Whiteman Park
Technical Report Series No. 1

A Study of the Brush or Black Gloved Wallaby *Macropus irma* (Jourdan 1837) in Whiteman Park

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WESTERN AUSTRALIAN PLANNING COMMISSION

WHITEMAN PARK

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A Study of the Brush or Black-gloved Wallaby *Macropus irma* (Jourdan 1837) in Whiteman Park

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PREFACE TO TECHNICAL REPORT SERIES

The Whiteman Park technical report series was introduced in 2002 to publish research and technical reports commissioned by the Whiteman Park Board of Management acting on behalf of the Western Australian Planning Commission.

Dr Stephen Davies of the Whiteman Park Board was instrumental in developing the concept and promoting the Park s research to the broader scientific and environmental community.

This series is aimed at universities and community organisations who may be seeking to understand the environmental values of Whiteman Park. The research covers a broad area of over 4,200 hectares in the localities of Whiteman, Cullacarbardee and Bennett Brook.

The series will be produced on an ad hoc basis with the aim of adding two to three titles per annum. Print runs will be limited and a small fee will be charged to recoup costs.

The first publications in the series are:

No.1 *A Study of the Brush or Black Gloved Wallaby Macropus irma (Jourdan 1837) in Whiteman Park.* Author : MJ & AR Bamford

No.2 *The Estimation of the Number of Western Grey Kangaroos in Whiteman Park - September 2001.* Author : MJ & AR Bamford.

August 2002

EXECUTIVE SUMMARY

The Brush Wallaby *Macropus irma* is a seldom-seen species that occurs only in the South-West of Western Australia. Its nearest relative, the Toolache Wallaby *Macropus greyii* of south-eastern Australia, is extinct. Although it is not currently considered threatened, the Brush Wallaby has declined in abundance and it is known to persist at only a few locations close to Perth. Whiteman Park is one such location, and a study was undertaken to gather information on the ecology of the species that would be useful for its management in the Park. The main aims of the study were to estimate population size and to examine habitat usage, patterns of movement and home range area requirements of the wallabies.

The study consisted of two phases: sweep surveys to determine overall patterns of distribution and abundance; and radio-tracking of individuals to determine patterns of movement, home range areas and habitat selection. The study began in May 1996 and field work was largely completed in June 1998.

Brush Wallabies were found to occur at an overall density of 0.16 wallabies/ha, which equates to a total population of 160 animals given an area of approximately 1,000ha of woodland in Whiteman Park. The wallabies were not evenly distributed, but favoured dense, low vegetation, with or without an overstorey and often associated with wetlands and damplands. They rarely ventured into cleared land and were rarely encountered in woodland areas with low or open understorey. One animal was attracted to water on a reticulated lawn but it would appear that Brush Wallabies do not need access to free water.

Animals sheltered during the day in or close to dense understorey vegetation but did not have a distinct resting site, and did not use the same site on a regular basis. They were crepuscular, with the greatest activity occurring around sunset and sunrise, but they moved around all night and occasionally during the day. This pattern of movement suggested that they forage primarily from shortly before sunset to shortly after sunrise. They tended to forage in more open areas than those chosen for shelter, and animals close to recently-burnt areas foraged in those areas at night but sheltered in dense, unburnt areas during the day.

Individual Brush Wallabies were sedentary. Females foraged over an average area of 5.3ha each night, while males foraged over an average area of 9.9ha. Over the course of a year, the most wide-ranging female moved over an area of 32.5ha, compared with 69.2ha for one male. This male moved his area of activity during the study. Areas over which animals moved overnight tended to be larger in autumn and much of winter than in spring and summer.

Brush Wallabies appeared to be solitary. A sub-adult female whose nightly foraging area initially overlapped that of an adult female assumed to be her mother, eventually established nightly foraging areas adjacent to and only slightly overlapping those of the adult female. This suggests that females may typically have overlapping home ranges but may avoid foraging close to each other on a nightly basis. The large nightly foraging areas and home ranges of males probably overlap those of several females. Observations on captive wallabies indicate that males are very intolerant of

each other, while females normally ignore other females. These observations, combined with the similarity in size of males and females, suggest that Brush Wallabies do not have the sort of complex social behaviour seen in most other kangaroos and wallabies.

Observations made throughout the study suggest that Brush Wallabies are very tolerant of disturbance, noise and light. Two animals lived close to Beechboro Road and one of these crossed the road at least once, while unusual vehicular and pedestrian activity seemed to have little effect on the movements of wallabies.

With respect to the management and conservation of Brush Wallabies in Whiteman Park, it is clear that the population is larger than previously estimated, although it is still smaller than what some authorities suggest is required for an isolated mammal population to be viable in the long-term. However, the wallabies in Whiteman Park are not completely isolated as there is potential for movement of wallabies from the north, which may be enhanced with future development of the Gnangara Conservation Park. This may require facilitation of movement of wildlife across Gnangara Road.

Suitable habitat is widespread in Whiteman Park and is also present in the area west of Beechboro Road. The most important habitat feature for Brush Wallabies appears to be dense vegetation (foliage cover estimated at >40%) about one metre in height, with or without an overstorey. Such vegetation is commonly associated with wetlands, damplands and the woodland margins of damplands. Recently-burnt areas, at least up to two years post-fire, are favoured for foraging but are not essential, whereas all wallabies required dense vegetation for shelter. Therefore, any use of fire in management needs to retain large tracts of unburnt vegetation that the wallabies can use for shelter. Given the tolerance of wallabies to disturbance, suitable vegetation in Whiteman Park is probably being used by the animals even close to areas of human activity.

ACKNOWLEDGEMENTS

Brush Wallabies are usually described as shy, secretive and difficult to observe; therefore it was anticipated that they would be a difficult subject to work with. We were not disappointed. This project would not have been possible without tremendous effort from all sorts of people who walked through rain-drenched bush, got up before dawn, stayed up all night, carried heavy equipment to and fro and, very rarely, saw a Wallaby. My thanks to my family, assorted students, their friends and their children, and to the various staff from Whiteman Park whose uncomplaining efforts under often trying circumstances made this research possible. Thanks also to staff of the Department of Conservation and Land Management and Perth Zoo for their help and advice, and to Dr Stephen Davies and Mr Harry Gratte for their enthusiasm, support and patience.

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A Study of the Brush or Black-gloved Wallaby *Macropus irma* (Jourdan 1837) in Whiteman Park

INTRODUCTION

The Brush Wallaby *Macropus irma* and the Western Grey Kangaroo *Macropus fuliginosus* are the only two macropodid species that are still widespread in the South-West of Western Australia, and both still occur in the Perth area. The kangaroo is the more abundant of the two, and even persists in some isolated populations in areas of remnant native vegetation, such as at Hepburn Heights and the Karrinyup Golf Course. The Brush Wallaby does not appear to persist as successfully in the face of urban development, although two animals were reported to be surviving in a few hectares of woodland at the Landsdale Farm School in Landsdale in 1998 (L. Boylan, pers. comm.); a specimen was killed on Joondalup Drive in Joondalup in early 1998; and the species has been reported from Koondoola Open Space. Despite these records, probably the largest and most secure population of the Brush Wallaby on the outskirts of Perth occurs at Whiteman Park.

Arnold *et al.* (1991) estimated that the Park supported 40 Brush Wallabies, compared with an estimated 1,100 Grey Kangaroos (Bamford and Bamford 1995a). Wann and Bell (1997) studied the diet of both species in the Park, but noted that the Brush Wallaby has been little-studied because it is solitary, secretive and rarely observed.

The Brush Wallaby is endemic to the South-West of Western Australia and occurs from Geraldton in the north to the region of Esperance in the south-east. Since European settlement, this range is believed to have declined by less than 10% (Kennedy 1992), but it is classed as Potentially Vulnerable because of recent population declines. The WA Department of Conservation and Land Management classes the species as Priority 4, which means that it has declined and requires monitoring, but that it is not currently endangered.

The range of the Brush Wallaby has probably not declined greatly because it apparently was not widespread in the wheatbelt woodlands which have been extensively cleared for agriculture. It occurs in forests which have been protected for the extraction of timber, and in sandplain woodlands and kwongan which largely grow in soils that are of marginal agricultural value. Despite this, the species was noted to have declined in abundance during the 1970s (Christensen 1983) and this was ascribed to an increase in predation pressure from the Fox *Vulpes vulpes*. Although adult Brush Wallabies, which weigh 8-9kg, may be too large to fall prey to the Fox, young wallabies lie within the Critical Weight Range identified by Burbidge and McKenzie (1989).

The closest relative of the Brush Wallaby, the Toolache Wallaby *Macropus greyii* of south-eastern South Australia and south-western Victoria, is believed to be extinct. Its extinction was probably due to habitat loss, as it occurred on the margins of wetlands in areas with good agricultural soil, and draining and clearing of these wetlands began as early as 1862 (Robinson and Young 1983). Hunting may have contributed to its

decline, as the species was taken for sport and its pelt, sometimes being hunted using packs of dogs to flush it from cover (Calaby 1984).

Little is known about the biology of the Brush Wallaby. Christensen (1983) considers it to be a solitary, grazing species of open forests, but Wann and Bell (1997) and Shepherd *et al.* (1997) found it to be a browser as well as a grazer, feeding upon a wide variety of grasses, shrubs and small trees. Ride (1980) notes that it occurs in dense tree-heaths (kwongan) of sandplain country as well as forest, while Bamford (unpub. data) has found it in dense understorey vegetation of *Banksia* woodland at Gingin and Badgingarra. The young are reported to be born in late autumn and to emerge from the pouch in spring (Christensen 1983), but Bamford (this report) caught a female with a small pouch young in February, and a second female which had no pouch young but was accompanied by an immature and possibly dependent female in June.

Because the Brush Wallaby is not often seen, the assumption is sometimes made that it is rare, but road surveys conducted in the Jarrah Forest by Batini (1971) found wallabies at a density of 7-25 per 100 miles, compared with 22-51 Grey Kangaroos. In these surveys, 277 wallabies and 709 kangaroos were seen, and both species were most abundant in areas that had been burnt 1-2 years previously.

The brush wallaby is unusual among the Macropodidae (kangaroo family) in not being sexually dimorphic. Of the 14 members of the genus *Macropus* recognised by Strahan (1983), only in the Brush and Toolache Wallabies are the males not larger than the females. This lack of size dimorphism is consistent with the reported solitary nature of the Brush Wallaby, as most other *Macropus* are social, with males gathering and defending groups of females in competition with other males. The only observations of Brush Wallaby behaviour have been made in captivity, where the females virtually ignore each other when housed together, while males are extremely aggressive towards other males but rarely interact with females. Hand-raised males are aggressive towards people.

Given the overall conservation status and lack of knowledge of the Brush Wallaby, its persistence in Whiteman Park so close to Perth is significant. Therefore, the then Ministry for Planning (now the Department for Planning and Infrastructure), which manages Whiteman Park for conservation and recreation, commissioned a study of the wallabies in the Park to aid in the management of the Park's population. There was particular concern that the population was small and that, with urban expansion around the Park, it would become isolated from other wallaby populations within a few years. Such small, isolated animal populations can be difficult to manage and may have little long-term viability.

The main aims of this study were to determine the size of the Brush Wallaby population in the Park and patterns of habitat usage displayed by the wallabies. There was also interest in the possibility of interactions between the Brush Wallabies and the Grey Kangaroos. In addition, the study of such a conveniently located population made it possible to learn something of the basic biology of the species, such as patterns of daily and seasonal movements.

METHODS

The study of Brush Wallabies in Whiteman Park had two main components: sweep surveys to determine overall patterns of distribution and abundance; and radio-tracking of individuals to determine patterns of movement and habitat selection. Field work for the project began in May 1996 and was largely completed in June 1998, although some supplementary data were gathered up to May 1999. Almost all field work was carried out in the Conservation Zone, between Woolcott Street and Gnangara Road (see Fig. 3). The project was carried out by Bamford Consulting Ecologists with much assistance from the staff at Whiteman Park and a vast assemblage of volunteers.

Sweep surveys

These surveys involved a line of people walking side-by-side on a set bearing and for a known distance, so that a known area was effectively searched for wallabies. The idea for these surveys was based on the observation that a single person walking through bushland would occasionally flush wallabies from within 5-10m, therefore it was felt that a line of people, with no more than 10m between adjacent observers, would flush all wallabies in front of them, making it possible to count wallabies over a known area. A similar approach was taken in 1990 (Arnold *et al.* 1991), but with three riders on horseback spaced 100m apart, with the large spacing presumably based on the assumption that a rider on horseback would flush wallabies from a wider area than a person on foot. This survey resulted in a population estimate of 40 wallabies in Whiteman Park. In 1995, however, this was repeated and it was noted that the only wallabies observed were flushed from within 5m of a horse and rider, suggesting that a horse does not flush wallabies from a larger area than a person on foot (Bamford and Bamford 1995b).

Sweep surveys carried out in 1996 involved from 10 to 15 observers on each occasion, with an attempt to keep the length of the line at 100m so that an area of approximately 10ha was searched for every kilometre traversed. Each survey started from a point that could be readily located on a map, and each leg of a survey followed a compass bearing. Whenever a wallaby was flushed, its location was recorded and notes were made on the site characteristics, such as position in the landscape and vegetation type. Six sweep surveys were carried out, covering areas of 24ha to 65ha, and their locations are given on Figure 1.

When disturbed during a sweep survey, Wallabies travelled at least 100m, and it was found that they could be flushed again. However, they displayed a strong tendency to move to the left or right, rather than straight in front of the sweep line. Therefore, it was unusual for an animal to be recorded twice.

During the sweep surveys, it was initially assumed that most or all wallabies present in the survey area were observed, as all wallabies seen were flushed from within 10m of observers. Because the wallabies waited until the last moment to move, they were close to the observers and therefore easy to observe even in dense vegetation. Even if not clearly seen, a fleeing wallaby makes a lot of noise. On three occasions, wallabies

waited until observers were so close that they actually hit people as they burst out of hiding, so there was a possibility that some wallabies may have been passed over by the line of people. However, during later attempts to catch wallabies, that used a line of people to flush the animals towards a net, it was found that a proportion of wallabies disturbed by people walking in line quietly moved away well ahead of these people, and were only seen because they ran into the net. There was even one capture attempt during which the people in the line saw nothing and had stopped walking, having got to within 10m of the net, and at that moment a wallaby appeared at the net and was caught. On another attempt, three wallabies were seen near the net when the people in the line had seen nothing. It was difficult to keep clear records with many people scattered over a large area, but on ten capture attempts over the period February to June 1997, the people in the line saw 27 wallabies, while a further 7 wallabies were seen only by the people based at the net. This suggests that in the sweep surveys, only about 80% of the wallabies actually present in a survey area were recorded by the people in the sweep line. The other 20% may have moved quietly ahead of the line. Therefore, this information was used to calculate the actual number of wallabies present in sweep survey areas.

Wallaby captures

Kangaroos and wallabies in general have a reputation for being difficult to capture safely (Hume *et al.* 1989). They struggle violently and can therefore injure themselves, and are also prone to a number of stress-related conditions, including shock and capture myopathy. Capture myopathy is a particular concern, as it may develop many hours after capture and therefore possibly after release, and can render the animal virtually incapable of movement. The condition is difficult to reverse. Because of these concerns, the WA Department of Conservation and Land Management (CALM) was very cautious about issuing a permit to undertake trapping of Brush Wallabies. Discussions were held with CALM personnel and a licence was issued, on the proviso that a range of capture techniques be investigated, that discussions be held with staff at Perth Zoo experienced in handling macropods, and that CALM be kept informed.

Several capture techniques were considered. For the capture of Western Grey Kangaroos, Arnold *et al.* (1986) used the anaesthetic alpha-chloralose in grain and water, with the animals being conditioned to come into bait stations before the drug was applied to the bait. Bait stations using oats were set up at Whiteman Park, but Brush Wallabies were found to visit these stations infrequently. In three evening watches of ten bait stations, only 2 wallabies were seen feeding on oats, while the bait was found to attract Grey Kangaroos (23 observations), the Quenda *Isoodon obesulus* (8 observations) and Rabbits *Oryctolagus cuniculus* (2 observations). Australian Magpies *Gymnorhina tibicen* and Australian Ravens *Corvus coronoides* were also seen feeding on the oats. It seemed that Wallabies were difficult to attract with readily-available bait, and that the chance of over-dosing smaller species, such as the Quenda, was considerable. There was also a concern that even if Wallabies did take oats containing alpha-chloralose, they could be very hard to find in the dense vegetation, and unconscious animals could be taken by predators or die from exposure.

Some wallaby species have been caught in large cage traps, but CALM did not approve of this technique, as high mortality rates have been recorded due to animals breaking their neck against the rigid frame and sides of the trap. Soft-walled traps have been developed, however, including a trap for catching the Swamp Wallaby *Wallabia bicolor*, which is similar in size to the Brush Wallaby (Pollock and Montague 1991), and the Bromilow Trap, which has been used for catching rock wallabies (Kinnear *et al.* 1988). Rock wallabies are smaller than the Brush Wallaby, but J. Kinnear (pers. comm.) has reported the capture of a Brush Wallaby that squeezed into a Bromilow trap. Soft-sided traps were considered, but were not used initially because it was expected that the Quendas, which are abundant in Whiteman Park, would set off the traps and get caught, making it impossible for the much less abundant Brush Wallabies to enter the trap.

J. Kinnear (pers. comm.) also reported on the use of water as a lure for rock wallabies, and therefore nine water baits were set up to see if wallabies were attracted to them. These consisted of 10L buckets set halfway into the ground, with sand cleared around them so that the tracks of visiting animals could be seen. At least one Wallaby and other animals did visit the baits, so funnel-entranced traps constructed of aviary mesh and fence wire suspended from angled steel pickets were erected around four of the buckets. These were designed so that the only rigid sections were on the outside and angled away from the mesh sides of the trap. These traps were not developed further, however, because it seemed that wallabies would not enter them. It also became apparent that after the initial visit of a wallaby to a water bait, such visits were very rare.

Other techniques based on luring kangaroos and wallabies into large pens using baits such as food and water have been widely used (Hume *et al.* 1989), but it appeared that Brush Wallabies were not easily manipulated through the provision of food and water, so no attempt was made to develop such techniques. Furthermore, such techniques may work well with social species of macropods, in which many individuals can be attracted to one site, but existing information and initial observations suggested that the Brush Wallaby is largely solitary, so the construction of large pens for the capture of a single animal that might not be attracted to bait did not seem worth pursuing. When herded into pens, macropods are also prone to considerable stress, as once in the pen, animals must be caught and subdued.

Large macropods have been successfully and safely caught using the combination of a spotlight and firing a rifle just above the animal's head to disorient or stun it (Robertson and Gepp 1982). The animal can then be approached and grabbed. This technique has apparently been used successfully by Mr I. Offer on the Brush Wallaby (S. Davies, pers. comm.), but attempts just to spotlight Brush Wallabies in Whiteman Park were unsuccessful. Brush Wallabies usually stay in dense cover, making a spotlight ineffective, but even specimens observed feeding in the open did not freeze in the spotlight beam as is often the case with macropods. Rather, they made a quick dash for cover. It seemed unlikely that this technique had much potential.

Hume *et al.* (1989) considered that shooting macropods with a tranquilliser was unreliable and hazardous because of problems with dosage, but Higginbottom (1989)

used this technique successfully with Red-necked Wallabies *Macropus rufogriseus*. However, she was working with a population that was habituated to observers and could therefore be approached closely. The shy and fast-moving Brush Wallaby was not considered a good candidate for this capture technique.

Because established techniques for catching macropods didn't seem to be suitable for the Brush Wallaby, a technique based on experience gained with the animals during sweep surveys was developed. It was found that the Brush Wallabies were most often encountered in dense understorey vegetation close to seasonally damp sites, and that they could be flushed by people walking in a line, with the result that the animals would usually move away from the people, albeit often at an angle. It was therefore reasoned that if some sort of trap could be established close to where the Brush Wallabies were resting during the day, then it should be possible to drive the Wallabies into this trap.

Several variations on this theme were trialled before a system was developed that was reasonably reliable. Early methods attempted and abandoned included a single net of lightweight mesh 100m long, and a 200m hessian fence with hessian pockets and aviary-mesh traps at 50m intervals. Ultimately, the successful technique was based upon two 100m long wings of hessian aligned in a V, with a net placed across a 5m wide gap at the apex of the V. The fences were approximately 1.5m high and were supported by star pickets placed at 5-10m intervals. The net was approximately 1.2m high but was actually 2.4m wide, and when set half of the net was spread out in front of the upright section of netting. This layer of netting lying on the ground could be raised quickly the instant a wallaby hit the net, effectively sandwiching the animal between two layers of mesh. The netting was commercially available material usually used for beach netting of Australian Salmon. The heavy mesh net was first used without the layer of netting on the ground and successfully caught two wallabies, but a number of wallabies simply bounced off it and were not entangled, so the lift-mechanism was introduced. The hessian fence and lift net technique is illustrated on Figure 2. Details on all capture attempts are listed in Table 2.

Before the lift-mechanism was introduced, the Wallaby Net was used six times for the capture of 2 wallabies. Thirteen wallabies were flushed during these attempts, 5 hit the net but 3 of these escaped. The final net arrangement used, the Wallaby Lift-Net, was employed on fourteen occasions and caught 6 wallabies. This was out of a total of 42 wallabies flushed, of which 10 hit the net and one jumped over it. The animal which jumped over the net had previously bounced off the net, and it cleared the 1.2m high net from a slow hopping start. The 4 wallabies that hit the net and escaped included one that jumped vertically from between the two layers of mesh, a wallaby that hit and bounced off the net before the person operating the lift-mechanism was able to pull the rope that lifted the layer of mesh from the ground, and two wallabies that managed to hop between the layers of mesh, past the people trying to catch them, and out the end. As far as could be recorded, only 2 wallabies went beneath the hessian fence, seeming to prefer to follow the hessian towards what appeared to be an obvious gap.

The rate of capture of wallabies does not appear to be very high even with the Lift-Net, but in the final seven attempts, 27 wallabies were flushed, 8 hit the net and 6 of

these were caught. In the first seven attempts with this net, only 2 of 15 wallabies that were flushed actually hit the net! The success in the last few months of the trapping programme was the result of refinements in the approach taken which resulted in more wallabies hitting the net. These refinements were the result of improvements in the understanding of where wallabies were likely to be sheltering and how they were likely to respond to attempts to drive them towards the fence and Lift-Net. Successful capture attempts had the following approach:

- The trapping location was selected and star-pickets put in place several days before a capture attempt was carried out. Selection of the trapping location was very important, as it had to be placed in an area where there were likely to be wallabies, while the Lift-Net had to be in a position where the wallabies were likely to run. Star-pickets were placed in a cross which gave four options for the V arrangement of the hessian fences (see Figure 2). The centre of the cross, where the Lift-Net would be located, was placed within dense vegetation of a seasonally damp valley. The hessian for the fencing was left in heaps beside the pickets.
- On the morning of the capture attempt, an advance party of four people walked very quietly into the capture area, erected the first V of hessian fencing and set the Lift-Net facing into this V. These people became the capture team. It was found that with four people on the net, one person could stay at each end of the net when a wallaby became entangled, while the other two people could move forward to catch the wallaby and get it into a bag.
- When the hessian fences and net were set, the capture team radioed the beating line of usually 10 people, who then walked towards the V. Members of the beating line walked casually, quietly and tried to keep about 10m apart. If the beaters made a lot of noise, such as clapping their hands and shouting, wallabies were inclined to panic and dash to the left or right, or even through the beating line, whereas if the beaters were quiet, wallabies were more likely to hop ahead of them and therefore towards the trap. The beaters did not so much drive wallabies ahead of them as disturb wallabies which would then run in the direction they wanted to run in. This was the reason that the Lift-Net was placed in dense vegetation, as wallabies commonly were found to be resting on the fringes of dense vegetation and would run towards the dense cover when disturbed. In some capture attempts when wallabies could not be driven into the net, it was realised that we were trying to drive them into woodland where there was only light cover. On these occasions, wallabies would hop through the beating line and, on two occasions, people were hit by wallabies.
- When a wallaby hit the net, the rope was pulled to trap it between the two layers of mesh. Wallabies were initially grabbed by the base of the tail and then across the chest, when it could be restrained by being held against the handler's chest, with the hind legs free and kicking away from the handler. The wallaby was then transferred to a hessian bag. Once in a bag, the wallabies became quiet and during all handling procedures while radio-collars were attached, the eyes of the wallabies were kept covered and only light pressure on the wallabies was needed to keep them still. The wallabies only became agitated if they could see or if any sharp noise was made. The first wallaby caught was sedated by a veterinarian from Perth Zoo, but this was found to be unnecessary and was not practised on other specimens. Wallabies were released into the area from where they had come and stopped within 50-100m.

- After the first V had been swept by the beating line, one line of hessian was moved to the opposite line of pickets, the Lift-Net was swung around and a second V was swept. This procedure could be repeated so that all four compartments around the cross arrangement of pickets could be searched for wallabies. Despite the levels of activity that occurred as each V was searched, it was found that wallabies could still be flushed into the capture area of the third or even fourth V. Nearby wallabies were clearly not disturbed by up to 14 people walking quietly around within 100m of them.
- Repeated attempts at the same location at regular intervals were sometimes unsuccessful, as wallabies seemed to be more nervous and inclined to scatter rather than move ahead of the beating line. This was probably the reason for the two failed attempts in August 1997.

The key features of successful capture attempts were placement of the fences in areas where wallabies were present; placement of the Lift-Net where the wallabies would run when disturbed; and keeping noise levels down throughout all procedures. Over the period December 1996 to September 1997, 8 wallabies were caught and collared (see Table 2).

Radio-tracking of Wallabies

When captured, wallabies were handled as quickly as possible to minimise stress. They were sexed, weighed and the pouch of females was examined to determine if young were present. Collars of synthetic belting were attached with two nylon nuts and sealed with a drop of "Super-Glue". The transmitter fixed to each collar was a standard two-stage unit packaged onto a 2/3 AA lithium battery. These transmitters operated on frequencies of 150.02 MHz (Channel 02), 150.04 MHz (Channel 04) and on up to 150.16 MHz (Channel 16), and transmitted at 40 pulses per minute. This was supposed to give a battery life of 21 months, although under field conditions it was found that the transmitters had an effective life of 14 to 20 months. Some were still transmitting at this stage, but had a range of barely 100m. When operating well, they had a range of 500m under all conditions, and could be detected at nearly 2km from very high points in the landscape. Transmitters were detected with the ATS Fieldmaster 16 Channel Receiver used in conjunction with a folding, 3-element antenna. All tracking equipment was provided by Sirtrak Electronics.

Wallabies were located by the standard procedure of triangulation, which involves determining a bearing to a wallaby from each of at least two known locations, with the position of the wallaby being given by the intersection of these bearings. Positions used as tracking locations were intersections of tracks, distinctive bends on tracks and high points that could be readily found on an aerial photograph. Whenever possible, bearings were taken from three locations, as the more bearings used, the more accurate the fix on the wallaby. Bearings were generally taken to the nearest 5^{o}, and when only two bearings could be used, they were discarded if they did not differ by at least 15^{o}. This was because, when the bearings were similar, the angle of intersection was shallow and therefore a small error in one bearing could lead to a large error in the estimated position of the wallaby.

From the time of capture, each wallaby was checked on at least two occasions each month for as long as the transmitter operated, or, in some cases, until the wallaby was found to have died or to have lost its transmitter. On one day (or sometimes more) each month, each wallaby was located in daylight (usually only once), while on a monthly basis, each wallaby was located at intervals from mid-afternoon of one day to mid-morning of the following day. The length of intervals between when wallabies were located ranged from less than an hour to 3 hours, but most intervals were from 1.0 to 1.5 hours in length. Intervals of >1.5 hours occurred only between 2300 and 0300 hours. Days when surveys were carried out, indicating which wallaby was located on each occasion and how often they were located, are presented on Table 3. All raw data are presented in Appendix 1. Note that during overnight sessions, at least the first two and last two observations were made in daylight in almost all months.

Data from radio-tracking were used to determine the patterns of movement of Wallabies, including over what area each animal moved in one night and over the course of a year, the time of day when wallabies moved and, in conjunction with vegetation maps for Whiteman Park provided by the Department for Planning and Infrastructure, the vegetation types they utilised. The data were also examined for seasonal variation, differences between males and females and the influence of recent fires.

Because wallabies almost never ventured from dense vegetation they were rarely observed, so it was generally not possible to check the accuracy of bearings and fixes by visually locating specimens. However, Channel 16 died or was killed shortly after being collared, while Channels 02 and 12 lost their collars, but the positions of these collars were determined for some time afterwards. The forequarters of Channel 16, with the transmitter still attached and operating, were found buried (by a Fox or Dogs) after suspicions were aroused that he hadn't moved very much. The soil over the remains appeared not to have been disturbed recently. Channel 02's collar was found caught in a bush, while Channel 12's collar was found lying on the ground in an area disturbed by wallabies, kangaroos and Quendas. Records were collected from the transmitters of Channels 02, 12 and 16 for several months, providing information on the accuracy of the triangulation system.

Channel 16 had probably died shortly after capture, due either to post-capture stress or to predation by Dogs, as a pack of Dogs was reported in the area a few weeks after he was caught. Therefore, all fixes made on Channel 16 were of a stationary transmitter, although this may have been moved between surveys. Over the period August 1997 to February 1998, Channel 16 was located over an area of 1.9 ha, with areas found during overnight surveys ranging from 0.2ha - 0.9ha (Table 5, see also Figure 11). The total area over which the collar was located may have included some movement due to the corpse being moved between surveys, but the areas found during single overnight surveys indicate the accuracy of the triangulation technique based upon two bearings only. The mean area found during overnight surveys was 0.44ha, which indicates that fixes obtained upon a stationary wallaby could vary by $\pm$37m when based upon two bearings. Fixes based upon three or more bearings would be more accurate than this.

Channel 12 lost her collar some time between the November and December overnight surveys. Over four surveys from December 1997 to March 1998 the collar was located over an area of 3.3 ha, but it was very likely to have been moved between surveys because it was in an area of high Quenda, kangaroo and wallaby activity. Areas determined during overnight surveys ranged from 0.4ha - 1.8ha, with a mean of 1.0ha (Table 5; see also Figure 10). This suggests an accuracy of ± 56m for fixes obtained on a stationary wallaby. This degree of inaccuracy resulted from the distance of Channel 12's transmitter from tracking locations (over 500m), the use of only two bearings and the difference between these bearings being only around 40°. The distance in particular meant that slight variations in bearings could result in very different fixes being obtained. Because of the position of Channel 12, fixes obtained on her were probably the least accurate made during the study.

Channel 02's collar was located over areas of 0.8 ha and 0.5 ha in February and March respectively (Table 5), and appeared to have been moved between these surveys (Figure 4). These two values correspond to levels of accuracy of ±50m and ± 40m. These sets of readings were based on only two bearings.

RESULTS

Sweep Surveys

Details on the six sweep surveys carried out are presented on Table 1. Thirty-three wallabies were seen over an area of 260ha, and therefore based upon the observation that only 80% of wallabies in an area are likely to be seen during a sweep, a total of 41 wallabies may have been present. This gives a density of 0.16 wallabies/ha over the area surveyed. The Conservation Zone of Whiteman Park has an area of *ca.* 700 ha, and at least a further 300ha of bushland is present adjacent to but outside the Conservation Zone, so the Brush Wallaby population in Whiteman Park probably contains about 160 animals.

This estimation is based upon the assumption that 0.16 wallabies per hectare is a reasonable approximation of the average density of wallabies in bushland in Whiteman Park. The wallabies were not evenly distributed, however, and therefore it is possible that the density estimate was biased because vegetation types either favoured or not favoured by wallabies were over-represented in the surveys (see Figure 1). However, the locations of sweeps were chosen to be representative of the Whiteman Park bushland, and there was no deliberate attempt to focus upon vegetation types where wallabies were found to be abundant.

On individual sweep surveys, the density of wallabies ranged from 0.068/ha to 0.22/ha (Table 1). Of the 33 animals observed, 16 were in *Banksia* woodland with a dense understorey on low-lying, level ground, the understorey containing some dampland plant species; 15 were in *Banksia* woodland or eucalypt open woodland with a dense understorey on the margins of seasonal damplands or wetlands; and 2 were in *Banksia* woodland on high ground. Of these last two specimens, the woodland where one was observed had dense understorey, while the other was in woodland with only moderately dense understorey. This last animal was lame in one hind leg.

The proportion of wallabies in each vegetation type does not reflect the proportion of each vegetation type in the area surveyed. *Banksia* woodland on high ground constituted approximately a quarter of the survey area, while the two vegetation types where most wallabies were seen each occupied less than a quarter of the survey area. A quarter of the survey area or more consisted of eucalypt open woodland with a low understorey and no wallabies were seen in this vegetation type.

At sites where wallabies were observed, estimates of projected foliage cover for the understorey below one metre in height all fell within 60-80% except for the lame specimen, where the understorey density was *ca.* 40%. The density of trees appeared to be unimportant. The specimens observed on 21st June and 28th July were in open woodland of Marri *Corymbia calophylla* and Modong *Melaleuca priessiana*, where the trees were tall (>10 m) with a projected foliage cover of *ca.* 20%. All other specimens were in *Banksia* woodland where the trees were small (<10 m) with a projected foliage cover of *ca.* 40%. During capture attempts, wallabies were also found in dense shrubland where bushes about one metre in height formed a dense layer of vegetation, but there was no overstorey.

Peak densities of wallabies observed within sweeps were as high as *ca* 3/ha, and similarly high densities were found when trapping was being attempted. Such densities occurred in areas with dense understorey vegetation. The association of wallabies with dense vegetation close to damplands is apparent on Figure 1, but it should be noted that the wallabies were not in the very densest vegetation in the lowest and dampest points of the landscape. The wallabies were in the fringing woodland around the margins of such sites, where the understorey is particularly dense. Such dense fringing vegetation was very apparent in the undulating landscapes of the eastern and southern parts of the conservation zone. However, in the north-west of the Park, around the Archery field, the landscape was uniformly low-lying, dense understorey vegetation was widespread and wallabies were abundant.

In addition to indicating the general vegetation types where wallabies usually occur, Figure 1 indicates where wallabies usually do not occur. They were absent from Marri woodland north of the Archery Field, in an area where the understorey was mostly rather open (<40% cover) but including areas where cover appeared to be adequate. They were also absent from some large areas of *Banksia* woodland on high ground, such as north-east of Park Street, and the areas where they were not encountered typically had a low density of understorey vegetation. The final vegetation type where wallabies were not recorded was in the central part of the Conservation Zone, between Park and Woolcott Streets, where the vegetation was a Marri open woodland with a low understorey of sedges.

These broad patterns of association with vegetation types make it possible to recognise two main areas of significance for wallabies in Whiteman Park. In the west, there is the drainage system of Bennett Brook, which has dense understorey vegetation, broad, low-lying areas and generally low relief, while in the east there is the system of high dunes with damplands in interdune swales. These two areas merge into each other along Woolcott Street, but are effectively divided by the Marri open woodland with a low understorey in the centre of the Conservation Zone.

Most wallabies found during sweep surveys were solitary and on the four occasions when 2 wallabies were disturbed at the same time (see Figure 1), it was not clear that they had actually been together. Given that the wallabies were concentrated in vegetation where the understorey was dense, these "pairs" may have been the result of chance. Alternatively, these "pairs" may have been the result of a loose association between an adult female and a nearly-independent joey. During radio-tracking, Channels 08 (a sub-adult female) and 10 (an adult female) were caught at the same location and were commonly together. There was no indication from the sweep surveys that wallabies form true pairs.

When disturbed, wallabies often moved rapidly to the left or right, even when that meant moving parallel to a line of people, rather than moving directly away from them. Some animals even ran directly into the line of people. The response of animals to disturbance was not necessarily to run away from the source of disturbance, but to run towards shelter, which was usually denser understorey vegetation than that in which they had been sheltering.

Wallabies did not have regular resting places. On almost all occasions when wallabies were disturbed, it was not possible to find a distinct resting place such as a cleared patch under a bush, or a patch of crushed leaves. On only two occasions were wallabies seen before they took flight. One of these was under a bush, squatting on its hind legs and grooming itself. The other was under a bush and lying on its side. In both cases, the place where the animal was first seen showed no sign of regular use. These observations were made in the late morning.

Grey Kangaroos were counted on three of the sweep surveys made for wallabies (Table 1). These three surveys covered an area of 160ha and resulted in the sighting of 21 wallabies and 28 kangaroos. It is probable that all kangaroos present were seen, whereas there may have been a total of 26 wallabies present. Although based upon only a small number of surveys, this suggests that Brush Wallabies and Grey Kangaroos occur in similar numbers in the natural vegetation within Whiteman Park. Observations during trapping attempts support this conclusion. Although accurate counts of kangaroos were not made during capture attempts, it was clear that wallabies outnumbered kangaroos in the sites chosen for capture attempts. Of course, such sites were chosen on the basis of the vegetation preferences found during the sweep surveys, so were strongly biased in favour of wallabies.

Radio-tracking of Brush Wallabies

As listed on Table 2, 8 wallabies were captured over a period of nine months and with the exception of Channel 16, each of these was tracked for from four to twenty months. Details on the Wallabies are presented on Table 4. Channel 12 was tracked for only four months, but the remaining 6 wallabies were each tracked for about a year. These 6 wallabies included 4 females (Channels 02, 08, 10 and 14) and 2 males (Channels 04 and 06). Channels 08 and 12 were immature females and at least Channel 08 may initially have been suckling occasionally, as radio-tracking later

found that she was often close to Channel 10, a probably lactating female with no pouch young.

The results of radio-tracking are presented on Figures 4 to 14 and Table 5. These figures present information on:

- The area used by each wallaby over all days and nights when data were collected;
- the area used by each wallaby on single nights; seasonal changes in the location of and area used by each wallaby;
- the relationship between vegetation type and areas used by the wallabies;
- the relationship in activity areas of two wallabies with overlapping home ranges; and the distance moved by wallabies in relation to the time of day.

Table 5 summarises information on the home range areas of the wallabies. All radio-tracking data upon which these figures and Table 5 are based appear in Appendix 1.

Home Range

The home range areas occupied by the wallabies through the course of the study ranged from 15.3ha to 69.2ha (Table 5). The two males (Channels 04 and 06) had the largest home ranges of 34.3ha and 69.2ha respectively, the females having home ranges of 15.3ha to 32.5ha. Overnight foraging areas reflected this difference between males and females, with mean values being remarkably consistent. Across the study, the mean overnight foraging areas of the two males were 10.1ha (Channel 04) and 9.7ha (Channel 06), compared with 3.4ha to 6.9ha for the females. Overnight, an average male Brush Wallaby (based upon Channels 04 and 06) foraged over 9.9ha (Standard deviation 5.56), while an average female Brush Wallaby (based upon Channels 02, 08, 10, 12 and 14) foraged over 5.3ha (Standard deviation 2.67).

Although adequate data were collected on only two males and four females, there was a suggestion that individuals moved over larger areas overnight in autumn and winter than at other times of the year. Figure 14 indicates that this pattern is strongest with the males, with large movements concentrated in the period March to July. The pattern was less clear with females, but in both sexes the large overnight areas of July were followed by very small overnight areas in August. This cycle was presumably related to reproduction and suggests that females may be receptive from autumn to mid-winter, although Channel 02, with a small pouch young in February, Channel 10 with no pouch young but possibly a dependent sub-adult in June, and Channel 14 with a large pouch young in September, do not suggest a consistent timing of reproduction.

In all specimens, the area over which they moved in one night represented only a small part of the total home range recorded over several months (see monthly overnight observations, Figures 4 to 11). For most specimens, there was no obvious pattern or sequence in the area over which they were recorded each month, but a pattern was apparent with Channel 06. From May to September 1997, Channel 06 was recorded only in the vicinity of dense vegetation around a dune valley, referred to as Hidden Valley No. 2 (see Figures 3 and 6). In October 1997, however, he moved across to the edge of dense vegetation in a valley to the west, known to Park staff as Hidden Valley. In November and December he was again around Hidden Valley No. 2, but on the overnight observations made in January and February 1998, he spent part

of the night in Hidden Valley. Subsequently, from March to June 1998, he was recorded almost exclusively in Hidden Valley, with only a brief visit to Hidden Valley No. 2 during overnight observations made in June. This sort of shift of the main area of activity would appear to be a male characteristic, as it was displayed by none of the four females on which data were collected for most of a year.

Only two of the wallabies were caught so close together that their home ranges overlapped. These were Channels 08 and 10 (Figures 7 and 8). It was suspected that Channel 08 was the dependent young of Channel 10, as they were caught close together, were often together at night and the larger female (Channel 10) had one elongate teat but no pouch young. Furthermore, during observations made on the night of 24-25 June 1997, light rain fell between 2030 and 2115 hours, and Channel 10 returned to Channel 08 for this period. During some overnight observations they appeared to be close together, and their overnight areas of activity overlapped extensively in June to September and November 1997, but not in October and December 1997, or from January 1998 onwards (Figure 12). It appeared that Channel 08 was beginning to forage independently of Channel 10 by October 1997, and was doing so consistently by the end of that year. Despite this, the two Wallabies showed no change in the distance between them for daylight records. Up to November 1997, the mean distance between the two wallabies on the basis of pairs of daylight records made at the same time was 162.7m (Standard deviation 133.6), compared with 196.1m (Standard deviation 112.3) from December 1997 and later. These values are not significantly different ($t_{0.05,\,36}$ =-1.645 < T = - 0.836). This lack of difference is probably because the two wallabies favour sheltering in dense vegetation and while their foraging areas may have changed, their sheltering requirements did not.

The independence of Channels 08 and 10 makes it possible to tentatively suggest that adult female Brush Wallabies occupy overnight foraging areas that are almost mutually exclusive. If this is the case and each adult female requires approximately 5ha (see above) overnight, then suitable habitat in Whiteman Park should be able to support 0.2 adult female Brush Wallabies per hectare. As males use overnight foraging areas approximately twice the size of females, that equates to an adult density of 0.3/ha in good habitat. This is less than twice the density (0.16/ha) determined from the wallaby sweeps which did not target good habitat. This is a fair correlation between the population densities determined by two different approaches.

Patterns of movement

Wallabies moved throughout the day, with the greatest activity around sunset and sunrise (Figure 13). They were active throughout the night, showed increasing levels of activity in the late afternoon and decreasing levels of activity after sunrise, but they did show some movement in the period from approximately two hours after sunrise to two hours before sunset. Despite this, wallabies did stay still for long periods in daylight. For example, on 9 May 1998, Channels 06, 08, 10 and 14 were located four times from 0830 to 1600 hours; Channel 14 moved between 1345 and 1500 hours but the other wallabies stayed still. The overall pattern was for wallabies to move occasionally in daylight, to begin moving around regularly in late afternoon, to undertake often large movements around sunset, to move around consistently overnight, to make some large movements around sunrise and then to settle down in

the early morning. This overall pattern is apparent for some of the overnight observations, such as that on Channel 02 in April 1997 (Figure 4).

The few direct observations made of wallabies in daylight suggested that they formed no nest and made no attempt to clear a patch of ground for their daylight "camp". Overnight radio-tracking supported the conclusion that they do not habitually use daylight "camps". Although on the mornings of some overnight observations individual wallabies did appear to return to approximately the same location where they had been the previous afternoon (for example, see Figure 4, Channel 02 in April 1997), the mean distance between the first afternoon position of one day and the last morning position of the previous day for all wallabies was 190.1m, (Standard deviation 119.6, based upon 68 pairs of observations). This is very similar to the mean distances recorded between adjacent observations at sunset (185.4m) and sunrise (195.6m).

Habitat usage

All the wallabies were trapped in the sort of vegetation previously established to be favoured by wallabies, so to some extent the sample of radio-tracked wallabies was biased in terms of their selection of vegetation type. Despite this, some clear overnight trends did emerge.

All wallabies favoured dense understorey vegetation in daylight and at night with the exception of Channel 04, who was recorded mainly in a recently burnt area just to the east of Beechboro Road at night (see Figure 5). For all wallabies pooled (excluding Channel 04), 85.6 % of 319 daylight records were in dense vegetation associated with dune swales, while 74.4 % of 360 night records were in dense vegetation, the balance of records being in woodland on dune ridges. Note that records that were on the border of vegetation types were not counted in this analysis. It appears that wallabies forage and shelter over a range of vegetation types, with a preference for burnt areas if available as demonstrated by Channel 04, but with perhaps a slight preference to shelter in areas of dense vegetation. This is consistent with the observation made during attempts to capture wallabies that they tend to shelter close to areas of dense vegetation, to which they retreat if disturbed.

Channel 04 was unusual because he was moving into a burnt area at night but sheltering in unburnt vegetation during the day. This area had been burnt in late autumn 1996 and several wallabies were foraging in it during 1997 and 1998. In early morning (daylight) drives along the limestone track running between the burnt and unburnt areas, up to 7 Brush Wallabies and 15 Grey Kangaroos were seen moving from the burnt into the unburnt area adjacent. This may represent a slight concentration of Brush Wallabies. These animals clearly stayed in the unburnt area until after sunrise, but not until 3 December 1997 was Channel 04 found in a position which suggested he stayed in the burnt area throughout the day. He was about 50m into the burnt area at 1315 hours (see Figure 7). This was approximately 18 months after the area had been burnt and 9 months after Channel 04 had been caught, and on all subsequent daylight surveys he was found in the unburnt area. When Channel 04's transmitter failed in April 1998, he was still sheltering in the unburnt area, so it

appeared that the area which had at that stage been burnt nearly two years previously still did not provide adequate shelter.

Channels 02 and 14 were also unusual, as the former regularly and the latter on one occasion moved onto lawn and pasture to forage at night (Figures 4 and 10). These two wallabies were the closest to such areas. The single record of Channel 14 on pasture was made in December 1997, while Channel 02 visited the lawns of the Archery field in April, June, November and December 1997, and January 1998. There is a summer bias in these observations, and it is possible that they were associated with the wallabies seeking water, either from supplies for stock or from sprinklers on the Archery field. Observations made by Wann and Bell (1997) indicate that wallabies in the vicinity of the Archery field do graze on the grasses of the lawn, but the attraction may be water rather than food. With the exception of Channels 02 and 14, none of the wallabies was known to visit a site where it could obtain free water, so presumably under normal conditions the wallabies get all their moisture requirements from their food. This may explain the presence of semi-succulent foliage, such as that of the Christmas Tree *Nuytsia floribunda*, in the dietary samples examined by Wann and Bell (1997).

Channels 04 and 14 consistently crossed tracks and firebreaks, and the home range area of Channel 14 was around one of the tracking locations from which bearings were taken. This meant that a vehicle drove through her home range regularly, but this seemed to have no effect upon her. On one night (January 1998, see Figure 5) Channel 04 crossed Beechboro Road and stayed west of the road for several hours. Brush Wallabies would appear to cross Beechboro Road regularly, as specimens killed on the road are recorded occasionally. Although she was never observed to cross Beechboro Road, Channel 02 was often very close to the road and was clearly tolerant of the light and noise from traffic. Channel 02 was also within an area regularly visited by members of the Archery club.

Miscellaneous observations on Brush Wallabies

During the course of radio-tracking Brush Wallabies, a number of observations were made concerning aspects of their biology. Despite the amount of time spent tracking wallabies, very few individuals were seen. When driving between tracking locations, wallabies were occasionally seen crossing the tracks, while Channel 10 was seen once, when she was deliberately approached to confirm that she was still alive. Channels 06 and 14 were deliberately approached for the same purpose, but moved without being seen or heard. Despite the scarcity of sightings, there was one location where wallabies were consistently seen, and this was on the Archery field.

During overnight observations of November 1997 and January 1998, up to three wallabies at a time were seen on the Archery field lawn up to 50m from dense cover, and they were grazing and possibly drinking from sprinklers. They were seen around sunset and before it was completely dark, and it is suspected that Channel 02 was among them on at least one occasion. On the evening of 28 January 1998, two wallabies were seen on the Archery field lawn at 1930 hours (sunset was 1940 hours). They were 200m from my position and about 50m from each other. Both appeared to be adults. One wallaby was grazing when the second emerged from the adjacent

bushland, hopped purposefully across to the first wallaby, which then responded by looking up and hopping a few steps towards it. The two wallabies sniffed each other's noses for a second, and then parted to graze separately. When grazing they were about 20m apart. Based on descriptions of captive males fighting, it is probable that these two animals were females.

Other observations were made on the effects of disturbance upon wallabies. It was clear that wallabies were not concerned by the noise and lights of traffic, and there were also reports from staff members of wallabies in parts of the park close to the Village and Workshop areas. Noise and lights at the Archery field did seem to discourage wallabies from moving onto the lawn area in the evening, but otherwise Channel 02 moved around in the cover of dense vegetation even when there was a lot of human activity about. The tolerance of wallabies to disturbance was made very apparent during the overnight observations of June 1997, when a teenage boy throwing rocks at cars on Beechboro Road wandered down Park Street at about 2200 hours. A report was made to Whiteman Park Staff and within 20 minutes there were five vehicles, including two police cars, driving up and down Park Street. The distressed boy was eventually persuaded to go with a teacher he trusted. Channels 08 and 10 were within 100 m of Park Street during all the activity, but had moved little when located after the additional vehicles had left.

The only other disturbance recorded was on the night of 24-25 June 1998, when a Fox began calling very close to Channel 14 at about 1945 hours. There was no indication that the wallaby responded in any way to the presence of this predator. It moved little for a period after the Fox called, and this may have been a response, but wallabies often stayed still for several hours at a time overnight.

DISCUSSION

Summary of the biology of the Brush Wallaby

Observations made throughout this study make it possible to summarise major aspects of the biology of the Brush Wallaby, particularly with respect to Whiteman Park. For example:

- Individuals are sedentary with females occupying a smaller home range than males, and males sometimes shifting their home range over time. Adult females forage over an average of about 5ha each night, with males covering twice that area. Overnight areas of activity tend to be larger in autumn and winter than in spring and summer, perhaps related to patterns of reproduction.
- Brush Wallabies would appear to be solitary although they may aggregate where dense vegetation provides shelter during daylight and where recently burnt areas provide food at night. Sightings of pairs of Brush Wallabies are probably based upon sightings of a adult female with a large, dependent young.
- Juvenile females probably establish a home range alongside that of their mother. It is not known where a juvenile male would establish his home range, but observations on captive animals suggest that males are very aggressive towards each other and young males would probably be displaced by resident males. This is the case in other macropod species (Hume *et al.* 1989).

- The population density of Brush Wallabies in the Conservation Zone of Whiteman Park is about 0.16 Wallabies/ha. This equates to a total population of about 160 animals. Wallabies are not evenly distributed and favour locations where the vegetation includes dense areas associated with wetlands and damplands. The least favourable areas for Brush Wallabies consist of open Marri woodland with a low understorey.
- Brush Wallabies do not normally drink and therefore rely on moisture content in their food. Wann and Bell (1997) found that they browse on a wide variety of shrubs and small trees. They show a preference for foraging in recently-burnt areas if available and there may be a slight concentration of Brush Wallabies around such sites. Such areas remain attractive for at least two years. Outside burnt areas, they forage over a wide range of vegetation types but only rarely leave native vegetation.
- Brush Wallabies are crepuscular with peak activity around sunrise and sunset, but they are likely to move at any time of the day or night and probably forage from before sunset to after sunrise. They do not have a regular daytime shelter.
- They are very tolerant of disturbance (light, noise, movement) and will even cross busy roads.

Conservation of Brush Wallabies in Whiteman Park

The population of the Brush Wallaby in Whiteman Park is much larger than the previous estimate of 40 (Arnold *et al.* 1991), but is below the commonly-used figure of 500 for a sustainable, isolated mammal population (Frankel and Soule 1981). However, the figure of 500 is only a guideline and the minimum viable population of a species can vary with aspects of its biology such as the proportion of adults that participate in reproduction (Usher 1987). In this respect, the Brush Wallaby is a good candidate for surviving in a small population, as it appears to have a breeding system in which males occur at about half the density of females, unlike the situation with many mammals, including other macropods, in which only a few males achieve reproductive success by claiming a harem of females.

There also seems to be no need to assume that the Brush Wallabies in Whiteman Park are isolated. They are clearly capable of crossing major roads, so the Wallaby population in Whiteman Park may be considered to be part of a larger population that extends into the land west of Beechboro Road, which is to be incorporated into the park, and to the north in the proposed Gnangara Park. Brush Wallabies are present west of Beechboro Road and around the Lexia wetlands north of Gnangara Road (pers. obs.). It is not known to what extent Brush Wallabies can move through the existing Gnangara pine plantation, but their ability to do so will probably improve with the development of Gnangara Park. Future plans for Gnangara Road should include a substantial wildlife underpass to facilitate the movement of a range of fauna species between Whiteman Park and areas to the north.

The frequency of movement of individuals across Gnangara Road may not need to be great to be of benefit to the Whiteman Park population of Brush Wallabies. According to Mills and Allendorf (1996), somewhere between one and ten migrants per generation is sufficient to maintain genetic diversity in a substantially isolated

mammal population. The generation time of Brush Wallabies is not known, but the adults caught for radio-tracking were probably at least 18 months old and all except Channel 16 were still alive over 12 months later. Channel 14 was still alive after nearly two years so was four to five years old at that time. Some macropods have a longevity of greater than 10 years in the wild (Russel *et al.* 1989), so it seems reasonable to assume that the natural longevity of Brush Wallabies is five to ten years. On this basis, a single migrant each year would be sufficient to maintain genetic diversity in the Whiteman Park population. It seems likely that such migration could be achieved naturally, but it could also be aided through the release of rehabilitated Brush Wallabies, although it is preferable that these come from a nearby population.

The Brush Wallabies in Whiteman Park are clearly dependent upon native vegetation and appear to make little use of pasture plants or introduced species. Therefore, conservation of native vegetation in the Park, even close to areas of human activity of which the Wallabies are tolerant, is important. Favoured vegetation is *Eucalyptus/Banksia* woodland with a dense understorey (projected foliage cover in the order of 40-60%) about one metre in height. The understorey vegetation seems to be more important than the overstorey vegetation and Wallabies also occurred in heath. Fire is beneficial to the wallabies in creating favoured foraging areas, but unburnt areas appear to provide adequate food and, more importantly, are essential for shelter. The fire management programme should aim to retain large tracts of unburnt vegetation but recognise that burnt areas are part of the dynamics of the Brush Wallaby's ecology.

The Brush Wallabies are very tolerant of noise, light and movement, with animals spending both the daylight hours and the hours of darkness close to major sources of potential disturbance. The highest concentration of Brush Wallabies was found in an area regularly used by members of an archery club. These observations indicate that suitable habitat close to areas of human activity is probably important for Brush Wallabies. However, it is still desirable to maintain large tracts of habitat with low levels of human activity.

Table 1. Results of sweep surveys for Brush Wallabies, with numbers of Grey Kangaroos seen in parenthesis. Locations of sweep surveys within Whiteman Park are indicated on Figure 1.

Date	Area (ha)	Brush Wallabies	Notes on locations of Brush Wallabies
21/06/96	24	2	Margin of dampland with *Corymbia calophylla*, *Melaleuca priessiana* and a dense understorey
28/06/96	44	3	Two in dense understorey of *Banksia* woodland adjacent to a shrub-thicket of a dampland (Hidden Valley). Third animal in *Banksia* woodland on a low rise beside Hidden Valley. This third animal appeared to have a weak hind leg
28/07/96	32	7	All specimens on the margins of damplands with *Corymbia calophylla*, *Melaleuca priessiana* and a dense understorey
02/08/96	65	11 (4)	All specimens in *Banksia* woodland with a dense understorey containing some dampland species. This *Banksia* woodland is on level, low-lying ground
15/09/96	57	5 (8)	Four specimens in *Banksia* woodland with dense understorey on level, low-lying ground. One specimen in dense shrubland on the edge of a seasonally damp valley
01/11/96	38	5 (16)	Four specimens in dense shrubland around a seasonally damp valley. One specimen in *Banksia* woodland with dense understorey on high ground
Totals	260	33	

Table 2. Attempts to catch Brush Wallabies, indicating date, time, location, method employed, and numbers of Wallabies encountered and caught. Methods are described in the text.

Date	Time	Location	Capture method	Number of wallabies
08/12/96	0600-0800	Archery Bush	Lightweight net	1 flushed, broke net
19/01/97	0600-0800	Track near Beechboro Rd	Fence and pockets	2 flushed; none caught
19/01/97	0800-0900	Archery bush	Fence and pockets	3 flushed; none caught
16/02/97	0630-0800	Archery bush	Fence and net (no lift mechanism)	1 flushed and caught (Channel 02)
23/02/97	0630-0800	Archery bush	Fence and net (no lift mechanism)	None flushed (1 feral cat)
09/03/97	0630-0800	Track near Beechboro Rd	Fence and net (no lift mechanism)	4 flushed, 1 hit net and 1 caught (Channel 04)
09/03/97	0800-1000	Archery bush	Fence and net (no lift mechanism)	None flushed
16/03/97	0630-0930	Archery bush	Fence and net (no lift mechanism)	4 flushed; 1 hit net but escaped
06/04/97	0730-0930	Track near Beechboro Rd	Fence and net (no lift mechanism)	5 flushed, 2 hit net, none caught
13/04/97	0700-0830	Track near Beechboro Rd	Fence and lift-net	2 flushed but could not be driven into net
13/04/97	0830-1000	Archery bush	Fence and lift-net	4 flushed but could not be driven into net
18/04/97	0700-0800	Track near Beechboro Rd	Fence and lift-net	1 flushed; hopped over net
27/04/97	0800-1030	Hidden Valley No. 2	Fence and lift-net	6 flushed but could not be driven into net
08/05/97	1000-1145	Hidden Valley No. 2	Fence and lift-net	2 flushed, 2 hit net but both escaped
14/05/97	1000-1130	Track near Beechboro Rd	Fence and lift-net	None flushed
14/05/97	1145-1300	Hidden Valley No. 2	Fence and lift-net	None flushed
25/05/97	0830-1130	Hidden Valley No. 2	Fence and lift-net	5 flushed, 2 hit net and 1 caught (Channel 06)
01/06/97	0830-1030	Water Bore Swamp	Fence and lift-net	2 flushed, 1 caught (Channel 08)
07/06/97	0830-0930	Water Bore Swamp	Fence and lift-net	1 flushed and caught (Channel 10)
13/08/97	1000-1230	Swamp NE of Hill 150	Fence and lift-net	7 flushed, 3 hit net, 2 caught (Channels 12 & 16)
25/08/97	1000-1200	Swamp NE of Hill 150	Fence and lift-net	5 flushed but could not be driven into net
30/08/97	0900-1100	Swamp NE of Hill 150	Fence and lift-net	5 flushed but could not be driven into net
14/09/97	0900-1100	Hidden Valley No. 2	Fence and lift-net	2 flushed; 1 hit net and was caught (Channel 14)

Table 3. Dates when radio-tracking of Brush Wallabies was carried out, indicating which animals were located, whether it was a daytime or overnight observation, and how many fixes were made. Values in parenthesis indicate when data were collected on stationary collars (collar fallen from the Wallaby or Wallaby dead). Details on each Wallaby, including its fate, are given on Table 4.

Date	Survey number	Type of survey	Wallaby number							
			02	04	06	08	10	12	14	16
21/02/97	1	daytime	1							
23/02/97	2	daytime	1							
07/03/97	3	daytime	1							
12/03/97	4	daytime	1	1						
09/04/97	5	daytime	1	1						
16/04/97	6	daytime	1	1						
23-24/04/97	7	overnight	13	13						
08/05/97	8	daytime	1	1						
21/05/97	9	daytime	1	1						
28-29/05/97	10	overnight	10	10	10					
07/06/97	11	daytime	1	1	1					
18/06/97	12	daytime	1	1	1	1	1			
24-25/06/97	13	overnight	10	10	10	10	10			
07/07/97	14	daytime	1	1	1	1	1			
17-18/07/97	15	overnight	13	13	13	13	13			
06/08/97	16	daytime	1	1	1	1	1			
22-23/08/97	17	overnight	7	7	7	4	7	6		(4)
06/09/97	18	daytime	1	1	1	1	1	1		(1)
25-26/09/97	19	overnight	9	9	9	8	9	9	9	(9)
14/10/97	20	daytime	1	1	1	1	1	1	1	(1)
23-24/10/97	21	overnight	10	10	10	10	10	10	10	(10)
07/11/97	22	daytime	1	1	1	1	1	1	1	(1)
22-23/11/97	23	overnight	10	10	10	10	10	10	10	(10)
03/12/97	24	daytime	1	1	1	1	1	(1)	1	(1)
10/12/97	25	daytime	1	1	1	1	1	(1)	1	(1)
28-29/12/97	26	overnight	8	8	8	8	8	(8)	8	(8)
13/01/98	27	daytime	1	1	1	1	1	(1)	1	(1)
21/01/98	28	daytime			1				1	
28-29/01/98	29	overnight	9	9	9	9	9	(9)	9	(9)
06/02/98	30	daytime	(1)	1	1	1	1	(1)	1	(1)
26-27/02/98	31	overnight	(10)	10	10	10	10	(10)	10	(10)
10/03/98	32	daytime	(1)	1	1	1	1	(1)	1	(1)
25-26/03/98	33	overnight	(10)	11	11	11	11	(11)	11	
15/04/98	34	daytime		1	1	1	1		1	
24-25/04/98	35	overnight		2	15	15	15		15	
09/05/98	36	daytime		1	4	4	4		4	
26-27/05/98	37	overnight			15	16	16		16	
15/06/98	38	daytime			1	1	1		1	
24-25/06/98	39	overnight			16	16	16		16	
23/07/98	40	daytime			1	1	1		1	
26/10/98	41	daytime				2			2	
19/03/99	42	daytime							1	
29/05/99	43	daytime							1	

Table 4. Details on radio-tracked Wallabies. The date when last located refers to when the animal is last known to have been alive and wearing a transmitting collar. General locations of capture are indicated on Figure 1.

Channel 02.	Sex: Female.	Age: Adult.	Weight: 8.5 kg
Date of capture: 16/02/97		Date when last located: 29/01/98	
Location of capture: Archery Field bush.			
Pouch contents: Very small joey, *ca.* 2 cm.			
Fate: After 29/01/98, signal was weak and no movement. On 09/05/98, collar (which was still transmitting) was found caught on a bush. Nylon bolts had snapped.			
Channel 04.	Sex: Male.	Age: Adult.	Weight: 7.7 kg
Date of capture: 09/03/97		Date when last located: 09/05/98	
Location of capture: Between Park and Woolcott Streets, close to Beechboro Road.			
Fate: Signal weak after 09/05/98. Detected at close range on 25/06/98, but this involved walking into the bush to where the animal was expected to be located.			
Channel 06.	Sex: Male	Age: Adult.	Weight: 7.0
Date of capture: 25/05/97		Date when last located: 23/07/98	
Location of capture: Hidden Valley No. 2			
Fate: No signal after 23/07/98.			
Channel 08.	Sex: Female.	Age: Immature.	Weight: 6.0 kg
Date of capture: 01/06/97		Date when last located: 26/10/98	
Location of capture: Water Bore Swamp (eastern end of Park Street).			
Pouch contents: None. Probably virginal. Channel 08 the joey of Channel 10?			
Fate: No signal after 26/10/98.			
Channel 10.	Sex: Female.	Age: Adult.	Weight: 6.8 kg
Date of capture: 07/06/97		Date when last located: 23/07/98	
Location of capture: Water Bore Swamp (eastern end of Park Street).			
Pouch contents: None, but one nipple elongate, so possibly still feeding a joey (Channel 08?).			
Fate: No signal after 23/07/98.			
Channel 12.	Sex: Female.	Age: Immature.	Weight: 4.8 kg
Date of capture: 13/08/97		Date when last located: 07/11/'97	
Location of capture: Swamp NE of Hill 150.			
Pouch contents: None. Probably virginal.			
Fate: Little movement after 23/11/97. Search made on 10/03/98 found collar undamaged on ground. Presumably animal was able to pull collar over its head.			
Channel 14.	Sex: Female.	Age: Adult.	Weight: 7.6 kg
Date of capture: 14/09/97		Date when last located: 29/05/99	
Location of capture: Hidden Valley No. 2.			
Pouch contents: Large, lightly furred joey (Male. Weight: 600 g). Joey was ejected and was too large to be pushed back into the pouch, but not large enough to stand.			
Fate: No surveys after 29/05/99. Joey was raised by a carer and is due for release.			
Channel 16.	Sex: Male.	Age: Adult.	Weight: 7.1 kg
Date of capture: 13/08/97		Date when last located: 13/08/97	
Location of capture: Swamp NE of Hill 150.			
Fate: No substantial movement after capture. On 10/03/98 the forequarters of Channel 16, including the still-transmitting collar, were found to have been buried by a predator.			

Table 5. Overnight home range areas (ha) for each radio-tracked Brush Wallaby. Home range areas were calculated based upon the minimum polygon to enclose all recorded locations of each specimen in each set of overnight observations. The overall area is based upon the minimum polygon to enclose all recorded locations for each specimen (see Figures 4 to 10). Note that values in parenthesis are areas calculated for stationary transmitters (Channels 02, 12 and 16).

Survey date	Survey number	Wallaby							
		02♀	04♂	06♂	08♀	10♀	12♀	14♀	16♂
23-24/04/97	7	6.9	8.5	-	-	-	-	-	-
28-29/05/97	10	3.4	14.0	11.4	-	-	-	-	-
24-25/06/97	13	7.2	14.9	8.7	7.2	9.6	-	-	-
17-18/07/97	15	3.7	16.0	23.8	13.4	7.3	-	-	-
22-23/08/97	17	1.2	3.3	1.5	4.1	3.4	3.1	-	(0.2)
25-26/09/97	19	5.3	9.6	12.9	3.0	5.5	4.5	4.5	(0.6)
23-24/10/97	21	4.1	7.0	10.9	3.5	2.9	8.6	6.4	(0.9)
22-23/11/97	23	4.1	7.6	3.5	6.7	7.6	5.3	5.4	(0.4)
28-29/12/97	26	2.2	11.7	3.3	5.0	1.4	(1.0)	3.5	(0.4)
28-29/01/98	29	9.0	8.0	9.2	10.0	3.2	(1.8)	2.7	(0.3)
26-27/02/98	31	(0.8)	3.7	7.1	6.4	7.0	(0.8)	2.9	(0.3)
25-26/03/98	33	(0.5)	17.2	4.1	8.6	7.5	(0.4)	3.2	-
24-25/04/98	35	-	-	15.6	6.2	3.7	(0.4)	2.3	-
26-27/05/98	37	-	-	4.9	7.0	2.7	-	1.7	-
24-25/06/98	39	-	-	18.6	9.1	8.5	-	1.4	-
Mean overnight area		4.7	10.1	9.7	6.9	5.4	5.4	3.4	(0.44)
Standard Deviation		2.40	4.63	6.42	2.87	2.64	2.33	1.60	(0.24)
Overall area		15.3	34.3	69.2	25.1	29.8	19.7	32.5	(1.9)

NB. The transmitter from Channel 12 in the period December 1997 to March 1998 was recorded over an area of 1.0ha (standard deviation 0.59).

Figure 1. Whiteman Park Conservation Zone and adjacent bushland, indicating vegetation types, where sweep surveys were carried out (solid lines) and where Brush Wallabies were located during these surveys (solid squares). Principal vegetation types are shown:
fine cross-hatching - seasonal wetlands (very dense understorey);
heavy stippling - eucalypt, banksia and paperbark woodlands in low-lying areas (very dense understorey);
light stippling - eucalypt and banksia woodlands on sandy flats (understorey variable);
unstippled - eucalypt and banksia woodlands on sandy ridges (understorey moderately dense).

The scale bar is 1km.

Figure 2. The system developed for the capture of Brush Wallabies. The upper pair of figures illustrates the Lift-Net in the set position (left) and after the net has been closed (right). Note that the hessian fences would have extended to the left but have not been illustrated. The lower figure illustrates the layout of the hessian fences (broken lines) in an area of dense, dampland vegetation (stippling) just south of Park Street in the east of the Conservation Zone. The centre of the cross is where the Lift-Net would be placed.

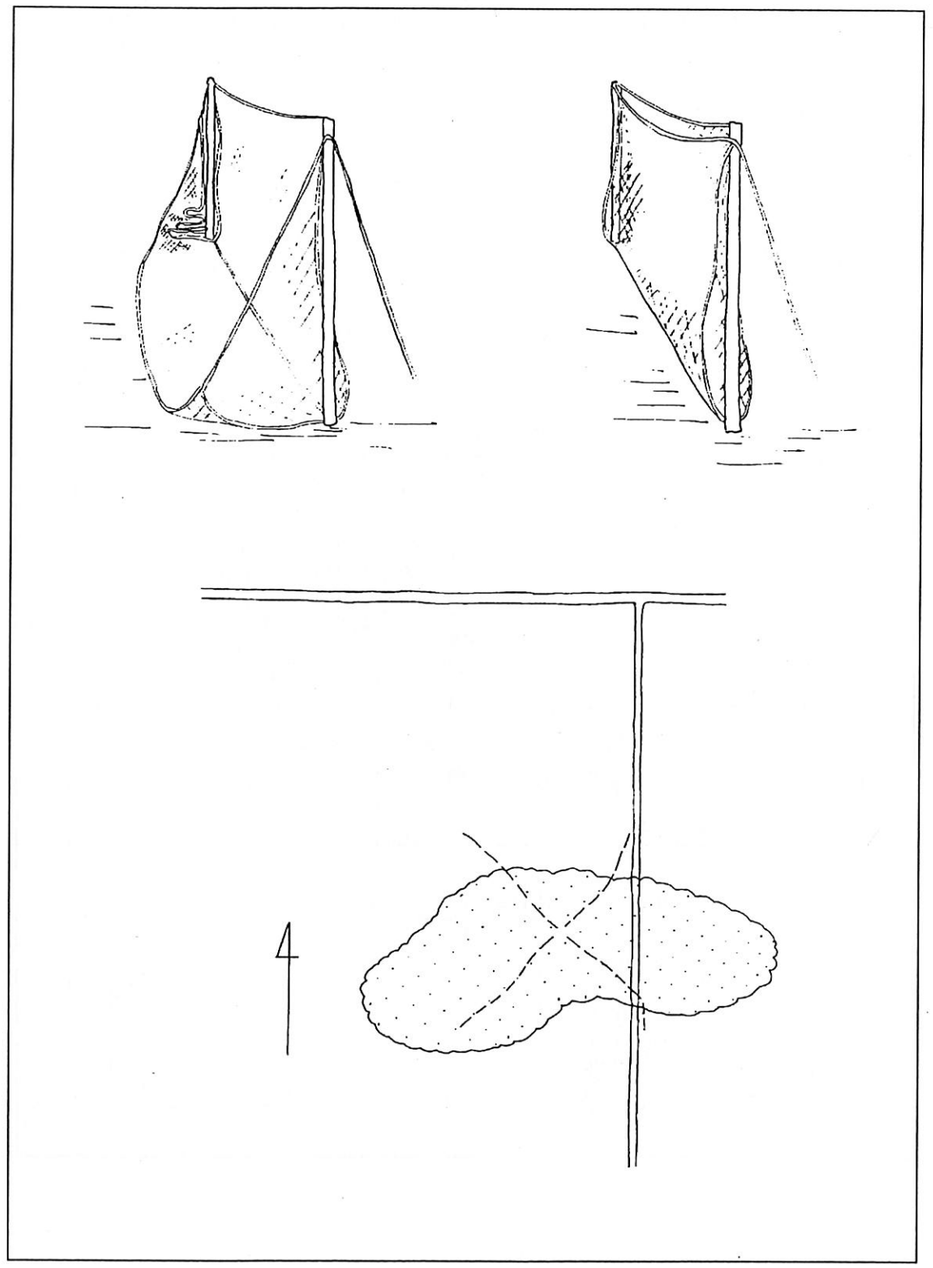
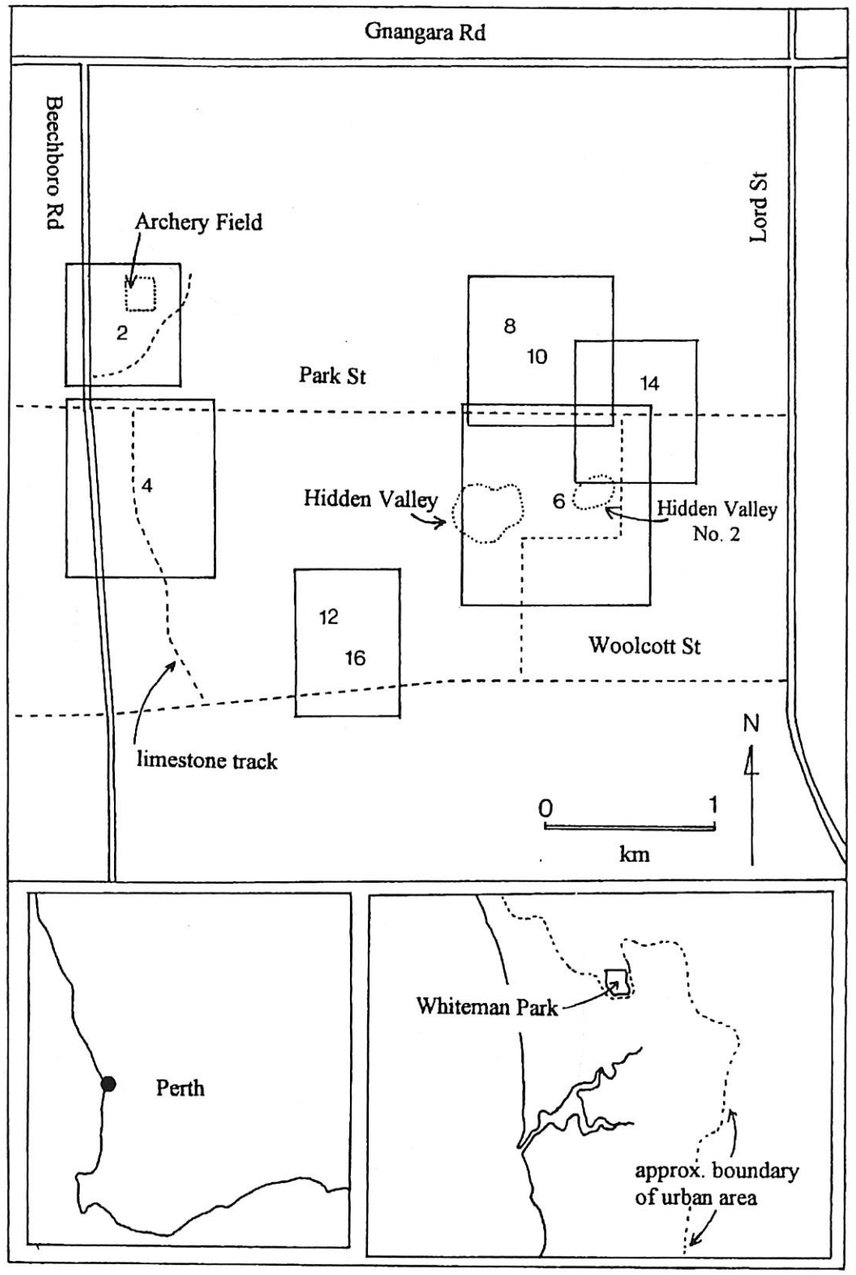


Figure 3. Whiteman Park showing main features mentioned in the text and the general locations of the eight radio-tracked Brush Wallabies (numbers 2, 4, 6, 8, 12, 14 and 16). Solid lines around each number enclose the area that is reproduced in detail in Figures 4 to 11. Insets show the location of Whiteman Park relative to Perth, and the position of Perth in the South-West region of Western Australia.



Figures 4 to 11. Maps presenting the results of radio-tracking. See Figure 3 for the location of each of these within Whiteman Park.

For each Wallaby, these results are presented in two forms: a map showing all locations at which a specimen was found, and a set of maps illustrating the monthly overnight observations, with one map for each month's data on each specimen. On every map, tracking locations from which bearings were obtained are indicated with an open square and a letter (A, B, etc), while open circles represent locations for Wallabies determined in daylight (before sunset or after sunrise), and closed circles represent records made at night (between sunset and sunrise). For Channels 02 and 12 only, triangles (open for daylight, closed for night) are used to indicate positions of the collar when this had fallen from the wallaby.

On the maps illustrating the monthly overnight observations for each specimen, a polygon of a fine broken line encloses all the locations determined for that specimen throughout the study, and therefore represents the maximum home range. Lines connect records in order from the first to the last record obtained in that month's overnight session. Arrows on these lines indicate the order in which records were made, with solid arrows on the lines joining records made around sunset, and open arrows on the lines joining records made around sunrise.

The main vegetation types are shown as cross-hatching (dense vegetation associated with seasonal wetlands), heavy stippling (dense vegetation associated with damplands and the edges of wetlands), light stippling (woodland with dense understorey usually on the edges of damplands) and open areas (upland *Eucalyptus/Banksia* woodland on dune ridges with understorey less dense than in areas close to wetlands). Tracks and roads are indicated by double solid lines, firebreaks by single solid lines.

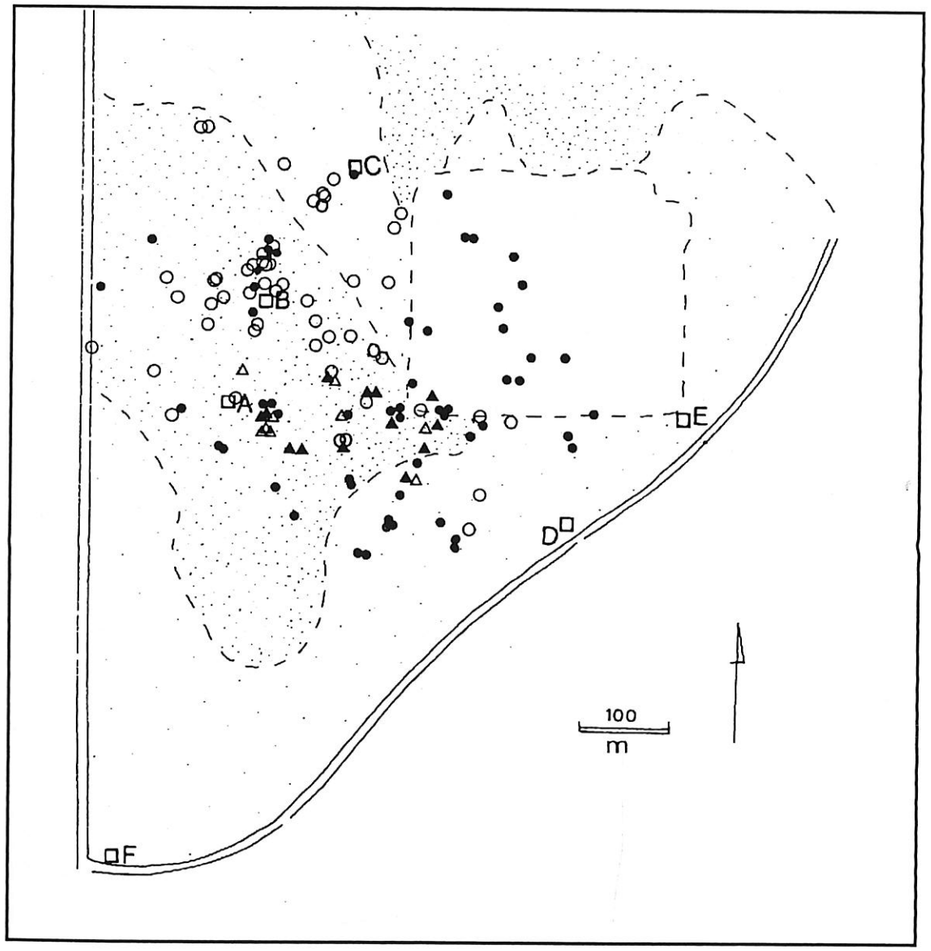
See Appendix 1 for raw data.

All scale bars are 100 m.

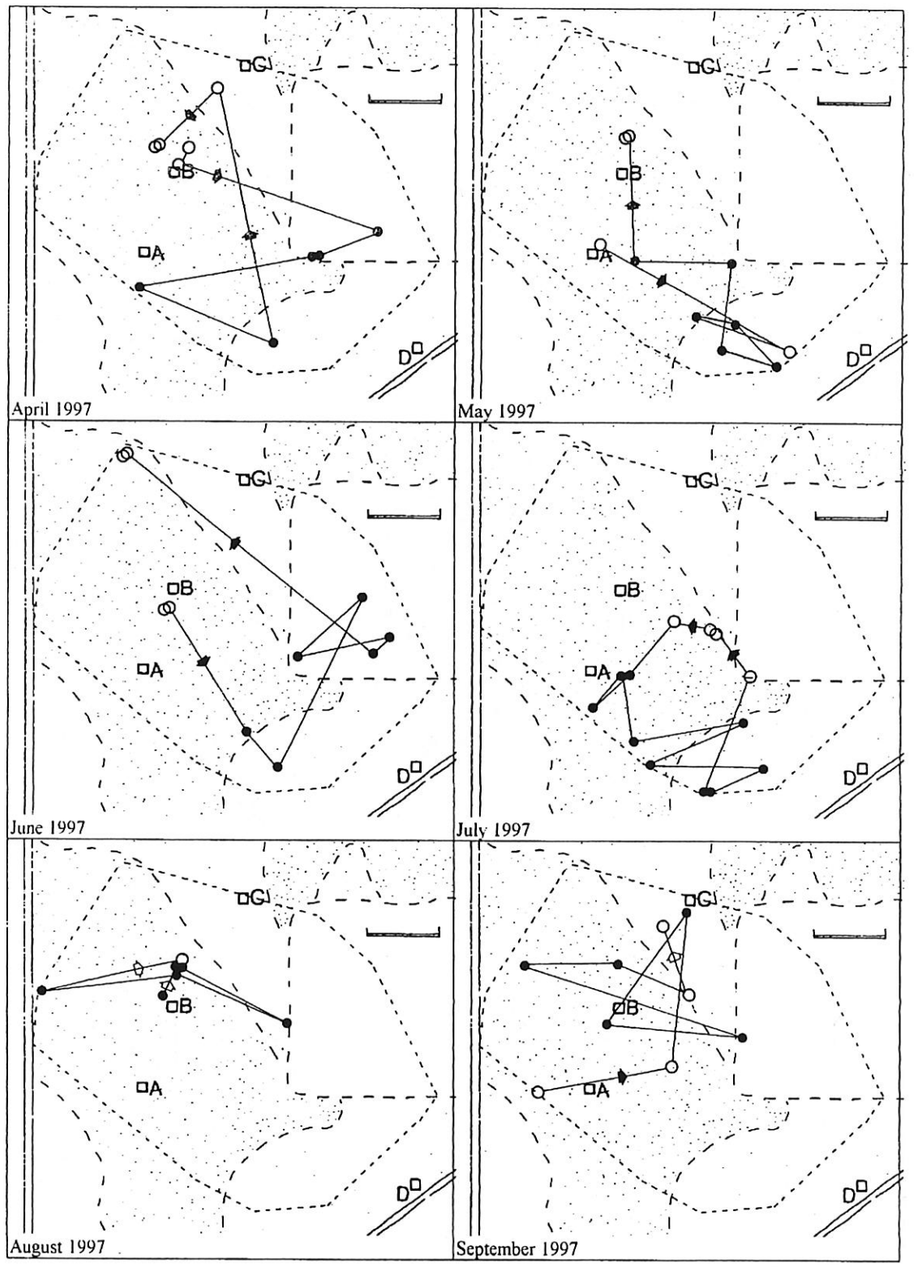
Figure 4. Results of radio-tracking of Channel 02, an adult female Brush Wallaby. Note that the approximately rectangular area enclosed by a broken line is the archery field; a mown, reticulated lawn.

On each map, tracking locations from which bearings were obtained are indicated with an open square and a letter, open circles represent locations for wallabies determined in daylight and closed circles represent locations determined at night. For further information see page 28 and Figure 3.

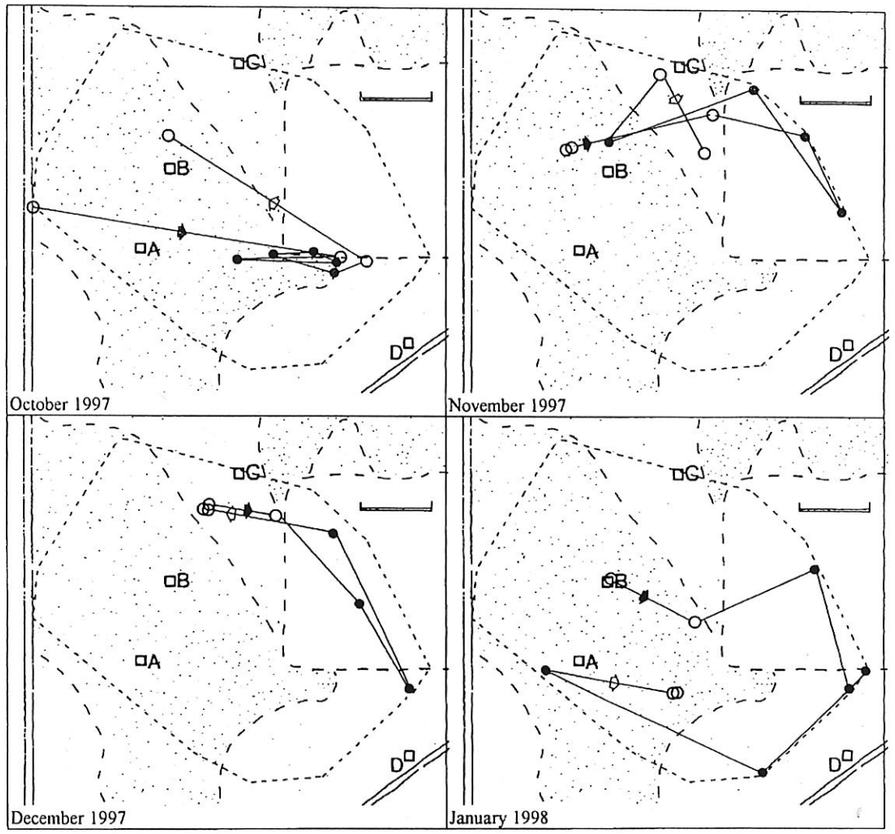
All locations recorded for Channel 02.



Monthly overnight observations on Channel 02.



Monthly overnight observations on Channel 02



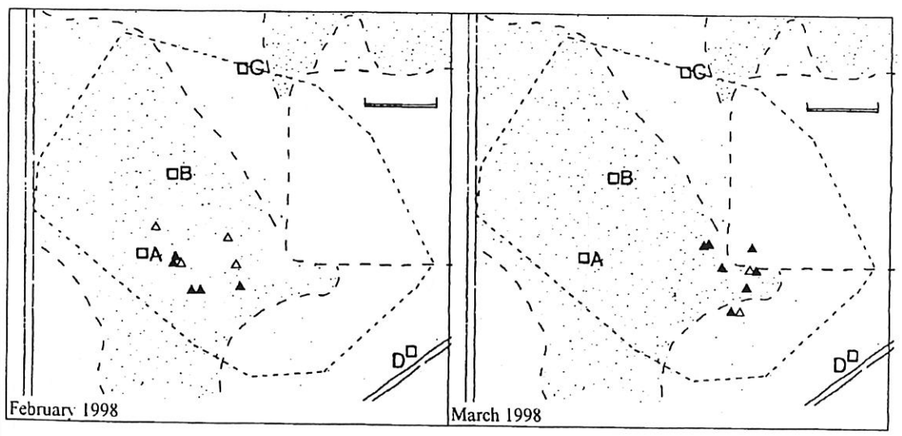
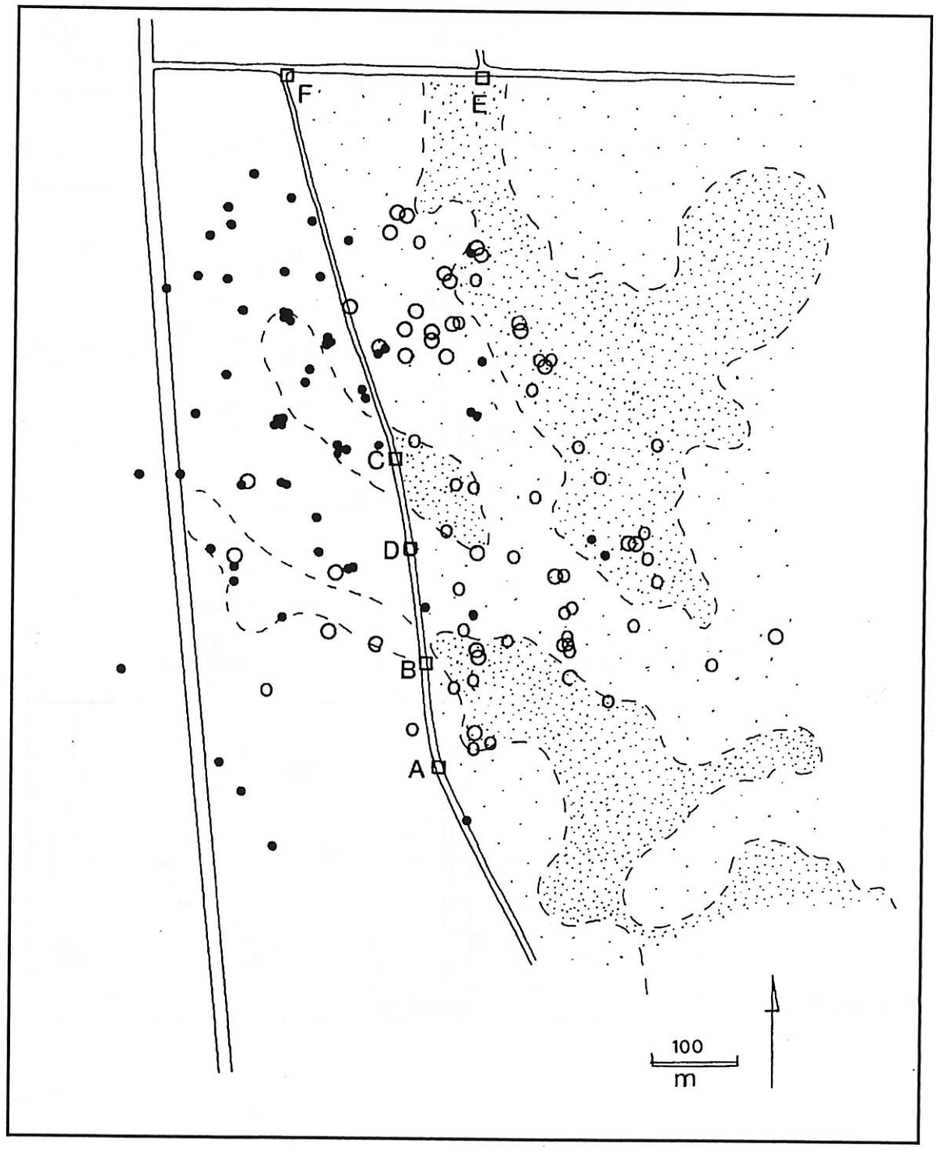


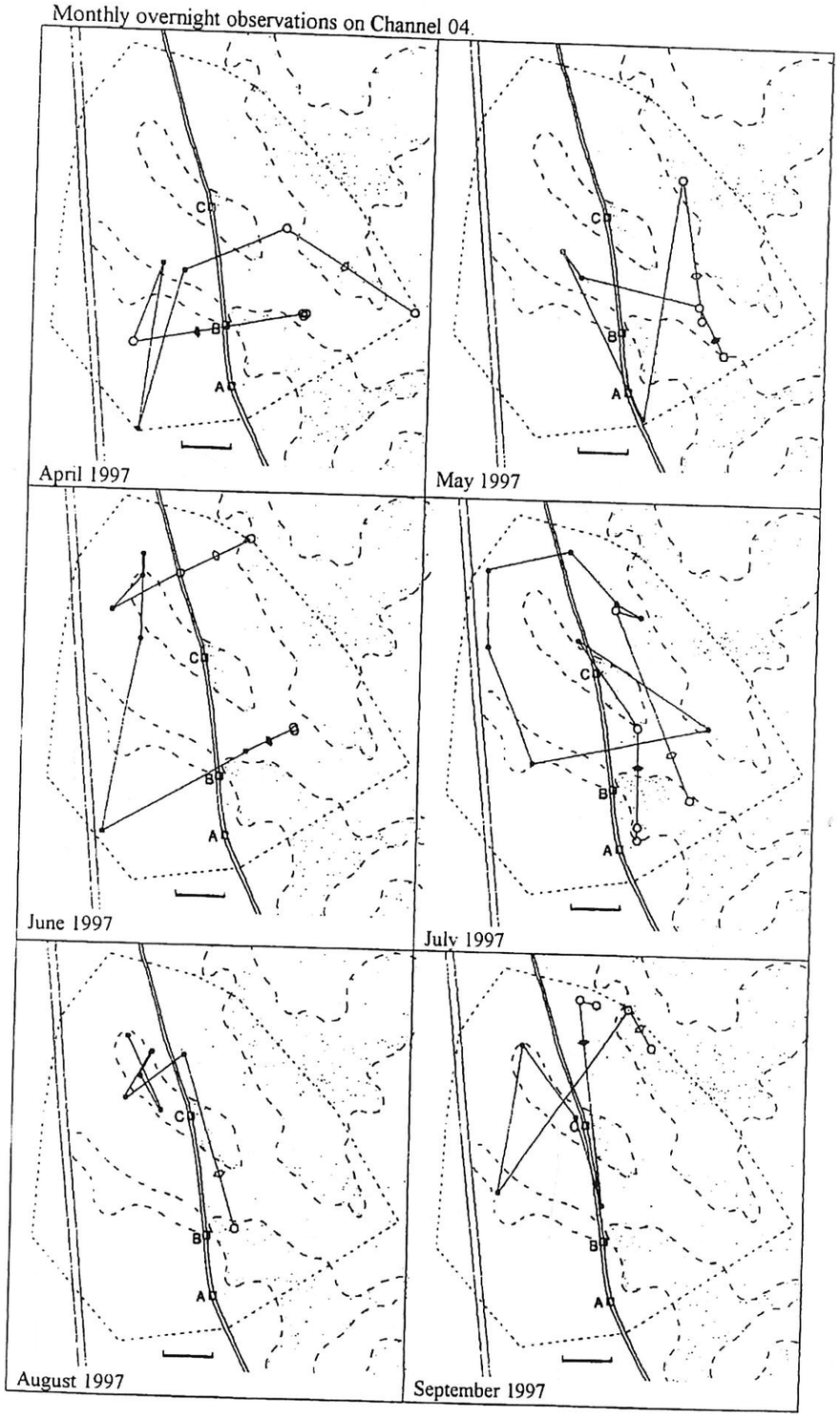
Figure 5. Results of radio-tracking of Channel 04, an adult male Brush Wallaby. The road along the western side of the Wallaby's home range is Beechboro Road. The area between Beechboro Road and the track on which tracking locations A, B, C and D were positioned had been burnt in autumn 1996.

On each map, tracking locations from which bearings were obtained are indicated with an open square and a letter, open circles represent locations for wallabies determined in daylight and closed circles represent locations determined at night. For further information see page 28 and Figure 3.

All locations recorded for Channel 04.



Monthly overnight observations on Channel 04.



Monthly overnight observations on Channel 04.

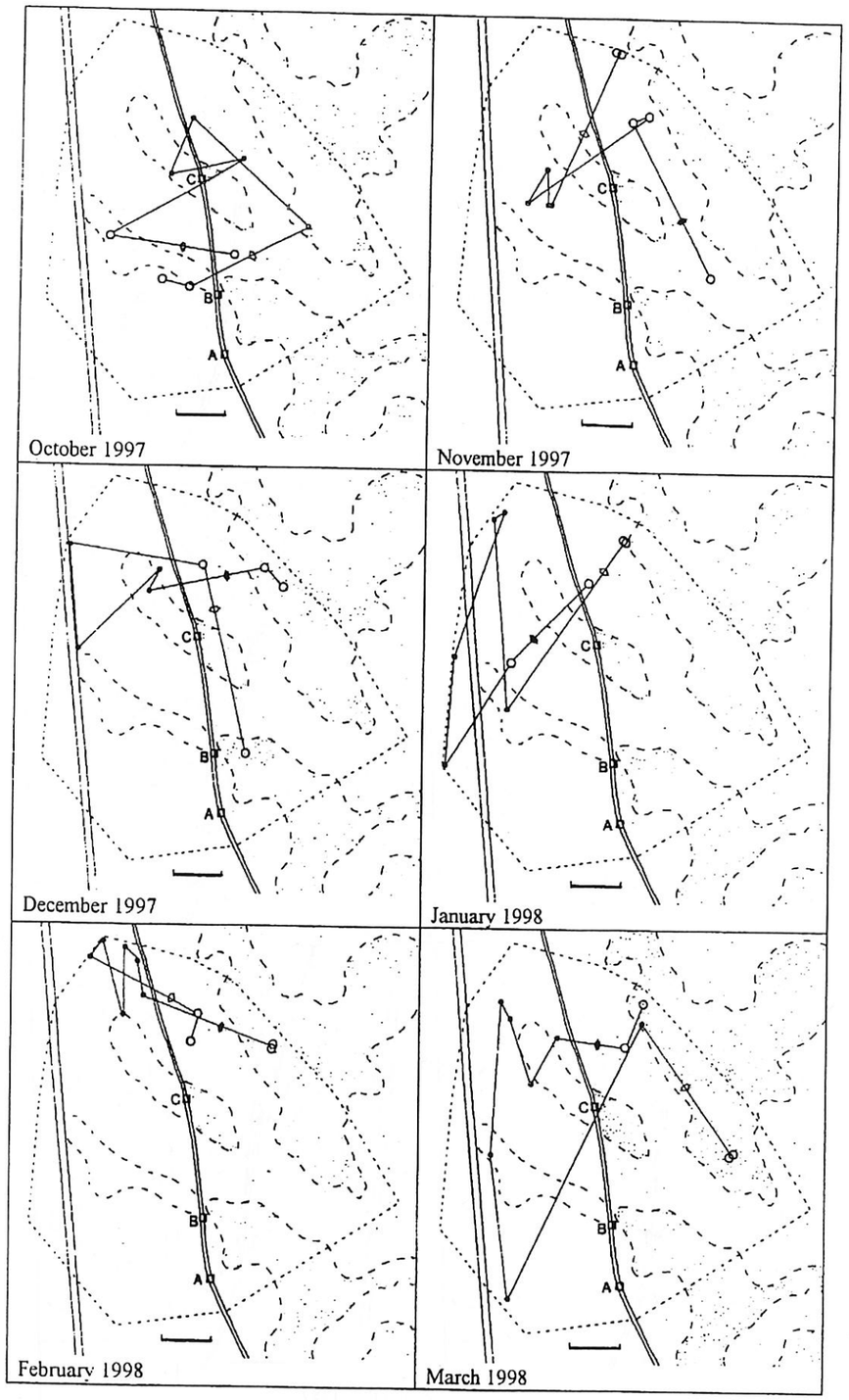
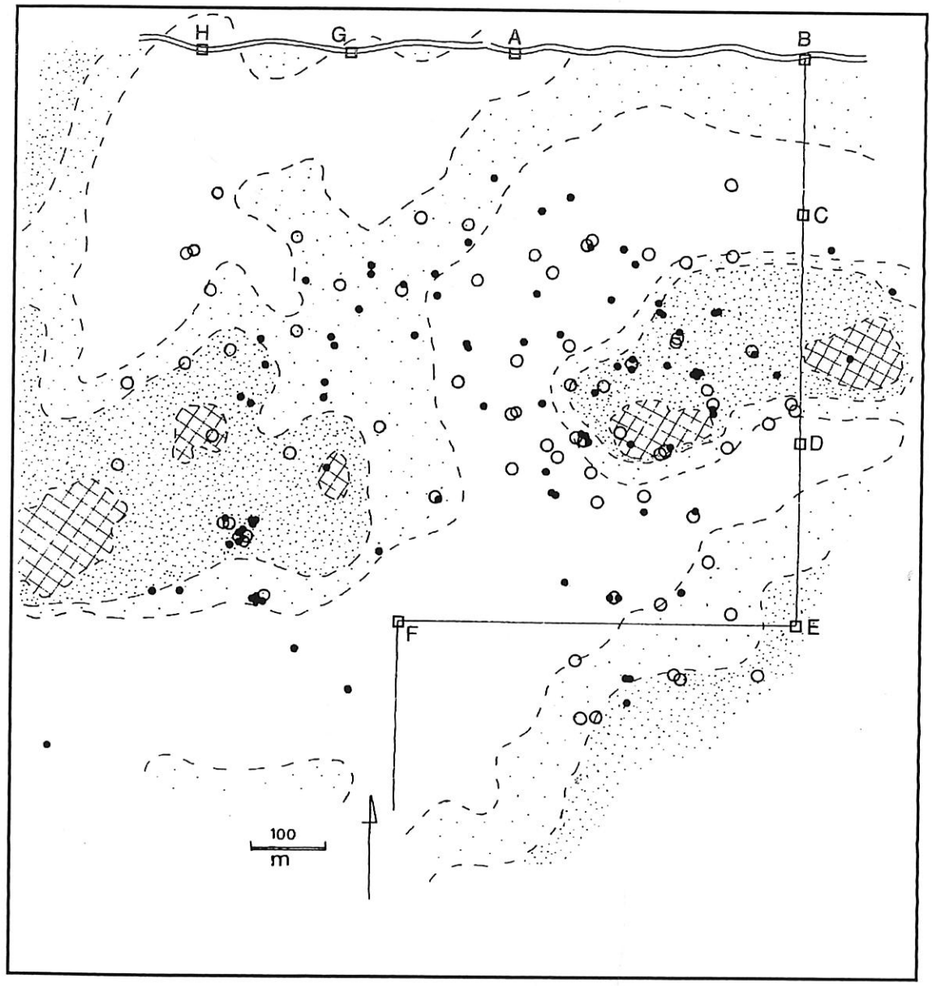
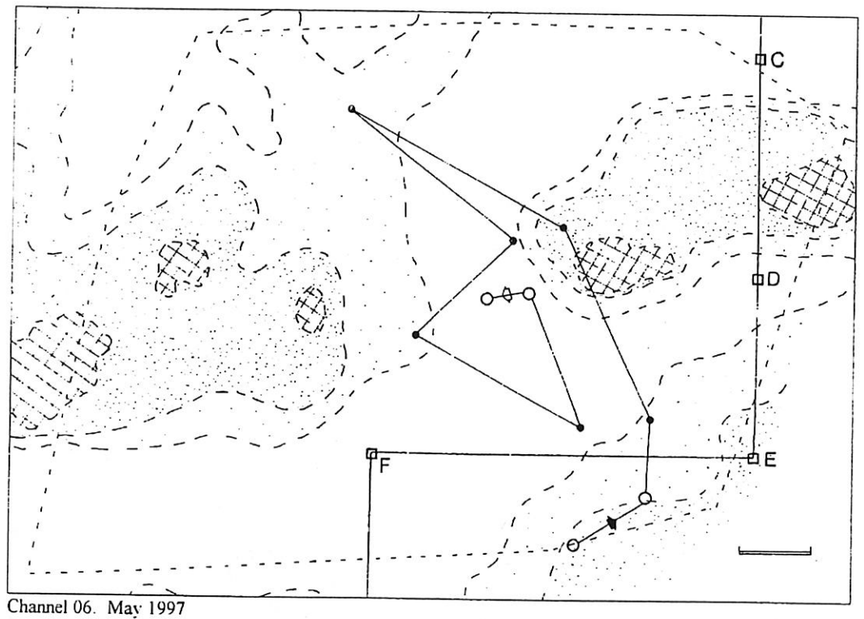


Figure 6. Results of radio-tracking of Channel 06, an adult male Brush Wallaby.

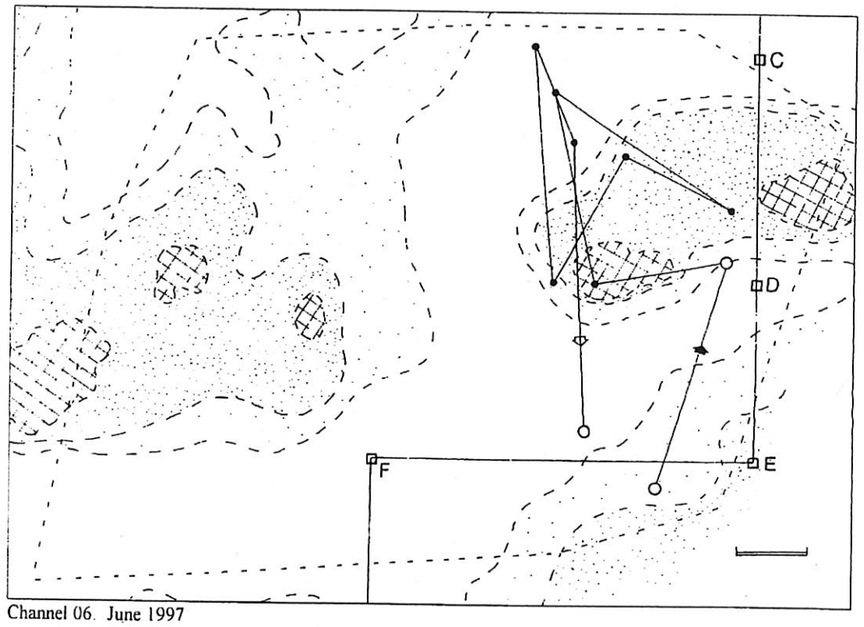
On each map, tracking locations from which bearings were obtained are indicated with an open square and a letter, open circles represent locations for wallabies determined in daylight and closed circles represent locations determined at night. For further information see page 28 and Figure 3.

All locations recorded for Channel 06.

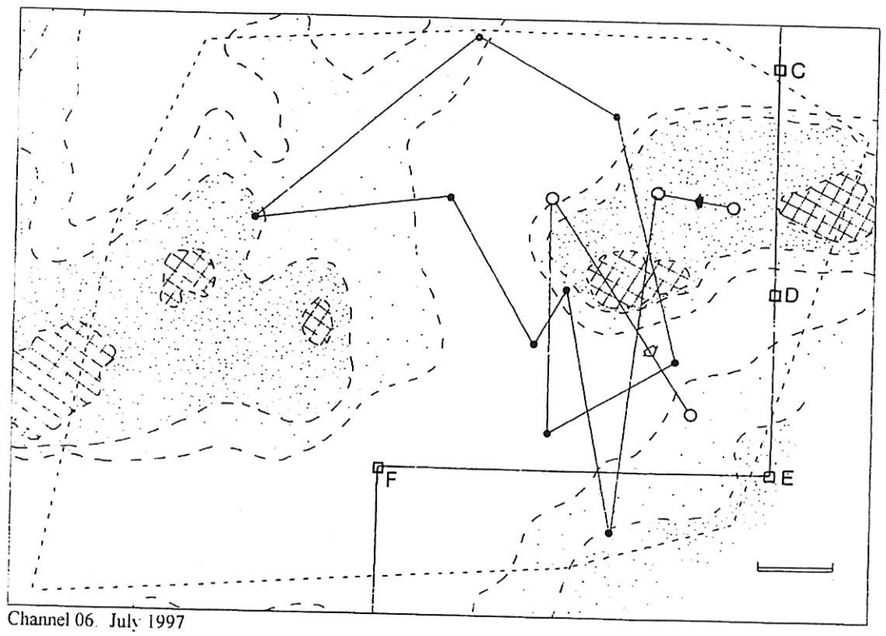




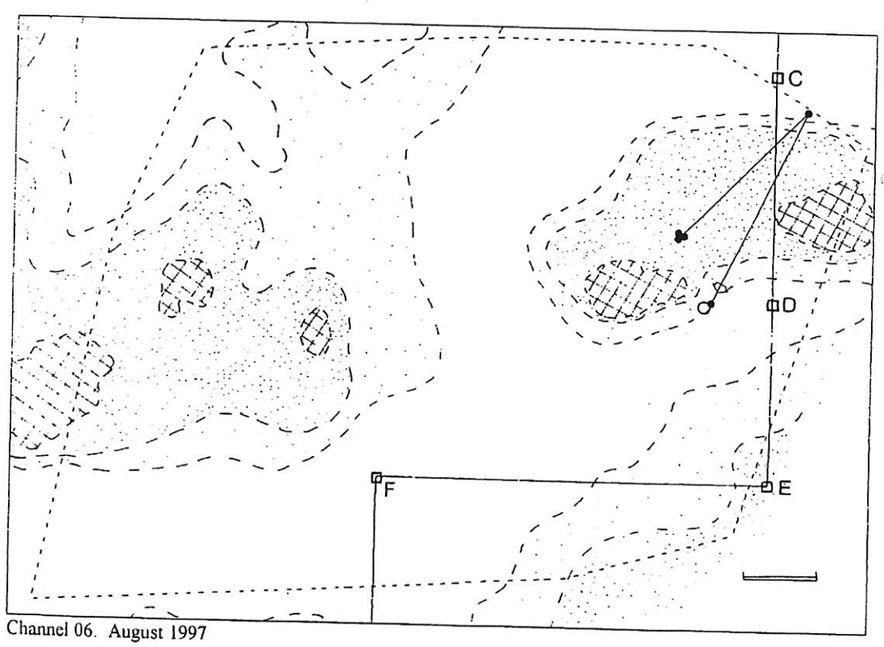
Channel 06. May 1997



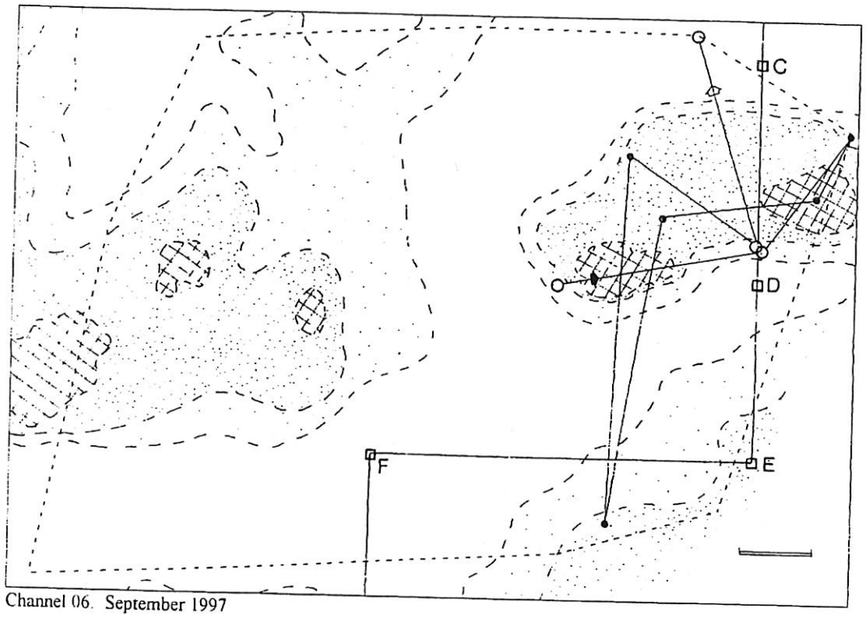
Channel 06. June 1997



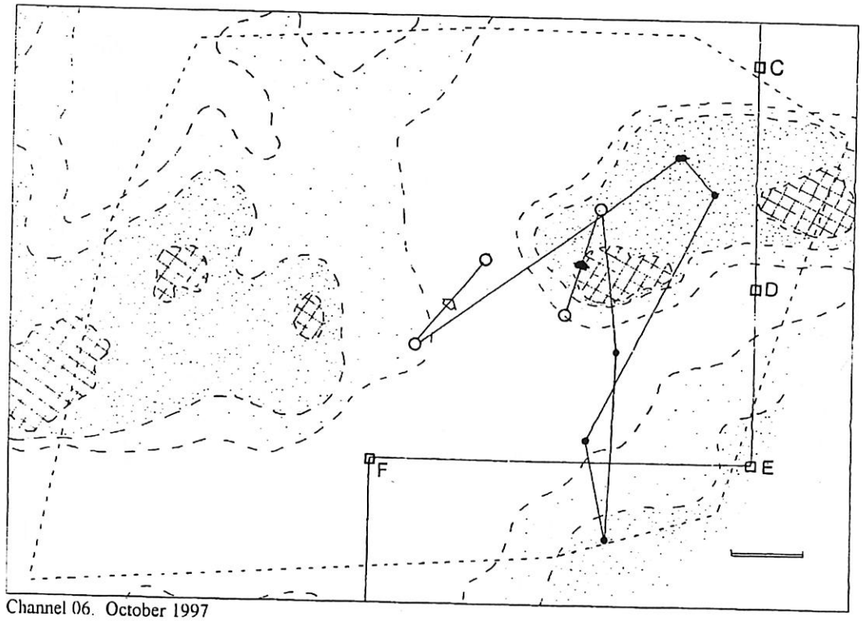
Channel 06. July 1997



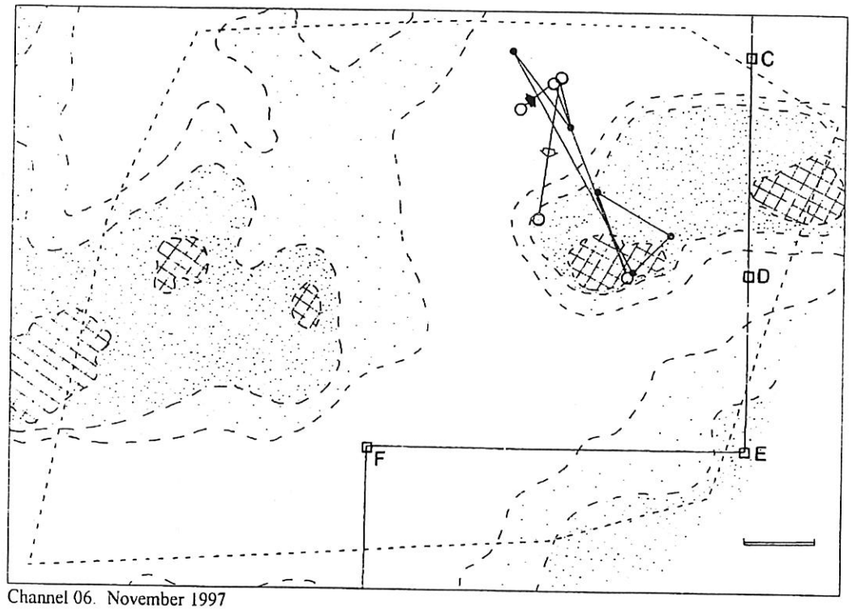
Channel 06. August 1997



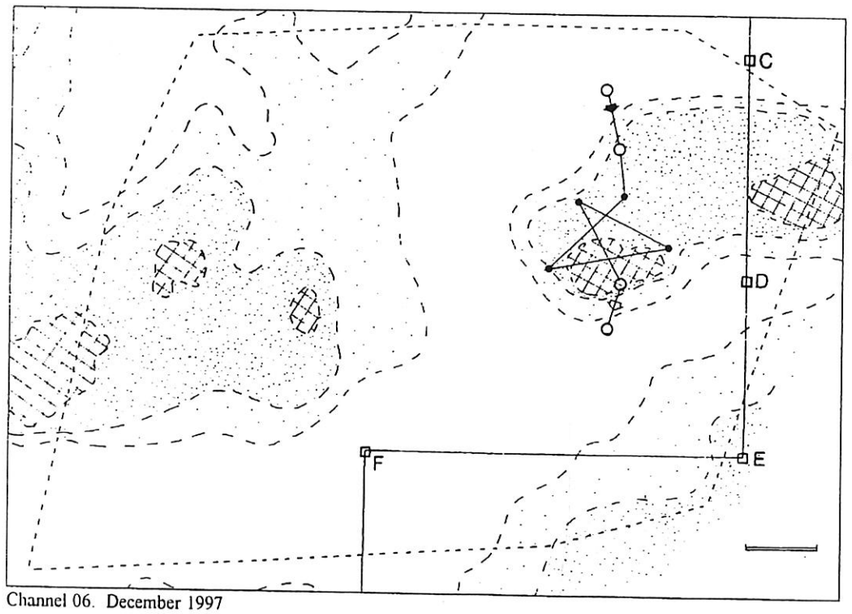
Channel 06. September 1997



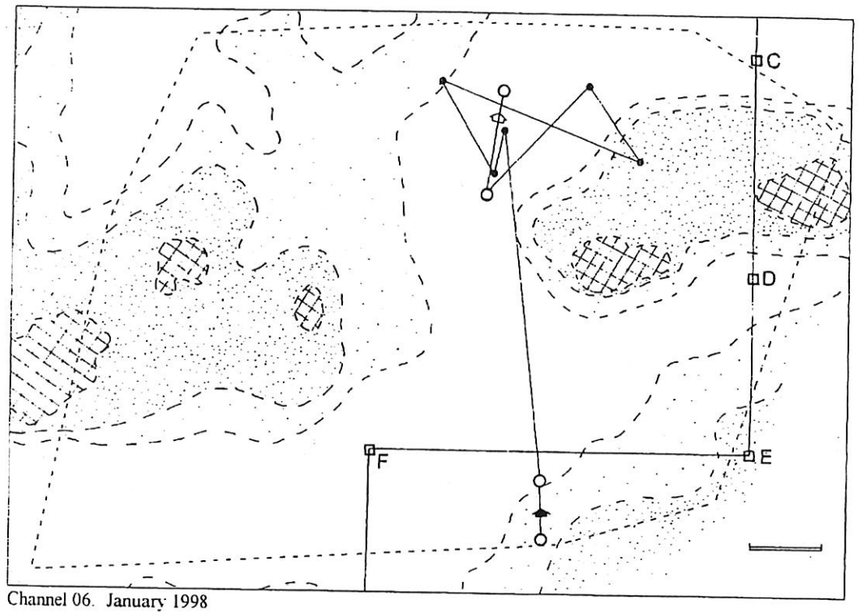
Channel 06. October 1997



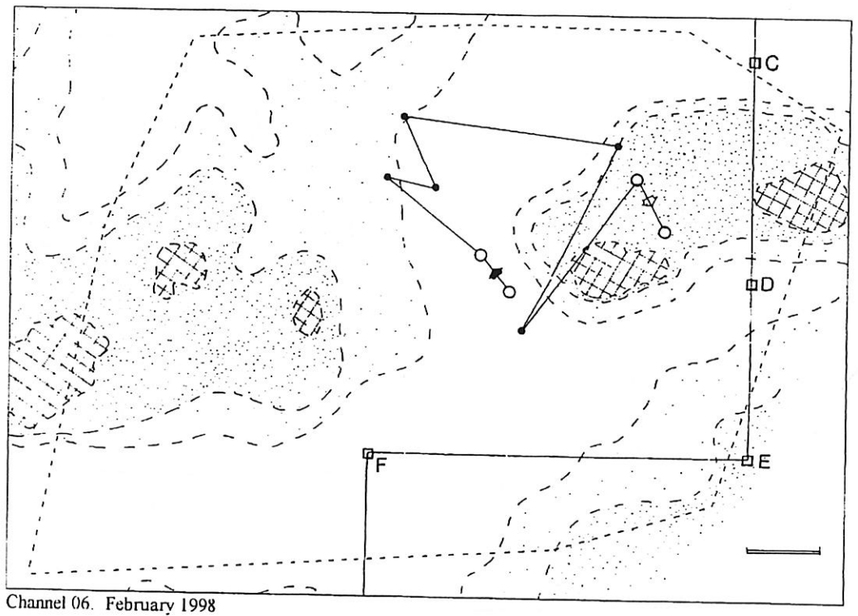
Channel 06. November 1997



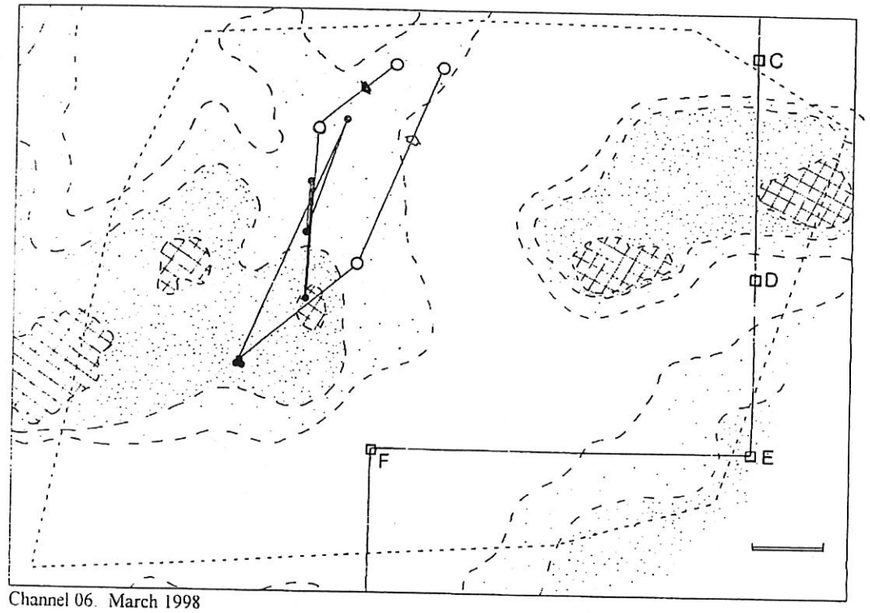
Channel 06. December 1997



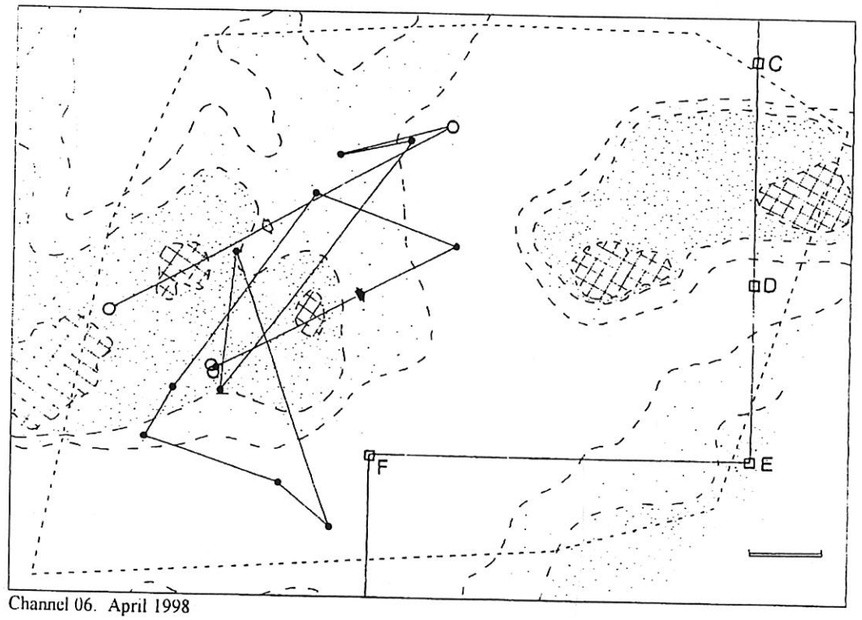
Channel 06. January 1998



Channel 06. February 1998

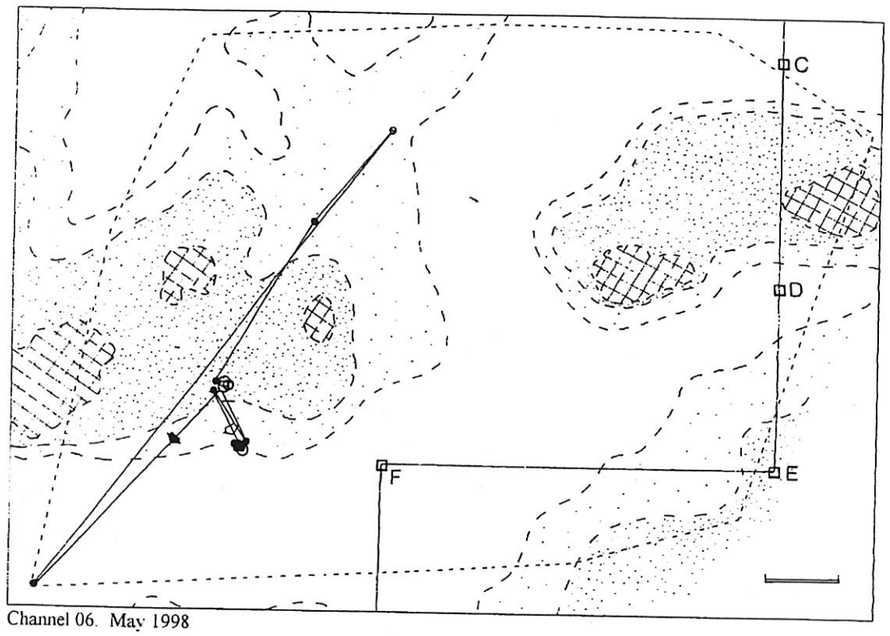


Channel 06. March 1998

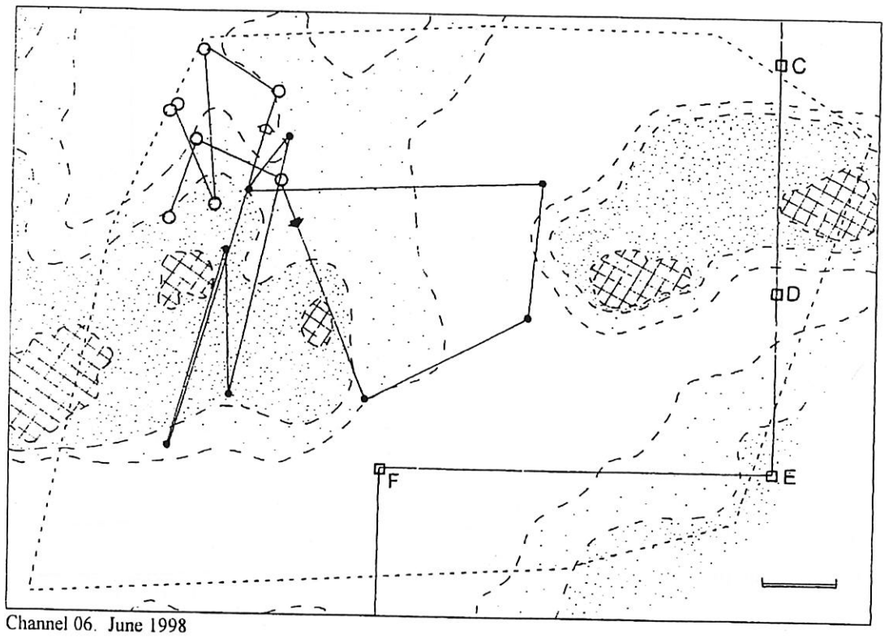


Channel 06. April 1998

Monthly observations on Channel 06



Channel 06. May 1998



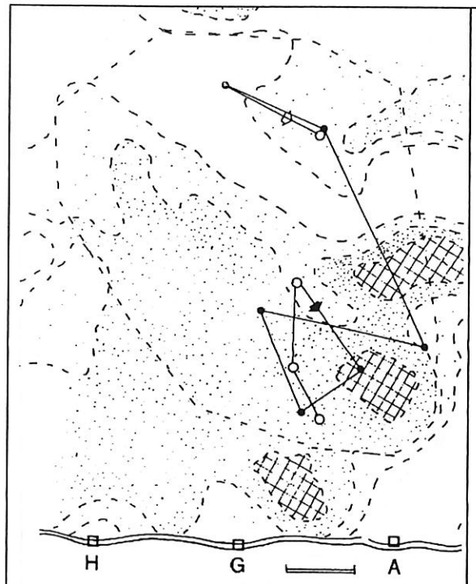
Channel 06. June 1998

Figure 7. Results of radio-tracking of Channel 08, a sub-adult female Brush Wallaby.

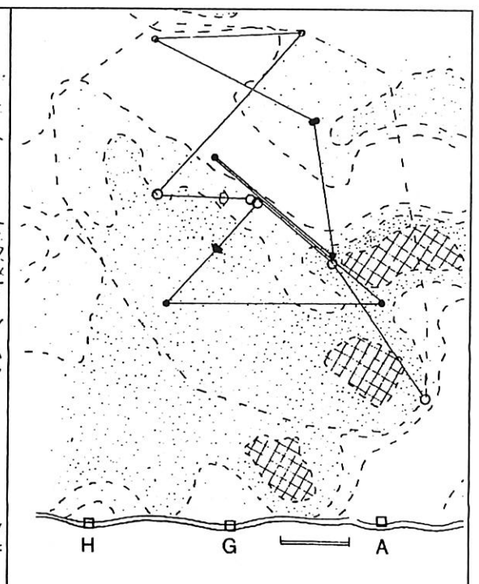
On each map, tracking locations from which bearings were obtained are indicated with an open square and a letter, open circles represent locations for wallabies determined in daylight and closed circles represent locations determined at night. For further information see page 28 and Figure 3.

All locations recorded for Channel 08.

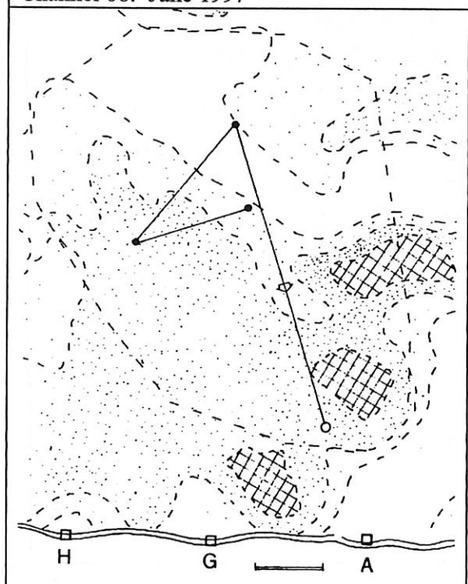
Monthly overnight observations on Channel 08.



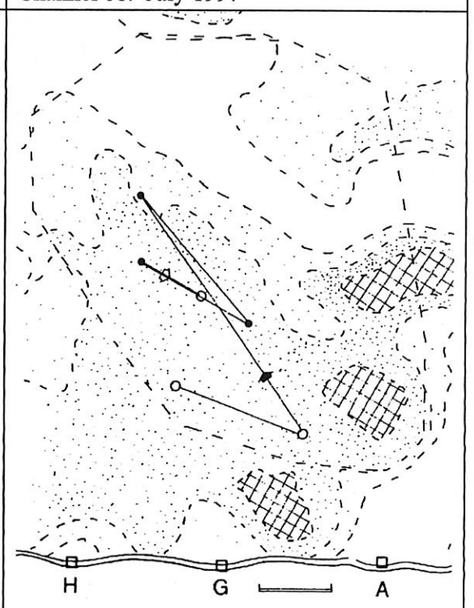
Channel 08. June 1997



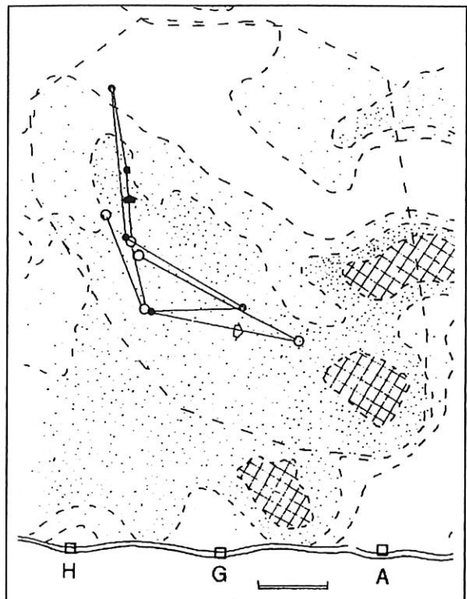
Channel 08. July 1997



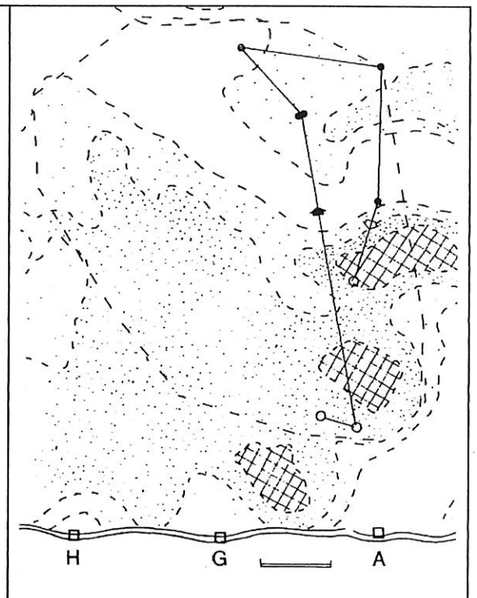
Channel 08. August 1997



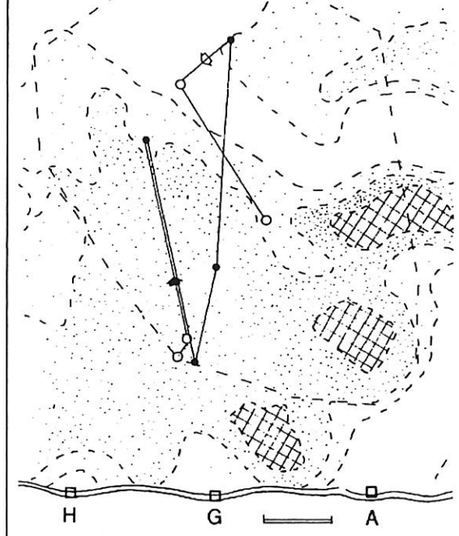
Channel 08. September 1997



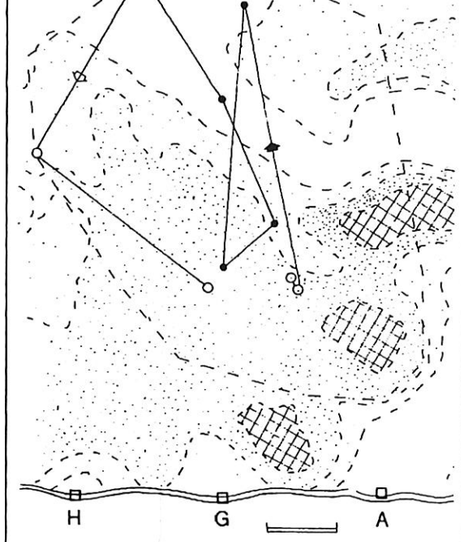
Channel 08. October 1997



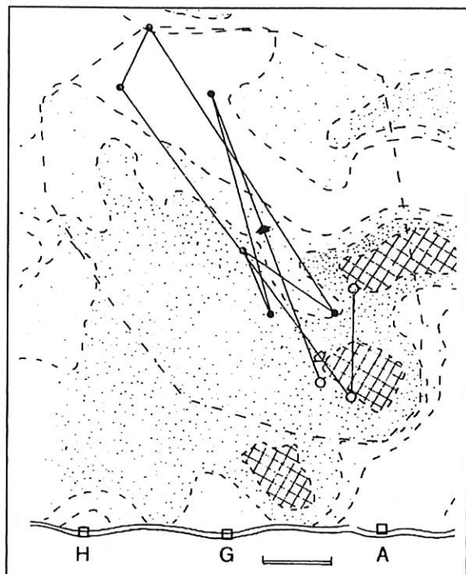
Channel 08. November 1997



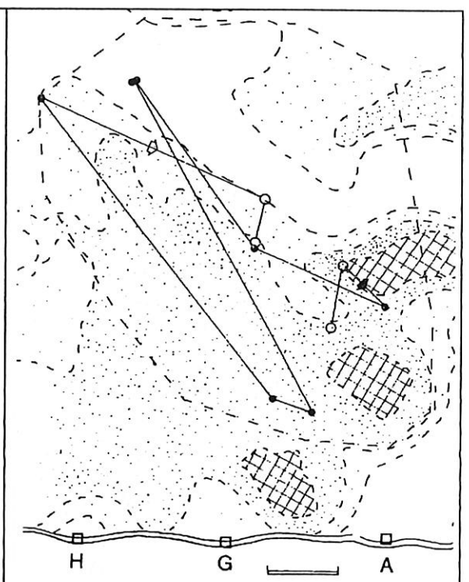
Channel 08. December 1997



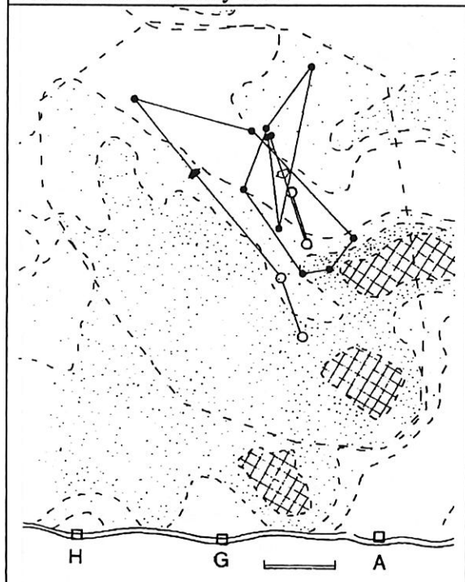
Channel 08. January 1998



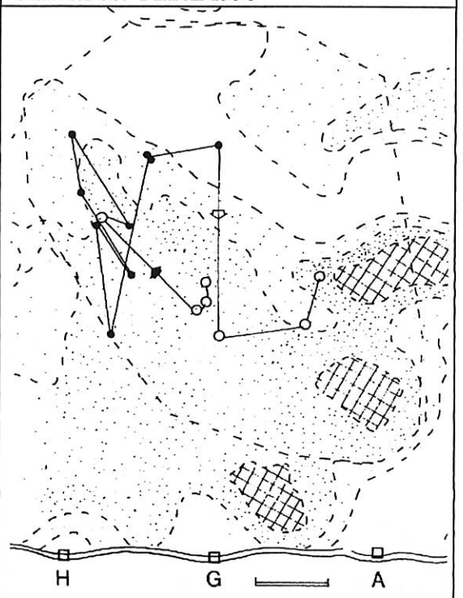
Channel 08. February 1998



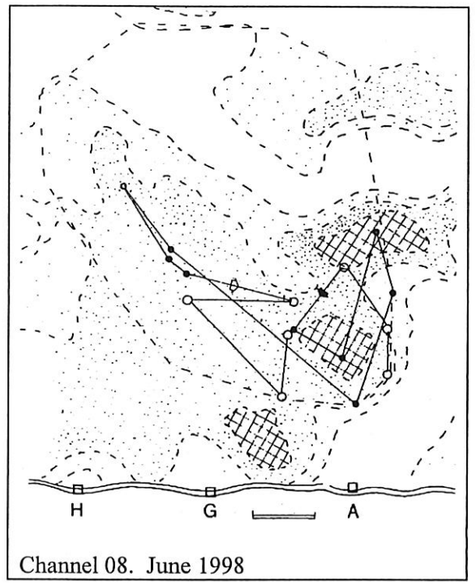
Channel 08. March 1998



Channel 08. April 1998



Channel 08. May 1998

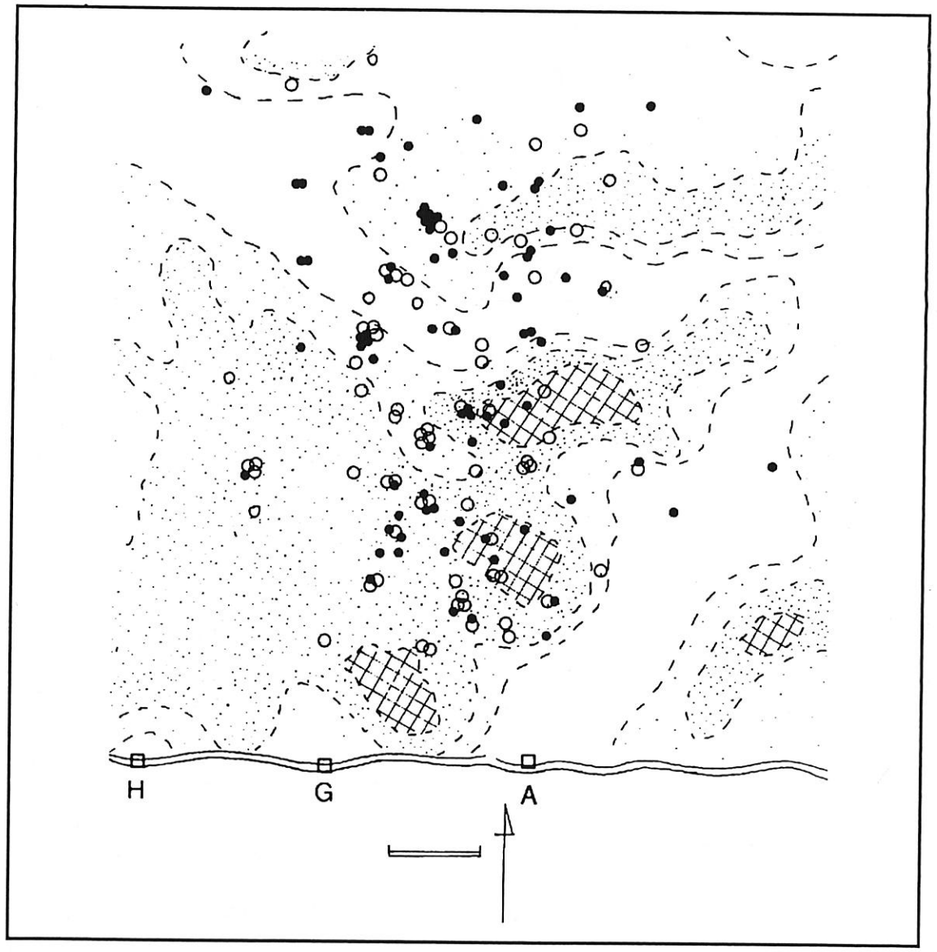


Channel 08. June 1998

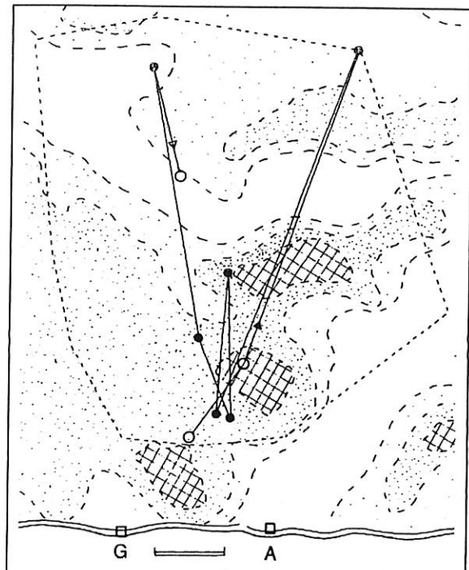
Figure 8. Results of radio-tracking of Channel 10, an adult female Brush Wallaby.

On each map, tracking locations from which bearings were obtained are indicated with an open square and a letter, open circles represent locations for wallabies determined in daylight and closed circles represent locations determined at night. For further information see page 28 and Figure 3.

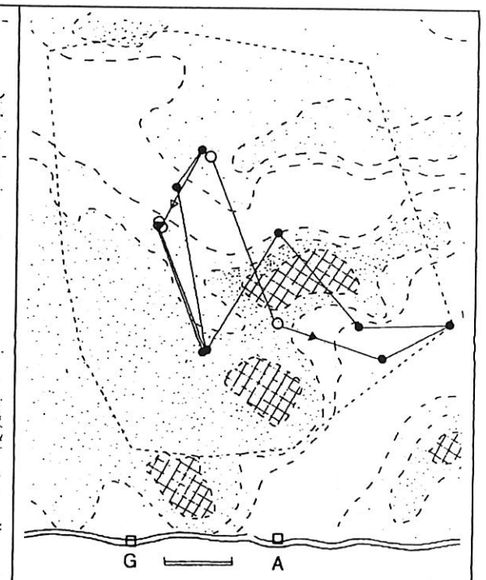
All locations recorded for Channel 10.



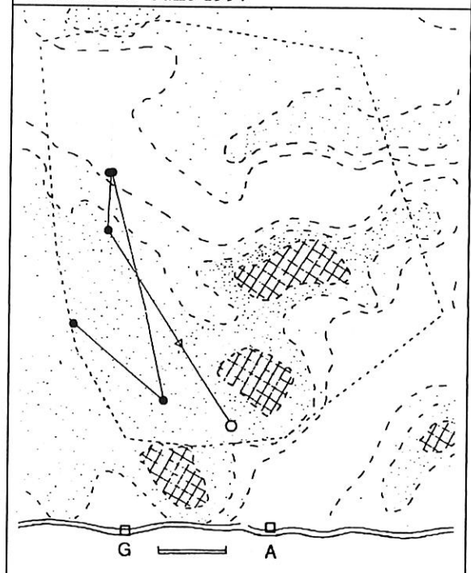
Monthly overnight observations on Channel 10.



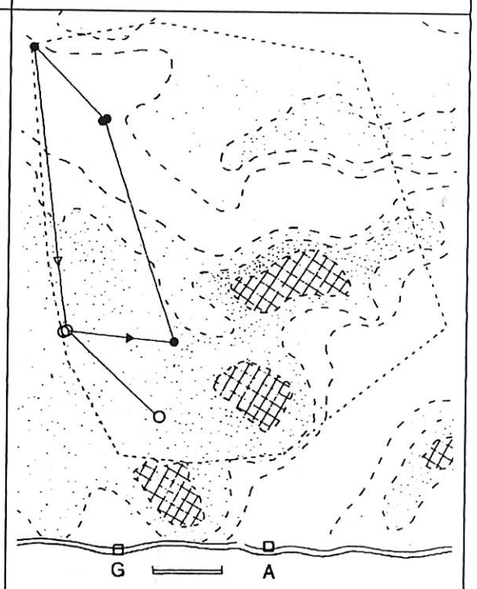
Channel 10. June 1997



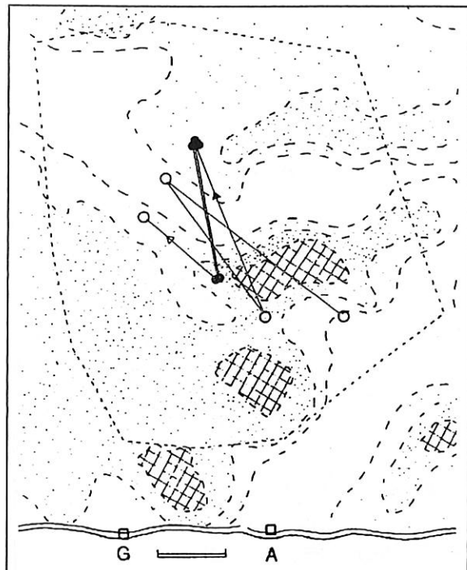
Channel 10. July 1997



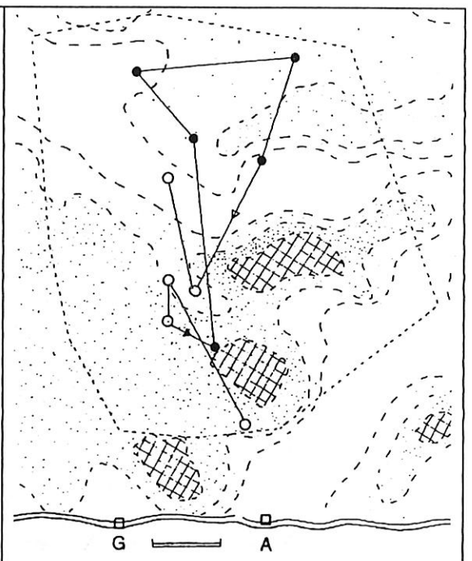
Channel 10. August 1997



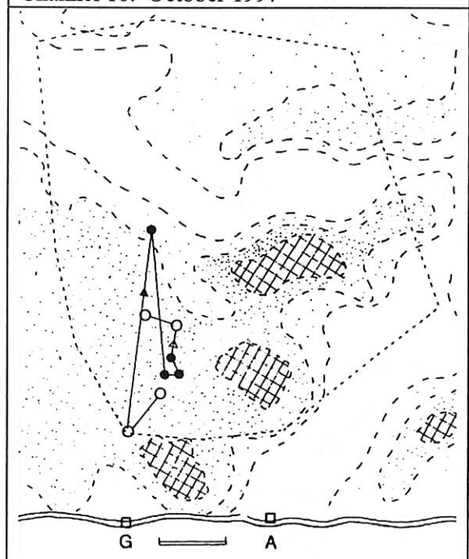
Channel 10. September 1997



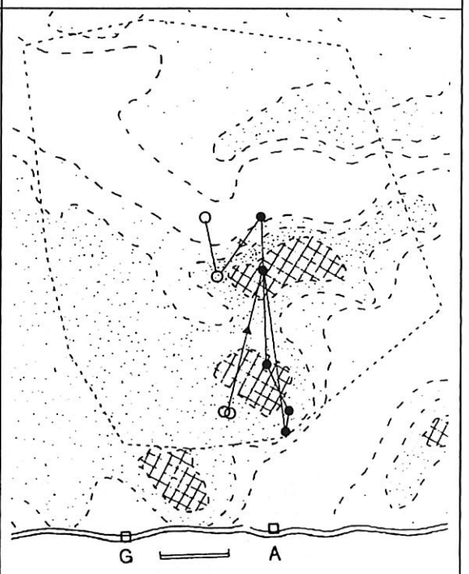
Channel 10. October 1997



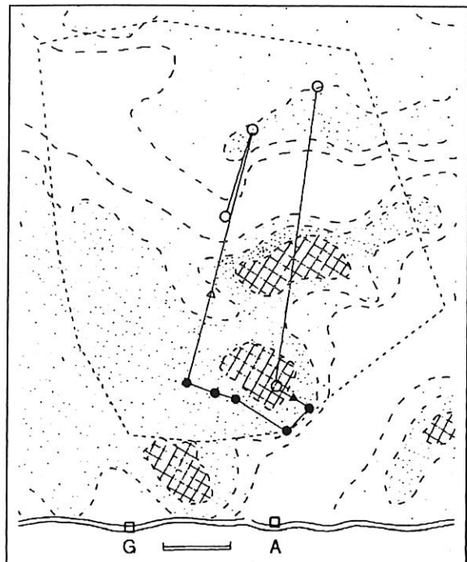
Channel 10. November 1997



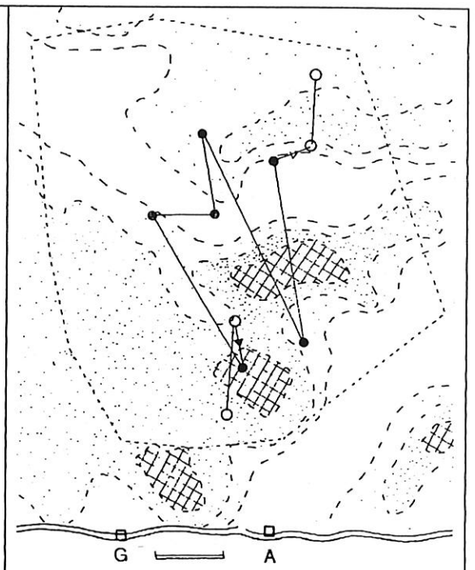
Channel 10. December 1997



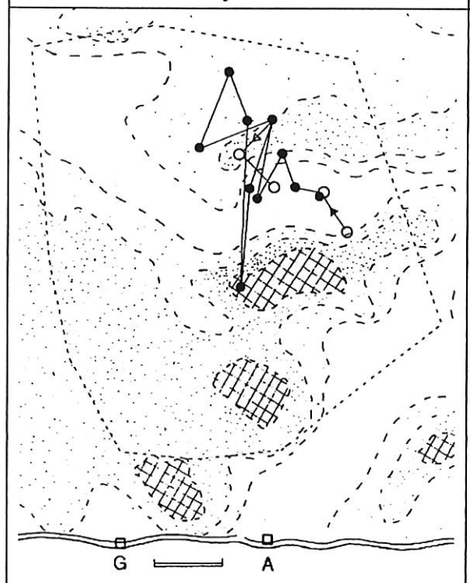
Channel 10. January 1997



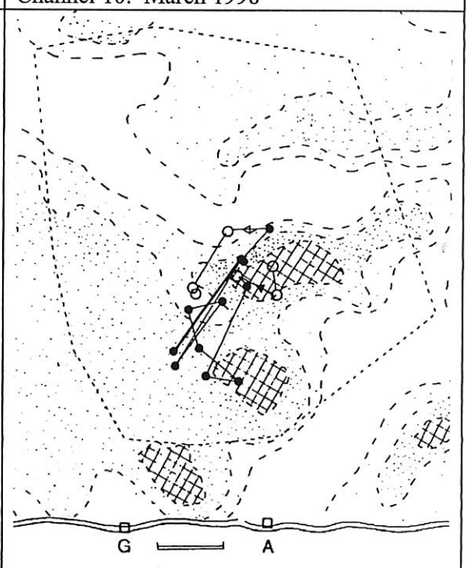
Channel 10. February 1998



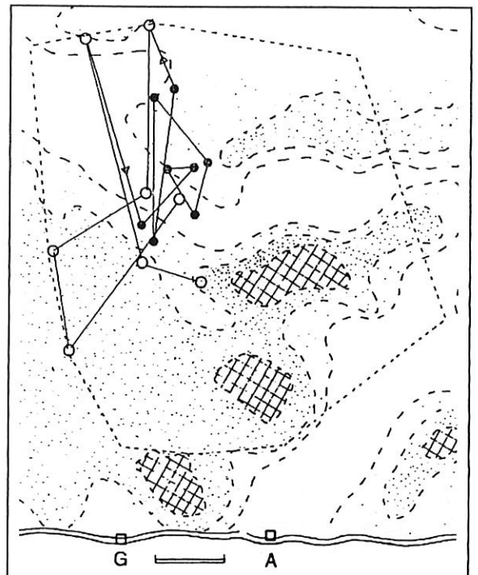
Channel 10. March 1998



Channel 10. April 1998



Channel 10. May 1998

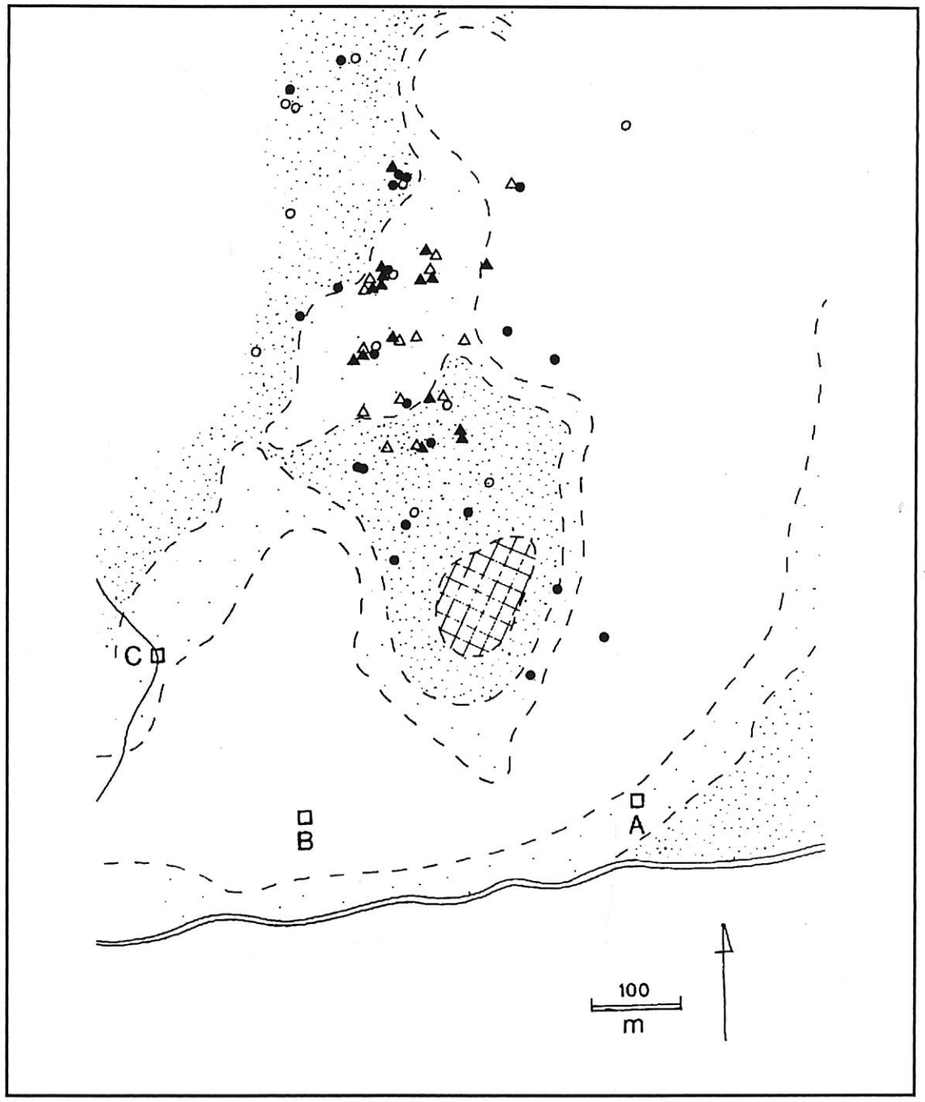


Channel 10. June 1998

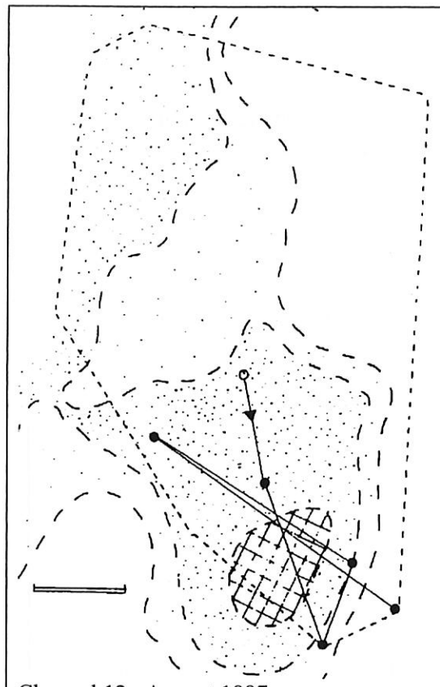
Figure 9. Results of radio-tracking Channel 12, a sub-adult female Brush Wallaby. Note that triangular symbols represent locations determined after the radio-collar is believed to have fallen from the Wallaby.

On each map, tracking locations from which bearings were obtained are indicated with an open square and a letter, open circles represent locations for wallabies determined in daylight and closed circles represent locations determined at night. For further information see page 28 and Figure 3.

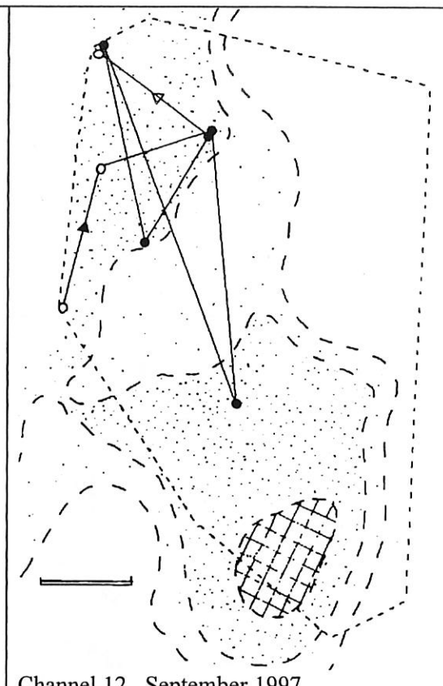
All locations recorded for Channel 12.



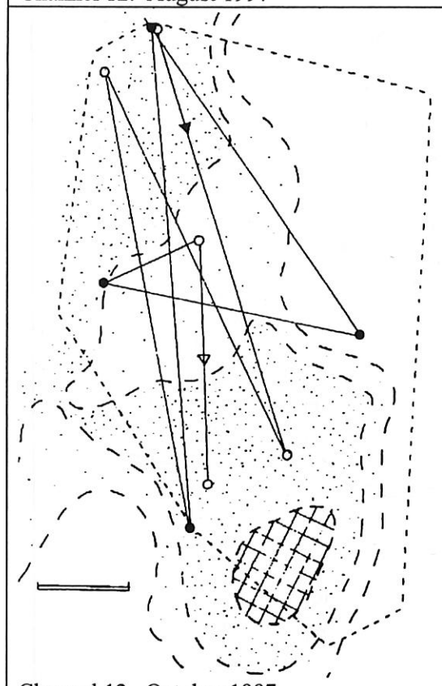
Monthly overnight observations on Channel 12.



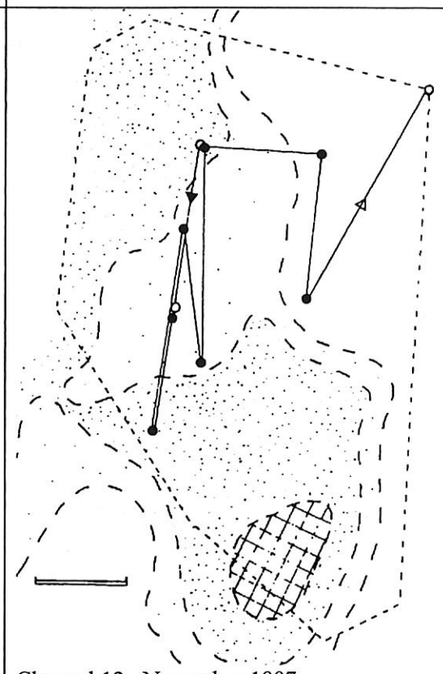
Channel 12. August 1997



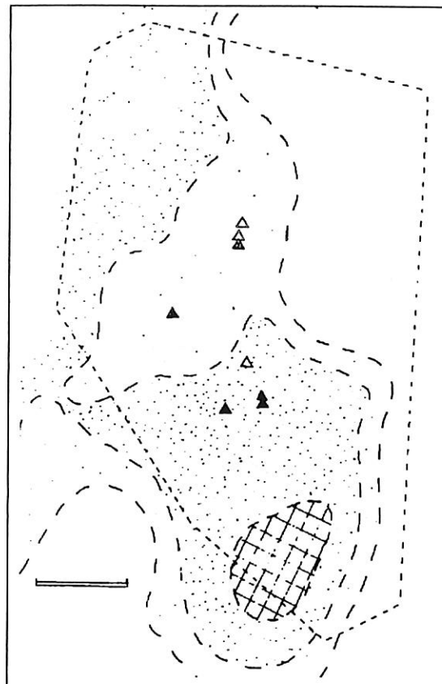
Channel 12. September 1997



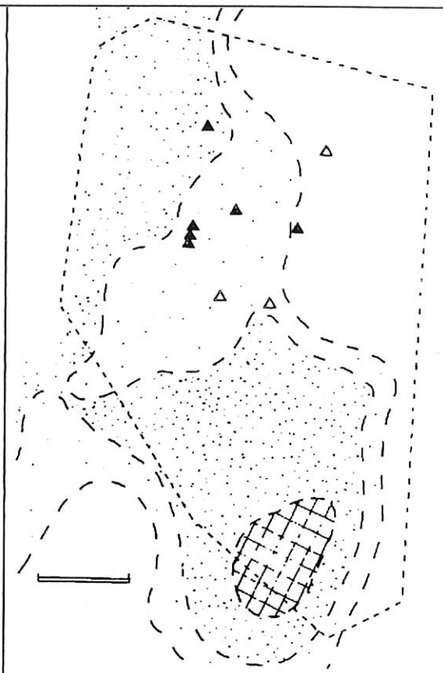
Channel 12. October 1997



Channel 12. November 1997

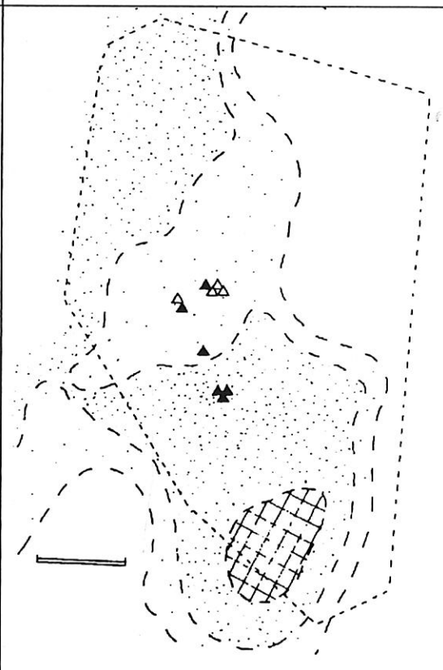


Channel 12. December 1997



Channel 12. January 1998

Channel 12. February 1998

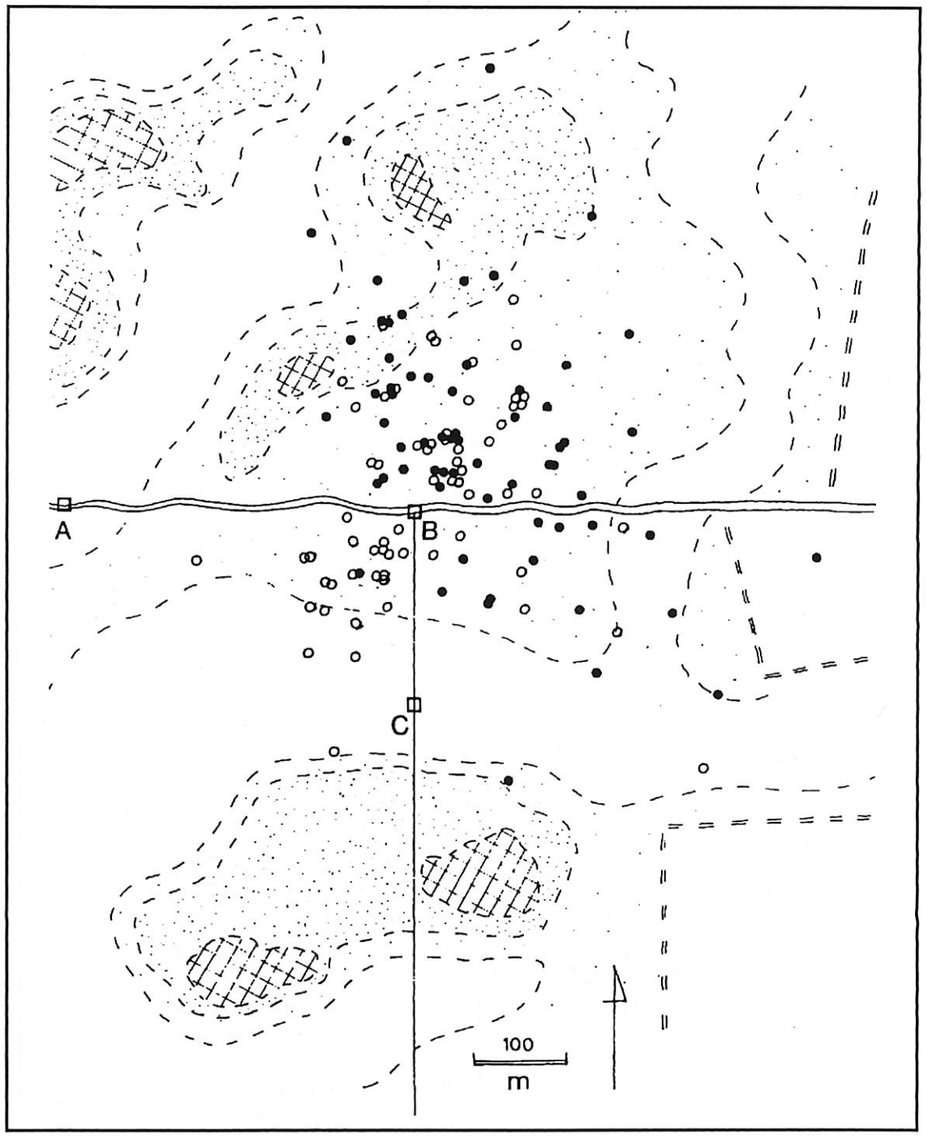


Channel 12. March 1998

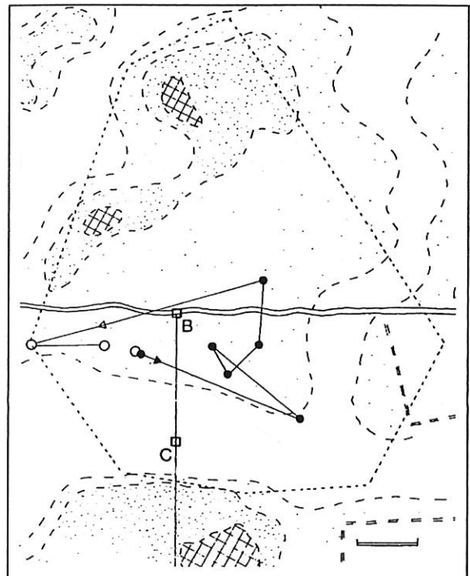
Figure 10. Results of radio-tracking of Channel 14, an adult female Brush Wallaby. Note that the double broken line indicates the fenceline dividing woodland from pasture.

On each map, tracking locations from which bearings were obtained are indicated with an open square and a letter, open circles represent locations for wallabies determined in daylight and closed circles represent locations determined at night. For further information see page 28 and Figure 3.

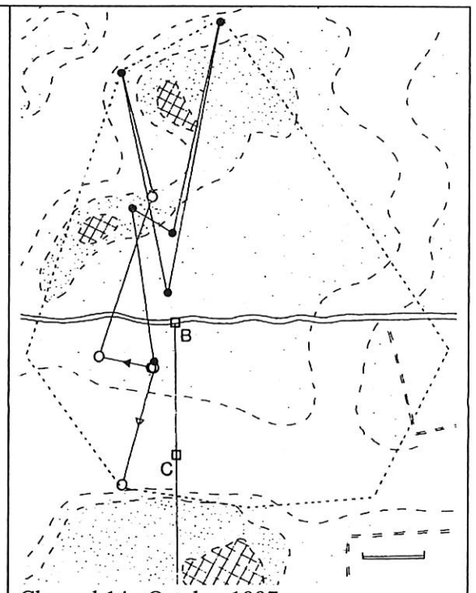
All locations recorded for Channel 14.



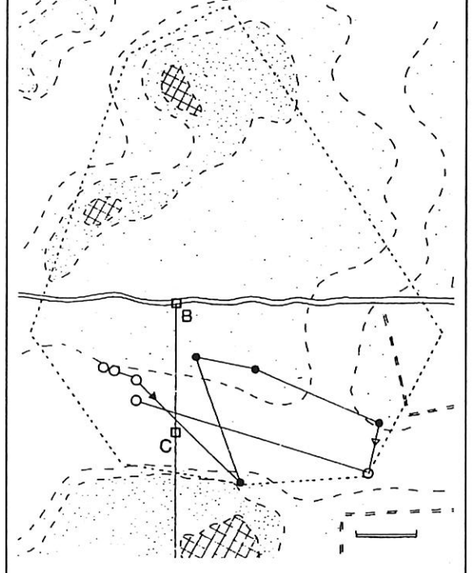
Monthly overnight observations on Channel 14.



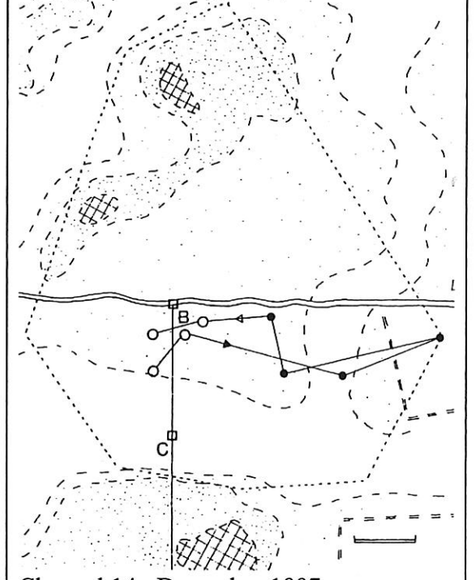
Channel 14. September 1997



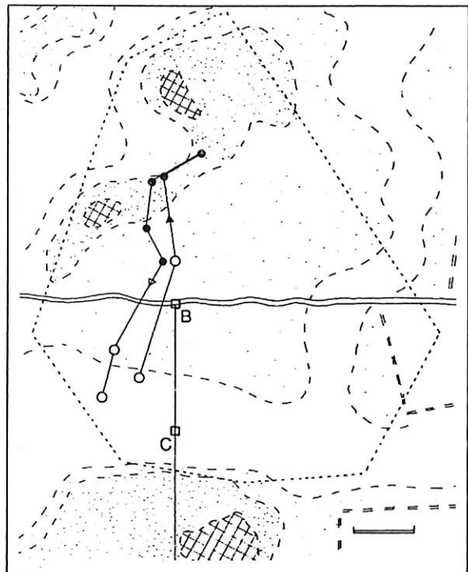
Channel 14. October 1997



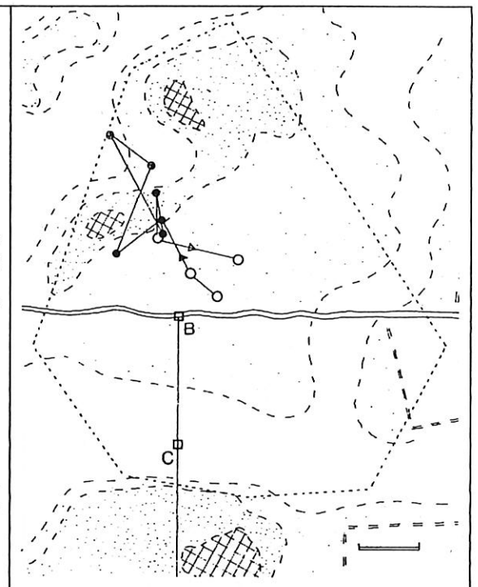
Channel 14. November 1997



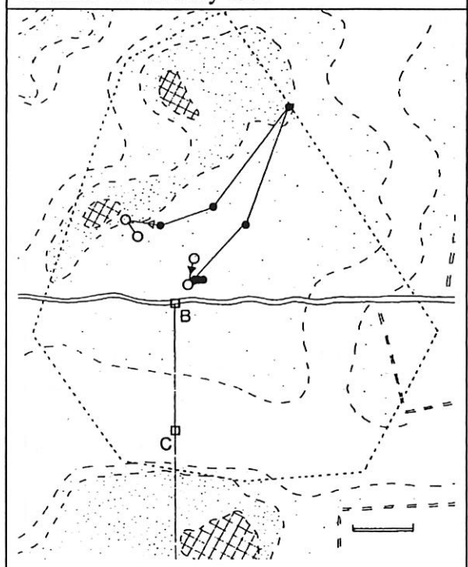
Channel 14. December 1997



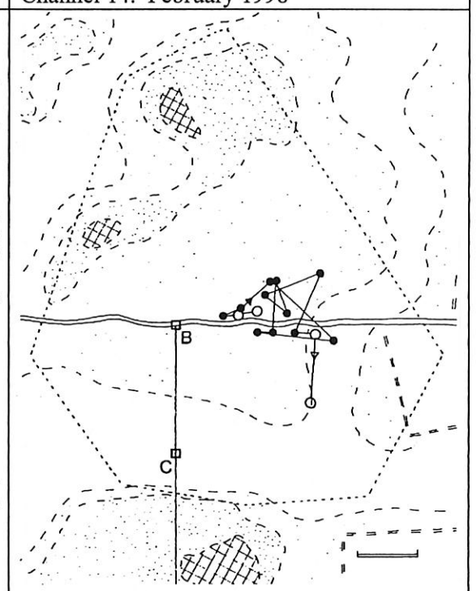
Channel 14. January 1998



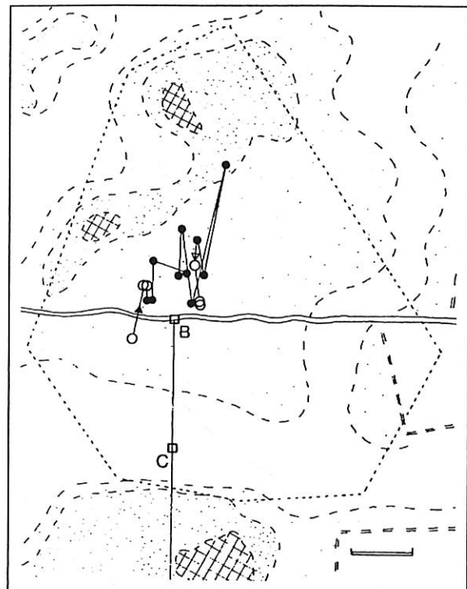
Channel 14. February 1998



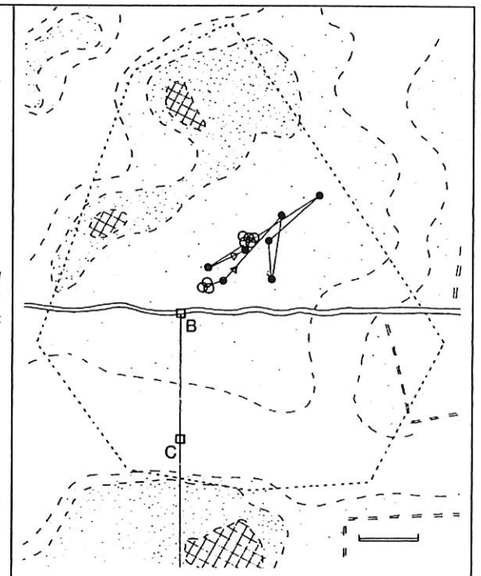
Channel 14. March 1998



Channel 14. April 1998



Channel 14. May 1998

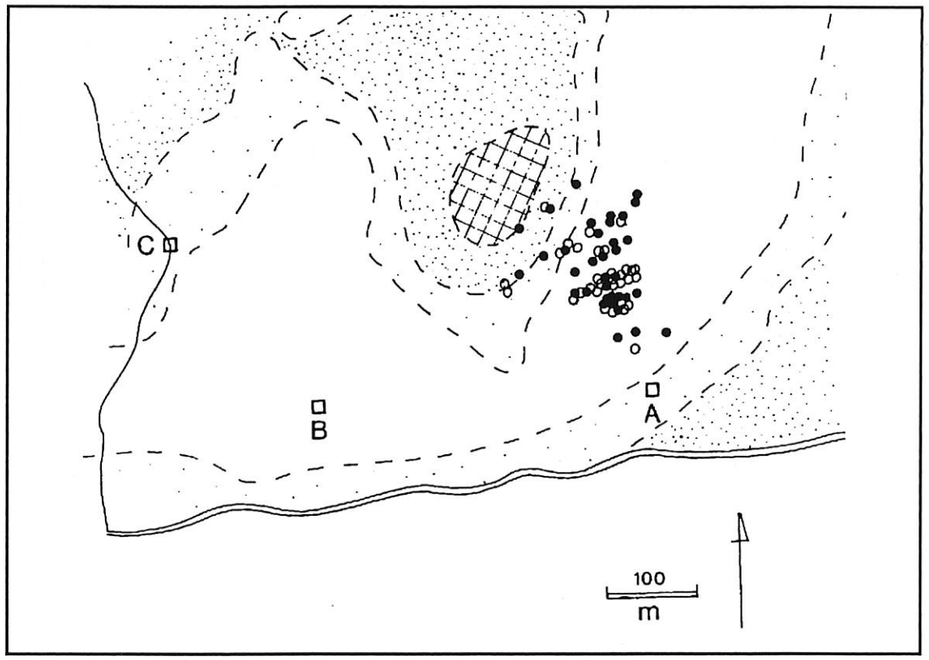


Channel 14. June 1998

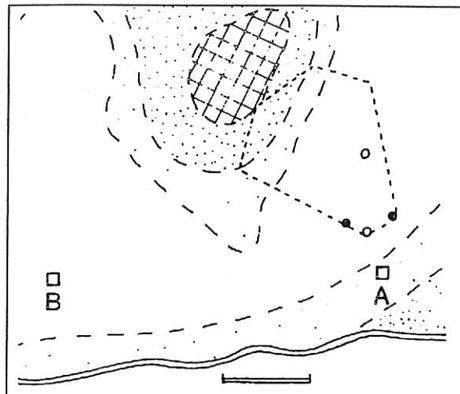
Figure 11. Results of radio-tracking Channel 16, an adult male Brush Wallaby. It is believed that this Wallaby died shortly after capture and that all locations were determined after its death.

On each map, tracking locations from which bearings were obtained are indicated with an open square and a letter, open circles represent locations for wallabies determined in daylight and closed circles represent locations determined at night. For further information see page 28 and Figure 3.

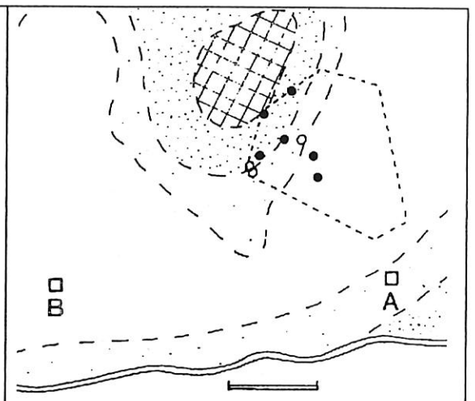
All locations recorded for Channel 16.



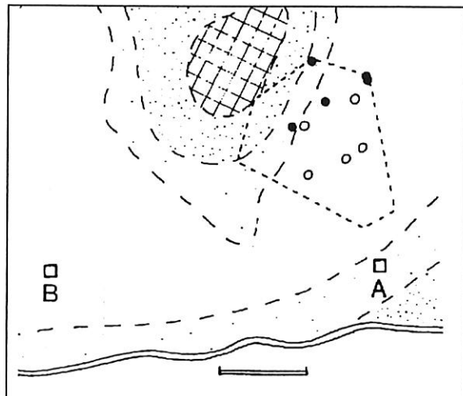
Monthly overnight observations on Channel 16.



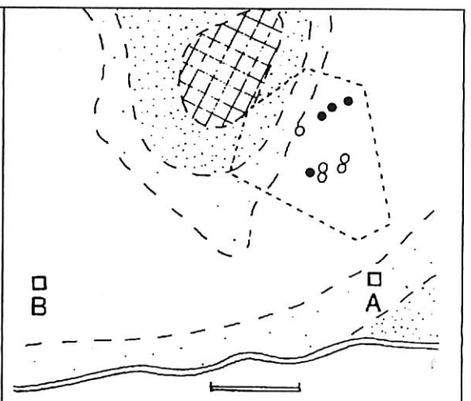
Channel 16. August 1997



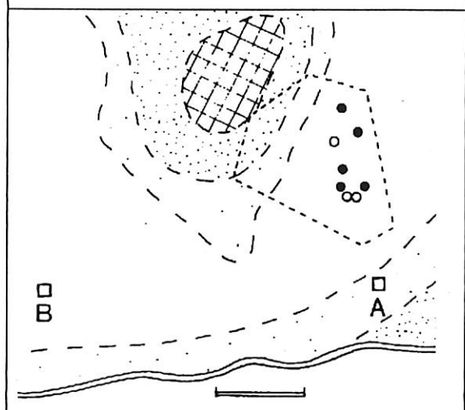
Channel 16. September 1997



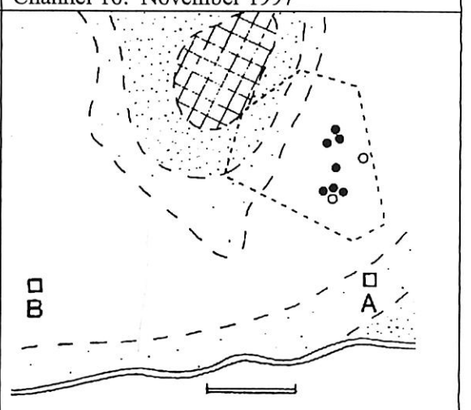
Channel 16. October 1997



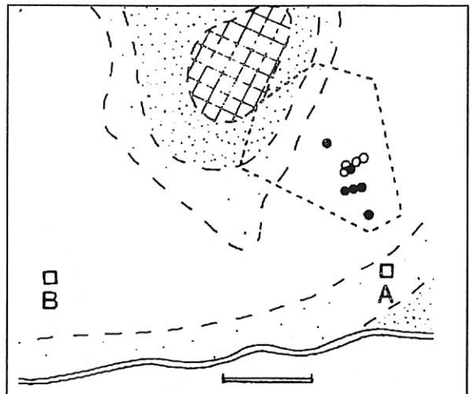
Channel 16. November 1997



Channel 16. December 1997



Channel 16. January 1998



Channel 16. February 1998

Figure 12. Areas over which channels 08 (closed circles) and 10 (closed squares) moved during overnight observations in each month. Open circles and squares within each polygon indicate daytime records made at the beginning and the end of the sampling period.

On each map, tracking locations from which bearings were obtained are indicated with an open square and a letter, open circles represent locations for wallabies determined in daylight and closed circles represent locations determined at night. For further information see page 28 and Figure 3.

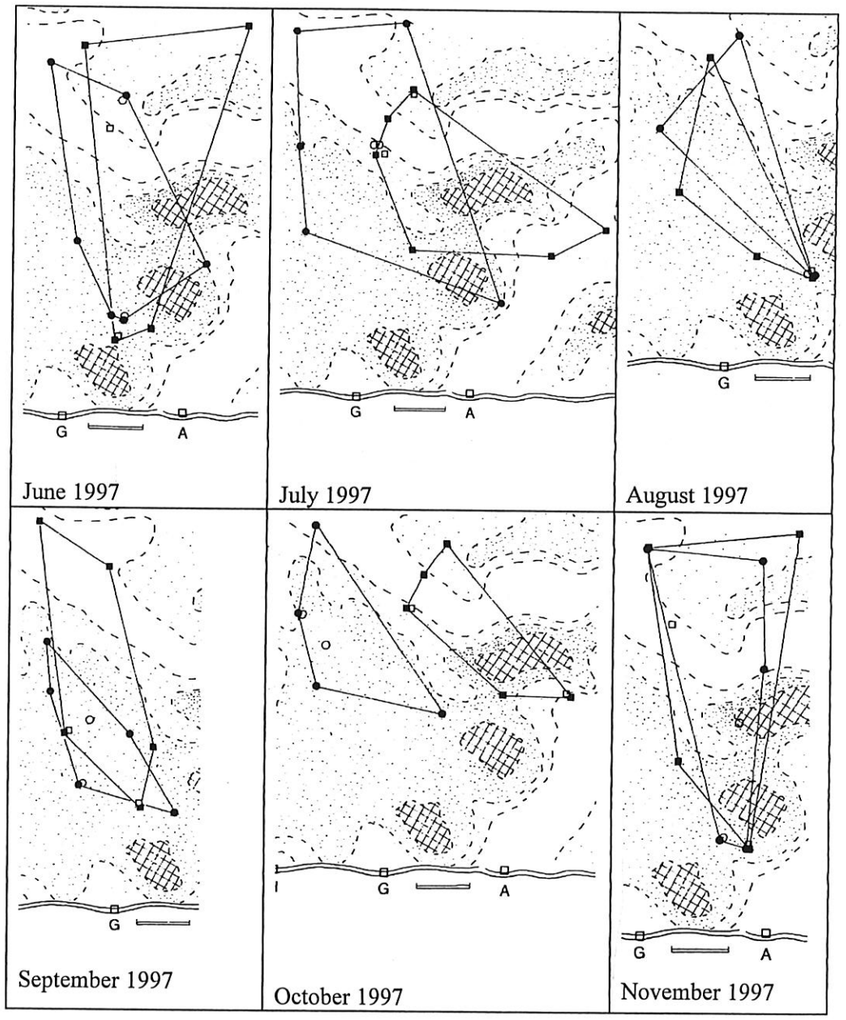


Figure 12 (cont.)

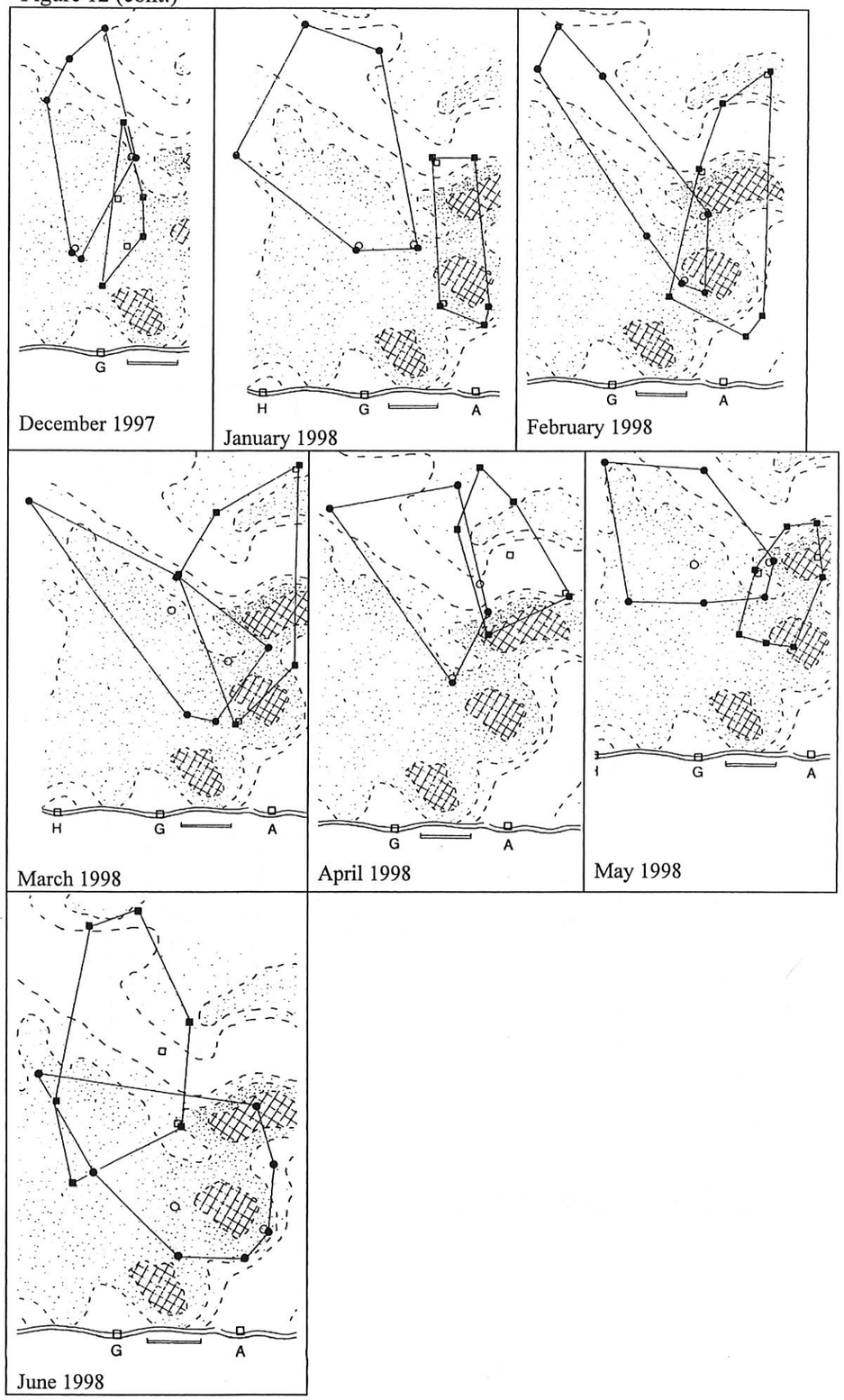


Figure 13. The mean distance moved (±1 Standard Error) by Brush Wallabies in relation to time of day for all specimens pooled, based upon the distance recorded between two sequential locations determined during radio-tracking. The time between the recording of sequential locations was usually 1 to 1½ hours, but was 3 to 4 hours for some pairs of records made late at night.
Pairs of locations were divided into time intervals as follows (numbers of pairs in parenthesis): Daylight - any two records from more than two hours after sunrise to more than two hours before sunset (46); Evening - the last two records made before sunset (70); Sunset - the last record made before and the first record made after sunset (71); Night - any two records from more than one hour after sunset to more than one hour before sunrise (379); Sunrise - the last record made before and the first record made after sunrise (75); and Morning - the first two records made after sunrise (61).

The two broken lines indicate the mean (±1 Standard Error) distance between 93 pairs of sequential locations determined for Channels 02, 12 and 16 when these transmitters were not moving.

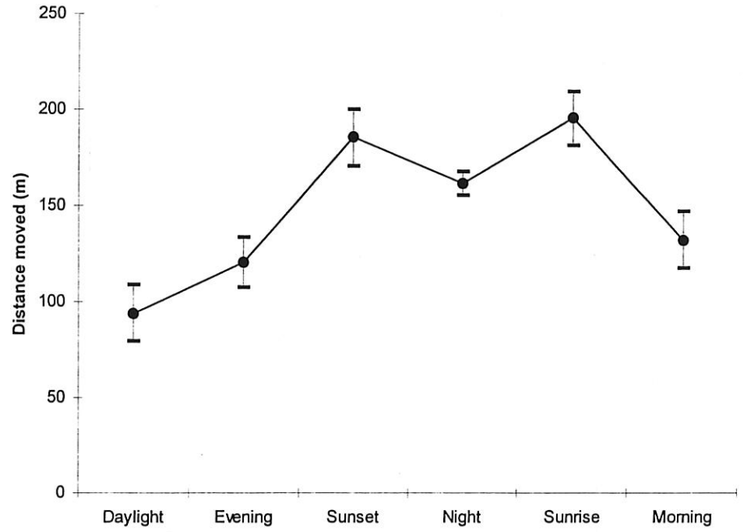
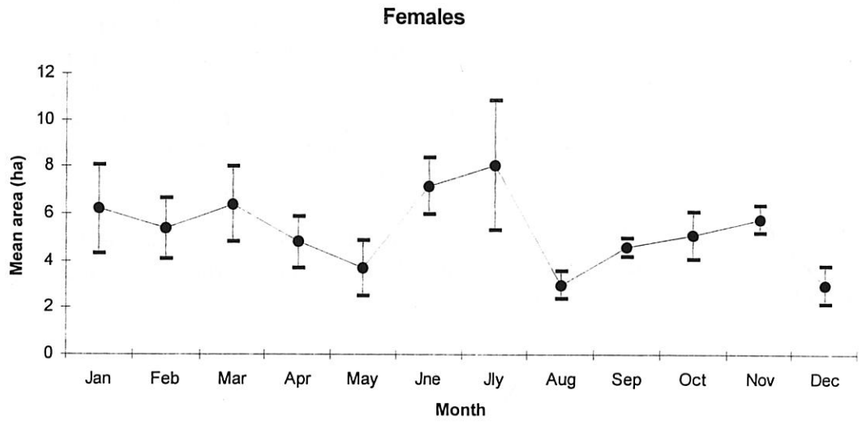
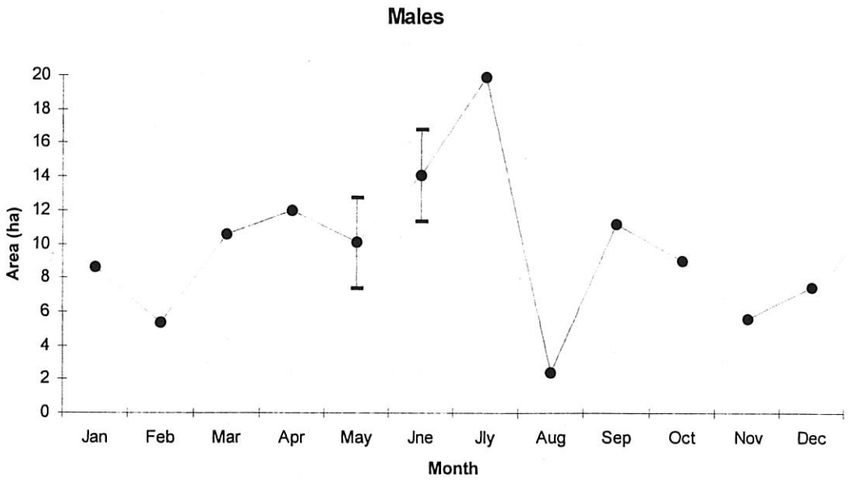


Figure 14. Mean overnight area of activity in each month for female and male Brush Wallabies. Values for females are based on records from 3 to 6 specimens, while values for males are based on records from 2 or 3 specimens.





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APPENDIX 1. All radio-tracking data collected on each Wallaby.
Note that the Tracking Locations are indicated in Figures 3 to 8. Whether a fix was obtained during daylight (Day, approximately between sunrise and sunset) or at night (Night, approximately between sunset and sunrise) is indicated. The time when fixes were obtained is given (24 hr clock).

Channel 02.

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
21/02/97	1	day (1350)	335	270					
12/03/97	4	day (1430)	40	95					
09/04/97	5	day (1115)	360	270					
16/04/97	6	day (1230)	15	310					
23-24/04/97	7	day (0945)		60	210				
		day (1430)		110	210				
		night (1930)				340	280		
		night (2035)				310	270		
		night (2200)				310	270		
		night (0100)				280	265	250	
		night (0335)				270	250		
		day (0655)				320	300		
		day (0735)	10	310					
		day (0900)	10	305					
08/05/97	8	day (1345)		10	270				
21/05/97	9	day (1045)	60	130					
28-29/05/97	10	day (0945)	90	190					
		day (1700)				270	240		
		night (1845)				280	260		
		night (2045)				280	255		
		night (2225)				260	240		
		night (0115)				270	250		
		night (0405)				300	270		
		night (0610)				290	270		
		day (0710)				310	290		
		day (0905)				310	290		
07/06/97	11	day (1100)				310	290		
18/06/97	12	day (1330)	355	290					
24-25/06/97	13	day (0900)				300	280		
		day (1645)				300	280		
		night (1800)				280	260		
		night (2015)				270	250		
		night (2100)				340	300		
		night (0105)				320	275		
		night (0330)				345	290		
		night (0550)				335	280		
		day (0650)				315	300		
		day (0830)				315	300		
07/07/97	14	day(1330)				290	250		
17-18/07/97	15	day (1100)				310	280		
		day (1650)				305	280		

Channel 02 (cont.)

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
17-18/07/97		night (1755)				290	270		
		night (1835)				280	265		
		night (1950)				290	270		
		night (2050)				275	260		
		night (2155)				290	260		
		night (0055)				270	255		
		night (0355)				270	245		
		night (0510)				265	245		
		night (0605)				265	245		
		day (0715)				305	270		
		day (0915)				310	280		
06/08/97	16	day(1200)				280	260		
22-23/08/97	17	night (1840)				305	285		
		night (2010)				310	290		
		night (2205)				310	290		
		night (0145)				320	280		
		night (0450)				310	290		
		night (0620)				295	280		
		day (0750)				310	290		
06/09/97	18	day (1350)				290		5	
25-26/09/97	19	day (1645)				285	270		
		day (1815)				300	275		
		night (1940)				325	305		
		night (2120)				300	280		
		night (0055)				320	285		
		night (0420)				300	285		
		night (0540)				310	290		
		day (0650)				315	290		
		day (0800)				320	300		
14/10/97	20	day (1000)				300		5	
23-24/10/97	21	day (0830)				290		355	
		day (1810)				320	270		
		night (1935)				295	270		
		night (2105)				320	270		
		night (2220)				310	270		
		night (0110)				300	270		
		night (0430)				300	270		
		night (0545)				310	265		
		day (0705)				330	270		
		day (0820)				310	290		
07/11/97	22	day (1315)				310		30	
22-23/11/97	23	day (1540)				305		10	
		day (1750)				305		10	
		day (1910)				330	305		
		night (2100)				350	315		
		night (2230)				0	300		
		night (2355)				340	315		
		night (0300)				310	290		

Channel 02 (cont.)

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
22-23/11/97		day (0430)				325	305		
		day (0550)				325	295		
		day (0815)				315	295		
03/12/97	24	day (1400)				310		25	
10/12/97	25	day (0920)				310		15	
28-29/12/97	26	day (1815)				320	300		
		day (1930)				330	305		
		night (2120)				340	295		
		night (2310)				0	255		
		night (0050)				340	310		
		night (0230)				340	310		
		day (0550)				320	300		
		day (0735)				320	300		
13/01/98	27	day (1230)				300		10	
28-29/01/98	29	day (1800)				305	285		
		day (1920)				310	280		
		night (2110)				350	310		
		night (2235)				0	260		
		night (0005)				10	270		
		night (0315)				260	240		
		night (0445)				285	270		
		day (0615)				290	265		
		day (0715)				290	265		
06/02/98	30	day (1425)				310		25	
26-27/02/98	31	day (1730)				295	270		
		day (1835)				290	270		
		night (2000)				290	270		
		night (2125)				290	270		
		night (2255)				285	265		
		night (0240)				290	265		
		night (0410)				285	265		
		night (0525)				300	275		
		day (0640)				300	275		
		day (0830)				300	270	10	
10/03/98	32	day (1445)					270	20	
15/03/98	33	day (0930)					270	20	
25-26/03/98	34	day (1715)				300	265		
		night (1830)				290	260		
		night (2000)				305	275		
		night (2110)				300	270		
		night (2230)				290	260		
		night (2350)				310	270		
		night (0320)				305	275		
		night (0450)				315	275		
		day (0615)				310	270		
09/05/98	36	day (1600)					270	20	

Channel 04.

Date	Survey number	Day or Night	Tracking Location						
			A	B	C	D	E	F	G
12/03/97	4	day (1505)	10	130					
09/04/97	5	day (0945)	35	45	90				
16/04/97	6	day (0930)	55	80					
23-24/04/97	7	day (0930)	45	80					
		day (1415)	45	80					
		day (1700)	45	80					
		day (1755)			195	210			
		night (2015)			190	220			
		night (0030)		220	190				
		night (0520)			180	200			
		day (0640)			130	105			
08/05/97	8	day (1315)	50	85					
21/05/97	9	day (1130)	70	90					
28-29/05/97	10	day (0945)	70	100					
		day (1630)	40	70					
		night (1745)			180	200			
		night (0335)					200	175	
		night (0545)					180	165	
		day (0720)					170	140	
		day (0850)		80		135	170		
07/06/97	11	day (1030)	70	140					
18/06/97	12	day (1300)		65			160		
24-25/06/97	13	day (0915)					170	150	
		day (1630)					170	150	
		night (1745)					180	160	
		night (2000)					200	185	
		night (2130)					210	180	
		night (0055)					225	180	
		night (0400)					220	180	
		night (0540)					220	190	
		day (0640)					210	165	
		day (0820)					180	130	
07/07/97	14	day (1300)					180	155	
17-18/07/97	15	day (1100)	70				180		
		day (1620)	50				180		
		day (1725)					180	160	
		night (1825)					200	165	
		night (1920)					165	145	
		night (2025)					200	180	
		night (2130)					220	195	
		night (0020)					235	205	
		night (0315)					220	160	
		night (0430)					190	150	
		night (0535)					180	145	
		day (0655)					190	150	
		day (0845)	80				175	160	
06/08/97	16	day (1145)	30	60			180	155	
22-23/08/97	17	night (1820)					220	180	

Channel 04 (cont.)

Date	Survey number	Day or Night	Tracking Location						
			A	B	C	D	E	F	G
22-23/08/97		night (2000)					200	170	
		night (2200)					210	175	
		night (0130)					210	170	
		night (0440)					210	180	
		night (0610)					200	160	
		day (0735)		70			180		
06/09/97	18	day (1315)	20	40					
25-26/09/97	19	day (1630)					200	140	
		day (1805)					210	145	
		night (1930)					185	165	
		night (2110)					195	165	
		night (0045)					220	180	
		night (0410)					205	185	
		night (0530)					180	130	
		day (0640)					180	130	
		day (0750)					170	135	
14/10/97	20	day (1050)	50	70					
23-24/10/97	21	day (0915)	5	25					
		day (1755)					205	185	
		night (1925)					180	150	
		night (2050)					200	170	
		night (0055)					200	170	
		night (0420)					200	160	
		night (0530)					165	145	
		day (0650)					190	170	
		day (0810)					195	175	
07/11/97	22	day (1400)		45				140	
22-23/11/97	23	day (1525)		70			170		
		day (1745)					190	150	
		day (1900)					185	145	
		night (2045)					200	165	
		night (2215)					210	185	
		night (2345)					210	180	
		night (0250)					205	180	
		night (0420)					205	180	
		day (0540)					210	140	
		day (0725)					210	140	
03/12/97	24	day (1315)	330	185					
10/12/97	25	day (1000)	10	50					
28-29/12/97	26	day (1810)					165	135	
		day (1920)					170	135	
		night (2110)					210	175	
		night (2300)					210	170	
		night (0040)					215	195	
		night (0215)					235	210	
		day (0540)					195	155	
		day (0645)	30	75			180		
13/01/98	27	day (1305)		10				160	

Channel 04 (cont.)

Date	Survey number	Day or Night	Tracking Location						
			A	B	C	D	E	F	G
28-29/01/98	29	day (1755)					190	160	
		day (1910)					210	185	
		night (2100)					210	190	
		night (2225)					220	200	
		night (2355)					240	200	
		night (0310)					240	205	
		night (0435)					205	185	
		day (0610)					190	140	
		day (0645)					190	140	
06/02/98	30	day (1440)					185	145	
26-27/02/98	31	day (1715)					165	135	
		day (1825)					165	135	
		night (1950)					220	170	
		night (2115)					230	170	
		night (2245)					240	180	
		night (0230)					220	180	
		night (0400)					250	200	
		night (0515)					245	205	
		day (0630)					195	150	
		day (0720)					195	155	
10/03/98	32	day (1405)	30					140	
25-26/03/98	33	day (1710)					180	135	
		day (1815)					185	150	
		night (1945)					210	170	
		night (2100)					210	180	
		night (2225)					225	190	
		night (2340)					230	195	
		night (0300)		295	250				
		night (0440)		235	205				
		night (0600)					180	140	
		day (0715)		60	110				
		day (0900)		60	110				
15/04/98	34	day (0945)		110			180		
24-25/04/98	35	day (1610)		50				140	
		day (1715)		50	95				
09/05/98	36	day (1630)	30	65					

Channel 06.

Date	Survey number	Day or Night	Tracking Location							
			A	B	C	D	E	F	G	H
28-29/05/97	10	day (1230)			200	220	240			
		day (1645)			205	210	250			
		night (1815)				220	290			
		night (2015)	170	210	235					
		night (2155)	200	250	260					
		night (0040)	180	215	240					
		night (0345)	190	220						

Channel 06 (cont.)

Date	Survey number	Day or Night	Tracking Location							
			A	B	C	D	E	F	G	H
28-29/05/97		night (0555)	170	200						
		day (0740)	170		230		300	50		
		day (0840)			230		300			
07/06/97	11	day (1000)	160	185						
18/06/97	12	day (1315)	150	190						
24-25/06/97	13	day (0930)	165		195					
		day (1600)	145		190					
		day (1715)	165	205						
		night (1935)	160	230						
		night (2145)	140	185						
		night (0040)	150	210						
		night (0330)	170	210						
		night (0520)	160	240						
		night (0615)	160	220						
		day (0810)	170	200						
07/07/97	14	day (1130)			200		280			
17-18/07/97	15	day (1100)	140		200					
		day (1635)	150	205						
		day (1730)	170		200					
		night (1835)	170	210						
		night (1930)	175	210						
		night (2035)	190	230						
		night (2140)	220	240						
		night (0030)	190	250						
		night (0325)	150	220						
		night (0445)	160		200					
		night (0545)	175	205						
		day (0700)	170	220						
		day (0900)	160	190						
06/08/97	16	day (1220)	140	210	250					
22-23/08/97	17	night (1935)	150	200						
		night (2135)	150	200						
		night (0120)	150	200						
		night (0415)	120	170						
		night (0600)	150	190						
		day (0715)	150	190						
06/09/97	18	day (1330)	165		230					
25-26/09/97	19	day (1620)	170	210						
		day (1755)	140	180						
		night (1910)	120	150						
		night (2050)	130	170						
		night (0030)	150	200						
		night (0355)	175	195						
		night (0510)	150	210						
		day (0625)	140	180						
		day (0730)	120	210						
14/10/97	20	day (1020)	160		200					
23-24/10/97	21	day (0845)	170		220					

Channel 06 (cont.)

Date	Survey number	Day or Night	Tracking Location							
			A	B	C	D	E	F	G	H
23-24/10/97		day (1730)	160	210						
		night (1900)	165	200						
		night (2025)	170	195						
		night (2145)	170	200						
		night (0040)	140	190						
		night (0400)	140	200						
		night (0510)	140	200						
		day (0630)	190	220						
		day (0750)	180	220						
07/11/97	22	day (1330)	150	195						
22-23/11/97	23	day (1555)	160	230						
		day (1730)	170	230						
		day (1845)	160	200						
		night (2025)	160	210						
		night (2200)	150	195						
		night (2330)	160	200						
		night (0230)	170	240						
		night (0400)	160	220						
		day (0530)	160	230						
		day (0745)	170	215						
03/12/97	24	day (1335)	170	210						
10/12/97	25	day (0940)	170	205						
28-29/12/97	26	day (1745)	145	220						
		day (1905)	150	210						
		night (2045)	160	200	235					
		night (2230)	165	215	220					
		night (0010)	155	190	210					
		night (0150)	155	215	225					
		day (0515)	160	200	210					
		day (0710)	165	200	210					
13/01/98	27	day (1245)	165		220					
21/01/98	28	day (0530)		200	240					
28-29/01/98	29	day (1740)	175	200						
		day (1900)	175						160	
		night (2035)	175	230						
		night (2205)	185	220					140	
		night (2335)	195						145	
		night (0245)	145	210					130	
		night (0420)	150	225						
		day (0540)	180	225						
		day (0700)	175	235						
06/02/98	30	day (1445)	190		245					
26-27/02/98	31	day (1645)	180	210	235					
		day (1805)	180	220						
		night (1930)	200	235						
		night (2100)	190	230						
		night (2225)	190	240						
		night (0200)	150		240					

Channel 06 (cont.)

Date	Survey number	Day or Night	Tracking Location							
			A	B	C	D	E	F	G	H
26-27/02/98		night (0345)	170	210						
		night (0500)	175	210						
		day (0615)	150	205						
		day (0700)	150		210					
10/03/98	32	day (1420)	205	240						
25-26/03/98	33	day (1645)	210		270					
		day (1800)	220	245						
		night (1930)	205	230						
		night (2045)	215	240						
		night (2210)	210	235						
		night (2330)	215	245						
		night (0240)	210	230						
		night (0420)	210	230						
		night (0545)	210	230						
		day (0700)	200	230						
		day (0915)	205		270					
15/04/98	34	day (1000)	210		245					
24-25/04/98	35	day (1630)	215	230	245					
		day (1730)	215	230	245					
		night (1830)	215	230	245					
		night (1945)	185		240					
		night (2030)	220	235	260					
		night (2125)	215	230	245					
		night (2215)	215	230	240					
		night (2250)	200	220	230					
		night (0130)	200	210	230					
		night (0220)	215	240	250					
		night (0430)	210	230	240					
		night (0520)	205	235	265					
		night (0600)	215	240	260					
		day (0645)		235	260					
		day (0800)	225	240	250					
09/05/98	36	day (0825)	220		250					
		day (1345)	210		245					
		day (1500)	220		250					
		day (1600)	220		245					
26-27/05/98	37	day (1300)	210		240					
		day (1630)	210		240					
		day (1700)	210		240					
		night (1745)	215		235					
		night (1840)	205	240						
		night (1930)	210	235						
		night (2045)	210		240					
		night (2145)	215		235					
		night (2240)	210	230	240					
		night (0115)	215		235					
		night (0300)	215		235					
		night (0545)	215		235					

Channel 06 (cont.)

Date	Survey number	Day or Night	Tracking Location							
			A	B	C	D	E	F	G	H
26-27/05/98		night (0630)	215		235					
		day (0725)	215		235					
		day (0830)	165		210					
15/06/98	38	day (1445)	230	245	255					
24-25/06/98	39	day (1610)	235		250				200	180
		day (1645)	235						210	180
		day (1730)	220						190	160
		night (1915)	200						170	165
		night (2010)	180						150	145
		night (2110)	175						140	130
		night (2200)	225						195	170
		night (2300)	225						190	
		night (0110)							190	175
		night (0340)	225						190	180
		night (0600)	210						195	185
		day (0650)	230						190	160
		day (0750)	250						215	185
		day (0830)	230						195	180
		day (0910)	240						215	185
		day (1000)	240						215	185
23/07/98	40	day (1630)	280						170	

Channel 08

Date	Survey number	Day or Night	Tracking location							
			A	B	C	D	E	F	G	H
18/06/97	12	day	320	290						
24-25/06/97	13	day (0930)	330	290						
		day (1600)	330	295						
		day (1715)	340	305						
		night (1935)	350	300						
		night (2145)	335	290						
		night (0040)	340	300						
		night (0330)	10	310						
		night (0520)	350	320						
		night (0615)	340	315						
		day (0810)	350	320						
07/07/97	14	day (1130)	310	290						
17-18/07/97	15	day (1100)	20	300						
		day (1635)	350	310						
		day (1730)	340	310						
		night (1835)	315	295						
		night (1930)	360	310						
		night (2035)	335	310						
		night (2140)	350	310						
		night (0030)	350	320						
		night (0325)	350	320						
		night (0445)	335	315						

Channel 08 (cont.)

Date	Survey number	Day or Night	Tracking location							
			A	B	C	D	E	F	G	H
17-18/07/97		night (0545)	350	325						
		day (0700)	325	305						
		day (0900)	340	310						
06/08/97	16	day (1215)	340	290						
22-23/08/97	17	night (0120)	340	310						
		night (0415)	320	300						
		night (0600)	340	315						
		day (0715)	340	290						
06/09/97	18	day (1330)	330	300						
25-26/09/97	19	day (1615)	310	290						
		day (1750)	330	290						
		night (2050)	325	305						
		night (0355)	330	300						
		night (0510)	320	300						
		day (0730)	325	300						
23-24/10/97	21	day (0845)	320						340	
		day (1725)	315	295						
		day (1900)	320	300						
		night (2030)	325	305						
		night (2150)	330	310						
		night (0040)	320	300						
		night (0400)	330	300						
		night (0510)	315	295						
		day (0630)	340	300						
		day (0750)	320	300						
07/11/97	22	day (1330)	340	315						
22-23/11/97	23	day (1555)	335	290						
		day (1730)	350	290						
		day (1845)	350	290						
		night (2025)	350	320						
		night (2200)	350	320						
		night (2330)	345	320						
		night (0230)	360	330						
		night (0400)	360	320						
		day (0530)	355	310						
		day (0745)	355	310						
03/12/97	24	day (1335)	330	280						
10/12/97	25	day (0940)	350						20	
28-29/12/97	26	day (1745)	305						345	
		day (1905)	310						350	
		night (2045)	325	305					350	
		night (2230)	305						0	
		night (0010)	325						5	
		night (0150)	330	325					355	
		day (0515)	335						10	
		day (0710)	340							
13/01/98	27	day (1245)	350						20	

Channel 08 (cont.)

Date	Survey number	Day or Night	Tracking location							
			A	B	C	D	E	F	G	H
28-29/01/98	29	day (1740)	340	300					15	
		day (1900)	340	300					20	
		night (2035)	345	320						
		night (2205)	325						0	
		night (2335)	340						10	
		night (0245)	335	315					5	
		night (0420)	335	315						
		day (0540)	315	300						
		day (0700)	320	295						
06/02/98	30	day (1445)	360	310						
26-27/02/98	31	day (1650)	340	295						
		day (1810)	340	295						
		night (1930)	340	315						
		night (2100)	335	300						
		night (2225)	335	305						
		night (0200)	350	305						
		night (0345)	335	315						
		night (0500)	330	310						
		day (0615)	350	295						
		day (0700)	355	310						
10/03/98	32	day (1420)	340	300						
25-26/03/98	33	day (1645)	345						25	
		day (1800)	350	310						
		night (1930)	0	310						
		night (2045)	335	305						
		night (2210)	330	310						
		night (2330)	330	310						
		night (0240)	330	290						
		night (0420)	320	290						
		night (0545)	320	305						
		day (0700)	340	310						
		day (0915)	335	310						
15/04/98	34	day (1000)	355	310					35	
24-25/04/98	35	day (1630)	340	300						
		day (1730)	340	315						
		night (1830)	330	310						
		night (1945)	335	320					10	
		night (2030)	360	310					15	
		night (2125)	350	310					20	
		night (2215)	340	310					20	
		night (2300)	330	315					10	
		night (0145)	340	320					10	
		night (0230)	350	325					10	
		night (0440)	340	310					10	
		night (0530)	340	320					10	
		night (0605)	340	320					10	
		day (0650)	340	315					20	
		day (0805)	335	320					25	

Channel 08 (cont.)

Date	Survey number	Day or Night	Tracking location							
			A	B	C	D	E	F	G	H
09/05/98	36	day (0830)	330	310					20	
		day (1345)	335	310					20	
		day (1500)	330	310					20	
		day (1600)	330	310					20	
26-27/05/98	37	day (1300)	330	300					355	
		day (1630)	325	300					0	
		day (1700)	320	300					0	
		night (1745)	320						340	
		night (1840)							345	10
		night (1930)							340	0
		night (2045)	320	300					340	0
		night (2145)	320						340	15
		night (2240)	320						340	5
		night (0115)	310						335	10
		night (0300)	330						350	10
		night (0545)	330						350	10
		night (0630)	340						0	20
		day (0725)	320						5	30
		day (0830)	350						15	50
		day (0930)	350						20	
15/06/98	38	day (1445)	315	285					350	
24-25/06/98	39	day (1610)	20						55	70
		day (1645)	10						50	60
		day (1730)	0						30	50
		night (1915)	350						20	60
		night (2010)	350						50	60
		night (2110)	10						30	50
		night (2200)	10						45	55
		night (2300)	5						60	
		night (0110)							350	20
		night (0340)	325						340	10
		night (0600)	320						350	20
		day (0650)	325						350	30
		day (0750)	340						30	45
		day (0830)	315						355	25
		day (0910)	335						30	70
		day (1000)	335						30	50
23/07/98	40	day (1630)	325						40	
26/10/98	41	day (0930)	355						55	
26/10/98	41	day (1030)	345						40	

Channel 10

Date	Survey number	Day or Night	Tracking location							
			A	B	C	D	E	F	G	H
18/06/97	12	day	350	320						
24-25/06/97	13	day (0930)	320	285						
		day (1600)	320	285						
		day (1715)	350	300						
		night (1935)	10	340						
		night (2145)	335	290						
		night (0040)	350	310						
		night (0330)	340	290						
		night (0520)	340	300						
		night (0615)	345	320						
		day (0810)	345	315						
07/07/97	14	day (1130)	350	290						
17-18/07/97	15	day (1100)	350	320						
		day (1650)	360	310						
		day (1735)	30	320						
		night (1835)	40	340						
		night (1930)	20	320						
		night (2035)	360	320						
		night (2140)	340	300						
		night (0055)	345	315						
		night (0325)	350	320						
		night (0445)	340	310						
		night (0545)	340	300						
		day (0700)	340	310						
		day (0900)	340	310						
06/08/97	16	day (1215)	330	295						
22-23/08/97	17	night (1800)	315	295						
		night (1940)	320	290						
		night (2140)	330	300						
		night (0120)	335	310						
		night (0415)	335	310						
		night (0600)	330	305						
		day (0715)	340	290						
06/09/97	18	day (1330)	340	300						
25-26/09/97	19	day (1750)	315	295						
		night (1910)	335	300						
		night (0030)	340	315						
		night (0355)	340	315						
		night (0510)	335	315						
		day (0625)	315	295						
		day (0730)	320	290						
14/10/97	20	day (1020)	340	300						
23-24/10/97	21	day (0845)	20	330						
		day (1725)	345	315						
		day (1900)	360	310						
		night (2030)	350	320						
		night (2150)	350	310						
		night (0040)	350	320						

Channel 10 (cont.)

Date	Survey number	Day or Night	Tracking location							
			A	B	C	D	E	F	G	H
23-24/10/97		night (0400)	350	320						
		night (0510)	350	310						
		day (0630)	340	310						
07/11/97	22	day (1330)	0	310						
22-23/11/97	23	day (1555)	350	290						
		day (1730)	340	305						
		day (1845)	335	300						
		night (2025)	345	300						
		night (2200)	350	320						
		night (2330)	345	320						
		night (0230)	5	335						
		night (0400)	0	325						
		day (0530)	345	305						
		day (0745)	345	315						
03/12/97	24	day (1335)	20	305						
10/12/97	25	day (0940)	340						35	
28-29/12/97	26	day (1745)	320						15	
		day (1905)	300						0	
		night (2045)	340						5	
		night (2230)	325						15	
		night (0010)	330						20	
		night (0150)	330						15	
		day (0515)	335						15	
		day (0710)	330						5	
13/01/98	27	day (1245)	340						10	
28-29/01/98	29	day (1740)	340						40	
		day (1900)	340						40	
		night (2035)	0	315						
		night (2205)	10						60	
		night (2335)	10						55	
		night (0245)	0						40	
		night (0420)	0	320						
		day (0540)	350	310						
		day (0700)	350	315						
06/02/98	30	day (1450)	350						40	
26-27/02/98	31	day (1650)	10	335						
		day (1810)	10						55	
		night (1930)	15	315						
		night (2100)	30	295						
		night (2225)	25						70	
		night (0200)	350	290						
		night (0345)	330	290						
		night (0500)	340	290						
		day (0615)	0	325						
		day (0700)	355	315						
10/03/98	32	day (1420)	360	340						
25-26/03/98	33	day (1645)	340						40	
		day (1800)	350	305						

Channel 10 (cont.)

Date	Survey number	Day or Night	Tracking location A	B	C	D	E	F	G	H
25-26/03/98		night (1930)	350	300						
		night (2045)	340	310						
		night (2210)	350	315						
		night (2330)	350	320						
		night (0240)	350	320						
		night (0420)	10	310						
		night (0545)	360	325						
		day (0700)	5	330						
		day (0915)	0	335						
15/04/98	34	day (1000)	350						40	
24-25/04/98	35	day (1630)	15	330						
		day (1730)	10	330						
		night (1830)	10	330						
		night (1945)	355	340					40	
		night (2030)	360	330					25	
		night (2130)	360	320					20	
		night (2225)	360	330					20	
		night (2300)	340	330					25	
		night (0145)	355	330					15	
		night (0230)	355	330					20	
		night (0440)	350	315					30	
		night (0530)	350	330					30	
		night (0605)	0	330					20	
		day (0650)	350	330					25	
		day (0805)	355	330					30	
09/05/98	36	day (0820)	345	320					5	
		day (1345)	330	320					15	
		day (1500)	340	320					10	
		day (1600)	350						10	
26-27/05/98	37	day (1300)	10	310					25	
		day (1630)	10	310					30	
		day (1700)	350	315					30	
		night (1745)	0	310					25	
		night (1840)	340	300					25	60
		night (1930)	350						30	60
		night (2045)	340	300					25	50
		night (2145)	340	310					20	45
		night (2240)	0	310					15	40
		night (0115)	330	300					20	55
		night (0300)	0	310					20	45
		night (0545)	330						30	45
		night (0630)	0	325					30	45
		day (0725)	345	320					20	45
		day (0830)	340	310					20	45
		day (0930)	340	310					25	
15/06/98	38	day (1445)	340	305					0	
24-25/06/98	39	day (1610)	340	310					20	40
		day (1645)	330	310					10	30

Channel 10 (cont.)

Date	Survey number	Day or Night	Tracking location A	B	C	D	E	F	G	H
24-25/06/98		day (1730)	340	315					0	5
		night (1915)	340	310					0	30
		night (2010)	335	320					15	25
		night (2110)	350	310					5	20
		night (2200)	355	305					5	30
		night (2300)	350	320					10	35
		night (0110)	345						5	20
		night (0340)	340						5	30
		night (0600)	350						5	25
		day (0650)	350						0	20
		day (0750)	345						0	30
		day (0830)	320						345	10
		day (0910)	310						345	20
		day (1000)	345						10	30
23/07/98	40	day (1630)	350	300					25	

Channel 12

Date	Survey number	Day or Night	Tracking location A	B	C	D	E	F	G
22-23/08/97	17	day (1645)	330	35	45				
		night (1910)	330	30					
		night (2110)	320	60					
		night (0100)	340	50					
		night (0350)	320	10					
		night (0540)	350	60					
06/09/97	18	day (1300)	340	5					
25-26/09/97	19	day (1545)	320	355					
		day (1730)	335	350					
		night (1845)	340	10					
		night (2030)	340	10					
		night (0010)	330	20					
		night (0330)	335	0					
		night (0445)	330	5					
		night (0605)	340	10					
		day (0710)	335	0					
14/10/97	20	day (1110)	320	345					
23-24/10/97	21	day (0935)	340	5					
		day (1655)	335	30					
		day (1830)	335	0					
		night (2005)	315	20					
		night (2125)	345	5					
		night (0015)	350	30					
		night (0330)	335	0					
		night (0450)	330	20					
		day (0605)	335	10					
		day (0725)	320	20					

Channel 12 (cont.)

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
07/11/97	22	day (1415)	330	0					
22-23/11/97	23	day (1500)	340	10					
		day (1700)	330	10					
		day (1820)	330	10					
		night (2000)	320	10					
		night (2140)	345	10					
		night (2310)	330	15					
		night (0200)	340	10					
		night (0345)	350	20					
		day (0510)	345	25					
		day (0700)	0	25					
03/12/97	24	day (1300)	325	15					
10/12/97	25	day (1015)	330	10					
28-29/12/97	26	day (1730)	340	15					
		day (1845)	340	15					
		night (2020)	330	20					
		night (2205)	330	10					
		night (2350)	340	15					
		night (0130)	335	25					
		night (0450)	335	25					
		day (0635)	335	20					
13/01/98	27	day (1320)	330	15					
28-29/01/98	29	day (1715)	340	20					
		day (1835)	350	20					
		night (2015)	335	10					
		night (2140)	340	15					
		night (2310)	345	20					
		night (0220)	340	10					
		night (0400)	335	10					
		day (0530)	335	10					
		day (0635)	335	15					
06/02/98	30	day (1530)	330	20					
26-27/02/98	31	day (1625)	330	10					
		day (1750)	335	15					
		night (1915)	335	15					
		night (2035)	335	20					
		night (2200)	330	10					
		night (0140)	335	10					
		night (0315)	340	15					
		night (0435)	335	15					
		day (0600)	335	10					
		day (0730)	335	10					
10/03/98	32	day (1355)	325	10					
25-26/03/98	33	day (1630)	335	15					
		day (1745)	330	10					
		night (1910)	330	10					
		night (2025)	330	20					
		night (2145)	330	20					

Channel 12 (cont.)

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
25-26/03/98		night (2300)	330	20					
		night (0215)	325	10					
		night (0400)	330	15					
		night (0530)	335	15					
		day (0630)	335	15					
		day (0800)	335	15					

Channel 14

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
25-26/09/97	19	day (1615)	100	230					
		night (1755)	100	230					
		night (1910)	105	130					
		night (2050)	95	135					
		night (0030)	110	140					
		night (0355)	95	110					
		night (0510)	85	65					
		day (0625)	110	260					
		day (0730)	100	250					
23-24/10/97	21	day (0845)	100	215					
		day (1730)	100	250					
		day (1900)	60	350					
		night (2025)	40	350					
		night (2145)	85	345					
		night (0040)	50	10					
		night (0400)	70	0					
		night (0510)	60	340					
		day (0630)	100	210					
		day (0750)	130	200					
07/11/97	22	day (1330)	90	270	340				
22-23/11/97	23	day (1555)	110	225					
		day (1730)	110	230					
		day (1845)	110	210					
		night (2025)	120	160					
		night (2200)	100	160					
		night (2320)	100	130					
		night (0400)	105	120					
		day (0530)	110	130					
		day (0745)	115	205					
03/12/97	24	day (1300)	100	150					
10/12/97	25	day (0940)		230	350				
28-29/12/97	26	day (1745)	105	200					
		day (1905)	95	160					
		night (2045)		110	70				
		night (2230)		95	70				
		night (0010)		120	50				
		night (0150)		95	40				

Channel 14 (cont.)

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
28-29/12/97	26	day (0515)		120	15				
		day (0710)		220	350				
13/01/98	27	day (1245)		230	355				
21/01/98	28	day (0530)		230	350				
28-29/01/98	29	day (1740)	110	210					
		day (1900)	80	0					
		night (2035)	60	355					
		night (2205)	60	10					
		night (2335)	60	350					
		night (0245)	70	340					
		night (0420)	80	345					
		day (0540)	105	235					
		day (0700)	120	220					
06/02/98	30	day (1445)	80	10					
26-27/02/98	31	day (1645)		60	15				
		day (1805)	80	10					
		night (1930)	65	350					
		night (2100)	70	315					
		night (2225)	55	350					
		night (0200)	45	340					
		night (0345)	70	350					
		night (0500)	60	350					
		day (0615)	70	345					
		day (0700)	80	40	20				
10/03/98	32	day (1420)	70	20					
25-26/03/98	33	day (1645)	80	20					
		day (1800)	85	20					
		night (1930)	85	40					
		night (2045)	85	30					
		night (2210)	85	20					
		night (2330)	75	40					
		night (0240)	60	30					
		night (0420)	70	20					
		night (0545)	70	350					
		day (0700)	65	330					
		day (0915)	70	330					
15/04/98	34	day (1000)		30	10				
24-25/04/98	35	day (1630)		80	25				
		day (1730)		80	30				
		night (1830)		80	20				
		night (1945)		80	25				
		night (2030)		65	30				
		night (2130)		95	55				
		night (2225)		95	35				
		night (2300)		95	40				
		night (0145)		65	30				
		night (0230)		85	40				
		night (0440)		70	30				

Channel 14 (cont.)

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
24-25/04/98	35	night (0520)		70	40				
		night (0600)		95	45				
		day (0645)		95	50				
		day (0800)		120	70				
09/05/98	36	day (0815)	65	5					
		day (1345)	65	25					
		day (1500)	80	40	15				
		day (1600)	75	25					
26-27/05/98	37	day (1300)		250	340				
		day (1630)		315	350				
		day (1700)		315	350				
		night (1745)		300	350				
		night (1840)		310	350				
		night (1930)	75	345	0				
		night (2045)	80	10	5				
		night (2145)	80	5	0				
		night (2240)	70	7	0				
		night (0115)		45	5				
		night (0300)	60	20	10				
		night (0545)		30	10				
		night (0630)	70	20	5				
		day (0725)		20	5				
		day (0830)		50	10				
		day (0930)		50	10				
15/06/98	38	day (1445)		120	40				
24-25/06/98	39	day (1610)		35	10				
		day (1645)		35	10				
		day (1730)		40	10				
		night (1915)		50	15				
		night (2010)		45	25				
		night (2110)		70	30				
		night (2200)		50	25				
		night (2300)		50	30				
		night (0110)		30	10				
		night (0340)		30	10				
		night (0600)		45	20				
		day (0650)		45	20				
		day (0750)		45	20				
		day (0830)		40	20				
		day (0910)		45	20				
		day (1000)		45	20				
23/07/98	40	day (1630)	70	30					
26/10/98	41	day (0930)		230	350				
26/10/98		day (1030)		230	350				
19/03/99	42	day (1100)	70	350					
29/05/99	43	day (1000)		260	355				

Channel 16

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
22-23/08/97	17	day (1645)	350	80	100				
		night (1910)	20	80					
		night (0540)	330	80					
		day (0650)	0	70					
06/09/97	18	day (1300)	325	70					
25-26/09/97	19	day (1545)	325	60					
		day (1730)	305	60					
		night (1845)	320	70					
		night (2030)	325	65					
		night (0010)	330	50					
		night (0330)	320	60					
		night (0445)	320	50					
		night (0605)	310	60					
		day (0710)	305	60					
14/10/97	20	day (1110)	330	50					
23-24/10/97	21	day (0935)	330	60					
		day (1655)	350	70					
		day (1830)	340	70					
		night (2005)	330	70					
		night (2125)	355	60					
		night (0015)	340	50					
		night (0330)	355	60					
		night (0450)	340	60					
		day (0605)	350	60					
		day (0725)	320	70					
07/11/97	22	day (1415)	340	60					
22-23/11/97	23	day (1500)	340	70					
		day (1700)	330	70					
		day (1820)	330	60					
		night (2000)	340	60					
		night (2140)	330	70					
		night (2310)	350	60					
		night (0200)	345	60					
		night (0345)	340	70					
		day (0510)	340	70					
		day (0700)	330	70					
03/12/97	24	day (1300)	340	65					
10/12/97	25	day (1015)	340	75					
28-29/12/97	26	day (1730)	340	75					
		day (1845)	340	75					
		night (2020)	345	60					
		night (2205)	335	75					
		night (2350)	350	65					
		night (0130)	340	70					
		night (0450)	350	75					
		day (0635)	340	75					

Channel 16 (cont.)

Date	Survey number	Day or Night	Tracking location						
			A	B	C	D	E	F	G
13/01/98	27	day (1320)	330	70					
28-29/01/98	29	day (1715)	330	75					
		day (1835)	355	70					
		night (2015)	340	65					
		night (2140)	340	70					
		night (0220)	345	65					
		night (0400)	340	75					
		day (0530)	330	75					
		day (0635)	330	75					
06/02/98	30	day (1530)	340	70					
26-27/02/98	31	day (1625)	340	70					
		day (1750)	345	70					
		night (1915)	350	70					
		night (2035)	340	75					
		night (2200)	345	80					
		night (0140)	335	75					
		night (0315)	335	65					
		night (0435)	340	75					
		day (0600)	340	70					
		day (0730)	340	70					
10/03/98	32	day (1355)	330	75					