{\text{unculled}} &= 6.474 + (-6.959)(0.99)^{\text{age}} \end{aligned}$$

The frequency of age classes for the two populations is shown in figure 5.1. The Kruskal-Wallis one-way analysis of variance showed there was no significant difference between the age structures of the culled and unculled populations ( $P = 5\%$ ) with a value of  $H = 0.08732$  with 1 degree of freedom.

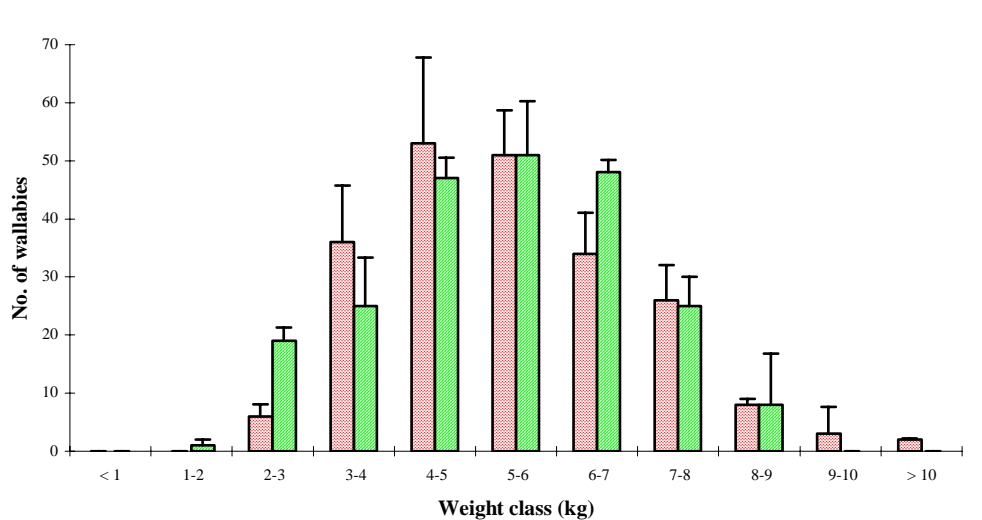


Figure 5.1: Comparison of weight classes for Tammar Wallabies from culled (red dots) and unculled (green stripes) populations on Kangaroo Island. Standard deviations indicated by error bars.

### 5.3.2 Pouch Young

A comparison of growth rates for the pouch young shows that the growth rates for the culled population was slightly faster for the earlier collection periods but at the July collection, the unculled population had a more rapid growth rate (table 5.1). The regression lines for growth rate for the two populations of pouch young were:

$$\text{weight}_{\text{culled}} = 26.34 + 0.943(\text{age})$$

$$\text{weight}_{\text{unculled}} = 43.46 + 0.652 (\text{age}).$$

Table 5.1: Comparison of growth rates in pouch young for Tammar Wallabies from culled and unculled populations on Kangaroo Island.

Time of collection	average age of pouch young (days)	average weight of pouch young (g)	growth rate of pouch young
<b><i>culled:</i></b>			
February	16.5	2.5	0.152
March	54.6	16.7	0.306
June	125.79	99.05	0.787
July	141.0	127.4	0.904
<b><i>unculled</i></b>			
February	-	-	-
March	39.15	11.92	0.304
June	96.16	66.71	0.694
July	141.8	150.5	1.061

### 5.4 Discussion

Culling is not having a significant effect on adult Tammar Wallaby body weight on the tested properties. However, if commercial harvesting was introduced, then the larger animals would be shot in preference to the random shooting of animals of all sizes - which was used in this project. Therefore, looking at only the heavier wallabies, a statistically significant difference was found to exist between the two populations. This suggests that general culling of animals of all sizes is having an effect on the remaining wallabies on the properties tested by increasing the weights in the culled population. This could be due to the greater amount of feed available to the remaining wallabies, but is an area of further research.

The comparison of age-related weight indicated that adult weights were slightly higher for wallabies at the same age in the culled populations, as shown by the intercept being approximately 8% higher. This trend was as predicted in the hypothesis.

There was no significant difference between the weights of pouch young for the two populations. A minor trend was detected during the earlier lives of the pouch young suggesting that more intensive culling could affect the weights of pouch young by increasing their weight gains.

## Chapter 6: Energy reserves

### 6.1 Introduction

Energy reserves are required to maintain animals through times of nutritional stress - such as lactation in females and mating in males. Kidney fat index is one method of measuring energy reserves and was first used by Riney (1955), who suggested using kidney fat index as a means of comparing body condition or energy reserves in Red Deer in different seasons and locations. This particular method discarded the perirenal fat both anterior and posterior to the kidney, with the retained fat and the kidney being weighed separately and the ratio of kidney fat weight to the kidney weight calculated as a percentage to give the kidney fat index. Since the development of this method of assessing energy reserves, it has been used in a number of species although there has been discussion as to its suitability for all species and seasons. Spinage (1984) used kidney fat index as well as kidney weight to assess body condition in Waterbuck (*Kobus ellipsiprymnus*) and Grant's Gazelle (*Gazella granti*) and found that seasonal changes in kidney weights did not sufficiently alter to affect the kidney fat index. Lochmiller *et al* (1985) compared bone marrow fat and Riney's (1955) kidney fat index as indicators of energy reserves in Collared Peccaries and found that kidney fat index was not a good indicator below values of 20% when marrow fat reserves were being mobilized, but that kidney fat index could be used when comparing seasonal changes in condition. Van Vuren and Coblenz (1985) reported that the kidney fat index was a valid technique for comparisons of body condition in sheep, although a poor comparison because of the allowances which should be made for seasonal changes in kidney weights.

Monson *et al* (1974) compared Riney's (1955) method of trimmed kidney fat index with total kidney fat index for White-Tailed Deer and found that Riney's method was less sensitive to increases in kidney fat because the fat deposits tended to increase in length anterior and posterior to the kidney rather than in diameter around the kidney. This was confirmed by Finger *et al* (1981), who found a correlation coefficient of 0.87 between percent body fat and kidney fat index in White-Tailed Deer - using total kidney fat method as described by Monson *et al* (1974) and not dissected kidney fat method as described by Riney (1955). However, Adamczewski *et al* (1987) used back fat thickness, total kidney fat weight and dissected kidney fat to compare carcass composition of Coats Island Caribou (*Rangifer tarandus groenlandicus*) of various ages and found that kidney fat weight was a better indication of the level of energy reserve than kidney fat index because the weight of the kidney alone did not reflect body weight in the caribou. Anderson *et al* (1990) also suggested that kidney fat mass is a better indication of annual fat cycle when assessing body condition in Rocky Mountain Mule Deer (*Odocoileus hemionus hemionus*).

Albon *et al* (1986) used total kidney fat index to assess body condition of female Red Deer and found that hinds in better than average condition had a higher probability of pregnancy than hinds of below average body condition. Choquenot (1993) used kidney fat index to assess body condition in wild Banteng (*Bos javanicus*) in northern Australia and found that condition increased as the Banteng

cattle aged from juvenile to adult, then declined again in the older females. Gallivan *et al* (1995) used kidney fat index to condition score Impala (*Aepyceros melampus*) and found that Impala in good condition could be differentiated by kidney fat index but not animals in fair to poor condition, nor was it suitable for young Impala in the lamb and yearling classes because they were still growing and not putting on fat stores. However, the indices showed that Impala grazing in an unmanaged, overpopulated area in the Mlawula-Mbuluzi-Simunye Nature Reserve and Protected Area in Swaziland were in poorer condition generally than the Impala grazing on the managed and Impala-culled area.

Backfat thickness has also been used as a measurement of body fat reserves, particularly in dairy cows (Staufenbiel *et al*, 1993). Back fat thickness is an objective measurement which has been correlated with subjective parameters such as feed intake, energy balance, milk yield, and fertility. Therefore back fat thickness is an important management tool for monitoring maximum production in dairy cows. Back fat thickness, using ultrasound, has also been correlated with the kidney fat index to indicate energy reserves in Barren-Ground Caribou (*Rangifer tarandus granti*) (Chan-McLeod *et al*, 1995)

Huot *et al* (1995) used a combination index of kidney fat index and femur marrow fat as an indicator of body reserves in Coyote (*Canis latrans*) and concluded that the index was a suitable predictor of changes in the nutritional state of wild Coyotes.

Leader-Williams and Ricketts (1982) found that seasonal changes in fat reserves in Reindeer on South Georgia was correlated with reproductive activities - declining in males after the rut and troughing in females at parturition. Also, males lost twice as much body tissue as females during the year with both fat and muscle protein being metabolized. White-Tailed Deer show seasonal variation in energy reserves with males increasing kidney fat index prior to the breeding season and females increasing kidney fat index following conception. These higher body condition levels occurred at the end of autumn and decreased during winter as energy reserves were required for thermoregulation, mating (in males) and for pregnancy/lactation (in females) (Johns *et al*, 1984). The reproductive status in Brown Hares in France was assessed and a correlation was found to exist between kidney weight and testicular weight in young males, as well as a very high kidney fat index in non-productive females. There was a seasonal fluctuation in kidney fat index with increases in spring/summer and decreases in autumn/winter (Pepin, 1987). Adamczewski *et al* (1995) used kidney fat mass and body mass to compare Muskoxen (*Ovibos moschatus*) to other ruminants and found Muskoxen to have similar fat reserves as sheep and cattle. They found that Muskoxen fat reserves are required to supplement reduced available winter feed but more particularly the latter stages of pregnancy and early lactation as the calves are born up to eight weeks prior to green feed being available. Hellgren *et al* (1995) found that a slightly higher kidney fat index in Collared Peccaries was associated with higher rainfall the previous year. They also found a higher kidney fat index in females just prior to parturition - and suggested a higher energy reserve requirement for late pregnancy-early lactation.

Millar (1981) found in White-footed Mice (*Peromyscus leucopus*) that fat reserves were not correlated with seasonal fluctuations but that fat reserves were negatively correlated with temperature and population density. Therefore fat reserves could be used as an indicator of maximum carrying capacity of the population.

Fat reserves could also be used as an indicator of seasonal nutrition. Grant and Temple-Smith (1983) found that body weight of adult Platypuses decreased during winter and increased again in summer and autumn - as determined by available food resources. Gerhart *et al* (1996) found that body fat and protein levels in adult female Arctic Caribou declined over winter and suggests this was due to under-nutrition. It is also suggested that the kidney mass decrease was also a result of reduced nutritional intake.

There is a seasonal fluctuation in gut fat (kidney plus mesenteric fat) in male Tammar Wallabies (Inns, 1980) with a low in early winter and a high in spring. This study also found that out of pouch joeys had low gut fat deposits to sustain them over their first summer and that growth was restricted during this period. Dissected kidney fat index was found to be the most responsive method of measuring body condition in Red and Western Grey Kangaroos (Caughley, 1962; Shepherd, 1987). Shepherd (1987) used kidney fat index to show that during the 1982 drought Western Grey Kangaroos were able to sustain lower body condition and for longer periods than Red Kangaroos, and that deaths in the populations under study were due mainly to starvation. It was also found that during the drought Western Grey Kangaroo pouch young were only slightly below expected body weight compared with Red Kangaroo pouch young - indicating that female Western Grey Kangaroos contributed more to the growth of their joeys than female Red Kangaroos.

Based on research in other macropod species, kidney fat index should be a good indication of body condition in Tammar Wallabies and that kidney fat index can be used to detect differences between managed and unmanaged populations.

## **6.2 Specific Methods**

The total kidney fat index, as described by Monsen *et al* (1974), was used in this study to assess energy reserves. The total peri-renal fat and the kidney were weighed together on a Sartorius PT210 portable electronic scales (accurate to the nearest 0.01 gram), then the peri-renal fat and the kidney were weighed separately. The kidney fat index was calculated as a percentage ratio.

The mean kidney fat index of the culled and uncultured population was calculated. The kidney fat index of the randomly selected adult wallabies was compared using regression analysis in Genstat with weight as the response variate and the two types of management (culled or uncultured) as the fitted terms.

All selected wallabies were classified into a kidney fat index class structure and the frequency of occurrence of kidney fat index classes of the culled and unculted populations was compared using Kruskal-Wallis one-way analysis of variance in Genstat.

### 6.3 Results

The kidney fat indices of the culled population ranged from 2.82% to 347.9% with a mean of 93.07% and a standard deviation of 79.67. The kidney fat indices of the unculted population ranged from 0.00% to 282.45% with a mean of 83.38% and a standard deviation of 71.17. The regression analysis of weight on management showed no significant difference ( $P = 46.6\%$ ) between culled and unculted populations with a  $V.R._{obs}$  of 0.53 with  $F_{1,131}$  of 3.84.

The frequency of kidney fat classes for the two populations is shown in figure 6.1. The Kruskal-Wallis one-way analysis of variance showed there was no significant difference between the kidney fat index classes of the culled and unculted populations ( $P = 5\%$ ) with a value of  $H = 0.04412$  with 1 degree of freedom.

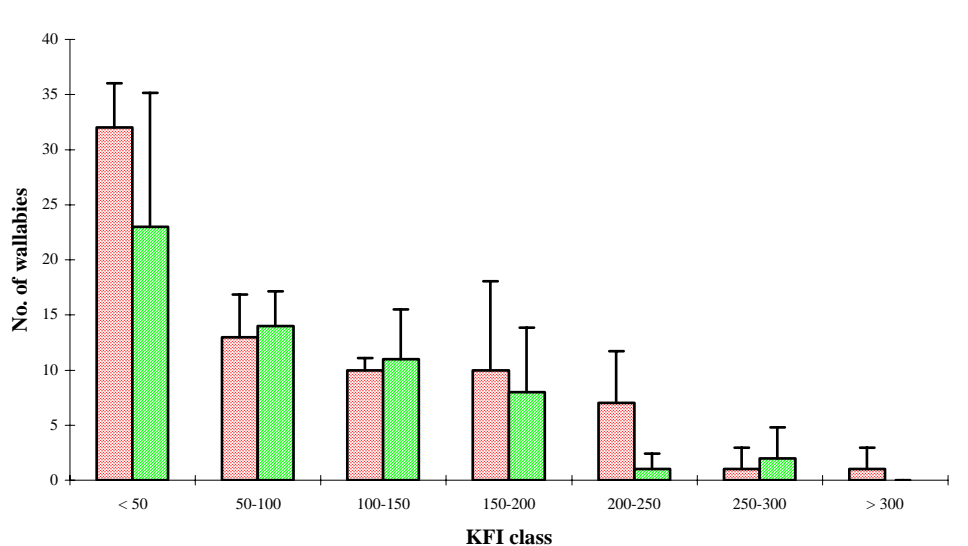


Figure 6.1: Comparison of kidney fat classes for Tammar Wallabies from culled (red dots) and unculted (green stripes) populations on Kangaroo Island. Standard deviations indicated by error bars.

### 6.4 Discussion

Culling is not having an effect on the kidney fat index ratios and there are no obvious trends to suggest that culling has any effect on the energy reserves of the wallabies on the properties tested. The accuracy for this particular characteristic could have been affected by the low numbers of animals selected for analysis from each site at each collection period. I feel that if a larger sample size had been selected, I would be more confident that these results were a reflection of the actual position in the tested populations.

## Chapter 7: Sex ratios

### 7.1 Introduction

Differences in sex ratios in populations may be helpful in determining other factors which could have an effect on the population. For example, the biased sex ratio in Reindeer herds on South Georgia, Antarctica occurs because adult males were found to live for seven to eight years whereas adult females were living for up to four years longer (i.e. for eleven to twelve years) (Leader-Williams, 1980). He also found that males tended to die in early winter (presumably due to loss of energy reserves during the rutting season) whereas females tended to die in late winter (presumably due to loss of energy reserves during pregnancy) with under-nutrition from lower levels of winter forage being the significant factor in carrying capacity. That is, both the age structure and the energy reserves of the Reindeer had an effect on the sex ratio.

Hoefs and Nowlan (1994) found that the male:female ratio of newborn animals on game reserves in Yukon Territory was affected by supplementary feeding with high quality feedstuffs. The species affected included Elk (*Cervus elaphus nelsonii*), Reindeer, Mountain Goats (*Oreamnus americanus*), Dall's Sheep (*Ovis dalli dalli*), Stone's Sheep (*Ovis dalli stonei*) and Caribou.

A study on Western Grey Kangaroos at Hattah-Kulkyne National Park, Victoria found a significant female bias in adults (3:1) although there was a very slight male bias in pouch young - indicating a high mortality which was accentuated during the 1982 drought (Norbury, 1987). Studies on the Tammar Wallaby indicate a balance sex ratio (Andrewartha and Barker, 1969; Inns 1980, 1982a and 1982b), however these studies do not indicate if there are differences in the sex ratios in Tammar Wallaby populations which are culled.

### 7.2 Specific Methods

The gender of all Tammar Wallabies, adults and pouch young, was recorded. The gender of all adult wallabies was compared using regression analysis in Genstat with sex as the response variate and the two types of management (culled or unculted) as the fitted terms. The ratios of males to females for culled and unculted populations was compared using chi-squared analysis for both the adults and the pouch young.

### 7.3 Results

The adult male:female ratio for the culled population was 1.85:1 and for the unculted population was 2.57:1. The regression analysis of sex on management showed no significant difference ( $P = 7.4\%$ ) between culled and unculted populations with a  $V.R._{obs}$  of 3.20 with  $F_{1,446}$  of 3.84. The pouch young male:female ratio for the culled population was 1.92:1 and for the unculted population was 2.47:1. The numbers of male and female adult wallabies is shown in table 7.1, with a clear male bias shown at most collections. The numbers of male and female pouch young is shown in table 7.2, again with a similar male bias.

Table 7.1: Comparison of adult male:female ratios for Tammar Wallabies from culled and unculted populations on Kangaroo Island.

Site	February	March	June	July	Total
<b>Culled sites:</b>					
• <i>Western River</i>	12:9 (21)	0	0	0	12:9 (21)
• <i>Brookland Park</i>	22:14 (36)	16:8 (24)	22:9 (31)	4:7 (11)	64:38 (102)
• <i>Jarumble</i>	26:21 (47)	27:5 (32)	26:16 (42)	0	79:42 (121)
subtotal:	60:44 (104)	43:13 (56)	48:25 (73)	4:7 (11)	155:89 (244)
<b>Unculled sites:</b>					
• <i>Leska Park</i>	0	20:8 (28)	20:9 (29)	5:5 (10)	45:22 (67)
• <i>Tandanya</i>	0	45:15 (60)	58:19 (77)	14:7 (21)	117:41 (158)
subtotal:	0	65:23 (88)	78:28 (106)	19:12 (31)	162:63 (225)
Totals:	60:44 (104)	108:36 (144)	126:53 (179)	23:19 (42)	317:152 (469)

Table 7.2: Comparison of pouch young male:female ratios for Tammar Wallabies from culled and unculted populations on Kangaroo Island.

Site	February	March	June	July	Total
<b>Culled sites:</b>					
• <i>Western River</i>	2:2 (4)	0	0	0	2:2 (4)
• <i>Brookland Park</i>	3:3 (6)	6:2 (8)	5:4 (9)	5:2 (7)	19:11 (30)
• <i>Jarumble</i>	9:7 (16)	3:2 (5)	13:2 (15)	0	25:11 (36)
subtotal:	14:12 (26)	9:4 (13)	18:6 (24)	5:2 (7)	46:24 (70)
<b>Unculled sites:</b>					
• <i>Leska Park</i>	0	4:2 (6)	5:4 (9)	3:2 (5)	12:8 (20)
• <i>Tandanya</i>	0	11:3 (14)	14:3 (17)	4:3 (7)	30:9 (39)
subtotal:	0	15:5 (20)	19:7 (26)	7:6 (13)	42:17 (59)
Totals:	14:12 (26)	24:9 (33)	37:13 (50)	12:8 (20)	88:41 (129)

#### 7.4 Discussion

There was no significant difference in the sex ratio between the two adult populations suggesting that culling is not having an effect on the sex ratios of the Tammar Wallaby on the properties tested. However, there is a marked male bias in both the adult populations as well as in the pouch young populations. This is in contrast to previous work on protected populations of Tammar Wallabies (Andrewartha and Barker, 1969; Inns, 1980, 1982a and 1982b), and could possibly be explained by the common practise of heavy culling of females in September/October. However this could not apply to the properties where culling is not normally carried out. The probable explanation is that the unexplained male bias in the pouch young is carried through into the adult population.

## Chapter 8: Parasites and disease

### 8.1 Introduction

Parasites can play a major role in the well-being of their host. Some parasites have no significant effect whilst others can have such an effect that death of the host occurs. Iason and Boag (1988) found that increased populations of gastro-intestinal nematodes (*Trichostrongylus retortaeformis*) has no apparent effect on the fecundity of Mountain Hares (*Lepus timidus*) nor on their body weight or kidney fat index - indicating either that the hare has a tolerance to the nematode or that the infestation is never severe enough to cause damage to the host. Bennet *et al* (1988) found that there was no measurable effect on the body mass of fifteen species of passeriform birds due to infections of blood parasites, although Bennet *et al* (1982) had found that overall younger waterfowl (anatids) were more susceptible to blood parasite infestations than older birds.

Maternal parasite infestations can have an effect on the unborn young. Rabbit kittens were found to have a reduced birth weight and survival rate when their mothers were infected with intestinal nematodes (*T. retortaeformis*) (Dunsmore, 1980). Hudson (1986) showed that a high intestinal nematode (*T. tenuis*) population reduced the clutch size and chick survival of Red Grouse (*Lagopus lagopus scoticus*) and that the breeding success in Red Grouse was significantly increased in older birds when the nematodes were treated with an anthelmintic. There are also seasonal, age and sex differences in levels of infestation as shown by Asanji and Williams (1987) in sheep and goats in Sierra Leone where intestinal nematodes increased in the dry season, younger animals had higher infestations than older animals, and females tended to have higher infestations than males.

Hudson *et al* (1992) found that higher burdens of caecal parasites (*T. tenuis*) were implicated in predator killed Red Grouse and found that the heavily infested birds were more susceptible to predation due to the emission of higher scent levels. They also suggested that this predation on heavily infested birds would lead to an increase in the size of the grouse population by removing the less viable members of the population.

Growth rates, fertility, productivity and body condition can be affected by parasite infestations, particularly in young animals. Isles *et al* (1985) found that gastro-intestinal nematodes had such an adverse effect on body condition of Friesian calves that they had to be treated with an anthelmintic at seven weeks of age. Gastro-intestinal nematode infections in pregnant heifers had an adverse effect on weight gain of the heifers and on the time of first mating (Nowosad *et al*, 1988). Muenstermann and Tome (1989) found that gastro-intestinal nematodes slowed down the liveweight gain of both young sheep and young goats in the Lolgorien area in Kenya, and De Rond *et al* (1990) also found that gastro-intestinal nematodes had an adverse effect on the growth of young heifers and on the milk production of dairy cows in Sri Lanka.

Parasites can cause one host species to have an advantage over another host species due to the level of tolerance to the parasite. The meningeal worm (*Parelaphostrongylus tenuis*) is carried harmlessly by the intermediate host, the

White-Tailed Deer but that the worm is a contributing factor in deaths of Moose (Schmitz and Nudds, 1994) and thereby acts as a controlling agent in moose populations which co-exist with White-Tailed Deer populations. However, Whitlaw and Lankester (1993) suggest that historical data do not support the claim that *P. tenuis* is responsible for the Moose population declines in the presence of White-Tailed Deer.

Diseases and parasites can alter stress levels in host species so that the host becomes more susceptible to other diseases or parasites. Boag (1988) suggests that the immune system of European Rabbits infected with myxomatosis become more susceptible to increases in helminth infestations and Yeruham *et al* (1992) suggest that stress in Awassi Sheep in Israel due to reduced nutrition, pregnancy and gastrointestinal parasites had an effect on the increase of haemoparasite (*Babesia ovis*) infection during autumn.

A number of parasites (nematodes, cestodes and coccidia) have been identified in the Tammar Wallaby and are found in the thoracic cavity, intestine and stomach (Smales and Mawson, 1978). The population density of the nematode species, *Labiostrongylus eugenii*, which is found in the sacculated stomach of the Tammar Wallaby (Smales, 1977a and 1977b; Smales and Sommerville, 1977) was selected to indicate relative parasite burdens between managed and unmanaged populations of Tammar Wallabies.

## 8.2 Specific Methods

The stomach contents were washed out of the stomach into a bucket of known volume of water and stirred gently to disperse the contents. A known volume of subsample was taken and placed on a coloured tray so that the nematodes could be clearly seen and counted. Only stage 2 and 3 larvae of *Labiostrongylus eugenii* were counted. The actual count of nematodes in the subsample was multiplied by the dilution factor of the water used to disperse the stomach contents.

The worm counts of the culled and uncultured populations was compared using regression analysis in Genstat with worm count as the response variate and the two types of management as the fitted term. The worm count class structure of the culled and uncultured populations was compared using Kruskal-Wallis one-way analysis of variance in Genstat.

The presence of other parasites, such as fleas and lice, were also recorded.

## 8.3 Results

The worm counts of the culled population ranged from 0 to 6,216 with a mean of 1,387 and a standard deviation of 2,347. The worm counts of the uncultured population ranged from 0 to 19,666 with a mean of 2,182 and a standard deviation of 3,524. The regression analysis of worm counts on management showed no significant difference ( $P = 18.1\%$ ) between culled and uncultured populations with a  $V.R._{obs}$  of 1.82 with  $F_{1,102}$  of 4.00.

The frequency of worm count classes for the two populations is shown in figure 8.1. The Kruskal-Wallis one-way analysis of variance showed there was no significant difference between the worm count classes of the culled and uncultured populations ( $P = 5\%$ ) with a value of  $H = 0.1788^{-6}$  with 1 degree of freedom.

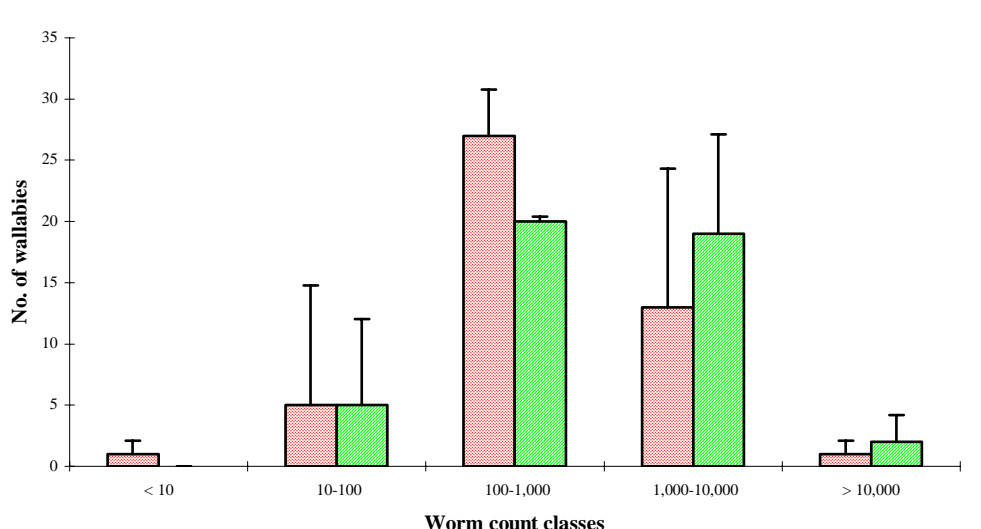


Figure 8.1: Comparison of worm count classes for culled (red dots) and uncultured (green stripes) populations of Tamar Wallabies on Kangaroo Island. Standard deviations indicated by error bars.

Lice were found on male wallabies at "Brookland Park" with 50% of males infested in July. There was a very low incidence of lice infestation on wallabies from the other properties.

#### **8.4 Discussion**

Although there was no statistical difference in worm counts between the two populations, there was a trend that worm counts were lower in the culled populations tested, suggesting that culling might have helped to reduce the worm burden within the tested populations.

A larger subsample of wallabies for worm counts would have increased my confidence in the results for this particular parameter.

## Chapter 9: Male Fertility

### 9.1 Introduction

Scrotal circumference has been used as a simple method of an indication of fertility in male domestic livestock for a number of years. It has been found that scrotal circumference, as a subjective measurement, is medium to highly heritable in a number of breeds of sheep, goats and cattle and is positively correlated with liveweight (Bongso *et al*, 1982; Swanepoel and Heyns, 1986; Schoeman and Combrink, 1987; Smith *et al*, 1989; Guerra and Ramirez, 1996; Keeton *et al*, 1996). Also, scrotal circumference is an indicator of the onset of puberty and sexual maturity, and can be used as a simple measurement for selecting sires of earlier maturity and higher fertility (Smith *et al*, 1981; Bongso *et al*, 1982; Ley *et al*, 1990; Ott, 1991; Wahid and Yunus, 1991; Andersson and Alanko, 1992; Mukasa-Mugerwa and Ezaz, 1992; Matharoo *et al*, 1994; Mussaddin *et al*, 1994). In fact, Graser *et al* (1994) found that scrotal circumference is one of the most cost effective selection indicators of fertility in Australian beef cattle.

Scrotal circumference has been found to change in response to non-breeding season and undernutrition due to reduced levels of testosterone in a number of species: Wapiti (*Cervus elaphus*) (Haigh *et al*, 1984); Collared Peccaries (Lochmiller *et al*, 1985); rams (Murray *et al*, 1991; Gastel *et al*, 1995); and Red Deer (Semiadi *et al*, 1995).

Kenagy and Trombulak (1986) found that in single-male breeding systems the testes were smaller in relation to body size but in multi-male breeding systems the testes were larger in relation to body size. This is thought to be a response for greater sperm production, higher mating frequency, and more successful sperm competition for fertilization of the same female mated by several males. Tammar Wallabies are multi-male breeding and so a larger scrotal circumference could be used as an indication of increased fertility in the male Tammar Wallaby.

Inns (1982b) found that there was no change in testes size in mature Tammar Wallabies but that there was an increase in the size of the accessory glands and in testosterone concentration during the breeding season. However, the testes increased during puberty until male wallabies reached sexual maturity at eighteen to twenty months of age. Therefore scrotal circumference could be used as an indicator of sexual maturity in Tammar Wallabies. There is no published work on the use of scrotal circumference as a simple indicator of fertility in the male Tammar Wallaby.

### 9.2 Specific Methods

The scrotum was removed from all male wallabies and the circumference was measured using a flexible fibreglass tape measure accurate to 1 millimetre.

The male fertility (scrotal circumference) of the culled and uncultured populations was compared using regression analysis in Genstat with scrotal circumference as the response variate and the two types of management as the fitted term. The frequency

of male fertility class structure of the culled and unculted populations was compared using Kruskal-Wallis one-way analysis of variance in Genstat.

### 9.3 Results

The scrotal circumference measurements of the culled population ranged from 60 mm to 250 mm with a mean of 164.92 mm and a standard deviation of 35.21. The scrotal circumference measurements of the unculted population ranged from 60 mm to 200 mm with a mean of 154.53 mm and a standard deviation of 31.11. The regression analysis of scrotal circumference on management showed a very significant difference ( $P = 0.7\%$ ) between culled and unculted populations with a  $V.R._{obs}$  of 7.34 with  $F_{1,303}$  of 3.84

The frequency of scrotal circumference classes for the two populations is shown in figure 9.1. The Kruskal-Wallis one-way analysis of variance showed there was no significant difference between the scrotal circumference class structures of the culled and unculted populations ( $P = 5\%$ ) with a value of  $H = 0.007556$  with 1 degree of freedom.

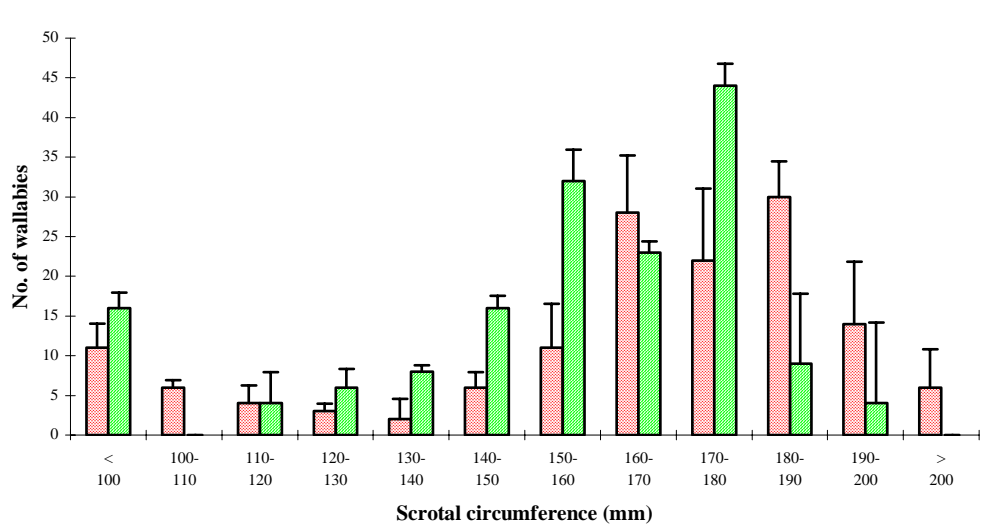


Figure 9.1: Comparison of male fertility, measured as scrotal circumference, in culled (red dots) and unculted (green stripes) populations of Tammar Wallabies on Kangaroo Island. Standard deviations indicated by error bars.

### 9.4 Discussion

As expected, there was a larger mean scrotal circumference in the culled populations tested, indicating that culling can be used to increase male fertility within a Tammar Wallaby population.

## **Chapter 10: Female Fertility**

### **10.1 Introduction**

There are a number of factors which can affect fertility in females of various species, including age, body condition, body size, and lactational state. Albon *et al* (1986) showed that body weight, body condition, age and previous lactation were positively correlated to increased fertility in Red Deer hinds but that body size was negatively correlated with fertility, such that a smaller, heavier hind in above average condition and having had a previous lactation was more likely to be pregnant than a hind which was larger but weighed less, have lower body condition and had not had a previous lactation.

There is no recent published work which looks at fertility in culled Tammar Wallaby populations. Therefore, as all female Tammar Wallabies over one year can potentially have a joey, the presence or absence of pouch young will be used as an indication of female fertility in managed and unmanaged populations of Tammar Wallabies - which may be affected by nutrition, disease, or age of the particular population.

### **10.2 Specific methods**

All females had their pouch examined for the presence of pouch young, or an elongated teat indicating a recent young at foot during the February collection. All pouch young were removed and euthanased. The percentage of females with pouch young was calculated for each site at each collection period. The female fertility (presence of pouch young) of the culled and uncultured populations was compared using regression analysis in Genstat with presence of pouch young as the response variate and the two types of management as the fitted term.

### **10.3 Results**

The mean female fertility of the culled population was 83% females with pouch young compared with a mean of 92% females with pouch young for the uncultured population. The regression analysis of female fertility on management showed no significant difference ( $P = 9.6\%$ ) between culled and uncultured populations with a  $V.R._{obs}$  of 2.81 with  $F_{1,141}$  of 3.84. Table 10.1 shows the numbers of females with and without pouch young at each site at each collection period. It also shows that 38% of females still had not had their pouch young by the middle of February.

Table 10.1: Comparison of female Tammar Wallabies with:without pouch young in culled and unculted populations on Kangaroo Island.

Site	February	March	June	July	Total
<b>Culled sites:</b>					
• <i>Western River</i>	5:4	-	-	-	5:4
• <i>Brookland Park</i>	6:8	8:0	9:0	7:0	30:8
• <i>Jarumble</i>	16:5	5:0	15:1	0	36:6
subtotal:	27:17	13:0	24:1	7:0	71:18
<b>Unculled sites:</b>					
• <i>Leska Park</i>	-	6:2	9:0	5:0	20:2
• <i>Tandanya</i>	-	14:1	17:2	7:0	38:3
subtotal:	-	20:3	26:2	12:0	58:5
Totals:	27:17	33:3	50:3	19:0	129:23

#### 10.4 Discussion

It appears that female fertility is not affected by culling. However, by looking at table 10.1, the fact that the unculted populations were unavailable for data collection in February, indicates that there was a bias in the results in the collection periods for which paired data are available, there is a slight trend towards increased fertility in the culled population, but the difference would not be significant. I also think that the age of the pouch young should have been taken into account when assessing female fertility, particularly as there were a number of pouch young born outside the normal January-February period (Tyndale-Biscoe and Renfree, 1987) - including two born in June at “Leska Park”.

Further studies need to be carried out on fertility in Tammar Wallabies, as indicated by a number of pouch young born “out of season” on unculted properties.

## Chapter 11: General Discussion

It is clear that culling, generally, is having a slight effect on the populations of Tammar Wallabies on the properties tested. Annual mortality rate, annual life expectancy, body weight, energy reserves, sex ratios and female fertility were all unaffected by culling. Trends were detected in age structure, juvenile recruitment, annual survival rate, pouch young age and parasite burdens - indicating that culling may be having a slight effect on the tested populations. Mean age, age-related body weight and male fertility were the only characteristics to show a significant effect due to culling.

The combination of all these parameters indicates that both the culled and uncultured populations are closer to maximum carrying capacity on the logistic growth curve than to the point of inflection, and that the culled populations are slightly lower on the logistic growth curve than the uncultured populations - as shown by the lower mean age and slightly higher juvenile recruitment rate in the culled populations (Teague and Decker, 1979; Robinson and Bolen, 1984).

Current culling levels on "Brookland Park" and "Jarumble" are conservative and much lower than they would be at maximum sustainable yield. I recommend a repeat of this project with sequential annual culls at progressively increasing levels on these properties, to enable the approximate point of inflection on the logistic growth curve to be determined. Such a study should include isolation of wallaby populations, with one maintained at carrying capacity and the other (by artificial removal) at maximum sustainable yield.

The small effects due to culling of the wallaby populations are in marked contrast to the results of Storch (1989), who found that different levels of culling on Chamois (*Rupicapra rupicapra*) showed pronounced differences in parameters such as kidney fat index and birth rates. Gallivan *et al.* (1995) also found that managed Impala showed differences in parameters such as body condition and kidney fat index when compared with unmanaged populations. This suggests that the wallaby culling level on the tested properties was having such a small effect on the overall population size that the density-dependant variables such as nutrition (and subsequently kidney fat index), growth, maintenance and reproduction are not being affected and therefore the expected differences between the culled and uncultured wallaby populations did not occur.

It has not been possible to calculate the maximum carrying capacity, and hence the maximum sustainable yield, for the wallaby populations on the properties tested, mainly because it was difficult to obtain an accurate count of wallabies present in the population at the time of shooting. Further research needs to be done on population estimates of the wallabies before a better estimate can be made on the population size.

## **Chapter 12: Conclusions**

### **12.1 Future Management of the Tammar Wallaby**

The results of this study indicate that the current level of culling of Tammar Wallabies is sustainable on the properties tested. Therefore it is feasible that a sustainable commercial harvest could be established at the current culling levels used on "Brookland Park" and "Jarumble". However, as the Tammar Wallaby population size on Kangaroo Island is unknown, the actual numbers available for an annual commercial harvest cannot be determined at this stage. A survey of Kangaroo Island farmers in February 1998 (see addendum) indicate a population of between 116,000 and 240,000 Tammar Wallabies with a density of 1.6 to 3.4 wallabies per hectare. However, as only 25% of surveys were returned, these data could be up to four times as high (that is, 500,000 to 1,000,000 wallabies in total)

A population survey needs to be carried out over the whole of Kangaroo Island to determine the actual population size as well as areas of higher and lower population densities to determine which properties have wallaby populations that are more suitable to sustaining a commercial harvest.

A management plan for the conservation and management of the Tammar Wallaby also needs to be developed and put into place before commercial harvesting can proceed (P. Alexander, personal communication). It is suggested that the management plan is similar to the one in place for the conservation and management of the larger macropod species on mainland South Australia (Alexander and Best, 1993) (R. Inns, personal communication).

### **12.2 Further Studies/Research**

Further research needs to be carried out in order to establish the actual Tammar Wallaby population size on Kangaroo Island. The difficulty of aerial surveying of the wallabies needs to be addressed by looking at other survey techniques suitable for Tammar Wallaby habitat - techniques such as spotlight counts, pellet counts, and road counts. Reference survey locations need to be established for ongoing population monitoring - especially if a commercial harvest is established. Population surveys need to be carried out over the whole of Kangaroo Island to establish the overall population size as well as areas of higher density and their population sizes.

Factors such as nutrition, diet, climate, and population density, which may limit population growth, also need to be studied - as they may be related to areas of high and/or low density over Kangaroo Island. Other areas of population dynamics which need to be researched include breeding ecology, fertility in females, juvenile/sub-adult survival rates, as well as farm management strategies for increasing productivity from wallaby harvesting.

Farmers need to become more involved with the Kangaroo Island Wallaby Steering Committee and to begin establishing a business plan for a commercial wallaby industry on Kangaroo Island - including harvesting methods, processing of carcasses, processing of skins, disposal/utilisation of waste products, value-adding to wallaby products, marketing of the products and animal welfare issues.

Marketing issues need to be addressed in order to identify marketing opportunities - local, intrastate, interstate and overseas.

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## Addendum

Summary results of a survey of farmers to ascertain culling levels of the Tammar Wallaby on Kangaroo Island. 117 surveys were returned from 425 posted to all landholders on Kangaroo Island. The location of each property is designated to the local telephone exchange in order to maintain confidentiality.

Locality (n)	Wallabies shot in 1997	Wallabies shot in 1996	Wallabies shot in 1995	Wallabies shot in 1994	Wallabies shot in 1993	Average property size (ha) (min-max)	Estimated wallabies on farm Min-max	wallaby density (wallabies/ha) (min-max)	1997 culling* (shot/present) (min-max)
American River (4)	180	162	100	100	100	446 (143 - 1,130)	1,104 - 2,600	0.5 - 2 (0 - 4)	6.5% - 25.0% (0% - 80%)
Cygnets River (21)	1,000	1,220	910	1,040	940	319 (0 - 1,000)	3,718 - 10,200	1.2 - 3 (0 - 31)	4.1% - 9.8% (0% - 100%)
Cygnets River + Wisanger (1)	100	100	100	100	100	663 (663)	501 - 1,000	1 - 2 (1 - 2)	10% - 20% (10% - 20%)
Gosse (22)	15,050	19,250	13,600	13,850	11,700	749 (130 - 2,833)	47,221 - 93,000	2.8 - 6.2 (0 - 21)	12.5% - 27.1% (0% - 80%)
Harriet (10)	3,060	2,870	2,745	2,173	1,693	740 (500 - 1,214)	17,210 - 38,100	2.3 - 5.3 (0 - 12)	6.4% - 13% (0% - 60%)
Karatta (13)	3,350	3,420	4,300	3,550	3,850	616 (32 - 900)	20,412 - 35,000	2.5 - 5.2 (0 - 16)	17.8% - 62.3% (0% - 250%)
Kingscote (4)	50	50	50	55	60	281 (16 - 950)	3 - 300	0 - 1.8 (0 - 6)	12.5% - 1250% (0% - 4000%)
MacGillivray (17)	1,045	785	865	665	870	674 (364 - 1,200)	7,115 - 17,300	0.7 - 1.7 (0 - 6)	3.6% - 9.4% (0% - 80%)
Parndana (6)	630	790	540	810	600	1147 (551 - 1,800)	5,506 - 12,100	0.8 - 1.8 (0 - 6)	5% - 10.3% (0% - 20%)
Stokes Bay (8)	3,070	2,550	2,250	2,060	2,070	597 (17 - 1,376)	5,305 - 11,600	1 - 3 (0 - 7)	15.7% - 870% (0% - 5000%)
Wisanger (10)	980	930	1,040	940	840	481 (4 - 1,789)	8,309 - 18,700	2 - 4.8 (0 - 28)	9.6% - 346% (0% - 3000%)
<b>Totals:</b>	<b>28,515</b>	<b>32,127</b>	<b>26,500</b>	<b>25,403</b>	<b>22,823</b>	<b>70,671</b>	<b>116,405 - 240,000</b>	<b>1.6 - 3.4</b>	<b>11.8% - 24.5%</b>

\* In several returns, the number of wallabies shot exceeded the estimated number present on farm.