

# Bait consumption and biology of tamar wallabies in the Rotorua region

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Published by  
Department of Conservation  
Head Office, PO Box 10-420  
Wellington, New Zealand

This report was commissioned by the Science & Research Unit

ISSN 1171-9834

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Reference to material in this report should be cited thus:

Lentle, R.G., Potter, M.A., Springett, B.P. and Stafford, K.J., 1999  
Bait consumption and biology of tammar wallabies in the Rotorua region. *Conservation Advisory Science Notes No. 221*, Department of Conservation, Wellington.

Keywords: Tammar wallaby, *Macropus eugenii*, poison baiting, pest control, Rotorua region

# Abstract

The research findings outlined in this report provide information on aspects of bait acceptance by, and the biology of, the tammar wallaby (*Macropus eugenii* Desmarest) in the Rotorua district of North Island, New Zealand. Emphasis has been given to information that is relevant to the cost effective control of this species by methods of poison baiting, shooting and trapping and to a suitable method of monitoring population levels.

Success in poison baiting is influenced by two sets of factors. Firstly, those which influence the likelihood of an animal encountering and commencing to eat a bait; secondly, those which increase the likelihood of ingestion of a lethal dose during a feeding event or a meal.

The first strategy has to do with manipulation of bait density (the number of baits per square kilometre), bait siting (preferential location of baits in the target species' known feeding area or travelling routes), and with inducing the target species to sample or to resample the bait (maximising its 'acceptance'). An appropriate and cost effective choice in respect of this strategy can only be made with a detailed knowledge of

- 1) the distribution of the target species within the terrain that it inhabits;
- 2) the particular locations at which the animal is liable to feed;
- 3) the relative acceptance and zone of influence of a bait, i.e. the distance that an animal may be attracted to a bait;
- 4) the likelihood of resource acquisition, i.e. prevention of access of other individuals to a bait by a dominant animal, and methods by which this may be minimised;
- 5) the animal's reaction to disturbance by baiting and other control operations.

With the exception of 3) above, these aspects are covered in the general biology section of this report.

The second strategy has to do with inducing an animal that has commenced eating a bait to continue eating until a lethal dose of poison has been consumed, i.e. enhancing bait 'palatability' by increasing positive and decreasing negative reinforcement (Le Magnen 1992) experienced during the feeding event. These aspects and those of 3) above are covered in the bait consumption section of this report.

# 1. Bait consumption

The digestive system of macropods is specialised to allow rapid throughput of low quality herbage (Hume 1984,1989). The results of a post mortem analysis of the particle size distributions of stomach contents, detailed in the general biology section of this report, show that tammars chew their food to a fine consistency, presumably in order to maximise the surface area that is available to the process of digestion. Thus it is probable that ease of chewing is a particularly important factor in the choice of a suitable poison bait substance for control of this species.

Bait choice experiments give some indication of the overall outcome of different combinations of 'palatability' and of 'acceptance' that exist when two bait substances are compared but do not assess the separate influence of each of these effects. Moreover, there is evidence that the simultaneous presentation of a number of different foods may in itself have an influence on the animal's feeding habits (Galef et al. 1990). Thus palatability is better assessed by comparison of overall rates of consumption when test animals are successively maintained on sole diets of each bait substance. This method presumes that ease of handling permits continued rapid ingestion whereas difficulties in handling cause slowing of ingestion. In such experiments, factors that influence 'ease of handling' may include distension of the stomach with ingesta, a situation that is particularly likely when animals are maintained on high bulk foods of low nutritional density. Some indication of the effect of gut distension may be obtained from a study of changes in the timing of feeding bouts during the feeding period. This method presumes that higher degrees of gut fill are more likely to occur later in the feeding period, and any increase in spacing of later meals is viewed as evidence of the effect of gut distension.

## 1.1 ACCEPTANCE TRIALS ON CAPTIVE TAMMARS

Two captive female tammars caught near the lake Okataina Outdoor Education Centre were offered a choice between carrots and high nutrient value pellets (90% milled maize and 10% milled barley). Carrots were strongly preferred, with neither animal consuming pellets when carrots were on offer.

## 1.2 PALATABILITY TRIALS ON CAPTIVE TAMMARS

Four captive female tammars, trapped near the Outdoor Education Centre at Lake Okataina, were each maintained on one of three feed types in rotation. A 'high quality' 7 mm by 15 mm, pelleted feed with a high proportion of soluble sugars and low proportion of fibre (90% milled maize and 10% milled barley); a low quality, 7 mm by 15 mm, pelleted feed with a low soluble sugar content and a high proportion of fibre (10% milled maize, 10% milled barley and 90% milled barley straw); or a diced 15 mm cubed carrot feed that was low in nutrient value by virtue of its high water content. All animals exhib-

ited some degree of nutritional compensation, i.e. they maintained energy intake by increasing their food intake. This was achieved by a significant increase in both the mean duration of feeding events and in the overall rate of consumption. The overall rate of consumption of low quality pelleted feeds (average  $0.016 \pm 0.001$  g/sec), whilst higher than that of good quality feed (average  $0.007 \pm 0.001$  g/sec), was significantly lower than that of diced carrots (average  $0.034 \pm 0.002$  g/sec) for all animals, with the last named being consumed in large quantities ( $711.7 \pm 28.8$  g per 24 h).

There was a relative decrease in the mean length of feeding event and an increase in the inter-feed interval length in the later part of the peak feeding period. This occurred with all feed types and indicates that some slowing of the rate of food ingestion may occur as a consequence of a greater degree of gut fill regardless of nutritional density of food. Subsequent microphone-collar studies on free-ranging tammars showed that inter-feed intervals were similarly increased in the later part of the peak feeding period. Thus the food intake of both captive and free-ranging tammars may be limited to some extent by stomach distension.

### 1.3 BAIT ACCEPTANCE BY FREE-RANGING TAMMARS

Mapua No. 1 bait was distributed within the trap sites at the farm site and on the Lake Okataina Outdoor Education Centre site during four trapping operations in which a total of 66 tammars were captured. Although a number of possums were attracted to this bait and seen to consume it, no tammars were ever seen to eat it, although they were observed to eat grass that was close by (as well as toast at the Outdoor Education Centre site).

### 1.4 EFFECT OF DRINKING BEHAVIOUR ON INGESTION

In island habitats, under exceptionally dry conditions, tammars have occasionally been observed to drink fresh (Vujcich 1979), and even sea water (Bakker et al. 1982), but it is generally considered that macropods are able to maintain water balance and foregut water content by choosing appropriately succulent plant material to eat (Nagy et al. 1990).

Drinking events which occurred when each of the four tammars were maintained on pelleted feeds were closely associated with feeding events, with 78 occurring within one minute of termination of a feeding event. Each drinking event was of short duration and there was a daily pattern of frequent small drinking events rather than a single large event. None of the four tammars was observed to drink during the period when they were maintained on carrot feeds. It is thus likely that, in addition to fulfilling the general requirements of whole body water balance, drinking is "food associated" (Kisseleff 1969) in tammars in order to maintain the optimal fluidity of foregut contents that is necessary for efficient fermentation.

## 2. General Biology

### 2.1 HOME RANGE SIZE

Inns (1980) obtained home ranges of between 44.1 and 13.2 ha for tammars in their natural habitat on Kangaroo Island, using the 100% convex polygon method. He attributed the large variation to seasonal variation in abundance of food.

Our radio-collar studies showed home range areas ranging between 10 and 39 ha using the same method and discounting, as an outlier, a single large male that changed its roosting site during the course of the study. These figures are of a similar order to those of Kangaroo Island tammars despite the considerable difference in climate and vegetation from that of the Rotorua district.

The high degree of home range variability in our results matches that found by Inns (1980), but in our case, in view of the presumed abundance of food brought about by recent control operations, this is less likely to be due to local variation in food supply. Two factors may account for this variation. Firstly, differences in body size. There was a significant correlation of home range size with body size, with the largest animals having the largest home ranges. (Note: Because of the sexual dimorphism in body size, males generally had larger home ranges than females.) Secondly, variation in the relationship between roosting site and feeding site (see below). The outlier of our home range study is a good example of this effect. The convex polygon area estimate of this home range, which included two roosting sites, was 68 ha.

### 2.2 VARIATION IN HOME RANGE SIZE WITH BODY SIZE AND GENDER

Croft (1989) reported that macropodid males commonly had larger home ranges than females. Inns (1980) found no significant differences between the home ranges of 8 male and 8 female Kangaroo Island tammars. Vujcich (1979) suggested that male Kawau Island tammars had greater home ranges than females. His study, however, did not distinguish between the effects of size and sex. McNab (1963) predicted that home range size should vary with body size, and Johnson (1989) reported this relationship in the red necked wallaby. Greater use of open grassland areas by males than by females has been shown in other graze-adapted macropod species (Arnold et al. 1994)

The radio-collar study showed that the home ranges of males, as well as being larger, tended to overlap those of a number of females (see grouping activities). The single male studied in the radio-microphone study was noticeably more mobile within its diurnal and nocturnal home range areas than the females. The radio-microphone and night vision studies showed that at night females and juveniles tended to graze close to the bush edge, and occupy the same positions for long periods. Conversely, the male tended to journey further from the bush edge, changing grazing site more frequently.

These sexual differences in mobility are further borne out in the results of our, and G.Williamsen's (1986) culling and trapping operations on farm pasture areas (our summer single night cull yielded 70 males, 29 females and 19 juveniles; our winter single night cull yielded 9 males and 5 females; G Williamsen's (1986) total for all hunts was 253 males, 14 females; our totals for trapping at the bush edge were 36 females and 30 males, of which 38 were juveniles).

### 2.3 PATTERN OF HOME RANGE USE

Nicholls (1971) described the year-round home range of a similar island wallaby species, the quokka (*Setonix brachyurus*), as consisting of a diurnal roosting area and a separate nocturnal feeding area linked by corridor. Tammars may have a similar pattern of home range use. Andrewartha & Barker (1969) described separate sleeping sites ("squats") of tammars on Kangaroo Island and Vuchich (1979), studying an introduced tammars population on Kawaii Island, described separate resting sites close to feeding areas, also commenting that sharing of resting sites was common in this species. Again, whilst Inns (1980) radio-collar study of tammars on Kangaroo Island did not report on nocturnal and diurnal groupings of radio-collar fixes, this worker did comment on tammars using trails to journey to and from feeding sites.

The radio-collar studies confirmed that tammars occupy spatially separate diurnal and nocturnal areas within their home ranges, spending the daylight hours in the bush interior and emerging on to grasslands or small clearings at night. The radio-microphone studies quantified this finding, showing that daytime ranges were generally less than 1000 metres from the ecotone or from significant grazing sites within the bush interior.

Daytime roosting sites (see temporal distribution of activity) were generally well sheltered from prevailing winds. The microphone study animals showed a high degree of loyalty to roosting sites, returning from nocturnal foraging expeditions on grasslands to rest within a few metres of the previous days' roosting site. However, during periods of fine weather, animals would sometimes lie up in sheltered areas within a few metres of the ecotone, sometimes hiding in hollow logs or under rocks. Typically animals would emerge from roosting areas just prior to dark, travelling to foraging sites along well used trails that were often situated on old logging tracks or benched areas. On fine nights, animals would continue to feed intermittently on grassy areas throughout the night, leaving just prior to dawn to return to their roosting sites.

### 2.4 SOCIAL ACTIVITY

It is generally agreed that group structure is less constant and well defined in a number of larger macropod species than in corresponding eutherian species (Jarman & Coulson 1989). Thus group composition of larger macropod species changes continually as peacefully coexisting subgroups that are resident in the area join and leave in a random manner (Russell 1984). This type of chance association on a feeding or resting site has been termed static in-

teraction. Conversely, tammam grouping activity has previously been reported as stable, i.e. members of the group continue to interact together on a long term basis, a phenomenon that has been defined as dynamic interaction. Christensen (1980) described Boyicup tammams as 'group territorial', but at the same time, stated that 'a certain proportion of the population, largely adult males, appears to move freely between two or perhaps more adjacent groups occupying different thickets'. Vujcich (1979) and Vuchich (1979) reported dynamic interaction in Kawau Island tammam populations, albeit on the basis of direct observation at a feeding station. Inns' (1980) radio-collar study on Kangaroo Island tammams also reported stable group composition.

Varying degrees of social bonding are reported within these groups. Whilst the association of female with young at foot has not been studied in tammams, it is generally reported in other macropod species, juveniles remaining at foot for as long as 20 months in some cases (Russell 1984). Tammam groups are known to be gregarious (Russell 1984). Christensen (1980) described 'family units' of tammams comprising a male, a female and a subadult joey, being sometimes caught together in a trap. During the reproductive season male tammams are thought to exhibit hierarchical promiscuity (Russell 1984), competing with other males for the right to hold dominion over groups of females, but only associating intensively with individual females during the few days of their oestrus. Christensen (1980) described a strict social hierarchy in Boyicup tammams at feeding stations, as did Vuchich (1979) for Kawau Island tammams, noting that females were sometimes dominant over smaller males. Vujcich (1979) considered that relationships were based on recognition as well as size.

A number of juvenile macropods including tammams are reported to give a coarse screeching call when lost (Russell 1984) and adult female tammams are reported to give a similar call in reply to the lost young (Russell, 1984) and when asserting dominance (Vujcich 1979). A study of the frequency of these vocalisations provides some insight into the extent of social interaction during different activities and at different sites.

There has been considerable debate as to the function of nocturnal grouping activity in macropods, some workers viewing it as a defensive activity against now-extinct predators (Clarke et al. 1995) or relating to reproduction (Jarman & Coulson 1989), others view it as a heat avoidance strategy (Dawson & Denny 1969).

The study showed that there was a significant tendency of Rotorua tammams to associate in groups, particularly during the daylight hours. The radio-collar studies demonstrated spatial interaction, i.e. an overlap of individuals' diurnal home range areas, presumably due to association of individual roosting sites in areas sheltered from the weather. The same radio-collar study also demonstrated positive dynamic interaction, i. e. that animals tended to associate together particularly males with females and females with juveniles.

Night vision observations of radio-microphone collared animal activity on nocturnal grazing sites showed that, whilst the same tammam groups tended to emerge on to the same site on consecutive nights, males were more mobile and tended to move away from the initial group. (However, it should be noted



that our observations were not carried out during the mating season.) Conversely, females, particularly those with juveniles at foot, stayed at or near the bush edge.

The microphone studies confirmed that females sometimes gave a deep screeching call and that this was most likely to occur during the time when animals were journeying to and from their nocturnal feeding sites, and least likely to occur when the animals were occupying their nocturnal feeding sites.

## 2.5 TIMING OF FEEDING ACTIVITY

Macropods are considered to be largely nocturnal in habit, feeding at night and resting up in roosting sites during the day (Clarke et al. 1995). A number of explanations have been suggested for this behaviour, namely anti-predator activity (Clarke et al. 1995), avoidance of heat (Dawson & Denny, 1969). However, feeding may be less exclusively nocturnal in tammars. Vujcich (1979) noted two peaks of feeding activity in Kawau tammars, a major peak late afternoon to early morning and a minor additional peak from 3 am to 5 am. Vujcich (1979) also noted that tammar wallabies fed more commonly in the day than parma wallabies, though this was less common during summer months.

Vujcich (1979) noted that faecal pellet concentrations on grassy areas were twice those that occurred in areas of cover.

The radio-microphone studies showed that free ranging Rotorua tammars spent an average of  $342 \pm 33$  minutes per day chewing food. Intermittent feeding events occurred throughout the day and night, with the exception of an interval of one to two hours at noon when the animals were relatively quiet. The temporal distribution of feeding activity was nocturnally crepuscular, with a late afternoon/early evening peak and a late night/early morning peak. Averaging feeding activity on a basis of number of minutes spent eating per quarter hour clock time, showed that intensity of feeding activity was more or less equal in the two crepuscular peaks. However, feeding events were closer together in the early evening peak and more spaced out during the late night/early morning peak. Gut content analysis studies confirmed a lower degree of stomach fill in early evening. Taken in conjunction with the findings of the leaf handling studies, this indicates relatively low efficiency of browsing versus grazing. Gut content studies also showed a tendency for the hindgut to be less full in the early evening feeding period than in the early morning feeding period. It is therefore probable that the hindgut is emptied during the process of intensive feeding. Temporal profiling of meal sizes showed that the longest feeding events consistently took place at the peaks of feeding activity and that feeding event length tended to gradually increase or to decrease at times leading up to or following the peaks in feeding activity. This distribution suggests that tammars do not group their feeding events into meals but that the stimulus to eat rises uniformly to a peak before decreasing again.

Individual feeding events tended to be significantly longer during the night time period as a consequence of the higher numbers of grazing events and

their longer duration compared to that of browsing events. Grazing activity was particularly common at night, particularly during fine weather, and browsing activity was generally more common in the day.

Periods of bad weather caused a general reduction of feeding activity, with the animals remaining in shelter for long periods. There was a noticeable increase in duration of less feeding activity when weather became settled after a period of inclemency.

Chewing rate was significantly slower when browsing than when grazing.

## 2.6 FEEDING BEHAVIOUR AND ITS RELATIONSHIP TO FIGHTING

Vuchich (1979) commented on the use of the forelimbs by tammars when browsing and their tendency to graze in the quadrupedal position, but did not give a detailed description of the manner in which leaves were detached and subsequently consumed.

Fighting over feed material was reported in Kawau Island tammars at artificial feeding stations (Vujcich 1979). This worker commented that the feeding stations may have increased fighting behaviour.

Infrared video studies of captive tammars showed that grazing was typically carried out in the quadrupedal position with the front legs sometimes tucked up. Browsing was carried out in the erect position, the leaves being grasped by mutual opposition of the front palms before being detached by biting through the petiole. Tammars were particularly clumsy in this operation and often dropped the leaf: they had a tendency to choose another fresh leaf rather than pick up the freshly dropped one.

Radio-microphone studies showed that the degree of integration between chewing and biting varied according to whether the animal was browsing or grazing. During grazing there was ongoing integration of biting and chewing for periods up to one hour. During browsing, cropping and chewing activities became separated, smaller leaves being ingested in a single bite and larger leaves taken piecemeal, each being followed by a period of intense chewing, usually at a significantly slower rate than that when grass was being chewed, a likely consequence of the mouth being more full.

Captive animals fed pellets less than 7 mm diameter by 15 mm or carrot cubes less than 15 mm in length ate in the quadrupedal position, with ongoing integration of chewing and cropping, as when grazing. Animals fed pieces of carrot or pellets greater than these dimensions applied a bite grip whilst in the quadrupedal position, subsequently rising to continue eating in the erect position in the same manner as when browsing. Fighting was frequent between animals eating favoured foods in the erect position and never observed between animals eating favoured foods in the quadrupedal position.

## 2.7 FEEDING PREFERENCES

Sanson (1989) classified all species within the genus *Macropus*, to which tammars belong, as either grazers or intermediate browser/grazers on the basis of their dental morphology. Kelsal (1965), studying the feeding habits of tammars in three locations on Garden Island, concluded that tammars were very adaptive feeders. Christensen (1980) reported that the stomach contents of four Boyicup tammars were 'almost entirely of green vegetative material; grasses and other monocotyledons are a major constituent'. Williamson (1986) reported the dietary content of Rotorua tammars based on cuticle characteristics of gut content. His results indicated that tammars are preferential grazers, the stomach content of animals shot in the vicinity of pasture areas containing up to 75% of pasture species. A number of forest species were also eaten, preferred foods being *Melicytus ramiflorus*, *Weinmannia racemosa*, *Geniostoma rupustra*, *Coprosma* species, *Hedycarya arborea*, and *Leptospermum* species. A number of macropod species including tammars (Kinloch 1973) are reported to prefer short to longer swards.

Night vision observations of microphone-collared animals showed they favoured areas of short sward. Subsequent examination of these sites showed that they comprised mainly grass tillers and were not sites of particularly high densities of clover. Grab samples from witnessed grazing sites in pasture areas and in clearings within the bush interior were subsequently analysed for organic nitrogen, simple sugar, and fibre content. There were no gross differences in the nutrient content of grasses from bush clearings and those of pasture sites. Thus animals journeying from bush to pasture were probably not foraging on a basis of nutrient content.

## 2.8 FOOD CONSUMPTION

Sanson (1989) categorised wallabies of the genus *Macropus* as specialised grazers or as intermediate browser/grazers on the basis of the form of the teeth with which they masticate their food, i.e their molar tooth morphology. Although Anderson (1927) showed that macropods used the action of the upper front (first, second and third incisor) teeth against the large single lower (procumbent incisor) tooth to sever grass and leaves during ingestion, very little further work has been carried out on this mechanism (Sanson, 1989). McArthur & Sanson (1988) reported that diet selection by macropods may be influenced by tooth wear.

Our studies have demonstrated significant wear of the surface of molar teeth by the second year of age and similar wear in that portion of the front incisor tooth row which is used for cutting grass and leaves. Thus small/young tammars use only the front few millimetres of their incisors to sever grass and leaves, whereas older/larger animals are able to employ a longer cutting edge that extends for up to one centimetre on each side of the mouth. Such differences are likely to bring about changes in dietary selection (resource partition) according to age and may account for differences in use of grasslands by larger males from that of smaller females and yearlings. Again differences in bite characteristics may result in baits of different physical form and substance having greater or lesser effect on certain portions of the population.

## 2.9 FOOD PARTICLE SIZES AFTER CHEWING

The particle size distribution of digesta in various locations through the foregut has been studied in a number of macropod species and compared to those of certain ruminant herbivores (Freudenberger 1992). The results indicate that, whilst particle size of digesta leaving the foregut is greater than that of ruminants, initial comminution of food by macropods is more extensive than occurs in ruminants, presumably as there is no opportunity for macropods to regurgitate and re-chew swallowed food, i.e. ruminate. These studies also showed that macropods do not possess gut mechanisms by which gut particles may be selectively retained according to size. Studies of the transit of marked food particles through the gut of tammars (Warner 1981) showed that passage of digesta in this species is relatively rapid compared to ruminants, a finding which has been cited as evidence for a nutritional strategy of rapid throughput of lower quality herbage.

The particle size distributions of the foregut contents of twenty tammars obtained from two sites were determined using a sieve array (Waghorn 1986). The results show that tammars chew their food to a generally smaller particle size than do other macropodid species. This result underscores the particular importance of comminutability in the success of poison bait substance operations against this species.

## 2.10 RESTING BEHAVIOUR

Tammars have been observed to rest in two distinctive positions (Russell, 1973), a 'sitting tail forward' position where the tail is brought forward between the outstretched hind legs, the body prone on this with the head resting above ground level; and a 'lying' position in which the body is lying side-on with the head in contact with the ground.

The study of captive tammars showed that the lying position was favoured during the hours of darkness and the sitting tail forward position favoured during the day. Resting in the sitting tail forward position generally continued for significantly longer periods (average  $1573 \pm 258$  sec) than in the lying position ( $229.5 \pm 24.4$  sec).

Field studies showed that animals would sometimes seek cover during the night feeding period, but rested for short periods only. In areas of sparse understorey tammars were observed to adopt cryptic behaviour, hiding in hollow logs or under boulders. During the day, animals were frequently seen resting in the sitting tail forward position. It is probable that this position is favoured in the day as it offers greater possibilities for surveillance and for silent departure and may also reduce passive heat uptake, i.e. surface area exposed to the sun. The use of the lying position at night counts against the hypothesis that tammars group together when feeding as an anti-predator strategy.

## 2.11 BEHAVIOURAL RESPONSE TO WEATHER CONDITIONS AND TO SEASON

Sensitivity to weather conditions is reported by Main & Yadev (1971), who noticed that tammars were not found on the wetter side of Kangaroo Island. Inns (1980) reported that nocturnal feeding activity of tammars was not affected by light rain, but that during periods of wet and windy weather tammars were to be found in the scrub on the margins of grassy clearings. Vujcich (1979) commented that the choice of roosting site by tammars was influenced by the degree of protection the site afforded from the weather. Inns (1980) reported a general reduction in home range size in winter compared to that of summer but found that fewer animals emerged on to grassy areas in summer. (The latter finding is probably a consequence of the harsh summer conditions on Kangaroo Island causing drying out of grass forage.) Vuchich (1979) reported that Kawau Island tammars selected resting sites that were situated deeper in cover during the winter.

Radio-microphone studies showed that feeding activity was reduced during periods of bad weather. The animals did not emerge on to open grassland areas in winds of over 800 ft min [sic.] or during periods of heavy rain, although in showery weather tammars would graze during fine periods and shelter in local cover during rain squalls. A period of prolonged inclement weather caused a subject animal that normally had sheltered close to the bush edge during the day to move to a more sheltered and distant roosting site.

## 2.12 REACTION TO DISTURBANCE

Christensen (1980) showed that Boyicup tammars remained in their home range area during and after a fire, sheltering in unburnt patches.

Dispersion detection analysis using a method that investigated the relative positions of consecutive radio-collar fixes showed that four out of six farm site animals subject to this analysis did not significantly shift their location beyond 50 metres from a mean point centred on the capture site following capture and subsequent release. The other two animals did shift their location in respect of the first five radio-collar sightings after being fitted with radio-collars, but dispersed no further after this.

A similar analysis carried out on six animals from the lake site showed that two animals did not disperse over 50 metres from a mean point centred on the trap site after capture and release, and that four did initially shift in respect of the first two radio-collar sightings after being fitted with radio-collars but subsequently dispersed no further.

Trapping results indicated that a proportion of radio-collared animals subsequently returned to the trap site environs following their initial capture and release. During the collaring phase of the radio-collar experiment, in which a total of thirty six animals (17 on the farm site and 19 on the lake site) were trapped and collared, there were 10 recaptures. In a trapping operation at the farm site seven months later, two of the original collared animals were

recaptured. In a subsequent trapping operation 18 months later, again at the same site, a further two of the original animals were recaptured. On the lake site, five of the original collars have been recovered from carcasses in places which, according to verbal reports, were within 1000 metres of the trap sites. On the farm site, one original collar has been recovered from a carcass within 50 metres of the trap site. To date no carcasses have been found or animals seen at distances greater than 1000 metres from the trap sites at which they were captured.

Night vision studies confirmed that animals were locally responsive to disturbance, two radio-microphone collared animals repeatedly emerged to graze nocturnally at an ecotone site 100 metres beyond the boundary fence of the trap in which they were caught two days earlier.

### 2.13 DISPERSAL

Inns (1980) reported, on the basis of the movements of radio-collared animals, that Kangaroo Island collared tammars showed low tendency to dispersal. Poole et al. (1988) studied the same population during the period 1982-1986 and found that a group of 184 marked animals which included 20 of the animals previously tagged by Inns continued to be re-trapped in the same area for the duration of the study. Thus 20 tammars were shown to be resident on this site during the period spanning 1972-1986. This led Poole et al to conclude that 'some animals at least may spend their lives in a restricted area'.

Apart from this general low tendency to dispersal, occasional larger movements have been reported, Poole et al. (1988) identified a single animal killed 5.2 km from its capture site 15 months after marking. Andrewartha & Barker (1969) reported the capture of a single tammar 16 km from the site of its capture less than one year after marking. Christensen (1980) recorded ten home range shifts in a two year study of an undisturbed population of tammar wallabies in South Western Australia. Two of these were by subadult males, one was by a subadult female, seven were adult males and five were adult females. These data suggest that adult male tammars are more likely to disperse than adult females; this led Johnson (1989) to classify tammars as showing low levels of natal dispersal but high levels of breeding dispersal.

Studies of the dispersal of radio-collared animals in Rotorua was marred by transmitter failure. However, the maximal distances moved by tammars from their site of capture during the 6 month period that some collars were functional were: 1950 m for adult males; 1000 m for adult females; 1100 m for juvenile males and 1550 m for juvenile females. Helicopter searches during this period confirmed that no animal with a functional transmitter had moved beyond these distances.

During the radio-microphone study in which three adult female and one adult male were observed more or less continuously for one month in spring, a period that included a four days of particularly inclement weather, the greatest distance moved was 990 m.

Thus there is no evidence of selective dispersal either by juveniles or by males.

## 2.14 TUBERCULOSIS VECTORING

Tuberculosis does occur in marsupials but, with the notable exception of the brushtail possum (*Trichosurus vulpecula*), is not common (Fowler 1986; Fox 1923; Francis 1958; Jones & Hunt 1983; Stableforth 1929; Tilden & Williamson 1957, Rao et al. 1991). A single case of tuberculosis (*Mycobacterium tuberculosis*) has recently been reported in a captive female tamarin in India (Rao et al. 1991). Postmortem showed numerous 4-6 mm firm grey nodules bulging from the surface of, and deeply embedded in, the substance of the liver, spleen and lungs.

Postmortems were carried out on 98 wallabies shot on a single night in the Okataina reserve. The liver and spleen of all animals was inspected. No macroscopic splenic or hepatic lesions were found.

# 3. Conclusions

Note that these conclusions refer solely to best practice in regard to the tamarin control and do not take into account any ancillary effects of the application of such strategies, e.g. their effect on non-target species.

## 3.1 ASSESSMENT OF POPULATION DENSITY

Pellet counts have been used as indicators of overall population numbers and of habitat use in a number of macropod species (Arnold et al. 1994). Warburton (1983) used cleared plot direct recruitment pellet counts to assess the efficacy of a 1080 gel broadleaf foliage bait control experiment on Bennetts wallabies in the Hunters Hills, South Canterbury.

- The distinctive pellet conformation of tamarins and the coupling of faecal voiding to nocturnal feeding indicates that sensitive estimates of local population densities may be obtained by faecal pellet counting on grassy areas adjacent to grass/forest ecotones.
- Although further work is needed to relate faecal pellet counts to absolute population levels, comparisons of pellet counts would nevertheless provide a basis for assessment of the effectiveness of control operations.

## 3.2 CONTROL BY POISONING

### a) Bait substance

Grain-based 1080 pellets have been used successfully to reduce numbers of Bennetts wallabies in the early sixties (Elgie 1961) as has spotlight hunting (Warburton 1983). A trial of 1080 gel applied to broadleaf foliage in an area of sparse understorey showed up to 95% reduction of populations as assessed by pellet counts. Greater numbers of females than males were killed in this operation. This was attributed to habitat segregation, the males preferring to feed in tussock rather than bush/scrub understorey. Warburton also commented that the technique was less likely to be so effective in areas where there was a greater availability of food plants in the understorey.

- The findings suggest that tammar foraging preferences are not based solely on energy density, but on ease of handling and on a 'succulent' water content that is sufficient to permit efficient mixing and fermentation in the foregut.
- Bait formulation may be particularly important in respect of water content and ease of chewing, as tammars do not ruminate and thus do not have any further opportunity to add saliva to their foregut content or to further fragment ingested food after initial swallowing.
- In view of the fact that young tammars have a more limited biting surface of their incisor teeth, it is probable that smaller more readily chewed baits will be needed to effectively impact on this portion of the population.
- Although tammars will accept novel foods, e.g. the consumption of toast by tammars on the education site, it is probable that quantities ingested are low, thus increasing the likelihood of sublethal dosage.
- Carrot baits are most likely to be successful, particularly for operations in areas where natural foods are relatively abundant. Carrot is easily chewed to requisite particle size (less than 1 mm) and has a high moisture content.
- Tammars have difficulties in the efficient handling and oral processing of leaves, and foliage is likely to be a less effective bait. Foliage baiting may be successful in areas of known food source foliage particularly within 1000 m of grazing sites. However, it would be advantageous to apply gel to petioles as these are usually bitten first. High numbers of leaves should be baited in view of loss from droppage.
- When pelleted baits are eaten, feeding events are more likely to be associated with, i. e. interrupted by, drinking events. Mapua 1 pelleted baits are not preferred in areas where there is adequate naturally occurring feed, even on sites where animals have become habituated to novel food substances.



b) **Physical form of the bait**

- Smaller (i.e. 15 mm by 15 mm) baits are likely to be more successful, as they are consumed in the quadrupedal position, are ingested more rapidly, and are less likely to be defended. The latter point is particularly relevant in respect of use in bait stations.

c) **Siting of baits**

All baits

- In broadcasting baiting operations, best kill will be obtained within 1000 metres of ecotone or large clearings, i. e. in areas of maximal population density.

Bait stations

- The fact that tammars do not tend to group their eating events into a series of separate meals reduces the likelihood of ingestion of large quantities of bait at a bait station.
- Bait stations should be sited with due regard to the typical home range structure of daytime roosting site linked by a communal pad run to nocturnal intensive feeding area, bearing in mind that intermittent feeding continues through most of the day and may occur at or near any of these sites.
- Bait stations are most likely to be encountered when they are situated on communally used pad runs particularly at ecotone edges. On such sites they are likely to be encountered at the time of most intense feeding activity, i.e the evening/early night feeding peak.
- The numbers of animals using particular pad run exits may be increased by screening off adjacent unbaited pad run exits with chicken wire, a technique that proved effective in our trapping operations.
- The consumption of baits at bait stations may be limited by fighting activity, i.e. resource acquisition, either between adult females, adult males or between adult females and juveniles. This may be reduced by use of traps that deliver baits at a sufficiently low level to encourage feeding in the quadrupedal position and by use of baits of appropriate dimensions.
- Because of induction of food-associated drinking, pellet baiting stations should, where possible, be sited close to sources of drinking water.

### 3.3 CONTROL BY SHOOTING

- Results of our culling operations show that spotlighting is more likely to enable a kill of males than females and juveniles, presumably in view of their greater mobility and their tendency to emerge further into open grassland than females and juveniles who tend to stay near the bush

edge. Concentration of hunting efforts on the bush edge may increase proportions of females and juveniles killed in spotlighting operations.

- Daytime shooting is unlikely to be cost effective in view of the high degree of cryptic behaviour exhibited by Rotorua tammars, e.g. hiding under boulders and in hollow logs.
- In view of the tammars' habit of temporarily relocating their grazing site when disturbed, repeated shooting culls will be most cost effective when conducted at intervals greater than seven days; our studies indicate this interval is generally sufficient for the temporary relocation to fully abate.

### 3.4 CONTROL BY TRAPPING

Trapping operations are a more effective method of removing juveniles and adult females than shooting, but the animals learn to avoid the trap after three consecutive days of use.

### 3.5 PROTECTION OF SMALL SITES OF HIGH CONSERVATION VALUE

- Single-strand wire fencing gives little protection, in view of the tammars' ability to negotiate them by pulling themselves through 6 inch gaps between strands or burrowing under the bottom wire (a procedure that can only be prevented by securing the wire to the ground at one metre intervals).
- A 70 mm mesh galvanised chicken wire fence, greater than one metre in height and suitably secured to the ground, is an effective deterrent and can be used to protect selected areas as well as aid bait station operations.

## 4. References

- Anderson, C. 1927. The incisor teeth of macropodinae. *Australian zoology* 5: 105-12.
- Andrewartha, H. G. and Barker, S. (1969) Introduction to a study of the ecology of the Kangaroo Island wallaby, *Protemnodon eugenii* (Desmarest) within Flinders Chase Kangaroo Island, South Australia. *Transactions Royal Society of Australia* 93: 127-32.
- Arnold, G. W., Steven, D. E. and Weeldenburg J. R. 1994. Comparative ecology of western grey kangaroos (*Macropus fuliginosus*) and euros (*M. robustus erubescens*) in Durokoppin nature reserve, isolated in the central wheat belt of Western Australia. *Wildlife Research* 21: 307-22.

- Bakker, H. R., Bradshaw, S. D., and Main, A. R. 1982. Water and electrolyte metabolism of the tammar wallaby, *Macropus eugenii*. *Physical Zoology* 55: 209-19.
- Christensen, P E. S. 1980. The biology of *Bettongia penicillata* (Gray 1873), and *Macropus eugenii* (Desmarest, 1817) in relation to fire. *Forests Dept of Western Australia Bulletin* 91.
- Clark, J. L., Jones, M. E. and Jarman, P. J. 1995. A day in the life of a kangaroo: Activities and movements of Eastern grey kangaroos, *Macropus giganteus* at Wallaby Creek. In *Kangaroos wallabies and rat kangaroos*. eds. G. Grigg; P Jarman and I. Hume. Surrey Beatty and Sons Pty. Ltd. N. S. W Australia pp. 611-618.
- Clark, J. L., Jones, M. E. and Jarman, P J. 1995. Diurnal and nocturnal grouping and foraging behaviours of free ranging eastern grey kangaroos. *Australian Journal of Zoology* 43: 519-29.
- Croft, D. B. 1989. Social organisation of the macropodoidea. In *Kangaroos wallabies and rat kangaroos*. eds. G. Grigg; P Jarman and I. Hume. Surrey Beatty and Sons Pty. Ltd. N. S. W Australia pp. 505-25.
- Dawson, T. J. and Denny, M. J. S. 1969. A bioclimatological comparison of the summer day microenvironments of free ranging kangaroos, sheep and feral goats in the Australian arid zone during summer. *Journal of Zoology* 177: 25-37.
- Elgie, H. J. 1961. Wallaby eradication by aerial poisoning. *New Zealand Journal of Agriculture* 102: 25-31.
- Fowler, M. E. 1986. *Zoo and wild animals medicine*. 2nd edn. pp. 572-576. W B. Saunders Company, Philadelphia.
- Fox, H. 1923. *Disease in captive wild mammals and birds*, 490 Lippin Cott, Philadelphia.
- Francis, J. 1958. *Tuberculosis in animals and man*. Pp. 159. Cassel, London.
- Freudenberger, D. O. 1992. Gut capacity, functional allocation of gut volume and size distributions of digesta particles in two macropodid marsupials (*Macropus robustus robustus* and *M. r erubescens*) and the feral goat (*Capra hircus*). *Australian Journal of Zoology* 40: 551
- Galef, B. G., Beck, M. 1990. Diet selection and poison avoidance by mammals individually and in social groups. In *Handbook of behavioural neurobiology* Volume 10 Neurobiology of food and food intake.
- Hume, I. D. 1984. Principal features of digestion in kangaroos. *Proceedings Nutritional Society of Australia* 9: 76-81.
- Hume, I. D. 1989. Nutrition of marsupial herbivores. *Proceedings Nutritional Society of Australia* 48: 69-79.
- Inns, R. W 1980. The ecology of the kangaroo island wallaby (*Macropus eugenii*) in Flinders Chase National Park, Kangaroo Island. MSc Thesis, University of Adelaide.
- Jarman, P.J. and Coulson, G. 1985. Dynamics and adaptiveness of grouping in macropods. In *Kangaroos wallabies and rat kangaroos*. eds. G. Grigg; P Jarman and I. Hume. Surrey Beatty and Sons Pty. Ltd. New South Wales, pp. 527-47.
- Johnson, C. N. 1989 Dispersal and philopatry in the macropodids. In *Kangaroos, wallabies and rat kangaroos*. eds G. Gregg, P. Jarman and I. Hume. Surrey Beatty and Sons Pty. Ltd. New South Wales.
- Jones, T C., and Hunt, R. D. 1983. *Veterinary pathology*. pp. 655 Lea and Febiger, Philadelphia.
- Kelsal, J. P. 1965. Insular variability in the tammar *Protemnodon eugenii* of Western Australia. PhD Thesis, University of Western Australia.
- Kinloch, D. I. 1973. Ecology of the parma wallaby (*Macropus parma* Waterhouse) and other wallabies on Kawau island, New Zealand. MSc Thesis, Univ. Auckland.
- Kissileff, H. 1969 Food associated drinking in the rat. *Journal of Comparative Physiology and Psychology* 67: 284-300

- Le Magnen, J. 1992. Neurobiology of feeding and nutrition. Academic Press London.
- Main, A. R. and Yadev, M. 1971. Conservation of macropods in reserves in Western Australia. *Biological conservation* 3: 123-33.
- McArthur, C. and Sanson, G. D. 1988. Tooth wear in eastern grey kangaroos (*Macropus giganteus*) and western grey kangaroos (*Macropus filliginosus*) and its potential influence on diet selection and population parameters. *Journal of Zoology* 215: 491 -504.
- McNab, B. K. 1963. Bio-energetics and the determination of home range size. *American Naturalist* XCVII 133-40.
- Nagy, K. A., Bradley, A. J., and Morris, K. D. 1990 Field metabolic rates, water fluxes and feeding rates of quokkas, *Setonix brachyurus*, and tammar, *Macropus eugenii* in Western Australia. *Australian Journal of Zoology* 37: 553-60.
- Nicholls, D. J. 1971. Daily and seasonal movements of the quokka, *Setonix brachyurus* on Rottnest island. *Australian Journal of Zoology* 19: 215-226.
- Poole, W. E. and Brown, G. D. 1988. Further records of life-spans of the tammar wallaby *Macropus eugenii* (Marsupialia: macropodidae), on Kangaroo Island, South Australia. *Australian Mammalogy* 11: 165-166.
- Rao, A. T; Acharjyo, L. N., Upidhyaya T. N., and Baliarsingh. S K. 1991. Generalised tuberculosis in a wallaby (*Macropus eugenii*). *Indian Journal of Veterinary Pathology* 15 (1) 43-44
- Russell, E. M. 1984. Social behaviour and social organisation of marsupials. *Mammalogy Review* 14 (3) 101-154.
- Sanson, G. D. 1989. Morphological adaptations of teeth to diets and feeding in the Macropodoidea. In *Kangaroos, wallabies and rat kangaroos*. eds G. Gregg, P Jarman and I. Hume. Surrey Beatty and Sons Pty. Ltd, New South Wales.
- Stableforth, A. 1929. A bacteriological investigation of cases: tuberculosis in 5 cats, 16 dogs, a parrot, and a wallaby. *Journal of Comparative Pathology and Therapy* 12: 163-168.
- Tilden, E. and Williamson, W. 1957. Unusual tuberculous lesions in a wallaby. *Journal of the American Veterinary Association* 131: 526-527.
- Vujcich, M. V. 1979. Aspects of the Biology of the parma (*Macropus parma* Waterhouse) and darma (*Macropus eugenii* Desmarest) wallabies with particular emphasis on social organisation. MSc thesis, Univ. Auckland
- Vuchich V. C. 1979. Feeding ecology of the parma (*Macropus parma* Waterhouse and Tammar (*Macropus eugenii* Desmarest) wallabies on Kawau Island. MSc Thesis, Univ. Auckland.
- Waghorn, G. C. 1986. Changes in the rumen digesta of cows during a restricted feeding period when offered fresh red clover, lucerne or lucerne hay. *New Zealand Journal of Agricultural Research* 29: 233-241.
- Warburton, B. 1983. An assessment using direct pellet recruitment, of a wallaby population poisoned with 1080 gel on broadleaf. Unpublished internal report No 20/719 NZ Forest Service.
- Warner, A. C. I. 1981. The mean retention times of digesta markers in the gut of the tammar, *Macropus eugenii*. *Australian Journal of Zoology* 29: 759-71.
- Williamson, G. M. 1986. The ecology of the dama wallaby (*Macropus eugenii* Desmarest) in forests at Rotorua, with special reference to diet. MSc thesis, Massey University.