The koalas of Campbelltown, south-western Sydney: does their natural history foretell of an unnatural future?

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ABSTRACT

The objective of this study was to relate the spread of the human population of Sydney to the natural history of the koala population in Campbelltown on its south-western edge. The first ever report of a koala by Europeans was near Bargo, just south of Campbelltown in 1798, making this population of great historical interest. In 1986, a housing development was approved in the Campbelltown suburb of Wedderburn, which threw the local koala population into the public and political spotlight. This peri-urban koala population is under threat from traffic from the Appin Road, potential construction of the Georges River Parkway and increasing urbanisation, exemplified by the development of Macarthur South and approval in 2007 of the South West Growth Centre. State Environmental Planning Policy Number 44 i.e. SEPP 44 (Koala Habitat Protection) requires two independent data sources to map koala habitat in a Local Government Area. Our study examined the value of using multiple independent data sets, generated from different methods, to establish the location of koalas in the Campbelltown area, and beyond, and derive a more reliable distribution map than those currently available. This provided a test of the value of independent data sets to establish the location of a population of a species that has had such an impact on the planning system. Further, this study gave us the ability to utilise modelled koala habitat from the local area, employ information from long-term population studies, particularly home range studies, enlist community data to support koala conservation, and assess the effectiveness of koala habitat conservation efforts in the area. The long-term future of this koala population depends on maintaining the integrity of koala habitat throughout the region, as well as in the Campbelltown LGA. Only a long-term commitment to koalas and their habitat will prevent the natural history of Campbelltown's koalas transforming into an unnatural future over the next 210 years.

Key words: community survey, home range, urban wildlife, modelled koala habitat, planning policy,

Introduction

The koala *Phascolarctos cinereus* population of Campbelltown, a Local Government Area (LGA) on the south-western outskirts of Sydney, presents an intriguing study of discovery, politics and science. The historical account places this population as part of the first koala population seen by the first European settlers in 1798 (Chisholm 1955, Lunney *et al.* 2009a). The politics began in the mid 1980s when a local population was rediscovered and there was much agitation to conserve it. The science employed in this study is a novel blend of ecological history, modern survey methods and population ecology, underpinned by GIS technology and bounded by planning and threatened species legislation. Our overarching objective was to relate the spread of the human population to the natural history of this koala population and consider its unnatural future given that the threats are expected to rise inexorably over the next 210 years, i.e. the length of time that this population has persisted in this location since European discovery. The study went beyond the boundary of any one modern discipline, and natural history is a good label for this interdisciplinary study.

In this study, we examined the value of using multiple, independent data sets, generated from different methods, to establish the location of koalas in Campbelltown, and the surrounding area, to derive a more reliable distribution map for the population than those currently available. We undertook this approach to provide a test of the value of independent data sets to establish the location of a population of a peri-urban species, especially one that has had such an impact on the formal planning system as the koala. Further, this study gave us the ability to model koala habitat, establish population studies, enlist community support for koala conservation, and design projects to assess the effectiveness of protocols for the conservation of koala habitat. In doing so, we draw on, and extend, a series of studies that address this subject using landscape ecological ideas applied to forested peri-urban habitats (Crowther *et al.* 2009; McAlpine *et al.* 2006, 2007, 2008; Rhodes *et al.* 2006, 2008a,b).

Understanding the natural history of a population of any species is enhanced if its distribution is known beyond the particular geographical location of local political

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interest. This study addressed that issue by placing the Campbelltown population in a regional context, as well as the wider NSW context. In addition, we contrasted the local distribution revealed by the different methods as well as the representation obtained by combining them. To do that, we drew upon a series of independent studies:

a) a state-wide community survey of koalas conducted by the Department of Environment and Conservation (DEC) (the department became DECCW in 2009) in 2006 (Lunney *et al.* 2009b),

b) koala locations from all systematic surveys conducted in the region that had been entered into the DECCW Wildlife Atlas,

c) a long-term koala study in Campbelltown, including data collected from radio-tracked and ear-tagged koalas in Campbelltown (Ward and Close 1998, Sluiter *et al.* 2002, Ward and Close 2004, Ward 2002),

d) mapped koala habitat from models created by the Australian Koala Foundation (AKF) (Callaghan *et al.* 2005a, b) based on counts of koala scats (pellets) under trees in the LGA, and

e) a major study of the terrestrial vertebrate fauna of the Greater Southern Sydney region (DECC 2007b).

The broad aim of this study was to examine the natural history of the koala in Campbelltown in the context of the history of political activity in the local area relating to koalas, the ecology of the koala in the region, and the range of methods used to identify the local distribution of the koala and its habitat preferences, particularly in this historically-important, peri-urban landscape (Lunney *et al.* 2009a). The specific aims of the study reported in this paper were to:

1. map the distribution of koalas in the Campbelltown area using data from the DEC 2006 NSW state-wide survey (Lunney *et al.* 2009b), and the DECCW Atlas records from DECC's systematic fauna survey program,
2. contrast the distribution revealed by each method as well as compare the distribution data with two independent koala habitat models, one created by DECCW based on validated Atlas records (DECC 2007b), and the other created by the AKF based on records of koala pellets under trees (Callaghan 2005a,b)
3. depict movement patterns of the koalas of Campbelltown, as derived from radiotracking koalas, and sightings of ear-tagged koalas, (collected locally by RC and SW) and contrast the movement patterns with the scale and shape of areas identified as koala habitat by the modelling procedures;
4. examine the population of koalas of Campbelltown in both a regional and state-wide context to provide a measure of the importance of the population and its likelihood of survival if it were to become isolated;
5. trace the history of the koala population in the shire to establish its historical significance and its relationship to the region (see Lunney *et al.* 2009a).

Methods

1. a) The 2006 NSW state-wide wildlife survey, with a particular emphasis on koalas, was conceived as a map-based questionnaire and the approach taken to the analyses was a novel application of estimates of species presence, as outlined in Lunney *et al.* (2009b). We employed a number of procedures to achieve a high resolution of locations. Among them was to divide the state into 26 map sheets, and to use a large (A2) high quality map, complete with user-friendly map locations to improve user accuracy. For the Campbelltown koala population, and southwards, the map sheet is shown as Figure 1a, with Figure 1b as a detail of Figure 1a. The map was on the B side, and the questionnaire on the A side (Figures 2a,b,c). For the map, the respondents to the survey were asked to note current locations (the last 2 years), and earlier records, and if the animal seen was dead, to mark it accordingly. The map was in Lamberts projection, which allowed the data from the returned surveys to be logged as digital records so that the co-ordinates were automatically recorded and available for further analyses. The level of resolution was 1 km for this projection. When the survey forms were sent out to 213,000 addresses in rural and regional NSW, the major cities of Sydney, Newcastle and Wollongong were excluded because the ratio of human population density to wildlife locations would be uneconomical via postal survey, and the population numbers of most species would be exceptionally low or non-existent. However, Campbelltown was included because it was known to carry a koala population and although it is regarded by Australia Post as part of Sydney, it is on the edge of Sydney and thus contiguous with the LGAs beyond the metropolitan area which were known to carry koalas. It was possible to include Campbelltown because the survey effort was dictated by postcode. In addition, Campbelltown was one of six locations (along with Gunnedah, Eden region, Coffs Harbour/Bellingen, Iluka and Port Stephens) where the postal effort was increased because of the chance to compare a 2006 data set with earlier surveys.

   b) The DECC Atlas records provide the standard tool for any investigator seeking wildlife locations from a local area to across the state. The Atlas is relied upon widely because of its size and scope, and it gives all users the sense that there is an equal access to this knowledge. It has proved to be increasingly popular since its inception in 1991, and it is in constant use. The Atlas is also employed when time is of the essence, or the scope of a project is large. For this current study, systematic fauna survey records from the Atlas were selected from and mapped for Campbelltown and the adjacent LGAs as a point of comparison with the 2006 DEC survey and the modelled habitat. The records selected from the Atlas for this study were those collected from systematic field surveys only, no community data and no incidental sightings (from the community or otherwise) were included.

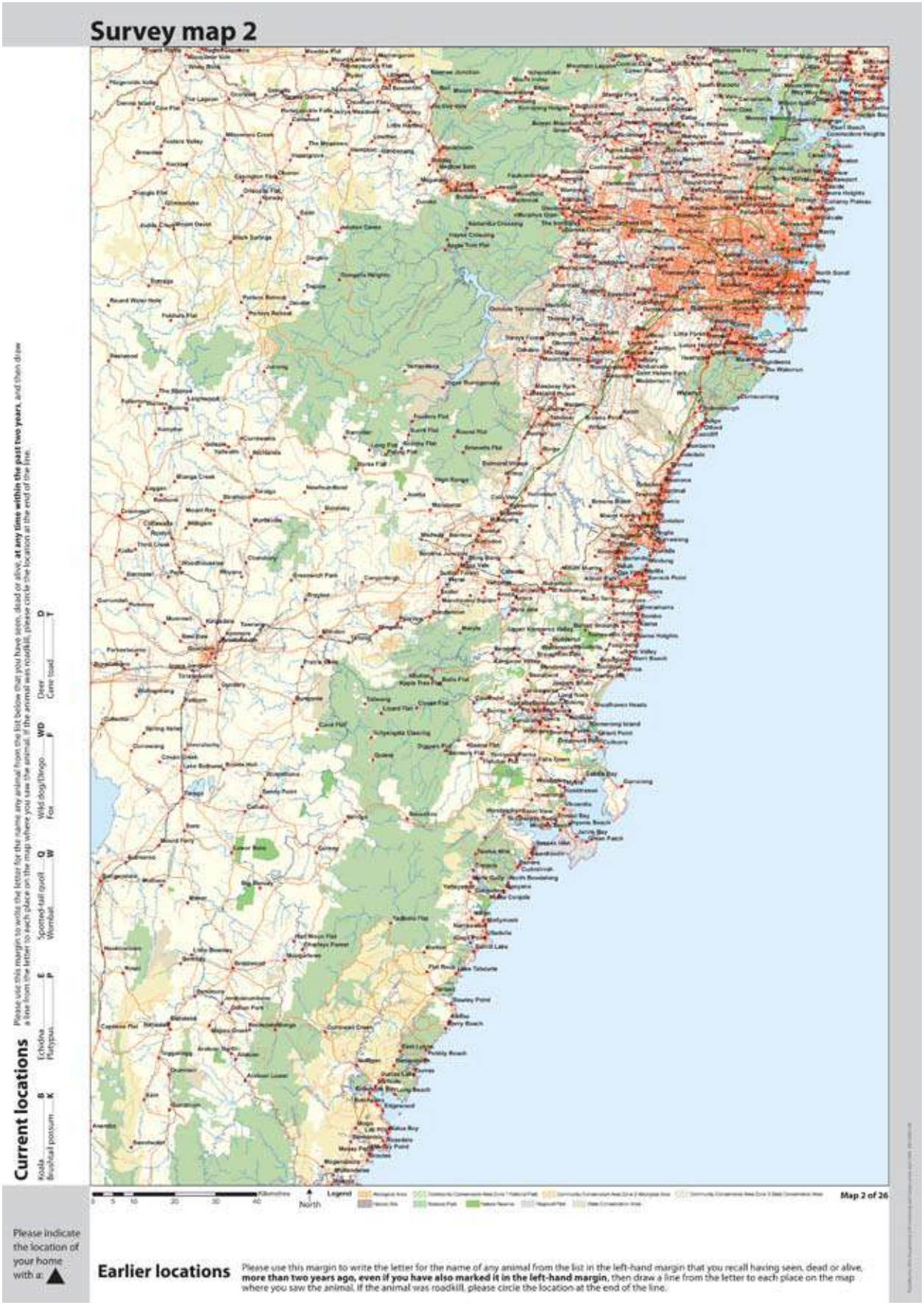


Figure 1a. The map, used in the 2006 DEC (now DECCW) postal survey of NSW wildlife, that covered Campbelltown and the surrounding areas. This is map 2 of the 26 maps used for all of NSW. This is side B of Wildlife Survey. The letter and questionnaire were on side A, which are shown in Figures 2a,b,c. The map is a user-friendly design upon which respondents were asked to mark the location of their wildlife sightings. The animal of interest here was the koala. This map size as posted was A2, i.e. four times the size shown here, which is A4.

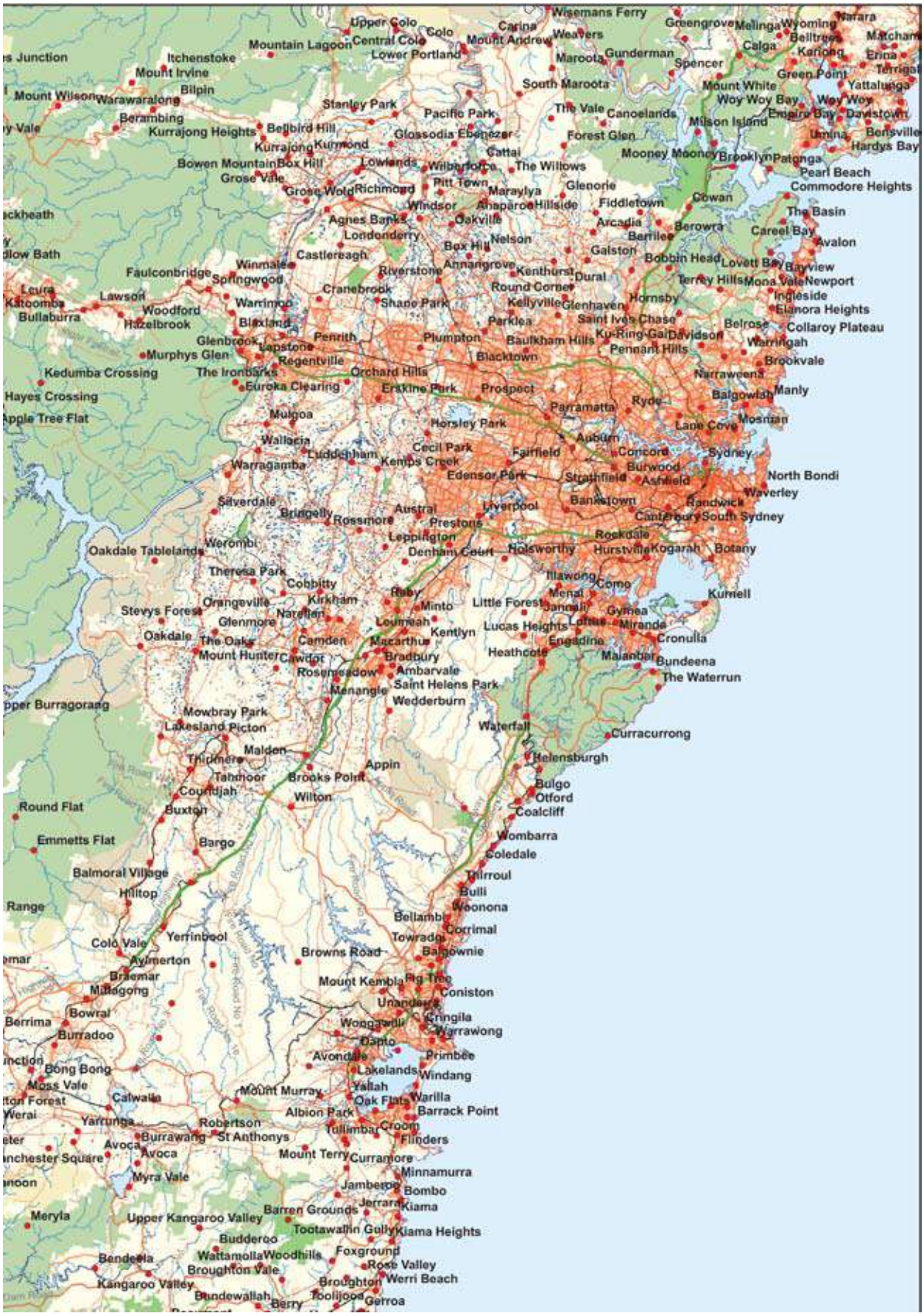
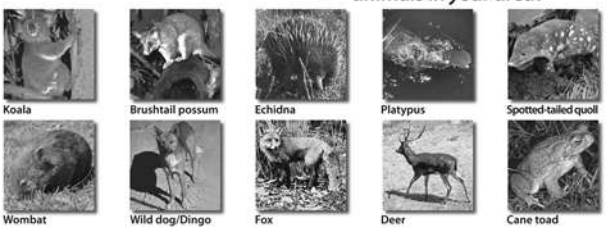


Figure 1b. This close up of the Campbelltown area is the same map as in figure 1, but now the same size as sent out in the 2006 NSW wildlife survey. This shows the degree of resolution, which is 1 km for records of wildlife sightings. The completed map and questionnaire was posted back to DEC in a replied paid envelope.

NSW wildlife survey *Have you seen any of these animals in your area?*



Dear Resident

We are seeking your assistance in a statewide survey of wildlife. Even one sighting from you is a vital part of a bigger picture. By filling out this survey, you will be helping conserve and manage our wildlife. Without your help, our task would be much more difficult.

By completing this questionnaire and pinpointing your sightings on the map overleaf, you will help us locate where particular wildlife species occur and how their distribution has changed since previous surveys. The information gathered will be used to assist in conserving the state's native wildlife and managing pest species. For example, the recently completed plan for conserving koalas requires an up-to-date survey.

Please complete the survey, even if you have only one sighting to report, and return it by post (in the accompanying envelope, no stamp required) before Friday, **2 June 2006.**

In return for the time you spend completing the questionnaire and map – which we greatly appreciate – we shall happily send you a copy of this map as a memento of your participation in the survey. Simply tick the appropriate box in the questionnaire.

Yours faithfully

Dan Lunney,
Mathew Crowther,
Jessica Bryant,
Susan Rhind,
Ian Shannon,
Vertebrate Ecology Team
Policy and Science Division, NSW Department of Environment and Conservation

Department of **Environment and Conservation** NSW

Please note: All information you supply, including your contact details, will remain strictly confidential. We will only use your contact details if we need to verify your sighting record. You can find out more about how the NSW Department of Environment and Conservation handles the personal information it collects by reading the department's privacy policy at www.environment.nsw.gov.au/about/rights.htm. Information about species sightings will be added to the Department of Environment and Conservation's Atlas of NSW Wildlife database. While data from the atlas database are provided to third parties under licence and made available on the atlas website, observer details are not provided outside the NSW Government. To view the atlas website, go to http://wildlifeatlas.nationalparks.nsw.gov.au/wildlifeatlas/watlas.jsp

How to complete the wildlife survey map over the page

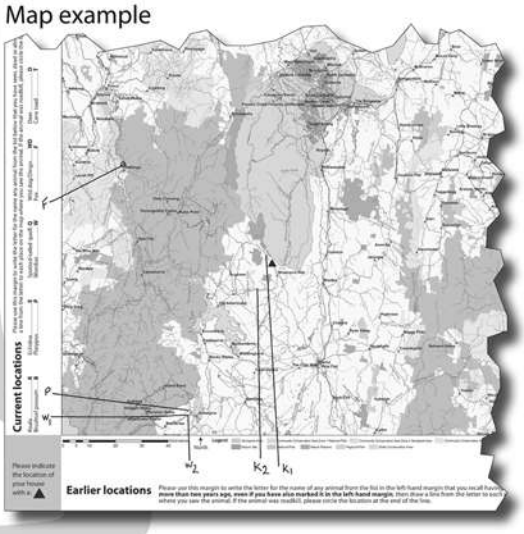
If you have seen any of the following animals (dead or alive), please draw a line on the map to where you saw them and use the following code to label the lines.

Koala	K	Wombat	W
Brushtail possum	B	Wild dog/Dingo	WD
Echidna	E	Fox	F
Platypus	P	Deer	D
Spotted-tailed quoll	Q	Cane toad	T

Then, as shown, put a circle at the end of the line if the animal was roadkill and – for any species you have seen more than once – number your sightings next to the letter that codes for it.

1. Current locations (Left-hand margin) Record sightings from the past 2 years in the left-hand margin.

Map example



2. Earlier locations (Bottom margin) Mark any earlier sightings (more than 2 years ago) in the bottom margin.

Questionnaire

1. What is your postcode? ☐☐☐☐
2. Please indicate where you live by drawing a solid triangle (▲) on the map over the page as shown in the map example. This is optional, but helps us to understand the distance between your home and the sightings.
3. How many years have you lived in this area? ☐☐
4. In recent years, some species of wildlife have increased in number while some have decreased and others have remained the same. These changes can be different in different parts of the state. For your local area please put a tick (✓) in the appropriate box for the following questions:

	Does the species occur in your local area?		If present in your area, is it increasing in number, decreasing or staying the same?			In your view, is the species a pest in your area?	
Species	yes	no	increasing	decreasing	same	yes	no
Koala							
Brushtail possum							
Echidna							
Platypus							
Spotted-tailed quoll							
Wombat							
Wild dog/ Dingo							
Fox							
Deer							
Cane toad							

5. Wildlife surveys should be carried out:
   every year ☐ every 5 years ☐ every 10 years ☐ every 20 years ☐

Health issues for koalas in your area

6. Did any of the koalas you saw appear to be unhealthy (for example, have weeping or pink eyes or wet or discoloured bottoms)? yes ☐ no ☐
7. Have you seen koalas in your area with young on their backs? yes ☐ no ☐

Optional questions

8. If you have anything you would like to add, we would appreciate your comments:
   .....
   .....
   .....
9. If you would be willing to be contacted to provide additional details about your wildlife sightings **and/or** you would like a copy of this map as a memento of the survey, please tick the appropriate box(es) and provide your details below.
   ☐ **YES**, I would be willing to be contacted to provide additional details about my wildlife sightings.
   ☐ **YES**, I would like a copy of the map.

Name: .....
Address: .....
..... Postcode: .....
Phone: .....
Mobile: .....
Email: .....

Optional for statistical purposes only:
Age ..... ☐ Male ☐ Female

10. If you have made any detailed notes about your wildlife sightings, we would like to record these officially as part of our ongoing Wildlife Atlas. For the atlas, any additional information you have, such as the date of the sighting, would be most useful. If you have several records relating to the same species, please list each sighting on a separate line on the table and code each one individually – for example, K1, K2 and so on, for koalas – and use the same coding on the map overleaf. **Don't worry if you are not able to provide this level of detail, simply skip this question**; the information about locations that you provide on the map is the most vital part of this survey.

	Species	Date	Location description	Accuracy	Observation type	Geographic coordinates (*optional*)	Other notes
	Code for species.	Specific or range of dates.	Describe the location as precisely as possible using place names, nearest landmark or cross-streets.	Estimate how accurate the location is (in metres).	O (Observed) R (Roadkill)	If possible, geographic coordinates and datum, in either zone, easting and northing; or latitude and longitude.	Any notes regarding the sighting.
Eg. 1	F	4/1/06	Snowy Mountains Highway, 4km North of Talbingo, Kosciuszko NP	500m	R	AMG 55 618200 6064500	
Eg. 2	K1	1980–1985	~12km north of Shannons Flat along Youk Rd (near Sentry Box Mountain)	2000m	O		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Thank you again for taking the time to complete this survey. **PTO**

Figure 2a. shows side A of the 2006 DEC NSW wildlife survey, featuring the letter to residents and the questionnaire. This was an A2 sheet, so the letter and questionnaire were in standard-sized fonts.

NSW wildlife survey *Have you seen any of these animals in your area?*


Koala


Brushtail possum


Echidna


Platypus


Spotted-tailed quoll


Wombat


Wild dog/Dingo


Fox


Deer


Cane toad

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Figure 2b. shows the letter to residents in detail.

Questionnaire

1. What is your postcode? ..... ☐☐☐☐

2. Please indicate where you live by drawing a solid triangle (▲) on the map over the page as shown in the map example. This is optional, but helps us to understand the distance between your home and the sightings.

3. How many years have you lived in this area? ..... ☐☐

4. In recent years, some species of wildlife have increased in number while some have decreased and others have remained the same. These changes can be different in different parts of the state. For your local area please put a tick (✓) in the appropriate box for the following questions:

	Does the species occur in your local area?		**If present in your area, is it increasing in number, decreasing or staying the same?**			**In your view, is the species a pest in your area?**	
Species	yes	no	increasing	decreasing	same	yes	no
Koala							
Brushtail possum							
Echidna							
Platypus							
Spotted-tailed quoll							
Wombat							
Wild dog/ Dingo							
Fox							
Deer							
Cane toad							

5. Wildlife surveys should be carried out:

every year ☐ every 5 years ☐ every 10 years ☐ every 20 years ☐

Health issues for koalas in your area

6. Did any of the koalas you saw appear to be unhealthy (for example, have weeping or pink eyes or wet or discoloured bottoms)? yes ☐ no ☐

7. Have you seen koalas in your area with young on their backs? yes ☐ no ☐

Optional questions

8. If you have anything you would like to add, we would appreciate your comments:

.....

.....

.....

9. If you would be willing to be contacted to provide additional details about your wildlife sightings **and/or** you would like a copy of this map as a memento of the survey, please tick the appropriate box(es) and provide your details below.

☐ **YES**, I would be willing to be contacted to provide additional details about my wildlife sightings.

Figure 2c. shows the questionnaire in detail. Together, the questionnaire and the map gave ample opportunity for a local resident to contribute to the questionnaire, particularly with its emphasis on seeking spatially-explicit information.

c) A program to radiotrack and ear-tag koalas in Campbelltown began in 1992, and it has been maintained ever since. The koalas were caught using standard procedures of flagging the koala down from the tree, and the collars carried standard VHF transmitters. Some koalas entered the program because they were rescued animals. All koalas that were caught, or rescued, were fitted with a numbered ear tag. The collared koalas were detected by tracking by day using an antenna, and the location and trees used were logged, along with the date. The locations were map co-ordinates, and each koala was of known sex, and had a name to help the records being tracked. The home ranges selected for this study were those of koalas that had a large home range so that it was visible when placed on a habitat map. This meant that most of these koalas had a high number of records, over 30 locations. The time interval covered was years in most cases. The home ranges that were selected for this study were those that displayed a range of shapes and locations. The method of depicting the home range was a simple minimum convex polygon, which involved constructing simple polygons using Hawth's Tools (www.spatialecology.com/htools/toodisc.php, last accessed 29 February 2008). For depiction of home range use and habitat selected, the kernel method is preferred, but the objective here was to show the shape and the outlying locations to illustrate how far individual koalas moved at certain points in their lives. More koala home ranges were available to choose from than were used because the point was to compare home range size and shape with the modelled habitat based on sighting records and the presence of pellets under trees, as well as the records from the 2006 DEC community survey and Atlas records. In addition, those koalas with long-distance movements identified by sightings, or recovery, of eartags were included because they answered a similar question, namely, what are the movement patterns of individual koalas across the modelled habitat boundaries in this LGA.

2. The comparison of the location of koalas by the different methods was made graphically and all the datasets were presented in the same spatial context, such as towns, land tenure and scale. The comparison of home range shapes was set against the locations of koalas by both of the survey methods, and then the home ranges were overlapped with the two independent approaches to modelling koala habitat. The approach taken was graphical, i.e. the separate methods were combined in maps for a visual display of movements across habitats to allow the starkest comparisons.

3. The regional scale of the koala population is shown on the maps presented displaying the results of the 2006 DEC survey and the Atlas records for the area from Ingleburn to Mittagong. The statewide location and significance is presented as part of the 2006 DEC survey, which was a uniform effort across the state and thus comparisons across the LGA and adjacent LGAs are valid. The Atlas has a marked limitation here in that it records sightings, but not effort, so that gaps in the distribution, or high concentrations in some areas, may reflect either no survey or an intense local effort for a special purpose, rather than an accurate, balanced picture of the distribution. In addition, the Atlas records have accumulated over time, so a full display of the Atlas records will not be a snapshot of the current distribution.

4. The history of koalas in Campbelltown and surrounding areas was examined by collating accounts from well-known texts on koalas, searching local records and seeking additional information from a range of sources to help establish the course of events in the first 15 years of the colony in NSW. A comparison of the detailed investigation of the early records with the picture of discovery in the general texts was undertaken and is reported in Lunney *et al.* (2009a).

Results

The DEC 2006 community survey data are displayed on Figure 3, with 3a distinguishing between all records and recent records, i.e. within the last two years, namely 2004-2006. The pattern of distribution is similar, with most of the more western records being absent from the recent records, such as near Cawdor and west of Cobbitty, west of Wedderburn and Kentlyn respectively. The distribution of the records shows a strong concentration around both Wedderburn and Kentlyn, and both stand out as the two largest clusters of records. In searching for a pattern, a few strands emerge. The most noticeable is the south-west orientation of the records from near Ingleburn at the northern end to near Sutton Forest at the southern end of this distribution shown in this map – a distance of about 80 km. The largest gap in this sequence is about 10 km. The next noticeable feature is the scarcity of records along the coast, with Stanwell Park and Austinmer carrying a record each, with another at Mount Kembla. These records are separated by about 20 km from the dominant axis of koala records. The community survey data are largely records from private land, but the wide scatter of records in the reserved land, particularly the Sydney Catchment Authority Special Areas, shows that community records do occur on reserved land and that this land does have koalas. This includes the newly-gazetted reserved areas and thus points to a good set of records in reserved land. A subset of the community records is the roadkill (Figure 3b). The eight records show that roadkill does occur locally, that it is not confined to the major highways, but that it is a feature that exists through the entire distribution of the koala on this map. If the roadkill map was all that was available, it would show a narrower distribution than all the community survey, underestimate Kentlyn and overlook Wedderburn, and fail to identify the importance of Campbelltown. It would, however, correctly identify the existence of a population of koalas along the main south-west axis that was identified by the full community survey data.

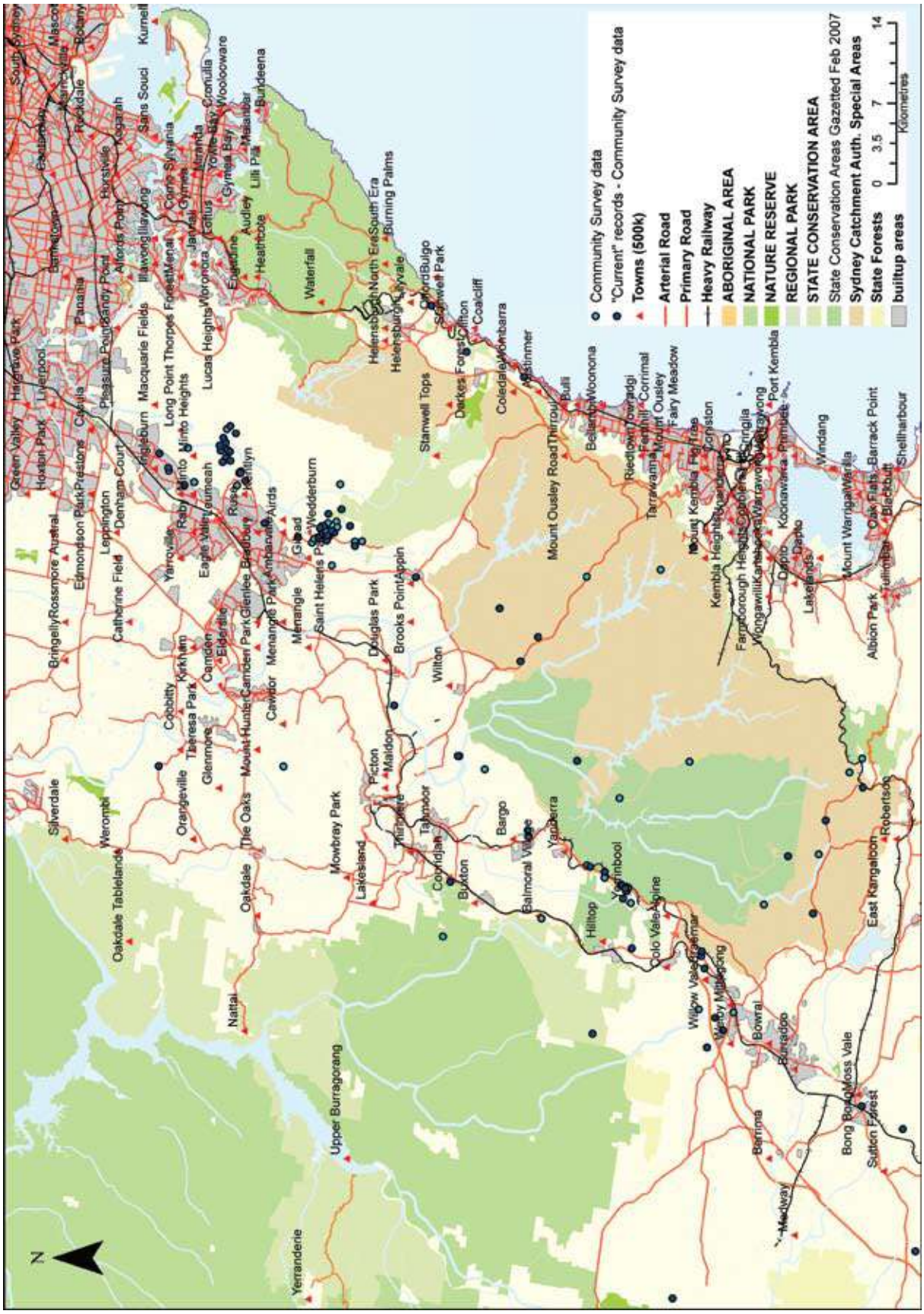

Figure 3a. The koala data from the 2006 NSW DEC Wildlife survey, showing both the recent (2004-2006) records and earlier records. These are set against the predominant land uses of the area. These data were collected as part of the statewide koala survey in 2006 of rural and peri-urban NSW. The locations show concentrations near Kentlyn and Wedderburn within the LGA, with a string of records down the Pacific Highway and a scatter across to Robertson. There are only rare records on the coast.

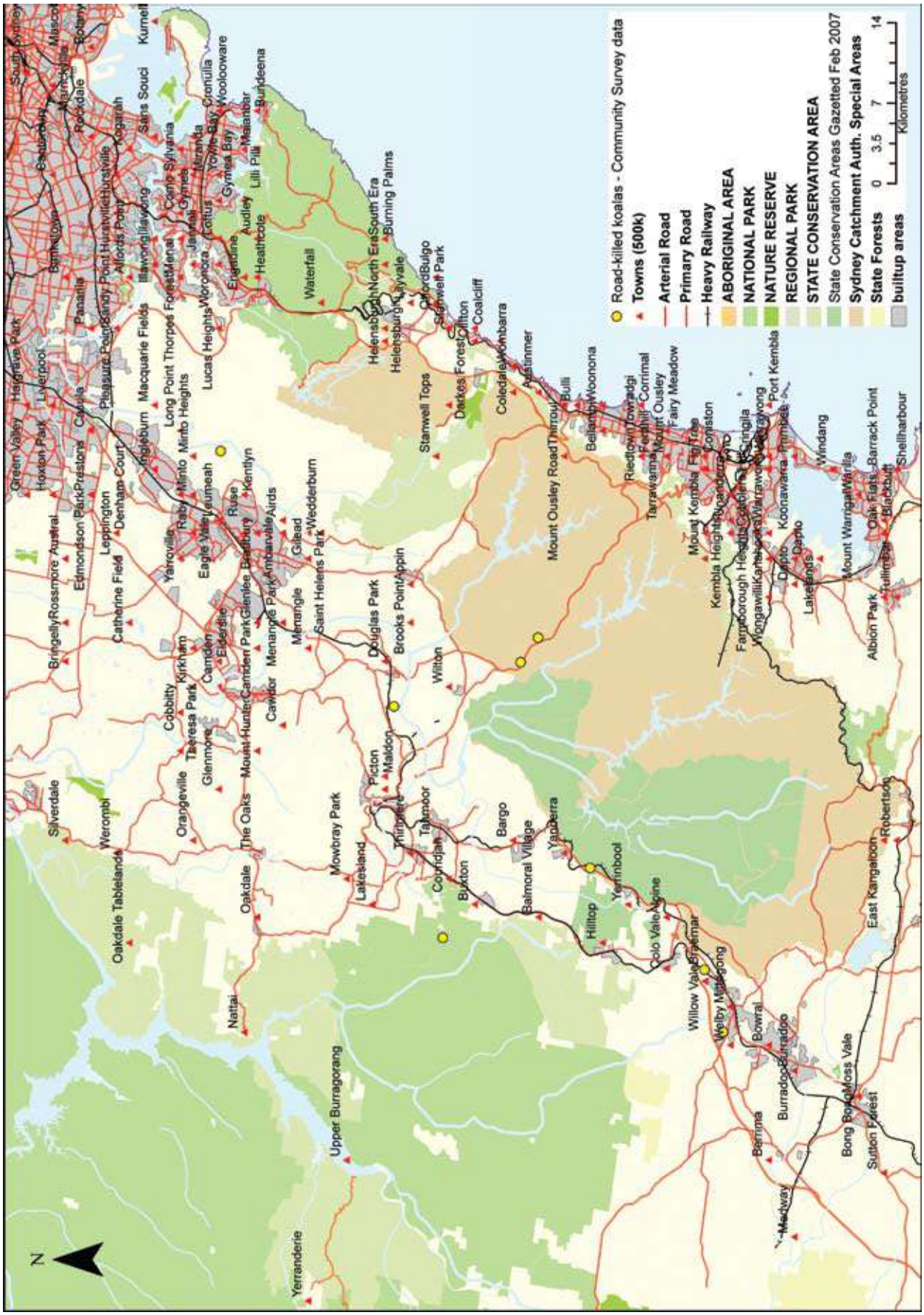

Figure 3b. The location of road killed koalas from the 2006 wildlife survey.

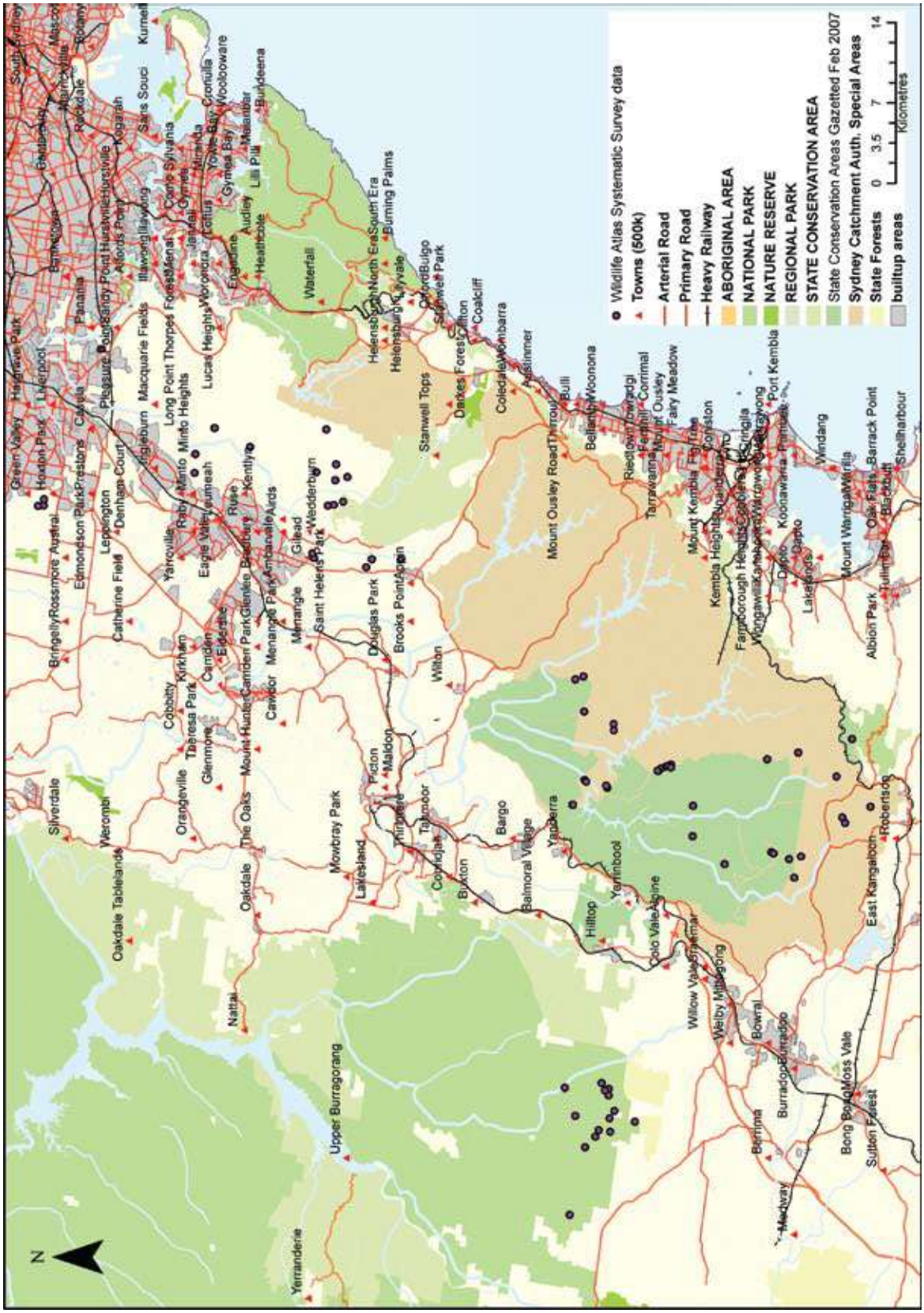

Figure 4. Wildlife atlas systematic survey data. The location of koalas from the DECCW Atlas. (This map does not include many incidental sightings through this area because of constraints within fields in the Atlas records.) The Atlas of NSW wildlife is a centrepoint for many individuals and organizations across NSW to find a wide range of species. Of particular interest are the locations of threatened species, such as the koala. There are scattered records near Kentlyn, Minto, Robertson, and to the north of Robertson into a new reserve, the Upper Nepean SCA, and a concentration to the west of this area, and west of the highway in Nattai NP. These will be relevant to anyone searching a particular property, such as for a development application (DA) but including the other datasets that were omitted from this map to allow a systematic comparison between the maps of the different techniques.

The DECCW Wildlife Atlas systematic survey data, shown in Figure 4, displays a similar orientation to the DEC 2006 community survey data. It does show a different emphasis, especially in that the number of records is predominantly on reserved land, both Nature Reserves and Sydney Catchment Authority Special Areas. It does identify Wedderburn as a local population, with only one record from Kentlyn, no records along the coast and none west of the Hume highway or the railway line until Dharawal Nature Reserve. It is consistent with the community survey, it does show the importance of the reserved lands, but it underestimates the records on private land. Thus, the map reflects where the systematic survey data were collected. Private land is much more amenable to the collection of community survey data.

The radiotracking data displayed as home ranges shows the strongest concentration around Kentlyn, but also a strong series of clusters around the Wedderburn area (Figures 5a and b for males and female koalas respectively). The distribution was only of local koalas, so the distribution is based on Campbelltown. When all the records from the DEC 2006 community survey data, the DECCW Wildlife Atlas systematic survey data and the radiotracking data were collated, the resultant distribution highlighted the Kentlyn and Wedderburn areas, as might be expected given the density of the radiotracking records, but it also confirms the strong south-west orientation of the koala population (Figure 6). It does point to the fact that the koala is not a coastal species in this part of NSW, and that it is both an animal of private land and Crown land. Koalas do not have a western distribution in this region, but there are scattered records. There were no records near Nattai.

The home ranges depicted as minimum convex polygons show the distances covered by koalas; however these simple polygons do not properly represent the area used by a koala. The shapes display a wide variety, with some being long and thin. These elongate home ranges point south-east from the recognised habitat at the eastern boundary and cross Dharawal Nature Reserve, arriving near its southern boundary. Those home ranges that are more rectangular are sufficiently large to occupy most of the preferred habitat shown by the AKF maps for Kentlyn, and the entire habitat at Wedderburn. The community survey data show a clustering of records, but the koala home ranges present a picture of koalas moving across all of a cluster and beyond. The clusters alone do not give a portrait of how individual koalas used the habitats and moved across the boundaries of habitats.

The complementary dataset is the records of movements shown by ear tags. The individuals depicted here were selected because of their long distance movements. What emerges from these records is that the local Campbelltown koalas move long distances compared to the size of the radiotracked home ranges, and move well beyond the cluster of records from surveys. This demonstrates the value of ear tags, which last for the life of the koala, compared to radiotracking collars, which are of shorter duration. In addition, a large number of koalas can be readily eartagged, but only a small proportion of the population can be fitted with radiotracking collars. Thus, tagging is more representative of the population and a better method of indicating movements of the population as a whole. For example, the ear tag results show that koalas also move far beyond the designated areas of identified koala habitat. These habitat boundaries do not set limits to koala movements. From the small sample shown here (Figure 7), individual koalas are within walking distance, i.e. the distance walked by the koalas, from Royal National Park and the designated growth centre for south-west Sydney. The converse must also be true, namely that koalas were likely to walk that far to become part of the Campbelltown koala population. This is likely from the south, and possibly a few from the east, as there were few or no koalas in other directions.

The AKF map of the modelled habitat for the koalas of Campbelltown is displayed with the community survey data from the 2006 DEC survey (Figure 8). The highest rank of habitat from the AKF study is the Secondary Habitat Class 2A. The next highest rank is Class 2B. Together, they correspond to the strong cluster of community records for the Kentlyn area. The habitat classes around Wedderburn are a mix, with much cleared land, with many of the records overlapping with AKF Class 2C. Overall, there is a high level of correspondence between the AKF modelled habitat and the community records.

The overlap of the minimum convex polygons of the koalas with the AKF habitat map shows a number of key features (Figure 9). The most striking is that the intricate pattern of the habitat is not matched by the simple polygons of home range shapes or sizes. Both the male and female koalas cover all classes of habitat, including cleared land. Another feature is that none of the koalas occupy the AKF's definition of best available habitat, Class 2A. Rather, the home ranges display an orientation and a shape that does not correspond to that habitat. This shows that while the identified AKF habitats may be essential parts of each home range, they do not form a boundary and that other non-koala habitats are included in the home range of many koalas. This especially applies to the long distance movements of the ear tagged koalas.

The habitat modelled using a validated subset of the Wildlife Atlas data (including systematic survey data) depicts koalas as occurring where there are suitable koala feed trees on fertile soils, at lower to mid elevations (Figure 10a). It shows a strong spatial pattern with the highest ranked koala habitat lying at the eastern edge of Campbelltown, and aligned along a south-west axis that runs from north east of Kentlyn, south-west through Wedderburn, through Appin, Wilton, towards Bargo, where it continues south-west. It then turns north-west in a fragmented fashion. In fact, the Y-shape formed from Minto Heights, to Bargo at the junction of the two arms of the Y, and then north-east to Silverdale, shows a strong pattern of fragmented koala habitat and cleared land. It appears that the Wedderburn to Minto Heights area, which includes Kentlyn, is the largest area of remaining koala habitat. The coastal strip has a few patches of koala habitat, and these are consistent with the 2006 community survey records, as well as the home ranges and

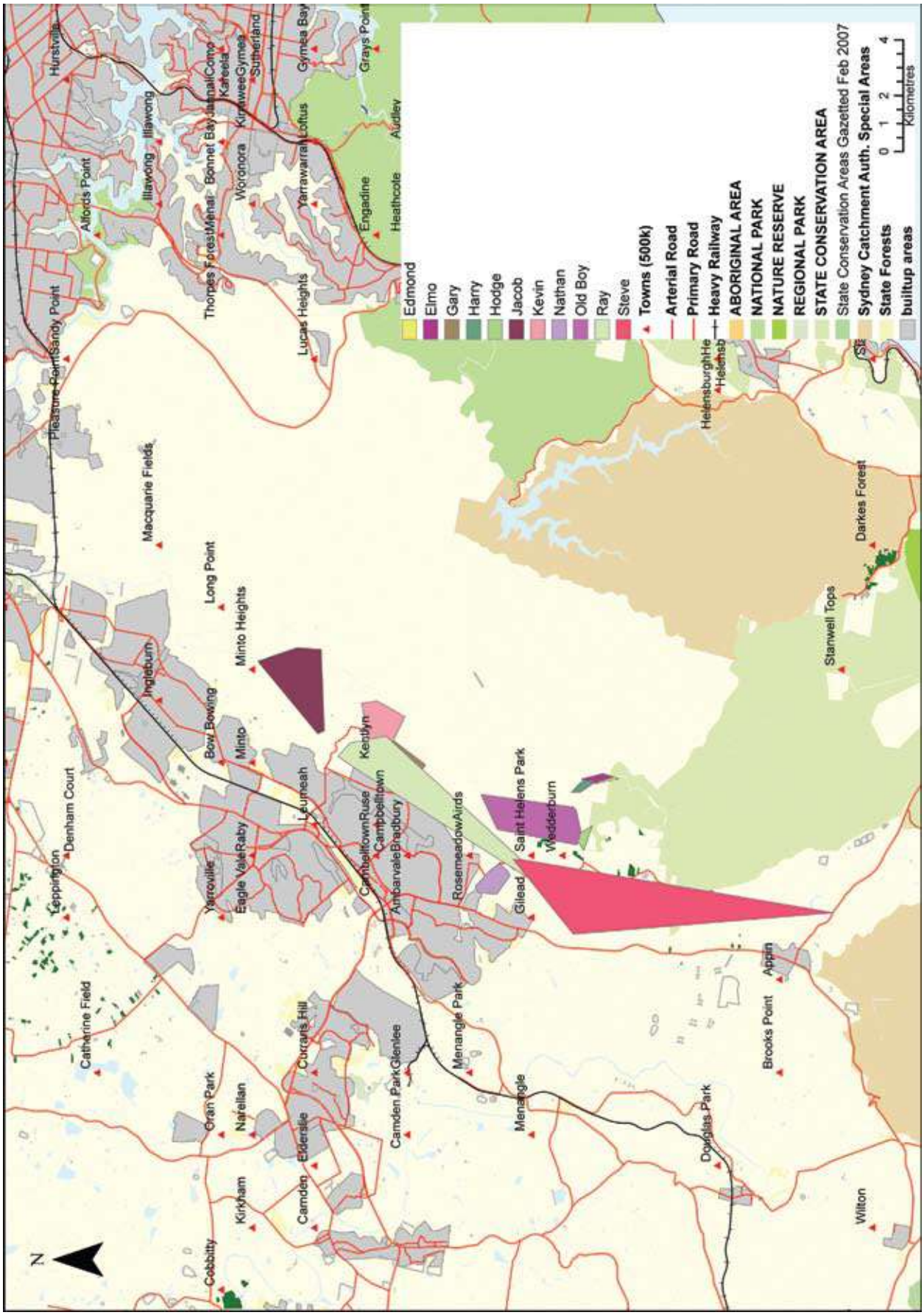

Figure 5a. The home ranges of male koalas from radiotracking data. These data were obtained during a long-term radiotracking program within Campbelltown LGA.

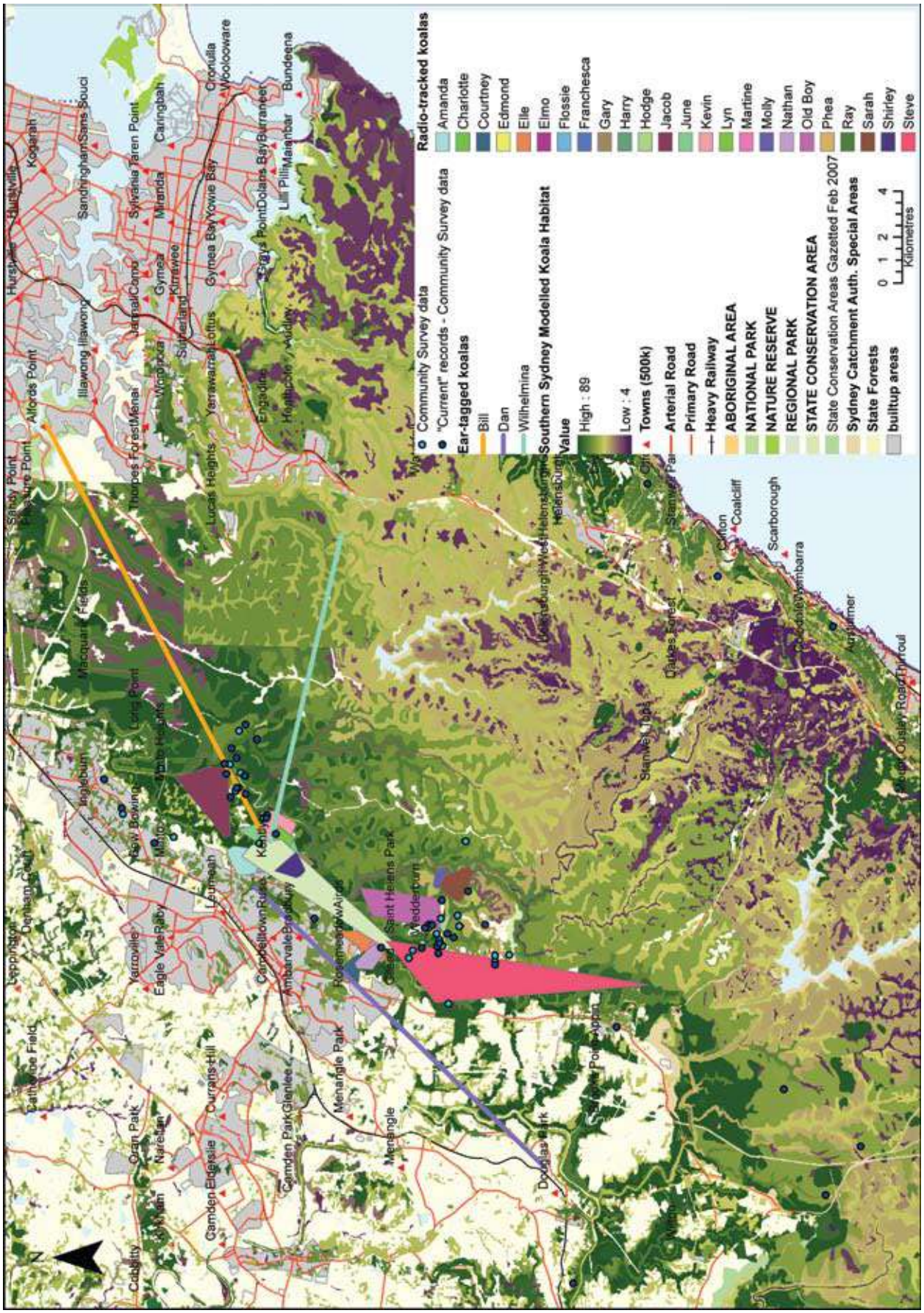

Figure 5b. The home ranges of female koalas from radiotracking data.

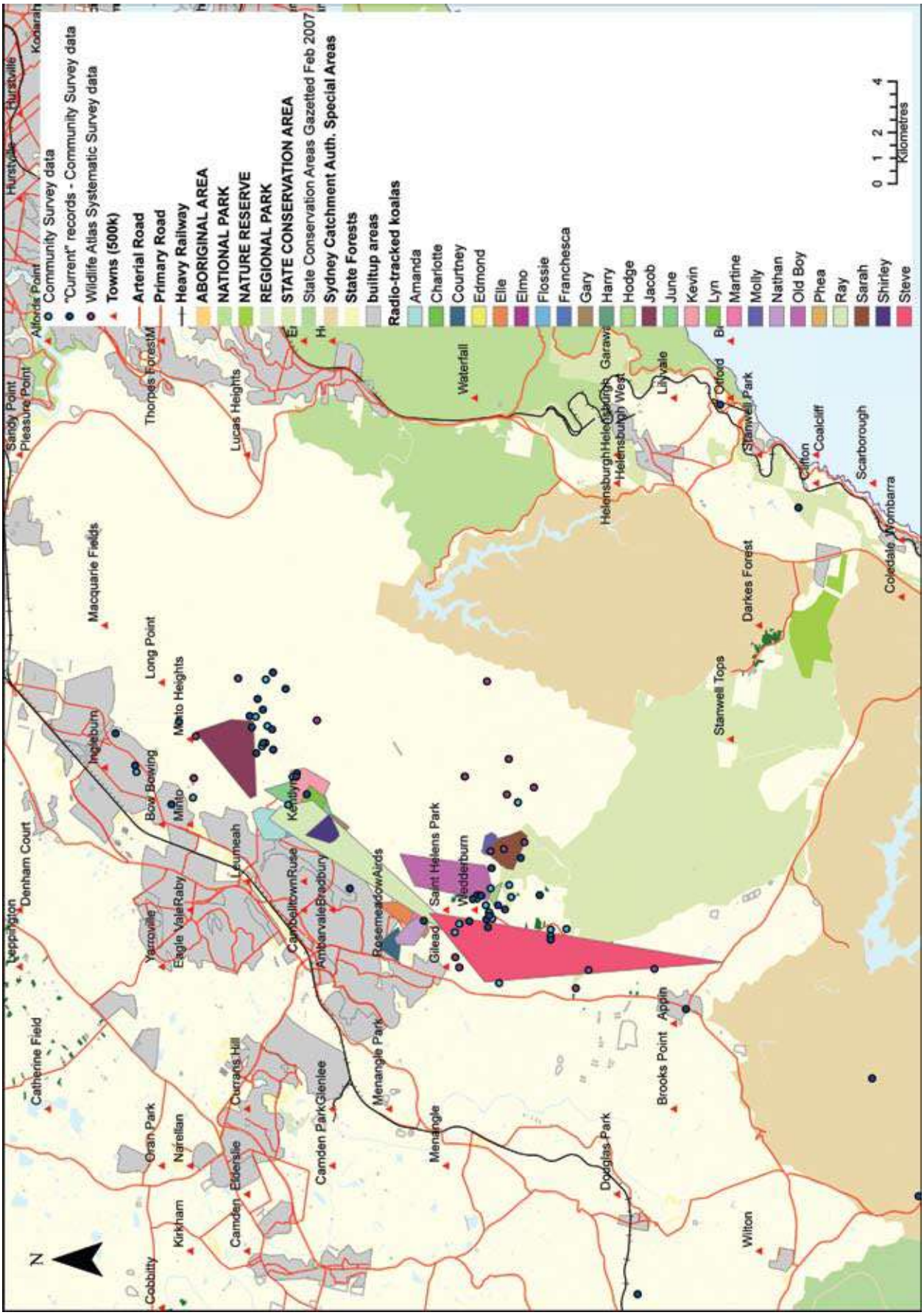

Figure 6. This map combines all the records from the DEC 2006 community survey data, the DECCW Wildlife Atlas systematic survey data and the radiotracking data. This shows that there is a number of concentrations, with one cluster around Wedderburn, and another around Kentlyn stretching up to Minto Heights. This highlights the value of combining independent data sets when identifying the distribution of a population of a cryptic species, such as the koala.

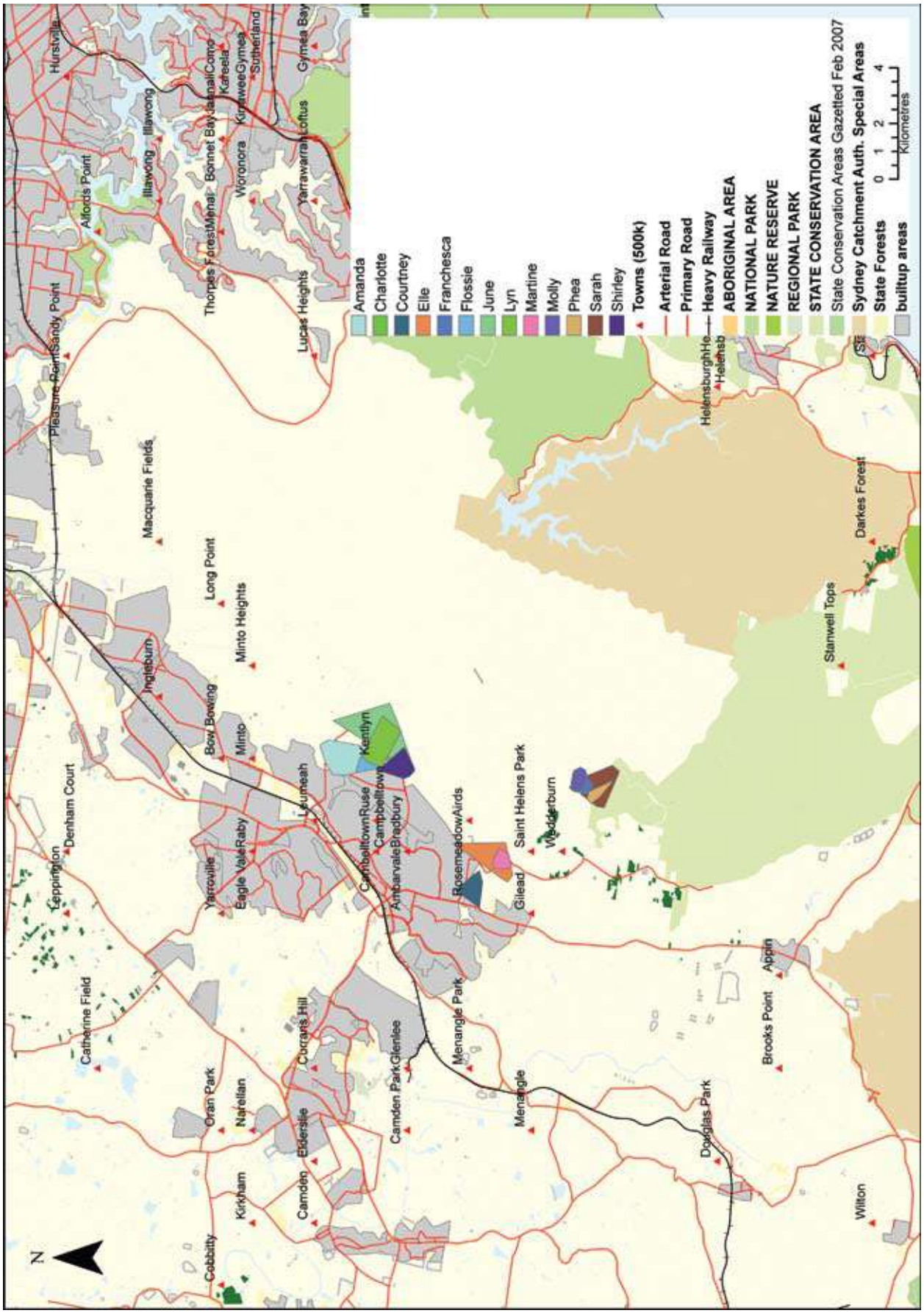

Figure 7. The long distance movements shown by koalas with ear tags.

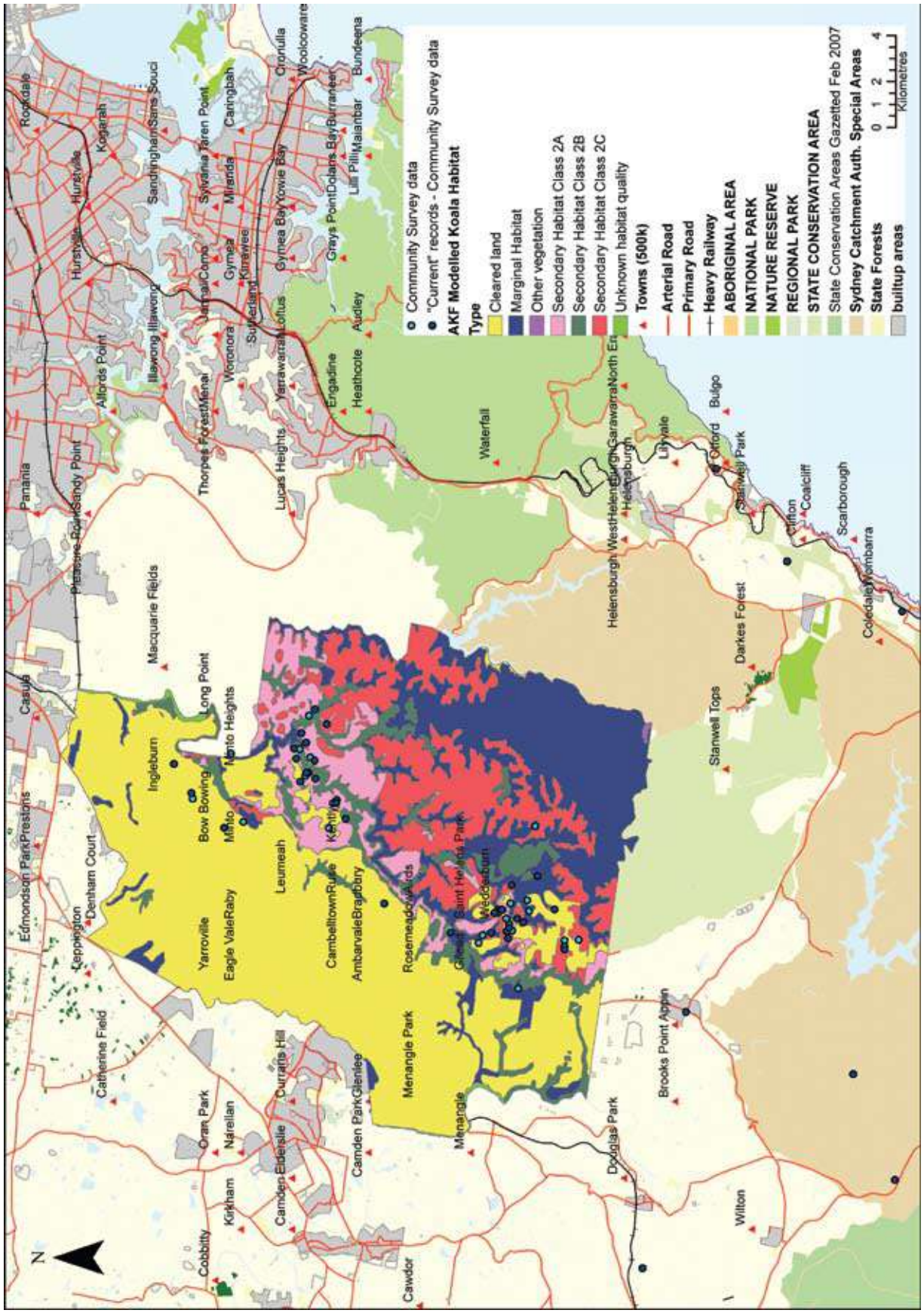

Figure 8. Koala habitat as modelled by the AKF (blocked bright colours), depicted with the 2006 community records. This AKF habitat map was based on extensive study of the distribution of koala scats found in quadrats under a random selection of trees found throughout the LGA. These data were then modelled against a vegetation map for the LGA to produce a habitat map as the basis for the comprehensive Koala plan of management (CKPOM) prepared to comply with SEPP44 (Koala habitat protection). Map supplied courtesy of AKF.

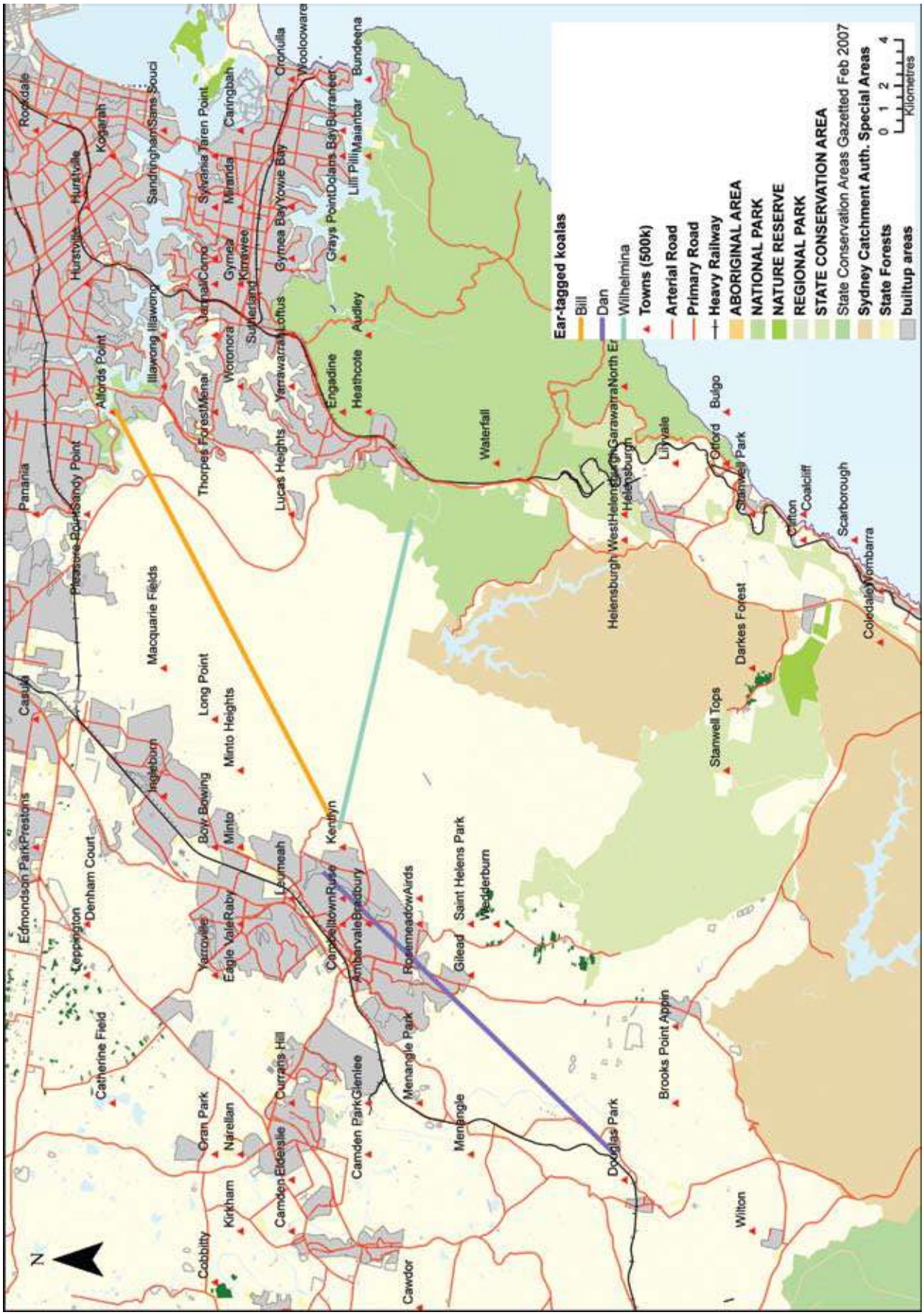

Figure 9. The modelled koala habitat by the AKF overlapped by both the koala home ranges, as minimum convex polygons, and the long-distance movements by koalas with ear tags.

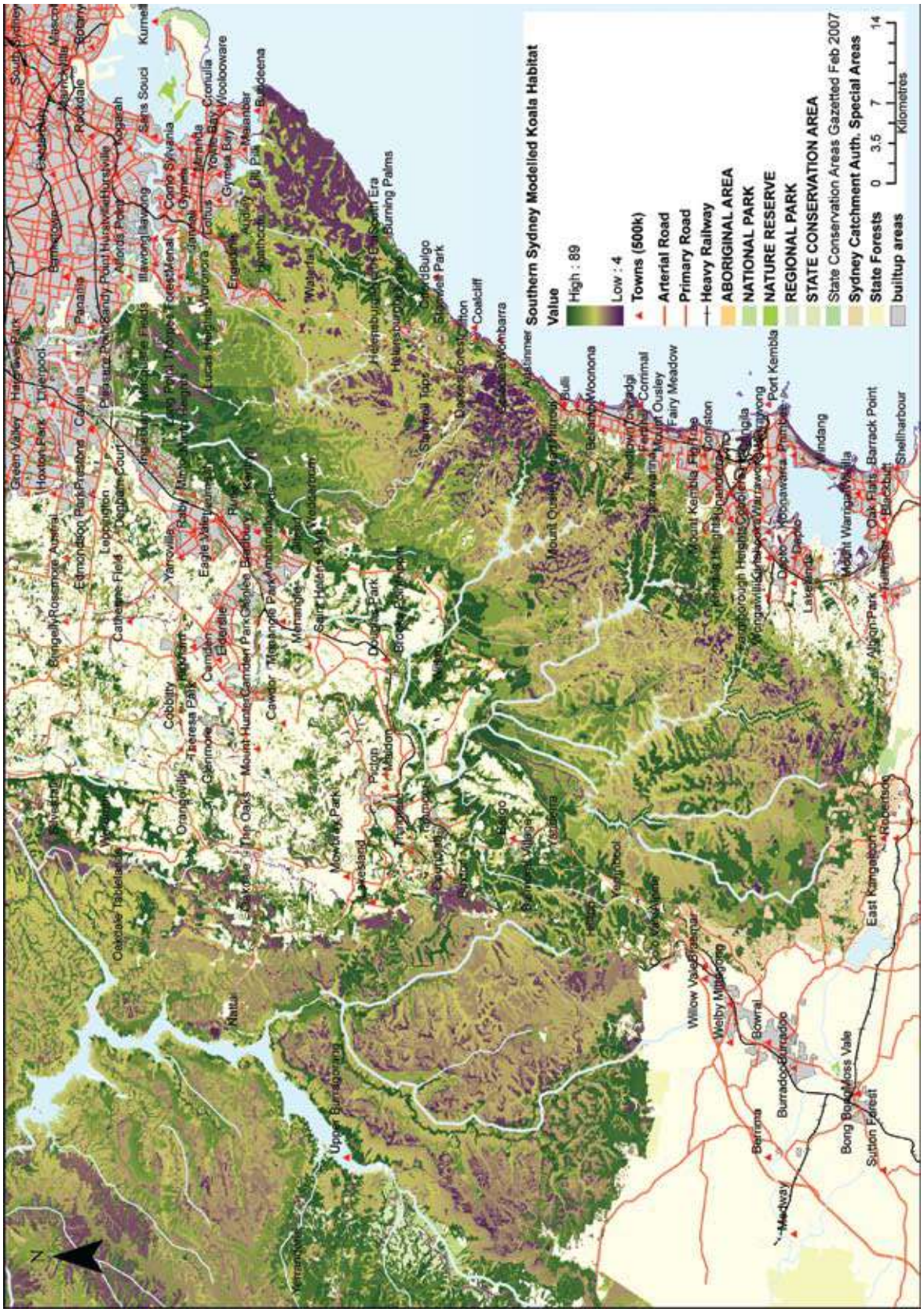

Figure 10a. Koala habitat modelled using a validated subset of the Wildlife Atlas data The map shows modelled Koala habitat from a major DECC study of terrestrial vertebrate fauna of the Greater Southern Sydney Region (done in collaboration with the Sydney Catchment Management Authority). Dark green is the best of the Koala habitat and it fringes the eastern edge of Campbelltown LGA. It also appears on the southern end of Nattai NP and is adjacent to cleared land to the south, which was not modelled. High quality habitat also appears on the shale ridges within the Upper Nepean SCA to the north of Robertson. There is a patch of high quality Koala habitat in the catchment of the Hacking River in the southern end of Royal NP, though there are no recent records of Koalas from this area. There is also a patch of high quality Koala habitat in the Upper Cordeaux catchment to the north-west of Mt Kembla although there are no recent records.

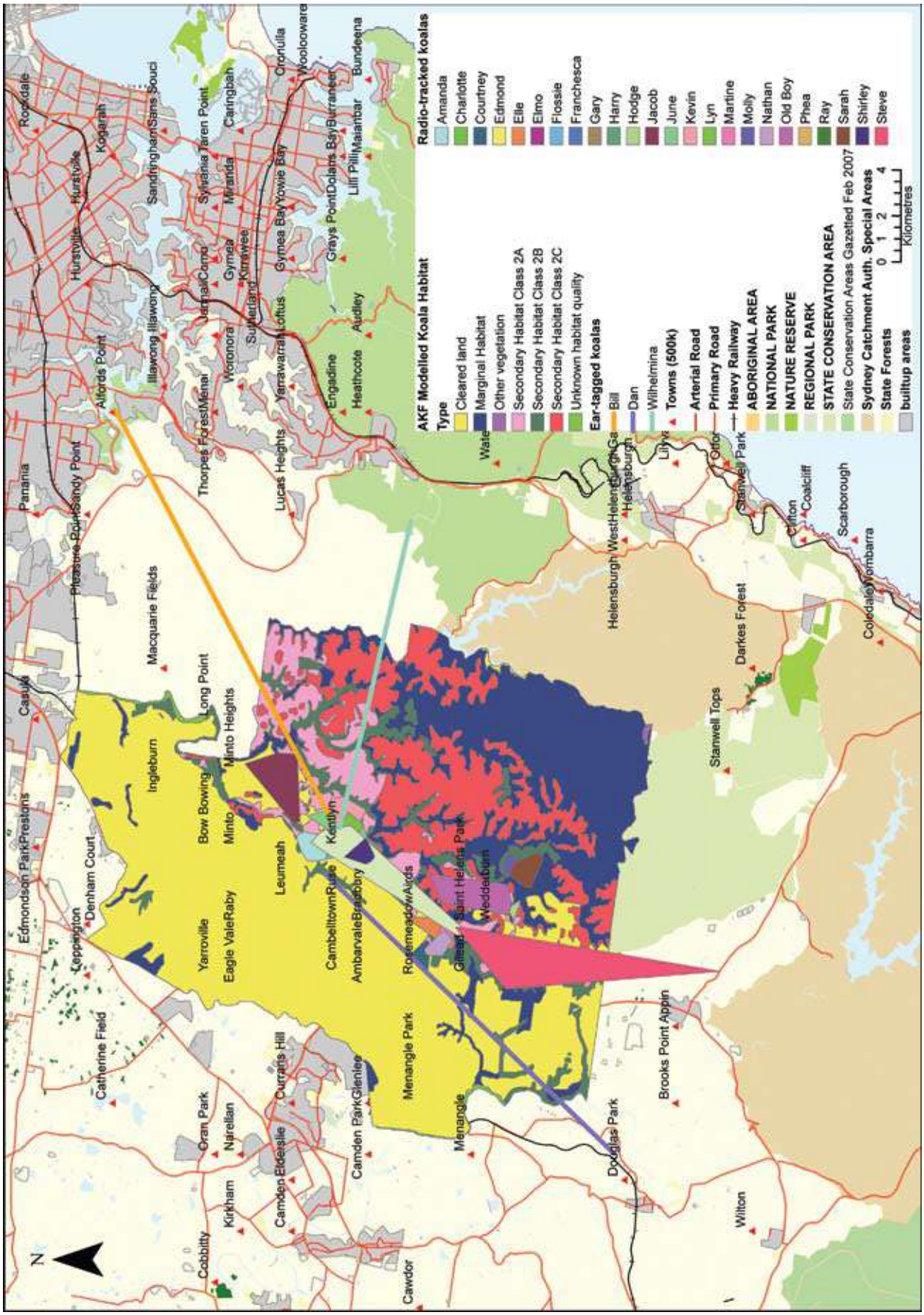

Figure 10b. Koala habitat modelled on Atlas records, as shown in Figure 10s, now overlapped with home ranges and movements of ear-tagged koalas. It shows the koala home ranges centred on the highest level of koala habitat, but that koalas will move long distances beyond the highest level of modelled habitat.

the movements of the ear-tagged koalas (Figure 10b). The low quality koala habitat over most of Royal National Park is consistent with the paucity of records in this area.

The regional distribution of koala records and koala habitat is well depicted in the preceding maps. The relative importance of this concentration of records is shown in the statewide picture (Figure 9 in Lunney *et al.* 2009b). This map shows that the population near Campbelltown is the largest south of Sydney, and that it is linked in a south-west direction, but this does peter out at about the point showing the end of the distribution in the preceding maps. The scattered, low density records south of Campbelltown, either down the coast, or further inland, and the scarcity of records in the Great Dividing Range, points to the Campbelltown region, i.e. Campbelltown south west for less than 100 km, is the centre of this south-western Sydney population. It does not show any connection to the north coast koala populations, nor the major location to the far north-west around Gunnedah.

The contemporary debate – its origins in the 1980s

In a major state-wide survey in 1986-87, koalas were identified as being present in Campbelltown (Reed *et al.* 1990). A NSW Koala Summit in 1988, held to examine management options for the state's koalas, carried two papers on the population at Wedderburn, within Campbelltown LGA. Dobson (1990) lodged a plea to help save the koalas at Wedderburn while Sheppard (1990) presented a history of the Wedderburn koala population. Sheppard (1990) stated that the population was re-discovered in 1986, noted that there were 85 records in a 28 month period, and commented that numerous koala young indicated that a breeding population was present. The threat to the population was stated by Sheppard to be a development for rural residential subdivision of 26 blocks of 4 to 10 ha, which had been approved by council prior to the discovery of koalas in the area. Sheppard also noted that, on 4 June 1988, *Interim Protection Order* Number 1 was placed on the area by the Minister for the Environment, Tim Moore. Sheppard also noted that this was lifted on 12 July 1988 after a Voluntary Conservation Agreement was drawn up with the owner, Yip Yan Pin P/L. Sheppard then stated that a union green ban was placed over the area, and added that it was the first green ban to protect animal habitat. In September 1988, Sheppard reported, the council commissioned CSIRO to ascertain the extent of koala habitat and, in October 1988, council resolved to rezone the land as Regional Open Space.

Sheppard (1990) claimed that, "All of the above occurred because of opposition by NPA [National Parks Association], Macarthur branch, and local residents' action group". We do not dispute the clout that these local groups delivered, however these actions and outcomes were made more possible by the results of the 1986-87 Koala Survey, and the rising interest of koala biology and conservation, at both state and national levels, by governments and researchers (Reed *et al.* 1990; Phillips 1990; Lunney *et al.* 1990). Further, the Koala Summit in 1988 - a state government initiative - not only gave Sheppard and Dobson a chance to throw a powerful spotlight on their local issue, but also to place Campbelltown's modern koala population in the historical record. We note that there is an interaction between applied research, including undertaking a state-wide survey, and the political and conservation interest in populations in Local Government Areas (LGAs). Neither approach, working alone, effectively drives policy nor reliably delivers sustainable local outcomes; it is the interaction that is so productive.

Examples of the interaction between science, politics and effective policies on koala management are:

a) the national survey of koalas in 1986-87, initiated by the federal government and carried out by each of the state governments (Phillips 1990; Reed *et al.* 1990),

b) the inclusion of the koala on the first-ever formal list of threatened fauna in NSW in 1992 (Lunney *et al.* 2000a), based largely on the state-wide survey of 1986-87,

c) the promulgation of the formal NSW planning instrument, State Environmental Planning Policy Number 44 (Koala Habitat Protection) (SEPP 44), in 1995 as a means of giving local councils both authority and administrative responsibility (Lunney and Matthews 1997),

d) the first approved shire-wide Comprehensive Plan of Management for Koalas under SEPP 44 (for Coffs Harbour LGA, Lunney *et al.* 1999, 2000b, 2002),

e) the National Koala Conservation Strategy (ANZECC 1998), and

f) the NSW Koala Recovery Plan (DECC 2008).

We contend that the koala population of Campbelltown, and the surrounding region, will be more likely to survive with all this attention, with the added benefit of sustained research and policy development on koalas, than any isolated effort by any single group. We also recognise that paperwork alone will not save koala populations, and that it takes local energy and determination to conserve this politically-sensitive species that has a biological predilection to be so specific in its selection of tree species, as well as the location of those tree species, particularly as so much koala habitat is on private land. The koala thus becomes an exemplar of a wildlife species conserved through public-private partnerships.

The 1988 political actions in Wedderburn are most illuminating. The NSW *Government Gazette* No 97 of 3 June 1988 noted that under the *National Parks and Wildlife Act 1974* that the Minister made an *Interim Protection Order* to protect a parcel of land of about 220 ha in the County of Cumberland and the Parish of Wedderburn to, "prevent damage or despoliation of the land or any part of the land, carrying out any development in relation to the land, the damage or destruction of any tree or other vegetation or removal of any tree from the land, or taking any action which interferes with or adversely affects the habitat of the species koala …".

We note that this was the first IPO placed, and although it was withdrawn, it did attract immediate attention to the fact that development at a local level was potentially inimical to the survival of this local koala population.

The report on this local population by Cork *et al.* (1988) was also instructive, particularly as the authors are experts in both koala biology and forest ecology, and were likely to know which locations would sustain arboreal marsupial populations. Using both prior knowledge and local information, they reasoned that grey gum *Eucalyptus punctata* was the preferred food tree in this area, and they identified koala habitat based on the proportion of this tree in the local vegetation communities. Sluiter *et al.* (2002) used cuticle analysis and came to the same conclusion, but added another local tree species, the blue-leaved stringbark *E. agglomerata*. In this finding, they concurred with the results of the study by Phillips and Callaghan (2000). Sluiter *et al.* (2002) also found that some of the koalas were resting in the densely-foliated turpentine *Syncarpia glomulifera.* A primary point here is the narrow range of local tree species upon which the koalas depend, the value of taking a critical approach by applying research methods, and the value of identifying rest trees as well as food trees.

Discussion

Home ranges

Home ranges determined through radiotelemetry are difficult and slow to calculate because of the effort to find the koala to obtain each fix and the time it takes, often years, to find the full home range of a number of individuals. This is in addition to the welfare considerations for the koalas being collared and tracked. However, this study has demonstrated the immense value of knowing this attribute of koalas, particularly for peri-urban areas and where detailed development plans are being considered. There is also an advantage of using local knowledge, rather than home range values from elsewhere. If one worked with just one figure, such as the area of a home range, it would take some juggling of the boundaries of the home range to fit them to the modelled habitat. Since home range shape was shown for these Campbelltown koalas, it is evident that a part of each of home range was not in identified koala habitat. This point is particularly true of the long distance movements shown by ear tag returns. Thus, many of these koalas were at risk of attack by dogs and death on the road. Dogs are nationally recognised to have a major impact on koala populations (e.g. ANZECC 1998) and a case study in Port Stephens has shown the magnitude of the impact (Lunney *et al*. 2007). The road deaths locally of koalas, as shown in the map, identify that roadkill remains a perennial threat to the local population.

One general conclusion that emerges from overlapping all the home ranges with the high quality habitat is that this habitat does not constitute a constraint on movement for either male or female koalas. Thus, a development proposal that covered all non-koala habitat, or low ranked koala habitat, and was immediately adjacent to the high ranked koala habitat, would constitute a risk for koalas, as well as being an impediment to movement. The reasons that koalas change locations are not at all clear from the available data, yet it does seem that, over the years, koalas relocate over many kilometres. If one were to hypothesise that such movements were essential for social or dietary reasons, than a block to movement would reduce survival and reproduction in the koala population.

Habitat modelled on sighting records of specific locations, or based on searches for koala scats (pellets) under trees, has the great power of providing a basis on which to map koala habitat. The strength lies in the great number of trees that can be assessed, although a good vegetation map is also essential for this exercise. Conservation of this modelled habitat will be the key to conserving koala populations that are shrinking in the face of an ever-increasing use of forest on coastal NSW. SEPP 44 (Koala Habitat Protection) was devised to assist local governments in NSW to deal with this pressing matter, but conservation of this habitat is in itself insufficient. The shape and size of these home ranges, and ear tag movements, in Campbelltown demonstrate that many individuals in the local koala population appear to have moved in and out of harm's way as they crossed roads and moved through suburban areas. Modelling habitat alone by sign, mostly koala pellets, or sighting records, does not give us quite enough information to be able to manage effectively, in the long-term, peri-urban koala populations under threat. This case study in Campbelltown has shown that there are major elements to a koala's life history, shown by home range sizes and ear tag returns that need to be taken into account when planning to conserve a local population. We consider that the principles established here can be transferred to other LGAs, and although more home range studies are imperative, some LGAs could design habitat conservation efforts more effectively by simply looking at the pattern displayed by this population.

Distribution of high quality habitat

The most striking feature of the southern Sydney koala habitat model, that was part of the study of the terrestrial vertebrate fauna of the Greater Southern Sydney region (DECC 2007b), is that the distribution of high quality habitat is patchy. There are many links and corridors of high quality habitat through the landscape. Farming and urbanization has both depleted and fragmented koala habitat since European settlement, but protection in either Sydney Catchment Authority land or the National Parks and Wildlife Service estate has maintained a spread of patches of koala habitat throughout this region. This habitat map is the most comprehensive interpretation of existing high quality koala habitat because it provides the best regional basis for managing both koalas and koala habitat. The community records, radio-tracking records and Atlas records were interpreted upon this basis. This map forms part of a major report based on five years of fauna survey and interpretation in the area.

The consistency among the different techniques in identifying the eastern portion of the Campbelltown LGA as high quality koala habitat allows the conclusion to be drawn that this area does contain a sustainable koala population. This population is being maintained by the local habitat quality, particularly tree species,

the underlying soils and the connectedness along the eastern edge of the LGA. This strengthens the case for maintaining the integrity of this entire habitat, particularly by preventing its loss, and by maintaining its connections to the south, and recognizing that incidental reports of koalas from this area do reflect a continuing population that is locally based on the eastern part of the LGA.

The differences disclosed by the differing techniques highlight the importance of Nattai National Park and the Upper Nepean State Conservation Area. The AKF map shows that the distribution of better habitat is in the Kentlyn area, and that the clusters of koala records around Wedderburn are in lower quality habitat. This finding points to a higher level of vulnerability of the population around Wedderburn, if the habitat were to be cleared or fragmented. The modelled habitat for the southern Sydney region shows that the Campbelltown population is linked by high quality habitat through Appin and Wilton to Bargo and beyond. This encompasses three adjacent sub-coastal LGAs (Campbelltown, Wollondilly and Wingercarribee). The 2006 community survey data does identify the existence of koalas along this stretch and increases the case for managing this habitat as a continuous strip rather than isolated records of koalas in disconnected patches. This is a major finding in that it shows the link, or overlap, among community records, systematic fauna survey records and habitat modelling.

The meaning of a local population

In 1986, the NPA threw a spotlight on the koalas at Wedderburn, an issue whose profile was raised by issuing the first ever to IPO in 1988 to conserve koala habitat. The study by Cork *et al.* (1988) was confined the area of particular political interest in 1988, and its comments on protecting koala habitat kept that focus. With the accumulation of knowledge of koala ecology in the intervening years, it is more advantageous to take in a larger area, and especially to see the continuity geographically of Campbelltown's koala population with that in the high quality modelled habitat in the two shires to the immediate south.

The 2006 community survey data are consistent with the modelled habitat for Greater Southern Sydney Region, but the scatter of locations is wider. This is consistent with the findings in Campbelltown that showed that the home ranges were centred on the areas with the greatest concentrations of koala habitat, but each individual radio-collared or ear-tagged koala moved away from this habitat during the years of study. The ear tag returns show a great capacity for the local koalas to relocate to new areas of their own volition. The message here is that barriers, such as the Hume Highway, have the potential to block this natural pattern of movement, or form a zone of high koala mortality for dispersing koalas.

The historical search disclosed a strong sense of the importance of the Campbelltown, Camden, Nattai, Bargo connection (Lunney *et al*. 2009a). The koalas were in Bargo and Nattai in 1798 and 1802, and these locations are part of the modelled habitat in the Greater Southern Sydney Region study. The area between Wedderburn and Kentlyn, and south-west to Nattai and Bargo shows a region largely altered by development, most clearing, but also roads, including major roads, and urban development. One might reasonably conjecture that all this land was koala habitat in 1798, and what remains is a broken ring of habitat around the development. The Upper Nepean and the Bargo River SCAs were gazetted in February 2007, and the map of koala locations over these new protected areas shows that their gazetting was important for koalas.

SEPP 44 Koala Habitat Protection

The current guidelines for producing a shire wide Comprehensive Koala Plan of Management (CKPoM) under SEPP 44 (e.g. Lunney and Matthews 1997; Lunney *et al.* 1999, 2002) require producing a habitat map based on two separate methods of identifying koala locations. The two methods for producing a map of modelled habitat are community survey and searching for koala pellets under trees to determine the tree species selected. The records for both approaches are each modelled against a vegetation map to produce a ranked habitat map, i.e. a vegetation map that has been ranked by koala choice. The two separate maps are then combined to produce one map of ranked habitat that takes into account the best of both techniques.

The effort to collect and interpret community survey data has been daunting to some planners. Without skill, the project could go awry, and it may not be easy for some assessors to interpret the data set. The apparently easier option is to produce a plan based on koala pellets under trees and use that to prepare a koala habitat map with ranked habitat classes. One can photograph the field work and the located pellets are the definitive statement that a koala used that tree. The current draft CKPoM for Campbelltown is in that category. It does not make use of a community survey data set, or a map of where the community has seen koalas, even if there were none at the time the pellet survey was carried out and the local trees were missed.

A limitation of the approach of determining the preferred trees, and thus the vegetation type that goes with those trees, is that it only reflects the recent use of those trees. Humid weather causes pellets to decay more rapidly than dry conditions, and thus influences which trees are recorded as habitat-use trees (Rhodes *et al.* unpublished data). Its strength is that it identifies trees by species, and that is such a valuable means of evaluating development applications, planning across a LGA, and habitat can be reliably ranked. A strength of the community survey data set is that is shows where koalas were, even if they are not currently present. A good example is in Iluka, where the population was regarded as extinct in 1999, but had been a strong population through the Iluka peninsula in the early 1990s (Lunney *et al.* 1996; 2002). If the population is ever to recover, such as through immigration, then the koala habitat would have to have been conserved, but a pellet-based survey would have been of little value in 1999.

The limitation of the community records is that the technique does rely on people having been to a location to have seen the koala. This limitation is apparent in the

Campbelltown area in that to the immediate east of the LGA is the no-go military area of Holsworthy. It may well contain good koala habitat and be a source of the koala population in Campbelltown, but it is out of bounds, so community records are not available. Nor, however, are pellet-based surveys because of this tenure boundary. Each method has its advocates, but the point of using both techniques in a CKPoM is that where one is weak, the other can make up for it because the techniques are additive. The community records will be stronger on private land, where people live, and the pellet survey will tend to be stronger where there are patches of trees with a resident population, and where those patches of trees are not on private property, especially where permission to enter the land is denied, or the pellet survey team is reluctant to seek permission to enter private land.

A rare opportunity to examine the strengths and limitations of the two techniques has been presented in this project at Campbelltown. The data sets we drew upon have allowed us to examine the unique value of each technique because each of the methods was collected independently. The first conclusion is that the historical record (Lunney *et al.* 2009a) shows that koalas would have occupied much of the LGA, not necessarily evenly, but the population of koalas would have stretched across the landscape from east to west, a picture that is no longer apparent. From a restoration viewpoint, the whole LGA could be rehabilitated as koala habitat, but any current pellet survey or community survey would not identify that continuity of potential habitat restoration.

Given that most of the current and future effort to conserve the local koala population will focus on existing koala populations, as well as koala habitat that is still standing, the emphasis here is to look at the relative merits of the methods for determining where those koalas exist and where that habitat can be found. The weakest guide was the DECCW Atlas. There were simply too few records in the LGA. The AKF habitat atlas produced a map of high reliability and clarity, and the conclusion can be drawn that it has produced a strong basis for planners in that it defines habitats in rank order with a high resolution of the location of the habitat. This is essential for planners working on decisions with small scope for error in drawing lines on maps with rules associated with them. The modelled habitat from the Greater Southern Sydney region was produced from survey data, i.e. sightings of koalas, and it has produced a first-rate map of the habitat along a gradient of habitat quality. Its resolution is high and it could serve as a planning map. From one perspective, the Greater Southern Sydney region modelled habitat has much in common with the AKF map in that it mapped koala habitat based on verifiable koala records. That they correspond is thus not surprising. The particular value of the Greater Southern Sydney region habitat map is that it covers the local region, including the two adjacent LGAs to the south and they have koala populations. Most importantly, the habitat model shows that there is a good strip of potential habitat on the western edge of the Campbelltown LGA, which is consistent with the historical record (Lunney *et al.* 2009a). It also has provided an excellent basis upon which to assess the contribution of the large 2006 statewide community survey data. In short, the community sightings were aligned with the modelled habitat, with each lending support to the value of the other.

The more important conclusion to be drawn from overlapping the koala habitat map that emerged from the Greater Southern Sydney region study with the 2006 community records from the statewide survey was that it showed how the Campbelltown population is connected to koala populations elsewhere. If Campbelltown is to retain its koala population, it will have to look south to the adjacent LGAs for that continuity. Koalas do not go north much beyond Campbelltown, nor to any reliable extent to the west, and the coast is not a source of koalas. From one perspective, it is Campbelltown that is at the end of a peninsula of koala habitat, and thus the one most likely to lose its population first from the koala population that lives on the edge, and just beyond, the south-western boundary of Sydney.

The novel overlap of the koala home ranges, and the movements gleaned from the ear tag records, on the habitat maps was that it demonstrated that koalas use much more than the habitat identified as their preferred habitat. This helps explain how koalas move from one location to another in the LGA, and render themselves vulnerable to local threats, such as from dogs or cars (DECC 2008). The survival of the koala population in Campbelltown may well be attributed to the capacity of koalas to move, which means walking on the ground, across roads and through people's backyards. It follows that if the population of koalas is to have a long-term future in the City of Campbelltown then the band of habitat identified in the study of the Greater Southern Sydney region that stretches from the eastern built-up edge of the Campbelltown, west of the Georges River, in a south-westerly direction needs to be conserved. It also means that if a major road on the eastern edge of Campbelltown were to be built (it is on the maps as a road reserve), it would bring in not only heavy traffic, which kills koalas, but it would consume this band of habitat. The major revelation of the movements of the ear tagged koalas is that these animals can move many kilometres, at least 10 km in a straight line, and more like 20 km, across non-koala habitat and potential barriers, such as busy roads.

A series of studies in a number of well-separated LGAs from Victoria to Queensland has demonstrated that the threats to the survival to the local koala populations differ in degree and threshold across the range of the koala (e.g. McAlpine *et al.* 2007; Rhodes *et al.* 2008a). They have shown not only that thresholds varied vastly across the regions, but also that they were generally higher than widely used rules-of-thumb that call for the preservation of at least 15 to 30 percent of a landscape as habitat. The research showed that appropriate targets for the proportion of native forest in the landscape for koala conservation of around 60 percent in Noosa, 50 percent in Port Stephens, and 30 percent in Ballarat. Unless conservation and planning efforts are effectively

coordinated across regions, and priorities recognise the importance of a hierarchy of habitat factors, including landscape context, the long-term prospects for managing koala (and other wildlife populations) will be diminished. These studies have produced a generic set of guidelines for koala planning (McAlpine *et al.* 2007; Rhodes *et al.* 2008a). This study in Campbelltown has added to that conclusion by demonstrating that a range of independent techniques, including long-term local population studies, can contribute to finding the local solutions that will be essential to conserve each local population.

The long-term future of the population

A potential threat, and possibly the largest threat, to the survival of koalas in Campbelltown is a proposed road - the Georges River Parkway (Ward 2002). This proposed road will run to the east of St Helens Park and Airds, and pass though Kentlyn. It would require clearing of breeding koala habitat on shale soils, cause a large number of road deaths of koalas, and would act as a barrier to koala movements from along Campbelltown's eastern border to habitat along the Georges River (Ward 2002). An impact of this magnitude would have a large detrimental effect on the breeding koalas to the extent that koalas could become extinct in the area. Following the suggestion of Ward (2002), it is strongly recommended that the Georges River Parkway not be built.

The area south-west of Sydney is set to experience large human population growth within the next 25 years. The City of Campbelltown LGA is expected to grow from a human population of 143, 076 in 2006 (Australian Bureau of Statistics 2007) to 187,001 by 2031 (NSW Department of Planning 2007). In response to these increases in human population, the NSW State Government has established the South West Growth Centre, covering 17,000 ha of the Liverpool, Campbelltown and Camden LGAs. This growth centre has the capacity for 115,000 new homes (Growth Centres Commission 2008). Although not within the current range of the koalas of south-western Sydney, the influx of a large number of people to the region has the potential for large impacts on the koala population. The new area has no rail network, hence the road traffic can be expected to grow heavily, as people travel to the major commercial centres of Campbelltown and other parts of Sydney. This increased road traffic represents a growing threat to koala populations. In addition, large numbers of people will also increase the numbers of dogs in the area, another threatening process for the koala.

The South West Growth Centre is one of the first areas in NSW to be subject to the Biodiversity Certification amendment of the *Threatened Species Conservation Act 1995*. Under section 126G, the Minister may confer biodiversity certification on an environmental planning instrument (EPI) if satisfied that the EPI, in addition to any other relevant measures to be taken, will lead to an overall improvement or maintenance of biodiversity values. The amendment no longer requires developers to address the 'assessment of significance' ('7-part test') required under section 5A of the *Environmental Planning and Assessment 1979* through the preparation of species impacts statements for flora and fauna, or by obtaining the concurrence of the DECCW or the Minister. Instead, the Certification pools a portion of the developer's infrastructure contributions through the special levy and uses it to purchase offset areas to protect remaining areas of endangered vegetation. The current Biodiversity Certification plan for the Western Sydney Growth Centre is as follows: to protect 2000 ha of native vegetation within the Growth Centre; to offset the 1867 ha of native vegetation to be lost within the Growth Centre through the provision of $530 million of funding for the protection of high value areas, both within and outside of the Growth Centre (DECC 2007a). Seventy-five percent of this funding will be spent outside the Growth Centre, with the rest to be used to acquire land within the Growth Centre, as identified in the SEPP Growth Centres State Environmental Planning Policy. The location of the offset areas is yet to be determined as of November 2009.

The Biodiversity Certification plan could have negative effects for the koalas of Campbelltown. The Biodiversity Certification study for the growth centre of south-west Sydney in 2007 relied on Atlas records and previous vegetation mapping as the source of information upon which to base the planning (Eco Logical 2007). No koalas were identified within the Growth Centre, based on NSW Wildlife Atlas records. However, the Growth Centre is certainly within a koala's dispersal distance from the Campbelltown population. If koalas do appear within the areas of the Growth Centre earmarked for development under Biodiversity Certification, they will not be protected by planning legislation. However, if the areas around the eastern side of Campbelltown along the Georges Rivers, which are outside the Growth Centres, are protected as offsets, this would help the long-term survival of the Campbelltown koalas.

The long-term future of Campbelltown's koalas is contingent upon the maintenance of koala populations to the south, and the continuity of the corridor between them. If Campbelltown were to be isolated from the southern populations there would be a far greater risk of a quick demise of the koalas of this LGA. Already these koalas are under threat from the ever-growing human population of south-western Sydney, which will be exacerbated by the Macarthur South development and the proposed southwest growth centre. This will bring more people, more cars, more dogs and more demand for land in future decades, and the koala habitat bordering the cleared lands are immediate obvious targets for loss and fragmentation from development to cope with Sydney's expansion.

In the context of Australia's koala populations, the Campbelltown population is historically significant (Lunney *et al.* 2009a). It was the population first seen by Europeans, and we can conclude that this population has remained as a continuous local population. The second point of importance is that it is an urban, or more correctly, a peri-urban population. In an Australian context, that is both attractive and liability. It is attractive to be able to see a koala in Campbelltown and appreciate that it is part of the

native fauna, and it is now a species with an international profile. It is a liability in that it does require sustained management of the major threats to its survival, namely, habitat loss, fragmentation of what remains, and dogs, cars and the occasional bushfires. To address this dilemma, the case grows stronger for a draft Comprehensive Koala Plan of Management to be passed by Planning NSW and implemented for the City of Campbelltown. We suggest, however, that it now be revised in the light of this study, and then resubmitted for approval. It also means, especially on the results of this study, that all the local LGAs need to work together to come up with a regional approach. SEPP 44 does not specifically call for multi-LGA CKPoMs, but the case for each adjacent council working together to produce such a document is now apparent. This is recognisably an administrative increase in workload for planners and environmental officers in councils, but here there is a case for increased co-ordination with both the State and Commonwealth government, a point noted in the *National Koala Conservation and Management Strategy* (DEHWA 2009).

In the case of the NSW State Government, the Koala Recovery Plan (DECC 2008) is of material assistance, as is SEPP 44. Further, the local office of NPWS is keen to play a role, as can be noted in the acknowledgements in that the Illawarra area office helped fund this study. In addition, the Sydney Catchment Authority manages land of considerable importance for the local koala population, and since it funded a major study of the terrestrial fauna, it has made a major contribution in that direction. The regional habitat model was prepared as part of that study. The AKF koala habitat model also contributes to identifying the important habitat, and university research efforts have also added much to this account. The independence of each of these approaches has also lent much to being able to see the whole picture more sharply.

The 2006 statewide community survey has been able to place this population in both a regional and a statewide context, and that has shown that this is a unique population, and is part of a larger population that extends in a south-westerly direction. Another gain of the overlap of all this information is that it has enabled us to conclude that the statewide survey has provided a more robust and consistent picture of koala distribution than the DECC Atlas. We note that the Atlas does not make that claim, but it is treated as a distribution map. When the south-west Sydney growth centre was being examined as a proposal, the Atlas was searched, no koalas were found with the area of the south-west growth centre, so koalas were not entered into the calculations. That misinterprets, in our view, the natural history of this Campbelltown population. Another beneficial outcome is that the 2006 statewide survey was, in our opinion, sufficient to supply the community records for the SEPP 44 CKPoM for Campbelltown. This has yet to be done for the existing draft, which relies on the AKF habitat model based on field work. More importantly, it does point to the potential for other LGAs to use the 2006 community survey data to fulfil that part of the SEPP for a CKPoM, and thereby save both time and money. This is a material benefit flowing from the 2006 statewide survey; an action triggered by the NSW Koala Recovery Plan, which is also expressed in the Priorities Action Statement (PAS) for the koala, the PAS being one of the outcomes of the 2004 amendments to the NSW *Threatened Species Conservation Act 1995*.

The long-term future of the koala population is thus dependent on maintaining the integrity of koala habitat throughout the region, as well as within the Campbelltown LGA. From 1798 when the first koala was spotted by Europeans at Bargo, to 2008 where a regional koala population remains, there have been great losses of habitat and a relentless development push that continues to deplete and fragment what remains. It will be our long-term commitment to koalas and koala habitat over the next 220 years that will prevent the natural history of koalas being converted into an unnatural future in this region.

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APPENDIX I

Darling Avenue on the eastern side of Campbelltown,

traverses koala habitat. On the right hand side of this photo is land with trees and grassy patches. It is reserved for a major road on the eastern edge of Campbelltown, marked on the 1997 Gregory's Road Map as Georges River Parkway. If it were ever to be constructed, it would, in our view, constitute a major threat the survival of the Campbelltown koala population.

Photo, Dan Lunney, January 2008.

A well-concealed koala *Phascolarctos cinereus* in a tree on land reserved for a possible major road on the eastern edge of Campbelltown. This is the koala that was the centre of attention by the group of researchers in the accompanying photo.

Photo, Dan Lunney, January 2008.

A group of koala researchers looking at a well-concealed koala in the branches of a low tree (see accompanying photo). Rob Close is the grey-bearded figure on the far left of the photo; Ian Shannon is the person in the centre of the photo, and Jessica Bryant is the person 3rd to the right of Ian Shannon, adjusting her sunglasses. Koalas are often hard to see, and this koala was tracked by Tristan Lee, the person 2nd from the right, holding the antenna, with the receiver slung over his shoulder. This is the land reserved for possible conversion to a major road bypass on the eastern edge of Campbelltown.

Photo, Dan Lunney, January 2008.

APPENDIX I

A tall tree, a grey gum *Eucalyptus punctata*, on private land near a house on Georges River Road. This is a favoured koala tree. Not visible in the photo is a koala, see accompanying photo.

Photo: Dan Lunney, January 2008.

Koala *Phascolarctos cinereus* in the tall grey gum in the accompanying photo. The koala is resting in a favoured tree, but the risk to its survival is high when it descends and crosses the local roads, especially the larger, busier roads. Koalas in this pose belie their threatened status in NSW, although the Campbelltown koala population is mentioned in the NSW January 2008 Koala Recovery plan (DECC January 2008).

Photo, Dan Lunney, January 2008.

Scratches, made by a koala, in the bark of a grey gum *Eucalyptus punctata* in Campbelltown. Scratch marks can indicate koala presence, but are not an effective koala survey method. Photo, Dan Lunney, January 2008.

APPENDIX I

The distinctive dung, or faecal pellet, or just pellet, of a koala. Determining koala presence and tree preferences can be reliably undertaken by searching for koala pellets underneath trees, with the usual technique being to search on the ground, in a 1 m radius around the tree trunk for a fixed time, up to 2 minutes, or until a pellet is seen. This pellet was under the grey gum in the accompanying photos.

Photo, Dan Lunney, January 2008.

Looking along Peter Meadows Road in the eastern edge of Campbelltown. This location is near where the koala was resting in the tall grey gum in the accompanying photos.

Photo, Dan Lunney January 2008.

Woodlands Road at the south-eastern edge of Campbelltown beside Spring Creek valley which supports several koalas. There have been two recent collisions with cars on this road. Rob Close is the figure in the photo.

Photo, Dan Lunney, January 2008.

Road-killed koala on the Appin Road at the T-junction with the Cataract Scout Camp Road, just south of Campbelltown. Mathew Crowther is the figure on the left, Rob Close in the centre, and Jessica Bryant on the right.

Photo, Dan Lunney, January 2008.

APPENDIX I

Rob Close leaning over the fence to pick up the dead koala noted in the accompanying photo, at the Appin Road at the T-junction with the Cataract Scout Camp Road, just south of Campbelltown.

Photo, Dan Lunney, January 2008.

Rob Close lowering the road-killed koala into a plastic bag, for later examination, and records.

Photo, Dan Lunney, January 2008.

Rob Close employs seeks community information through all sorts of means, such as this message on the window of his car. Rob Close can be seen through the windows.

Photo, Dan Lunney, January 2008.