Real time Monitoring of Rehabilitated Kangaroos

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Abstract

Radio-telemetry in various forms has been used by researchers for many years to track the movements of wildlife. Until relatively recently, the majority of tracking devices were simple radio beacons that required the use of directional aerials to locate and record the position of the animals being studied. Recent enhancements have allowed tracking devices to provide accurate position information by including a GPS unit in the device. In support of a research project being conducted to study rehabilitated kangaroos after they have been released back into the wild, a low cost, real time positioning system was required that could track up to 50 animals simultaneously at multiple release sites throughout south east Queensland. Several existing commercial solutions provide accurate real time position information by transmitting the GPS information via the ARGOS satellite system. Others achieve the same result by sending SMS messages. Devices which do not provide real time information act as data loggers and allow the position information to be extracted after the tracking device has been retrieved. Of these options, satellite tracking is the ideal solution but is inherently expensive with costs of approximately $500 per animal per month. In a project tracking 50 animals for 12 months this would amount to $300,000 in satellite charges. The units which employ SMS messaging are unsuitable due the poor mobile phone coverage in the majority of research locations in Australia. Up front costs are also significant with commercially available tracking devices costing around $6,000 per unit. Although they have been used in many previous studies it was also felt that neck collars were unsuitable for kangaroos. As none of the many equipment manufacturers were able to satisfy the requirements it was decided to develop custom built tracking harnesses based around VHF radio and the APRS technology which is currently used around the world for vehicle tracking. This paper reviews the capabilities of off-the-shelf tracking devices and discusses the suitability of the various implementations for use with kangaroos.

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1 Introduction

Radio-telemetry in various forms has been used by researchers for many years to track the movements of wildlife and many books and papers have been written on the subject. In order to support my PhD research into post release survival of rehabilitated kangaroos I examined the commercially available wildlife tracking systems and came to the conclusion that they were in the most part extremely expensive and did not provide the functionality that I required. The only available option for real time monitoring of animals is the ARGOS based satellite collars. The purchase price of these collars combined with the on-going ARGOS fees meant that number of animals being tracked and the duration of the tracking would be severely curtailed.

This led me to investigate the possibility of building my own tracking devices and to investigate, why, in the 21st century wildlife researchers were still essentially using technology that was developed nearly 40 years ago. There just had to be a better method than spending large amounts of time wandering around in the field with directional antennas to obtain information about the movement of wildlife.

The obvious first place to start was by reviewing what was available and this eventually caused me to look at the techniques currently used for tracking vehicles. In this paper I will present the results of these investigations and describe the tracking devices that I am in the process of building that will result in a cost effective, real-time tracking system specifically designed around the needs of wildlife researchers in Australia.

In addition to reviewing the available tracking hardware, I also reviewed the available software for processing the collected information. My needs were fairly straightforward. I wanted to be able to collect position information in real-time and display the details on a map. I didn't want to spend a fortune on elaborate GIS software and I wanted the interface to be user friendly, directed specifically at the needs of wildlife researchers and most of all, available for display across the internet. Once again the available offerings fell well short of my expectations either in terms of price, ease of use or functionality and again led me down the path of developing my own mapping software using the freely available Google Maps API. Having spent the early part of my life as a mathematician and the past 25 years as a software developer, this was not as difficult as it may sound. In this paper I will describe the mapping interface that I have developed and is currently in use tracking Koalas in Redlands shire.

All of this was essentially infrastructure that was required to support my PhD project and that in my naivety I expected to be readily available. The project itself

is intended to monitor the survival of rehabilitated kangaroos and to determine what factors influence their ability to survive when released back into the wild. In this paper I will describe the background to this project.

2 Summary of tracking technology

2.1 Radio beacons and Triangulation

For the last 40 years or so, the traditional view of radio tracking is of an animal fitted with a radio collar and a field worker walking around the bush with a directional antenna recording location information. This approach works reasonably well but suffers from a number of drawbacks.

- In long term studies, we often cannot track the animals several times a day, every day of the study. This means that we have to take samples and draw an inference from the samples.
- Radio signals are often blocked or deflected by vegetation or terrain, so it may turn out that the animal cannot be located on the day that we choose to track it. Readings do not always cover the full range of weather conditions, and may not include adequate readings during the night when movement through the bush is restricted.
- The very act of approaching the animal may change its behaviour and hence affect the validity of the readings. This is Heisenberg's Uncertainty Principle as applied to wildlife research.
- In the event of a mortality occurring outside of a scheduled tracking period it may be some time before it is detected, by which time it may not be possible to determine the cause.

Some of these issues can be addressed by using a triangulation technique whereby three or more directional antenna take simultaneous compass bearings on the radio signal and these are then plotted on a map to determine the approximate location of the animal. This approach limits the amount of trudging around that is required and thus minimises the disturbance of the animals and their environment. It does however have the potential to introduce additional errors into the accuracy of the location data.

2.2 GPS, DGPS and WAAS

The biggest advance in radio tracking, and in fact in navigation in general, came about with the introduction of the Global Positioning System (GPS).

2.2.1 Global Positioning System (GPS)

The NAVSTAR GPS system consists of 24 satellites in continuous orbit around the earth controlled and monitored by a series of earth stations. The satellites are operated by the US Defence Department and the first ones were launched in 1978 with the full contingent of 24 in operation by the middle of 1993 (Ferguson 1998). The satellites are divided among six orbital paths designed in such a way that any location on earth will have a minimum of six satellites in view at all times. A GPS receiver requires 4 satellites to obtain an accurate position fix. The receiver calculates its position relative to each satellite by measuring the time delay in the signals transmitted by the satellites. This information is used in a form of spherical triangulation to determine the position of the GPS receiver. (Millspaugh and Marzluff 2001; DePriest 2002)

Prior to May 2000 the signals available to civilian GPS receivers contained a deliberate random error intended to limit the accuracy of the system to users other than the US defence department. This error, known as Selective Availability (SA), meant that the computed position was on average only accurate to within 50 metres. Since the removal of SA, positions are generally accurate to within 10 metres.(Ferguson 1998; Millspaugh and Marzluff 2001) Errors still exist in the position calculation caused by such things as variations in the satellite clocks, atmospheric interference and inaccuracies in the GPS receiver. Various techniques have been employed to improve positional accuracy by correcting for the different error factors. The most important of these are DGPS and WAAS, both of which we will discuss shortly.

From an operational perspective, there are various architectural features of the GPS system that need to be taken into account when designing and setting up a GPS based radio tracking system. A major consideration is concerned with the 4 hour life-time of the ephemeris data that is downloaded into the GPS receiver from the satellites. Ephemeris data is transmitted every 30 seconds by each satellite and is required by the receiver to compute the positions of the satellites in the sky.(DePriest 2002) A modern GPS receiver can download the ephemeris data in about 36 seconds, add on the 15 or so seconds to obtain a fix and we have a rough idea of how long our receiver needs to be active in our tracking devices. Since the ephemeris data is considered to be valid for 4 hours, any subsequent position fixes within the next 4 hours can be computed in about 15 seconds. (Ferguson 1998; Millspaugh and Marzluff 2001) If we design our transmission schedule in order to conserve battery power and decide to transmit position information every 4 hours we will most likely require the maximum time to compute the position and defeat the original purpose. Using a 2 hourly transmission schedule will on average consume less power, and provide more data, than a 4 hour schedule due to the reuse of the ephemeris data. Note that

some texts (Millspaugh and Marzluff 2001) for example, state that the refresh of the ephemeris data can take up to 12 minutes. This is not the case for modern 12 channel GPS units.

2.2.2 Differential GPS (DGPS)

DGPS is a mechanism for improving the accuracy of GPS receivers by using a series of land based beacons to calculate position errors caused by atmospheric conditions and clock errors. The DGPS beacon knows its own position to a high degree of accuracy and is thus able to compare the data received from the satellites with its own known position and thus calculate the inherent errors in the signals. The beacon transmits the correction data which can be received by a DGPS receiver which is a separate device that can be connected to the GPS receiver. The accuracy of the correction data is dependent on the proximity of the GPS receiver to the DGPS beacon but in general will increase the accuracy to within 1-5 metres.(DePriest 2006)

The usefulness of DGPS is limited in Australia by the fact that beacons are maintained for coastal shipping navigation and are thus only available along the coastal strip. This lack of availability of beacons and the requirement for an additional receiver effectively eliminates DGPS from the picture for wildlife tracking.

It is possible for a GPS receiver to store additional data (in the form of satellite ID and pseudo-range data) with every GPS position to enable differential correction of GPS positions at a later time without requiring the use of DGPS beacons. This process is generally unsuitable for wildlife tracking as it requires a more complex (and more expensive) GPS unit and increases the size of the data for each GPS reading. In addition, the procedure for performing the post-processing of the data is not in itself a simple process.

2.2.3 Wide Area Augmentation System (WAAS)

WAAS, (also known as WADGPS and EGNOS), is a relatively new method of correcting GPS errors. It is similar in concept to DGPS with the major exception that an additional receiver is not required to receive the correction signals. Ground stations with precisely known co-ordinates collect correction data and pass it to a master station which uploads the data to a geo-stationary satellite, which in turn sends out the correction data. This data is received by one of the free available channels in a WAAS enabled GPS receiver. Use of WAAS will increase the accuracy of the GPS position to within 3 metres.(DePriest 2006) Unfortunately WAAS is not yet available in Australia and it will be quite some time before it will be of practical use in remote areas.

2.2.4 Local Corrections

In most of the Australian mainland, neither DGPS beacons nor WAAS is available to correct errors in GPS readings. It is however possible to correct the majority of errors by using a form of differential correction that I call the Field Augmentation System (FAS). The basic principal of all GPS correction systems is that by taking a GPS reading at a location of known position and comparing it the instantaneous location given by the GPS unit, the error in the reading can be computed and used to adjust readings taken at nearby locations. The calculated correction factor can be sent to other GPS units to allow them to correct their readings.

Based on this principle, if we can identify a fixed location on a map, such as a building or a street intersection for example, we can take a GPS reading of that position and determine its “real” location from the map. We can then calculate the local error and use this as a correction factor to be applied to all the other position fixes that we take in the general area at about the same time. A useful side effect of this system is that it also corrects for incorrectly calibrated maps.

We can use this in a traditional wildlife radio tracking situation using directional antenna, by taking a GPS reading at the same fixed location each time we go out to record the locations of animals. We can then manually, or programmatically correct all the readings taken during that tracking session using the calculated correction factor. This technique can in practice achieve a high degree of positional accuracy with no additional investment. As we shall see shortly this feature has been built into our APRS wildlife tracking system by having the local repeater stations send their GPS location data at predefined intervals. In this situation our radio repeaters are in effect functioning as DGPS beacons.

It has been noted by some sources that this form of “poor mans DGPS” may not be effective as DGPS correction requires knowledge of which satellites were used to determine the location fix. In the absence of DGPS and WAAS in the majority of Australian locations, personal experience has shown that this technique is effective in reducing position errors.

To see the effect of GPS errors in practical terms a difference of 0.00001 degrees of Latitude is equivalent to about 1.1 metres of difference on the ground (at the latitude of Brisbane), and a difference of 0.00001 degrees of Longitude is equivalent to about 1.0 metres on the ground. This means that we have to be extremely diligent about the precision of our calculations. If we chose to round our Latitude and Longitude readings to 3 decimal places (ie +/- 0.0005) then we introduce a potential error of up to 50 metres in both Latitude and Longitude in

real terms which means that we can only be sure that our location lies within a circle with a radius of about 70 metres from our recorded position.

2.3 ARGOS Satellite systems

The ARGOS satellite system is run by a subsidiary of the French Space Agency in Toulouse. ARGOS collects data from special transmitters known as PTT's (Platform Terminal Transmitters) and delivers the data to subscribed users through the internet. Tracking collars combining a GPS receiver and a PTT can thus provide close to real-time tracking of wildlife. Unfortunately the costs associated with using ARGOS are extremely high at about $500 per animal per month. Combined with the $6,000 price tag of a GPS satellite collar, this makes this form of tracking prohibitively expensive for any sizable tracking project.
For example, to track 50 kangaroos for 12 months would cost about $300,000 for the purchase of the collars plus another $300,000 for the ARGOS tracking costs.

2.4 GPS data loggers

Another type of radio collar incorporating a GPS receiver is the GPS data logger. These devices are designed to record GPS positions at predefined intervals and to store the information in the collar for later retrieval. Data loggers can either simply store the data until the collar is retrieved, or store the data but allow it to be uploaded on command using a local radio link.(Millspaugh and Marzluff 2001) The majority of these systems are also equipped with a standard VHF or UHF radio beacon that allows the animals to be located using a directional antenna.

2.5 Real-time using SMS

A recent innovation in tracking collars involves the combination of a GPS receiver and SMS messaging via the GSM mobile phone network to provide real-time tracking. Originally developed by Tracker in Finland and now being adopted by other collar manufacturers this technology is a big step forwards for tracking devices. Unfortunately, in most areas of Australia where wildlife research is conducted, the GSM network is unavailable which makes this otherwise attractive alternative unusable.

3 Automatic Position Reporting System

3.1 APRS overview

APRS is a digital tracking system developed by radio amateurs and is currently used mainly for vehicle tracking.(Wade 2000). The technology arose from the

concept of packet radio which in turn arose from packet switching networks. It is basically a communication system which transmits discrete “packets” of information across wide areas using anonymous repeater stations. A repeater station will simply listen for packets and retransmit them. The packets fly around in the ether until eventually they reach the intended recipient. This principal was taken up by amateur radio enthusiasts to develop the first APRS systems.

The basic components of an APRS system are a tracking device and a network of digital repeaters (digi-peaters). The tracking devices themselves consist of a GPS receiver, a smart audio encoder and a radio transmitter. The GPS receiver is instructed by the smart encoder to record a location fix at a programmable interval. This fix is used to construct a digital radio packet in a pre-defined format. The packet is converted to audio tones by the smart encoder and dispatched at low power by the radio transmitter. This signal is then picked up by any repeater station within range and retransmitted at increased strength to enable it to be picked up by still more distant repeaters. Eventually the signal will reach the intended base station where it is transferred into a PC via a Terminal Node Controller (TNC).

In the 1990’s the enormous free bandwidth of the Internet was to allow real-time global monitoring of APRS signals. A large amount of the APRS traffic is being monitored and fed into the global APRS internet system. This allows for tracking signals to be received in real-time without the need for a VHF receiver and a TNC.

3.2 APRS and wildlife tracking

The big question was could we harness the power of APRS for use in tracking wildlife in remote areas of Australia? And the answer, of course, is yes. The components used to construct the tracking collars are readily available and, as an added bonus, are relatively inexpensive. The various components of the APRS system are shown in Figure 1.

In Australia there is not an established network of APRS repeater stations and so we may need to install one or more solar powered repeaters at each release site for the duration of the tracking project. However, since our data entry is performed across the internet, we only need to boost our signal far enough to reach a base station that has internet access. In many situations this means simply as far as the research station, ranger station or homestead at the release site.

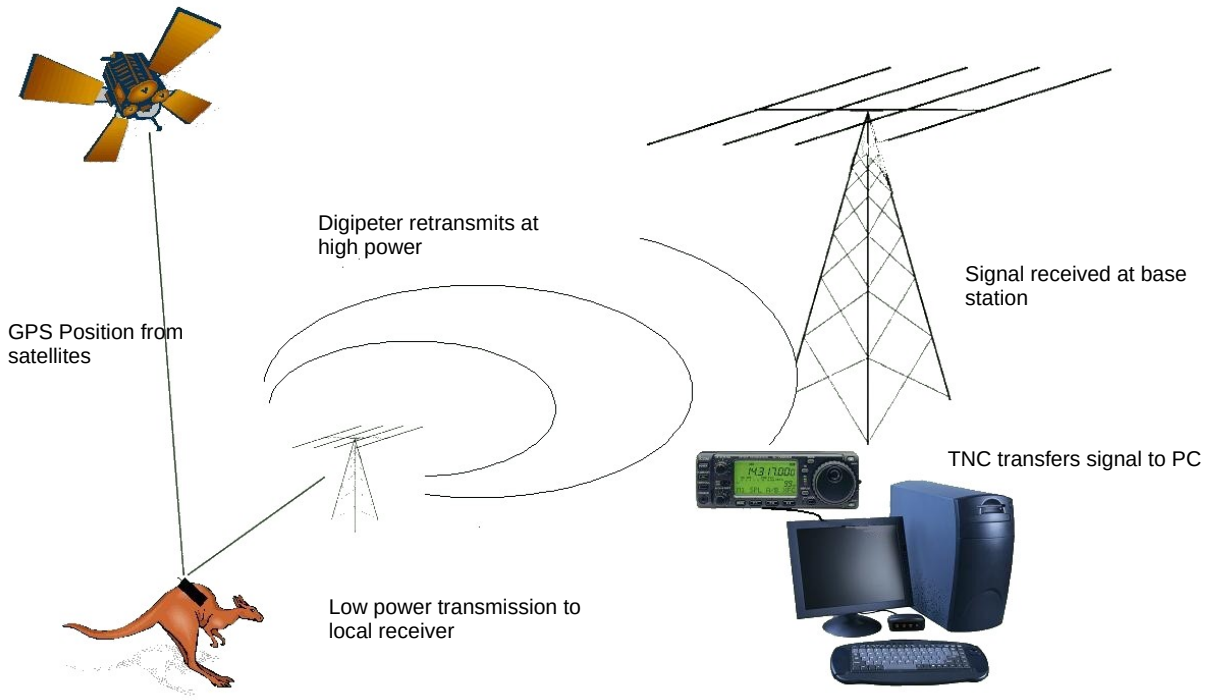

Figure 1 The main components of the APRS wildlife tracking system

3.3 APRS tracking devices

The tracking devices used by the APRS system consist of a small GPS unit, a smart audio encoder and a VHF transmitter, (along with the power supply, aerial and so on) which can readily be built into a collar or harness, suitable for kangaroos and other small to medium sized mammals. The core components are shown in Figure 1.

An enhancement to the use of standard GPS receivers is the Fastloc® GPS receiver developed by Wildtrack Telemetry Systems (UK). This type of GPS does not require ephemeris or almanac data and consequently can obtain a reliable fix in a fraction of a second. This has major ramifications for the power consumption and hence battery size of the tracking devices. A significant increase in the battery life and decrease in the time between fixes will have a marked influence on the quality of the data obtained and the lifetime of the tracking project.

Figure 2 APRS components, GPS above and smart encoder below. Radio transmitter and batteries not shown.

3.4 Collars and Harnesses

In my personal opinion, attaching tracking devices to kangaroos using neck collars is not an ideal solution. Kangaroo's necks are a one of the most fragile parts of their bodies and neck collars are prone to get caught on fences and undergrowth and interfere with the normal behaviour of the animals. Our intention is to use small backpack type harnesses with biodegradable straps to allow for automatic drop off at the end of the study, and to provide a break point in the event that the harness gets caught on a protruding object.

3.5 VHF digipeters

The VHF digipeter is simply a radio transmitter/receiver that constantly monitors the APRS frequency and retransmits any incoming signals at higher strength. We plan to construct self contained, lockable boxes with an integrated solar panel and self supporting fibreglass VHF antenna on a welded galvanised sled suitable for transport in the tray of a ute, or the back of a 4wd. A lock down chain and radio-active materials labelling will help to discourage theft of the units in remote areas.

3.6 Base stations

The Base station comprises a VHF antenna , a VHF receiver and a Terminal Node Controller (TNC). The TNC is a USB device for transferring radio signals into a PC.

Incoming APRS packets are filtered by software running on the PC and either stored locally or passed to a web application to be stored in a MYSQL database on a website.

3.7 Mapping

There are various mapping interfaces to APRS all of which have their particular strengths and weaknesses. We have chosen to implement our own interface using the Online Animal Records System developed at the Long Grass Nature Refuge and the freely available Google Maps interface. This gives us total flexibility in the implementation and has the immeasurable advantage of being web based. This means that the position information can be entered and viewed from anywhere that an internet connection is available.

3.7.1 Google Maps

For those not familiar with Google Maps, it is a terrific facility that has a totally free web page programming interface using Javascript. It has accurate street level information available for all of Australia with the added advantage of satellite image overlays and programmable user defined maps. I have used the custom map interface to implement 1:25,000 topographic map overlays in our release sites as shown in Figure 2.

The Online Animal Record System that forms the framework for our online tracking interface also has the facility to manually enter position information that has been obtained using a handheld GPS. This means that fixes obtained from

standard radio tracking collars can be displayed using the same interface. This data can also be entered over the internet.

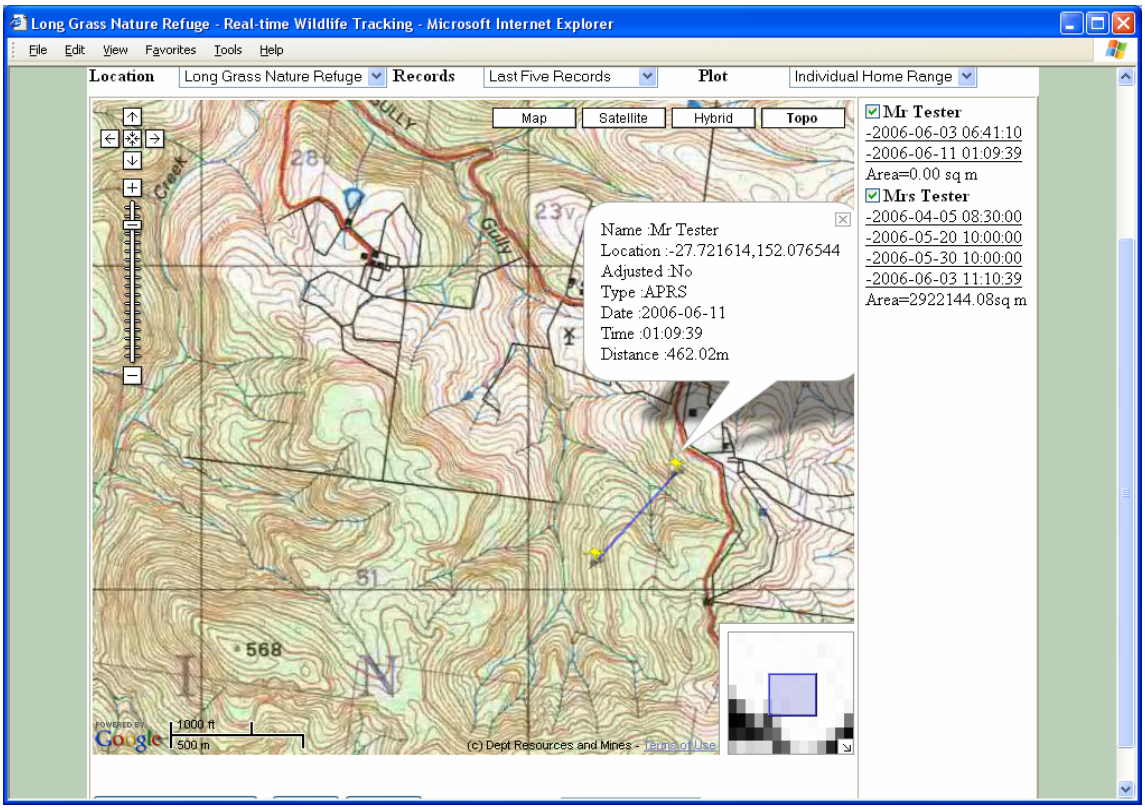

Figure 3 Customised Topographic Map Display in Google Maps

This interface is currently being used to track Koalas in Redlands Shire in Brisbane. Position information is determined, using directional radio collars and a hand-held GPS. Figure 3 shows the degree of detail that is available from the satellite images in populated areas. Switching to MAP mode on this screen displays detailed street maps.

Many commercial tracking collars include additional hardware known as a mortality sensor, which performs various functions depending on the type of collar in use. This additional circuitry increases the size and power consumption of the tracking device. Because of the nature of our new tracking devices we are able to shift this functionality away from the hardware and program it into the mapping interface. This Software Mortality Sensor can be programmed to sound an alarm, send an email or even an SMS message if the animal's position does not change for a predetermined length of time and can be set at different values for each individual animal, and can be modified "on the fly" without having to retrieve the collar. This not only reduces the cost, size and complexity of the tracking device but also enormously increases its flexibility.

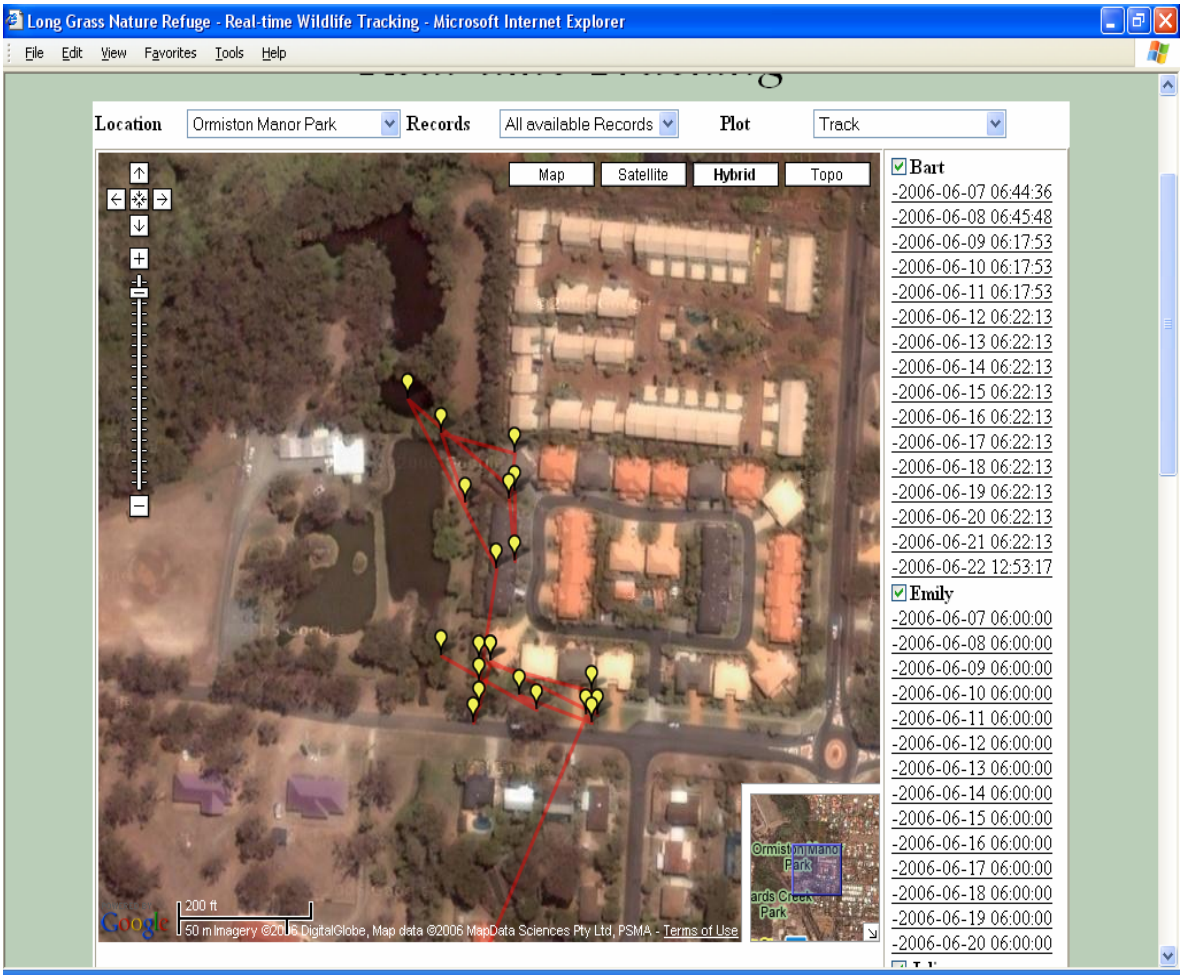

Figure 4 Tracking interface developed using Google Maps

4 The kangaroo tracking project

Everything that we have discussed so far is essentially infrastructure required for a PhD research project that will be conducted over the next 3 years with the aim of quantifying the survival rate of rehabilitated kangaroos following their release into the wild. As part of this project I plan to compare the monitored survival rate of rehabilitated kangaroos with the survival rate of the resident kangaroo populations and attempt to determine the effects of various release preparation strategies on the measured survival rates. It is hoped that this information will help wildlife carers in the selection of release sites and in the design of effective release programs for rehabilitated kangaroos.

Central to the question of survival of kangaroos following release back into the wild is an understanding of the major causes of success and failure of past wildlife reintroduction programs.

4.1 Why Reintroductions and Translocations Fail

A review of all known documented macropod reintroductions in Australia prior to 1991 (Short *et al.* 1992) concluded that the majority of them had been unsuccessful and in all cases the lack of success could be attributed to the failure to control predators at the release site. The failure of various other documented reintroduction programs for birds and mammals have similarly been attributed to high mortality due to predation of which those described by (Pahl 1987; Priddel and Wheeler 1994; Augee *et al.* 1996; Fajardo *et al.* 2000; Fischer and Lindenmayer 2000; Priddel and Wheeler 2004; Molony *et al.* 2006) are but a few examples. In many cases these relocations were spectacularly unsuccessful. A notable example of this is the 670 Quokka released between 1972 and 1988 at a 254 hectare field station at Jandacot in Western Australia. By the end of 1988, despite exhaustive trapping, only 9 Quokka were detected at the release site. (Short *et al.* 1992). Another example is the study done in Victoria into the relocation of troublesome urban possums by the RSPCA, in which it was concluded that the majority of animals were killed by predators within 3 months of release (Pietsch 1994).

Armed with this overwhelming body of evidence, combined with personal experience of many groups of released kangaroos in a relatively predator controlled environment, I find surprising the repeated claims by wildlife carers that all of their rehabilitated animals were alive more than 12 months after release. This statement would be unbelievable even if it weren't for the fact that mortalities amongst wild populations of kangaroos are known to be significantly greater than zero. Consider even the local population of Agile wallabies at Darwin's East-point reserve of which more than 1000 from an initial population of over 2,500 were killed by dogs and motor vehicles in less than 7 years.

4.2 Wild Dogs in SE Australia

Laurie Corbett, who is recognised as one of Australia's foremost authorities on the dingo, concluded in 1995 that there were no populations of pure dingos in southern Australia. (Corbett 2001). To many people this is probably an extreme view but even the Australian Dingo Conservation Society, which was formed specifically to protect the dingo, agree that the dingo populations of south eastern Australia consist of more than 90% hybrids.

Now why is it so important to make the distinction between dingos and wild-dogs? Apart from the differences in breeding cycles and behaviour that occurs when dingos cross with domestic dogs(Corbett 2001), there is an ethical issue that needs to be dealt with before we can discuss the concept of controlling wild dogs. The ethical issue comes about because dingos are as much a part of the Australian native fauna as are kangaroos so if we were dealing with pure dingos we would have difficulty justifying the argument that we should control one native animal in order to improve the survival prospects of another native animal. When we are discussing hybrid dogs the ethical argument does not arise. We are no longer discussing the relative merits of one native animal over another, but instead are discussing the control of a feral animal in order to allow the survival of native fauna.

4.2.1 Options for dealing with Dingos

The reality is that dingos (and now wild dogs) have long been a part of the ecology of Australia and kangaroos have developed strategies to minimise their losses to predation. Recent studies have concluded that a certain level of dingo activity serves to reduce the effects of other predators such as foxes and cats and also serves to keep the prey species alert for predators. The conclusions from this are that total eradication of dingos from an area may actually be detrimental to kangaroos, which will be easy prey when dogs eventually migrate back into the area.

However, when dealing with the release of rehabilitated kangaroos, we are not looking at a normal situation. When animals are released into a new area, for whatever reason, the initial week or two involves a raised level of activity whilst the animals become familiar with the terrain, locate food, water and resting sites, interact with the local population, become familiar with local sights, sounds and smells and determine which are safe and which are dangerous areas. All things related to the general process of "settling in". During this period of heightened activity they are particularly prone to predation.

Once they have settled in to an area, kangaroos establish vigilance patterns that allow them to deal effectively with dingos. With rehabilitated kangaroos who have never encountered a wild dog before, the most important encounter is the first one. A moment's hesitation in recognising the threat or reacting to the threat is enough to lead to the animal falling victim to the dingo. It is important therefore that rehabilitated kangaroos are able to recognise dingos as predators before they are released back into the wild.

The options available to us for dealing with dingos when releasing rehabilitated kangaroos are

- Predator Exclusion
- Predator Control
- Predator Recognition Training
- Predator Disruption

4.2.2 Predator Exclusion

The design and use of predator exclusion fencing is well documented. When dealing with reintroductions of endangered species, such as the Bilby, the cost of construction and on-going maintenance can be justified, however, it is difficult to imagine a situation where it would be possible to totally exclude dingos from a release site for rehabilitated kangaroos. Indeed, if the release site is fenced, can it really be claimed that the animals have been returned to the wild?

There are also several downsides to exclusion fencing.

- The animal populations within the fenced area become genetically isolated from the population at large with the potential for in-breeding.
- Vigilance behaviour becomes relaxed over time with the result that should a dingo breach the fence, or a kangaroo escape, the chance of mortality is significantly increased.
- In the absence of predation and avenues for migration, population management procedures need to be implemented.

In general, exclusion fencing is not a viable option for kangaroo release sites.

4.2.3 Predator Control

Depending on the numbers of dingos in the area, control measures such as shooting, baiting and trapping may need to be used for several months prior to any planned release. The discussion of the use of 1080 baits to control wild dogs is a long and contentious one which I do not want to enter into in this paper. Use of soft jawed traps is similarly contentious. As for shooting, personal experience has shown that in forested or semi-forested country, the only effective method of shooting wild dogs is by “calling them in” by simulating dingo howls. Except in the case of large population densities, opportunistic shooting of dingos is unlikely to be effective.

As with exclusion fencing there is a danger of overdoing the control measures. Total temporary eradication of dingos can lead to relaxed vigilance behaviour by the kangaroo population that leaves them open to large rates of mortality when the dingos eventually return to the site.

4.2.4 Predator Recognition Training

As mentioned previously, the most important encounter that a rehabilitated kangaroo will have with a wild dog is the first encounter. If the animal is not able to immediately recognise that a wild dog poses a threat and take flight, the first encounter will generally be the last. To this aim, several researchers (Griffin *et al.* 2000) have developed techniques for training captive animals to recognise predators prior to being released. This training utilises classical conditioning techniques whereby a conditioned stimulus (CS) is paired with an unconditioned stimulus (UCS) to produce a conditioned reflex (CR). The UCS elicits the CR as an unlearned, reflexive response. After several repetitions of the CS+UCS, the CS alone will elicit the same response as the UCS. In plain language we present the kangaroos with a model dingo (CS) and at the same time frighten them with loud, unfamiliar noises (UCS) to cause them to take flight (CR).(Griffin *et al.* 2001)

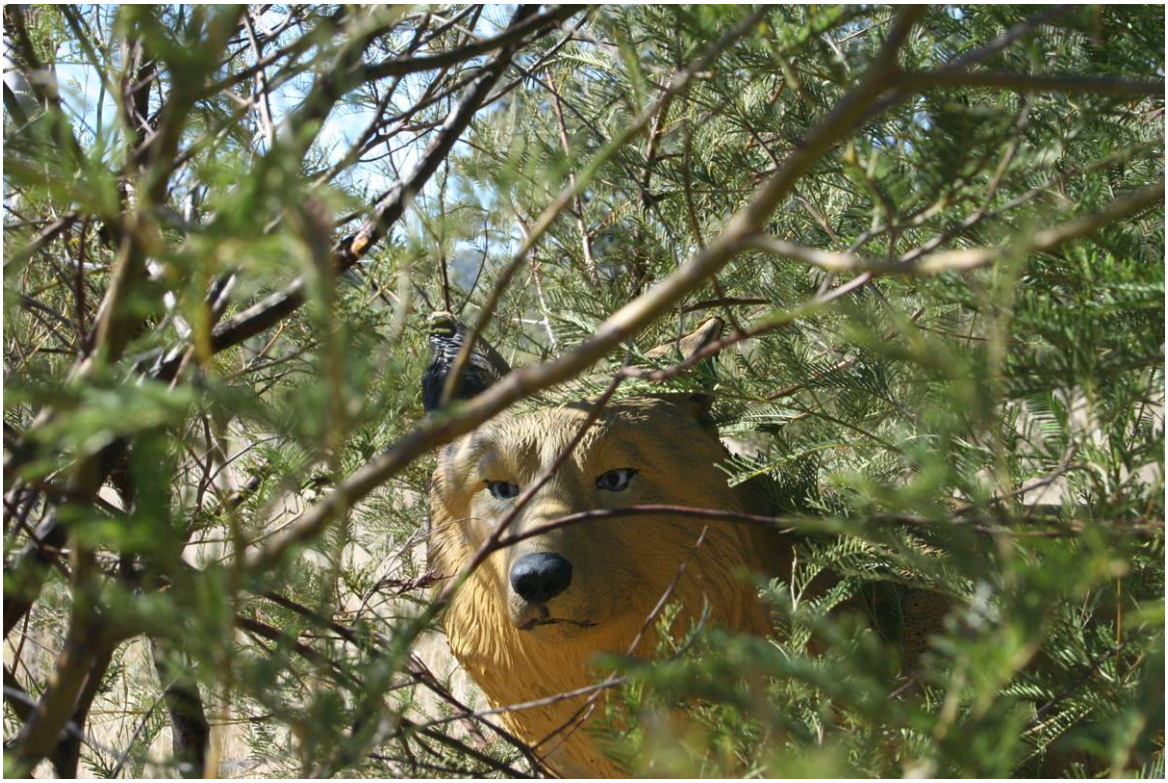

Figure 5 Full-sized dog model used for Predator Recognition Training

For Predator recognition training at Long Grass Nature Refuge we use a full size 3D rubberised Wolf model (available from Archery suppliers) painted to look more like a dingo as shown in Figure 4. A month prior to release the kangaroos

are given 3 training sessions over a period of several days as recommended by Griffin et al (2000).

Needless to say, the common practice of wildlife carers of raising kangaroos alongside domestic dogs is likely to result in the animals failing to react sufficiently quickly to survive their first encounter with a wild dog.

4.2.5 Predator Disruption

Given that it is generally accepted that wild kangaroos develop strategies to deal with wild dogs, and given that the most critical period following release into the wild is the settling in period, it is possible to increase the survival rates of kangaroos that are being released alongside an existing resident population, by disrupting the hunting patterns of wild dogs during the settling in period. The disruption process consists of patrolling the release site, either on foot or in a vehicle, several times each day between late evening and early morning in the weeks immediately following the release. This strategy was original used with considerable success against foxes when releasing rabbits to supplement the local population in the Ebro valley in northern Spain(Calvete and Estrada 2004) and has been adapted for use with kangaroos and wild dogs at the Long Grass Nature Refuge.

5 Conclusion

Radio tracking of wildlife is an essential tool for wildlife researchers across a whole range of species, environments and fields of research. Recent technological advancements combined with the enormous expansion of the internet have provided a framework to improve the quality and quantity of data available to the researcher whilst at the same time reducing the amount of expensive and time consuming field work that is required to obtain the data.

This paper has discussed a new generation of tracking devices that are under development and shown how the data obtained from these devices can be displayed in a cost effective, user friendly web based framework. It has presented the outline of a tracking project that will use the new devices to study the post release survival of rehabilitated kangaroos in south east Queensland.

References

Augee M, Smith B, Rose S (1996) Survival of wild and Hand-reared Ringtail Possums (*Pseudocheirus peregrinus*) in Bushland near Sydney. *Wildlife Research* **23**, 99-108.

Calvete C, Estrada R (2004) Short-term survival and dispersal of translocated European wild rabbits. Improving the release protocol. *Biological Conservation* **120**, 507-516.

Corbett L (2001) 'The Dingo in Australia and Asia.' (J.B. Books: Marleston)

DePriest D (2002) How Your GPS Works. http://www.gpsinformation.org/dale/theory.htm.

DePriest D (2006) Differential GPS. http://www.gpsinformation.org/dale/dgps.htm.

Fajardo I, Babiloni G, Miranda Y (2000) Rehabilitated and wild barn owls (*Tyto alba*):dispersal, life expectancy and mortality in Spain. *Biological Conservation* **94**, 287-295.

Ferguson M (1998) 'GPS Land Navigation.' (Glassford Publishing: Boise)

Fischer J, Lindenmayer D (2000) An assessment of the published results of animal relocations. *Biological Conservation* **96**, 1-11.

Griffin AS, Blumstein DT, Evans CS (2000) Training Captive-Bred or translocated animals to avoid predators. *Conservation Biology* **14**, 1317-1326.

Griffin AS, Evans CS, Blumstein DT (2001) Learning specificity in acquired predator recognition. *Animal Behaviour* **62**, 577-589.

Millspaugh JJ, Marzluff JM (2001) 'Radio Tracking and Animal Populations.' (Academic Press: San Diego)

Molony S, Dowding C, Baker P, Cuthill I, Harris S (2006) The effect of translocation and temporary captivity on wildlife rehabilitation success: An experimental study using European hedgehogs (Erinaceus europaeus). *Biological Conservation* **130**, 530-537.

Pahl L (1987) Survival, Age Determination and Population Age Structure of the Common Ringtail Possum, *Pseudocheirus peregrinus* ina *Eucalyptus* Woodland and a *Leptospernum* Thicket in Southern Victoria. *Australian Journal of Zoology* **35**, 625-639.

Pietsch R (1994) The fate of urban Common Brushtail Possums translocated to sclerophyll forest. In 'Reintroduction Biology of Australian and New Zealand Fauna'. (Ed. M Serena). (Surrey Beatty & Sons: Chipping Norton)

Priddel D, Wheeler R (1994) Mortality of Captive-raised Malleefowl, *Leipoa ocellata*, Released into a Mallee Remnant within the Wheat-belt of New South Wales. *Wildlife Research* **21**, 543-552.

Priddel D, Wheeler R (2004) An experimental translocation of brush-tailed bettongs (*Bettongia pencillata*) to western New South Wales. *Wildlife Research* **31**, 421-432.

Short J, Bradshaw SD, Giles J, Prince RIT, Wilson GR (1992) Reintroduction of macropods (Marsupialia: Macropodoidea) in Australia-a review. *Biological Conservation* **62**, 189-204.

Wade I (2000) (Ed.) 'APRS Protocol Reference.' (Tucson Amateur Packet Radio Corp: Tucson)