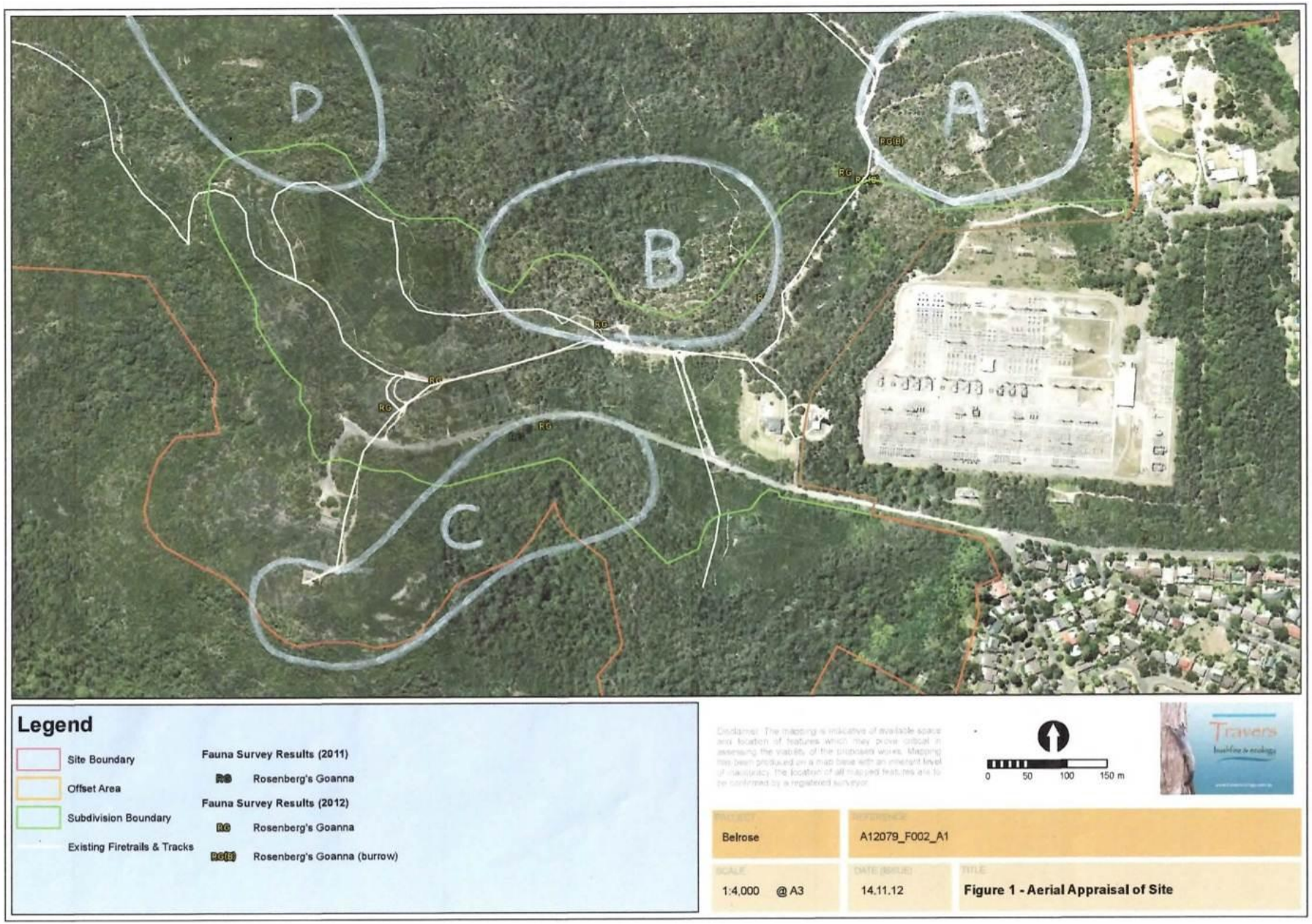

Figure 1 - Map of region showing the four selected survey sites.

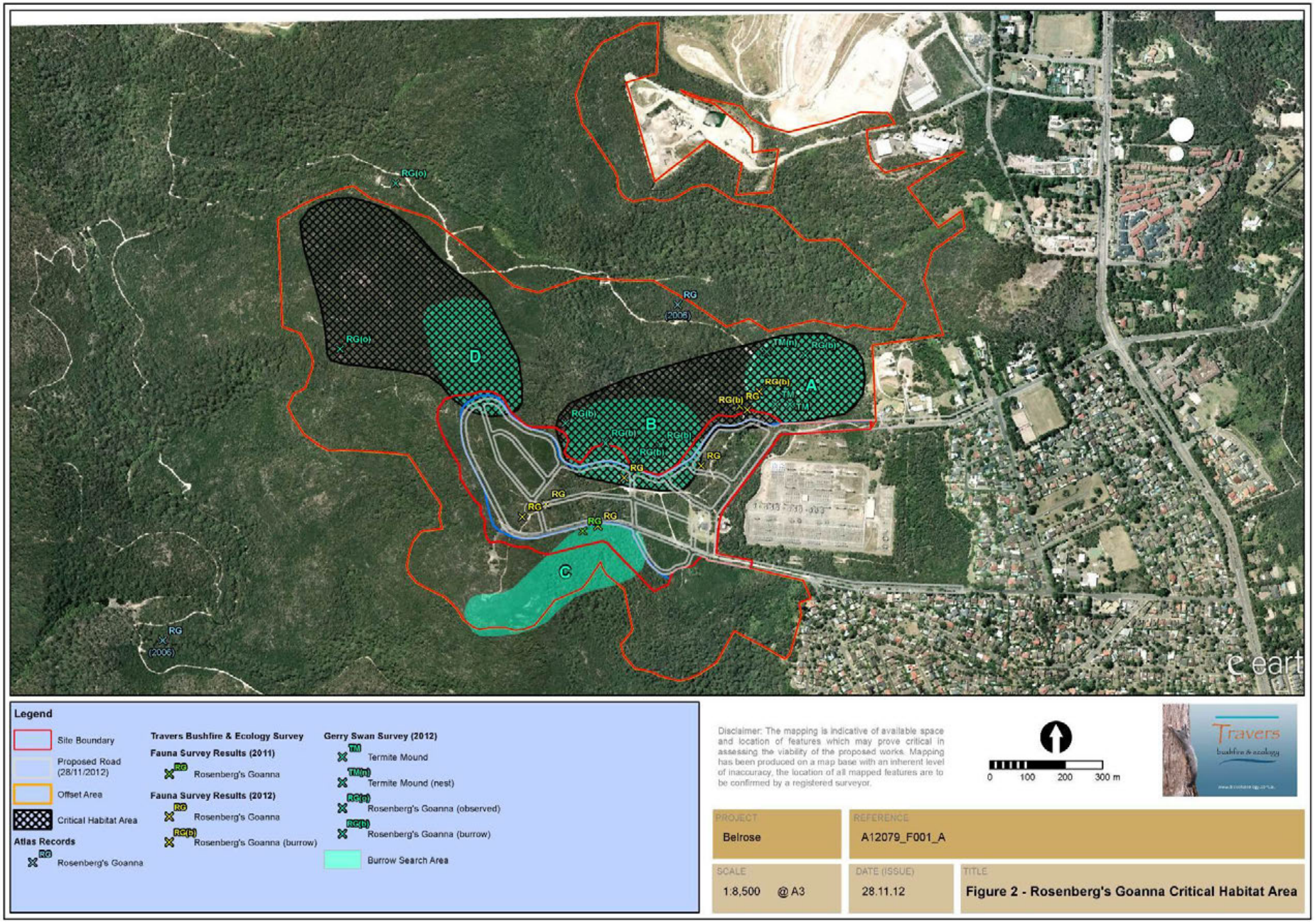

Figure 2 – Habitat areas within study area for Rosenberg's Goanna

Cygnet Surveys & Consultancy
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16th March 2017

To:
Corey Mead,
Travers bushfire & ecology,
38A The Avenue, Mt Penang Parklands,
Central Coast Highway,
Kariong, NSW 2250.

Dear Corey,

Belrose Planning proposal: Rosenberg's Goanna assessment.

In 2012 I carried out a survey of areas adjacent to the proposed subdivision on behalf of Travers bushfire & ecology to assess if the population of Rosenberg's Goannas at the site would be significantly impacted.

My conclusions at that time were that:

- The proposed residential site was not critical to the survival of the population.
- There is adequate habitat surrounding the proposed residential site to support a viable population.
- The proposal would not restrict movement or connectivity for the local population.
- There was no significant impact.

Since that time you have advised me that following a recent bushfire review there are increased impacts from APZ's resulting in an additional loss of .82ha of the important habitat area.

Having had an opportunity to inspect the addition to the APZ with you this morning, I am of the opinion that this does not change my original assessment and conclusions.

Regards,

Gerry Swan, Principal
Cygnet Surveys & Consultancy.

Threatened Frog Specialist Report

A6

Assessment of the distribution and habitat use by the Giant Burrowing Frog and Red Crowned Toadlet at Ralston Ave Belrose

Prof Michael Mahony
Newcastle University

June 2013

Contents

EXECUTIVE SUMMARY

In January 2013 a brief was accepted to undertake habitat searches for potential breeding areas of the Giant Burrowing Frog (GBF) at a site at Ralston Avenue Belrose where a planning proposal for a residential subdivision (=subject site) was prepared. In earlier fauna studies conducted at the subject site by Travers Bushfire and Ecology a juvenile GBF had been collected in a trap line on the sandstone plateau at the site within the proposed residential subdivision footprint. The objective of the investigation was to address the significance of impact of the proposal on the GBF; 1) whether habitat on the plateau is critical to the survival of the GBF population and which parts of the landscape (subject site = residential zone, and surrounding areas) are likely to be important for breeding; 2) whether there is adequate habitat surrounding the proposed residential zone to support a viable population; and 3) whether the proposal is likely to result in significant restriction of movement or connectivity for the local population. An assessment of the potential impact of the proposal on the local population of the Red Crowned Toadlet (RCT) which was known from the area was also sought. Advice was also sought on relevant mitigation measures for these two threatened frog species. Habitat assessments at the subject site were conducted in February 2013.

- The outcome of habitat assessment was that there was no identified breeding habitat for the GBF within the subdivision boundary with the possible exception of a small drainage line on the north eastern edge of the subdivision boundary.
- Several breeding locations for the RCT were detected with only one on the plateau, one at the head of a drainage line to the south, and two in a seepage on the north-east of the subdivision zone.
- It was concluded that the potential significance of impact of the proposal on both threatened frog populations may not be from direct removal of breeding habitat on the sandstone plateau, but possibly from the removal of sheltering (burrowing) and foraging habitat of the GBF and RCT. The potential for indirect impact by alteration to hydrology of habitats outside the subject site was noted.
- Following the habitat assessment it was concluded that there was adequate habitat outside the proposed residential zone to support a viable population of the GBF and RCT, but this needed to be confirmed by targeted surveys.
- The potential for the residential zone to disrupt movement corridors for the GBF were assessed and without specific information on the breeding, shelter and foraging habitats the significance of potential corridors was unknown and targeted surveys were recommended.

Following the recommendations from the habitat assessment targeted surveys were conducted to identify likely breeding areas of the GBF including tadpole searches and shelter locations, and to expand on the knowledge of the habitat used by the RCT. Targeted surveys were conducted in the period April to June 2013, and coincided with several significant rainfall events which are known to trigger amphibian activity.

- One breeding site was identified for the GBF. This site is in the valley to the north of the plateau and greater than 300 m from the subject site boundary. Intensive and extensive surveys of semi-permanent and permanent pools in drainage lines emanating from the plateau were undertaken and no other breeding location was found. The seasonal and climatic conditions at the time of the survey were ideal for detection of the GBF.

- No adults or juveniles GBF were detected in habitat considered to be suitable for burrowing or foraging. It is concluded that the density of GBF at the site is low, and that it is most unlikely that habitats on the plateau are used routinely for shelter and foraging. Furthermore, it is not likely that development with break a corridor that connects breeding habitat with foraging and shelter sites since there are no identified breeding sites close to the plateau.
- The considerable distance of the identified breeding habitat from the plateau and the relatively large area of surrounding habitat indicate that indirect impacts on hydrology are unlikely to impact on the GBF breeding habitat.
- In conclusion it is not likely that the proposal will impact on the local viable population of the GBF.
- There is no need for the placement of buffer zones around habitat on the escarpment since there are no identified breeding, sheltering or foraging habitat.
- Additional breeding habitats of the RCT were detected in targeted surveys and twelve breeding locations were identified within the study area outside the subject site. It is concluded that the local population occurs along most of the semi-permanent drainages and soaks that occur near the escarpment and down slope from the plateau. All of these breeding locations will not be directly impacted by the proposed development. There are four identified breeding locations within the subject site; one on the western end of the plateau (human made pit), two on the rock face seepage in the north-east, and one at the head of the drainage line to the south.
- The assessment concludes that movement of the RCT will mostly be in the escarpment and mid-slope areas and development of the plateau will not have a significant effect on the local population due to the removal of habitat or the breaking of corridors.
- The potential for impact on the population of the RCT is assessed to be related mostly to indirect impacts on the hydrology of the breeding habitat (rate, volume, and water quality of discharge). Specific mitigation measures are required to ensure that the hydrology of these sites is not altered by the proposal.

INTRODUCTION

The aim of this survey and assessment was to determine the distribution and abundance of two threatened amphibian species the Giant Burrowing Frog *Heleioporus australiacus* (GBF) and the Red-Crowned Toadlet *Pseudophryne australis* (RCT) on land at Ralston Avenue Belrose. A full description of the subject site and purpose for the assessment is provided in the report by Travers Bushfire and Ecology (2013).

Specifically the survey and assessment aimed to identify the habitat of the two threatened amphibians at the subject site and in the local area, and to assess the potential for the proposal to impact on the local viable population of these frogs. These are terrestrial frogs; they have specific habitat requirements and are listed as habitat specialists under the *NSW Threatened Species Conservation Act* 1995.

The GBF is a large (adults up to 82 mm in length) and robust terrestrial frog. The RCT is also a terrestrial frog but it is relatively small (adults up to 28 mm in body length). As its name suggest the GBF requires suitable sites in which to burrow and seek shelter. These burrowing sites are typically well away from the breeding site and are usually in sandy moist soils that are at least 0.2 m deep (Stauber 2006) and can be found in open forest and heath vegetation communities and less commonly in closed forest (> 70% canopy cover). Adult and juvenile frogs forage on the forest floor at times when the weather conditions are suitable (i.e. moist and humid with low wind so that the animals do not desiccate) (Penman 2005). Breeding sites occur in ephemeral pools and soaks associated with upper level drainages (Penman 2005; Penman, Lemckert et al. 2005; Stauber 2006). The egg mass is deposited in a foamy nest and the tadpoles are aquatic (Anstis 2002). Minimum larval periods ranged from 33 to 47 weeks at 11 breeding sites over a period of two years (Stauber 2006).

The RCT has a very different biology to the GBF. Adults are most commonly associated with breeding sites which are ephemeral pools and soaks that form on the escarpment of eroded Hawkesbury Sandstone parent rock. Adults forage on the forest floor but they spend the majority of their life near to the breeding site (Stauber 2006). The clutch of eggs is composed of a relatively small number (mean of 21) of relative large eggs (ovum diameter 1.6 – 2.8 mm)((Thumm and Mahony 2002; Thumm and Mahony 2005). The clutch is deposited beneath moist leaf litter and soil at the edge of an ephemeral pool. The period of embryonic growth and development can vary greatly depending on the flooding of the ephemeral pool. In many cases the clutch is deposited prior to rain occurring and it is not until the site is flooded that hatching occurs and the tadpole stage is then aquatic (Thumm and Mahony 2002; Thumm and Mahony 2005). There is a level of uncertainty surrounding the length of the tadpole stage mostly because some records are based on tadpoles raised in captivity which may lead to either a faster or slower development rate than in nature. A mean period of 78 days (minimum of 45 days) was determined in captivity with tadpoles held at the field temperature and fed ad libitum (Thumm and Mahony 2005). Hydro-period requirements for RCT tadpoles have been investigated in the field and only 4 of 12 sites with tadpoles resulted in successful metamorphosis and they all required hydroperiods greater than 110 days (Stauber 2006).

Both species occur predominantly on habitats found on Hawkesbury sandstone and to a much lesser degree on the Narrabeen Group of sandstones, both of Triassic origin (Thumm and Mahony 1999). Hawkesbury Sandstone derived soils are shallow (50 cm deep), highly permeable and of low fertility. They include Lithosols, Earthy Sands, Yellow Earths, Yellow and Red Podzolic Soils and Siliceous Sands (Chapman 1989; Chapman 1989). The study area occurs on the Lambert soil landscape unit and the landscape is described as “undulating to rolling low hills on Hawkesbury Sandstone, local relief 20-120

m, slopes < 20%. Rock outcrops > 50%. Broad ridges, gentle to moderately inclined slopes, wide rock benches with low broken scarps, small handing valleys and areas of poor drainages. Open and close heathlands, scrub and occasional low open-woodland" (Chapman 1989; Chapman 1989).

Most breeding sites of the GBF are located in the upper parts of the topography, i.e. found associated with plateaus and slopes and not the valley floor. Investigations of the aspect of all locations in the NSW Atlas of Wildlife revealed no preference for any aspect segment (Stauber 2006), and there is no indication that aspect plays an important role in the distribution of breeding sites. There is a positive association with moderate slope (i.e. 6 to 11^{o}) and minimal association with flat or steep areas. The Hawkesbury sandstone geology is often found in the higher parts of the topography, a fact reflected in the topographical distribution as well as the landscape morphology of the habitat of both species. Hawkesbury Sandstone weathers into deep precipitous gorges with reasonably sized creeks that flood during rain and then dry to a series of pools. These creeks are fed by numerous laterals of varying sizes and permanence. Most breeding locations of the GBF and RCT are within the top one third of elevated landscapes where these laterals are found (Stauber 2006). Bioclimatic species profiles have been produced for both species (Penman 2005; Stauber 2006) and the principal climatic components of the distributions describe a gradient of increasing precipitation and moisture index, and decreasing radiation, temperature range and temperature maximum. Both frogs mostly occur in areas that experience higher precipitation and associate moisture indices, and lower temperature ranges and lower temperature maxima compared to average values representative of the Sydney Basin. Stauber (2006) postulated that such preferences are likely to be beneficial to the aquatic larvae and terrestrial life stages of both species which require a reasonable period for successful larval growth to metamorphosis. Successful metamorphosis in habitat away from permanent watercourses in places where moisture holding capacity of soils are poor largely depends on replenishing rains, and reduced temperatures that result in lower evaporation rates. A milder climate is expected to convey benefits to tadpole development and provides for an extended breeding and larval period.

The habitat requirements of the GBF have been investigated in several detailed studies (Penman, Lemckert et al. 2005; Stauber 2006; Penman, Mahony et al. 2007; Penman, Lemckert et al. 2008). In summary breeding sites are not usually associated with cliffs, but is found predominantly on the upper slope, but also on mid slope and on flat ridges. The species also utilises gullies. Their habitat occurs in closed forest, open forest, woodland and various heath types. Ground story cover is generally greater than 50% with a mean height of 0.3 to 0.6 m and a diversity classification of 5 to 19 species. Top storey coverage was predominantly 5 to 75% and never exceeded 75%. Coverage from all three layers combined exceeded 75%. Breeding sites are associated with pools and in creeks, and crayfish are usually present and fish are absent. Water courses are ephemeral or spring fed. Breeding pools are semi-permanent (=ephemeral), and generally not permanent with soil or rock shelves making up the substrate and sides. Stauber (2006) found that GBF use flat ridges more often than RCT do. In these situations GBF use pools in hanging swamps or artificial small dams, whereas RCT are absent from such places.

RCT breeding sites are frequently found on the upper slopes or mid slop, but never in gullies or flats, and Thumm and Mahony (2005) reported that 68% are found within 200 m of cliffs. At these sites breeding groups consist of small groups of closely spaced individuals, and aggregations occur in suitable microhabitat (e.g. dense leaf litter piles). Movement of RCTs relative to the breeding locations has been investigated using marked individuals (Thumm 2005; Stauber 2006). In a study period of over 290 day the majority of recaptured individuals (82%) were less than 7.5 m from the location of first capture and the biological interpretation is that the animals showed high site fidelity (Stauber 2006). Low individual movement distances and the aggregation behaviour observed suggest that populations may be able to persist in relatively small areas of suitable habitat. The spatial requirements of individuals and populations however are predicted to be much higher than the space and resources offered by breeding

sites alone. One individual marked female was observed to use habitats that were 200 m apart and this indicates a considerable terrestrial movement for such a small frog.

Breeding biology and larval development of the RCT has also been closely investigated. Thumm (2005) reported a high rate of mortality in the period from embryonic development to metamorphosis and postulated that this was due to the unpredictable nature of rainfall in the Sydney Basin and the ephemeral character of breeding sites used by this frog. In most cases low survival was attributed to drying of the breeding site. This high mortality rate is balanced by a highly specialised breeding biology whereby the adult females are capable of breeding multiple times in a year and in all seasons compared to most frog species where breeding occurs only once and in a specific season.

The specific objectives of this investigation were to:

- Use knowledge of habitat requirements of the GBF and RCT to assess the likely breeding sites, burrowing and foraging habitats, and identify potential movement corridors. Utilise tadpole searches to confirm the occurrence of GBF and RCT breeding sites.
- Conduct terrestrial habitat searches to locate burrowing and foraging habitat.
- Use this information to consider potential impacts on the local viable population and to recommend buffers to protect habitat.

MATERIALS AND METHODS

Throughout this report the following terms are used; the subject site refers to areas within the site boundary (see Figure 1) and are equivalent to the subdivision zone. The study site includes the larger area of the site offset and up to 1 km from the site boundary. The topography, vegetation and condition of the subject site and study area are described in detail in the Ecological Assessment report by Travers Bushfire and Ecology (2013).

Field surveys focused on two target species the Red-crowned Toadlet, *Pseudophryne australis* (RCT) and Giant Burrowing Frog, *Heleioporus australiacus* (GBF), but also recorded the occurrence of other amphibians at the site and other fauna such as crayfish and fish. Often the occurrence of different species provides evidence of habitat quality and associations that provide important information on the likelihood of occurrence of the threatened frogs.

Field surveys for habitat assessment were conducted in the period 8th Feb to 16th Feb 2013. This was followed by targeted surveys conducted between 16th April to 8th June 2013. Nocturnal surveys were conducted on 16/4/2013, 24/4/2013, 8/5/2013, 8/6/2013 and diurnal surveys on 7/5/2013, and 25/5/2013.

Habitat assessment: After inspection of maps of the fauna records and survey outcomes for the subject site and study area, plus vegetation, topographic and soil landscape layers of the study area (see Figure 1), the subject site was inspected on foot. During this broad habitat assessment specific habitats that could potentially be used by the GBF and RCT were identified and a targeted survey strategy developed which involved the field survey methods that are described below. The targeted habitats for the GBF included small drainage lines that emanate from the plateau area, hanging swamps and soaks. Qualitative assessment of the leaf litter depth, soil composition and depth in each of the vegetation units were made by means of a small hand trowel and rule. Targeted searches for the RCT included seepages and soaks associated with the sandstone rock shelves and the coastal upland swamp vegetation community.

Stratification of the study area: The study area was subdivided by vegetation community and landscape into the following areas for field surveys. The plateau (above 155 m contour) which broadly corresponds with the subject site; the escarpment and bench areas below the plateau (below 155 to 125 m contour); mid-slope areas (below 125 m contour) with special emphasis on the drainage lines that emanate from the plateau. The location of semi-permanent (ephemeral) and permanent drainage lines were identified from a topographic map and these were given identifications such as N1 to N4 and S1 to S3 for drainages from the north and south of the plateau respectively.

Visual encounter surveys (VES): This method involves nocturnal searches for frogs using head torches. Adult and juvenile GBF that are active on the soil surface can be detected by spotlighting. This method is not useful for the RCT which does not have suitable reflective eyeshine. VES was conducted in habitats that were considered as suitable for the GBF (plateau, escarpment and benches, and mid-slope areas). Searches involved walking through the stratified habitat areas.

Targeted VES surveys were conducted for the GBF in habitat identified in the preliminary investigation as containing suitable soil structure and in vegetation communities that are known to form part of the preferred habitat for foraging and burrowing. Surveys were conducted along the contours where benches between rock escarpments occurred. These benches provide series of steps in the escarpment and were found to support open forest and heath communities with deep leaf litter and coarse sandy soils to a depth of at least 0.2 m. VES were also conducted along several tracks that run perpendicular to the escarpment (see Figure 1).

Searches of potential breeding habitat: This involved diurnal searches for tadpoles in pools, soaks and drainages. Where tadpoles were found a selection of individuals were collected and placed into clear plastic sample jars with water from the pool (~ 250 ml). Tadpoles were identified by reference to the field guide of Anstis (2002). A hand lens (10X) was used to examine the mouth parts, position of the spiracle, anal opening, pigmentation and body and tail shape of the tadpoles. Tadpoles were returned to the pool after identification. In one case tadpoles were held for a longer period to gain positive identification when one of the descriptive features did not accord with that in the guide of Anstis (2002). A positive identification of the tadpoles of the GBF was obtained from Marion Anstis (May 2013).

Aural surveys (AS): This involved listening for the characteristic male advertisement calls of the target species, and at identified potential habitats it involved the use of call-response. Most aural surveys were conducted during nocturnal surveys but they were also used with diurnal surveys for the RCT.

Automated Sound Recorders (ASR): At three locations that were considered as potential breeding habitat for the GBF and RCT we deployed digital sound recording devices (Songmeter SM2+). The locations were; 1) coastal upland swamp EEC (33^{o} 43' 41.99S 151o 12 18.52E), 2) North-east rock seepage area (33^{o} 43' 29.49S 151o 12 21.84E), and 3) sandstone drainage and pool (33^{o} 43' 24.57S 151o 12 22.43E). They were in place for 54 days (16th April to 8th June) and were programmed to record for a ten minute period every hour between 1400 and 2200 hours. Recorded sound was analysed using the sound recognition software SoundID pro, and positive records were confirmed by listening to playback. To test for false negatives a selection of recorded periods was analysed by listening.

Rainfall: Daily rainfall data (January to June 2013) for the study area was obtained from the Bureau of Meteorology site at Belrose (**Number** 66182, **Lat:** 33.75° S **Lon:** 151.23° E **Elevation:** 158 m). There were several significant rainfall events (i.e. > 50 mm rainfall in 48 hrs) in the first six months of 2013, and where possible field surveys were targeted to follow these events, since amphibian activity is triggered by rainfall and the outcomes of breeding which results in tadpoles can be detected after these events. In late January there was 177 mm of rainfall over a three day period (27 to 29th); in February 52 mm (2nd

and 3rd) and 58 mm (23rd and 24th), in March 65 mm (1st and 2nd), in April 87 mm (3rd to 5th), and in May 72 mm (23rd to 25th).

Targeted field surveys were conducted over a period and in the season when weather conditions were ideal for the detection of the GBF and RCT. The first three months of the year resulted in above average rainfall for the study site. Heavy rainfall events are known to trigger breeding for the GBF and RCT, and the late summer and early autumn period are known to be peaks in the breeding season (Lemckert and Mahony 2008). The equal highest number of recorded male calling observation for the GBF have been made in the February-March period (Lemckert and Mahony 2008).

Results

Giant Burrowing Frog

No adults or juveniles were observed by VES or AS survey methods, and no records of male calling were obtained from the three ASR devices, and none were heard during habitat searches. No adults or juveniles were found in targeted VES along contours and perpendicular to contours, and no adults were observed or heard in searches near the identified breeding location.

Tadpoles, which are a direct indication of a breeding location, were found on the 24/4/2013 at one location (33° 43' 13.09S 151° 11' 54.54E) within the study area but outside the subject site. This breeding site is located towards the bottom of the valley to the north of the plateau in the catchment of Bare Creek. The site is at the base of a relatively large mid-slope area that is dominated by dense low and tall Heath vegetation that has a moderate slope up to 10°. The breeding location consists of a deeply eroded ponded area that feeds into a gutter that runs for a distance of 33 m along the upper side of the Heath walking track in Garigal National Park before it overflows across the surface of the track at the lower base of a small drainage bund ('wo-boy'). Tadpoles were observed in the ponded area, the gutter and in small pools on the upper and lower side of where the water flowed over the track. The eroded pond appears to be human made although the purpose is not evident. The walls are up to a metre high, non-vegetated, and are formed of bare earth indicating that it is not a natural drainage course. There are indications of an old fence (star pickets) at the scoured pond site. The base of the pond area is of fine sandy silt that is derived from the eroded area.

Due to the significance of the breeding location, with respect to its hydrology and proximity to the subject site, the origin of the water that supplied the pond and drainage was investigated. Water was observed to drain into the pond from a series of natural rock shelves about 10 m to the east and about 2 m above the pond. The pond is not part of a drainage line, although one occurs not more than 10 m away and is associated with a mitre drain and concrete culvert that passes under the track. Water depth in the pond was between 10 and 50 mm, in the drain it was up to 60 mm, and in the smaller pools between 10 and 30 mm. The pond was covered (>90%) by dense heath vegetation (Hakea and Banksia spp) but because it was deeply eroded there was a distance of about 1.5 m between the pond and the vegetation cover. The gutter was covered (>90%) by thick vegetation from the bank immediately above it and from smaller shrubs along its side, and it also contained a substantial amount of leaf litter material. The smaller pools were not covered but there were emergent reeds. The substrate of the pond, gutter and pools was of fine white to yellow sand. It was evident from the shallow flow and appearance of the sandy substrate that following heavy rainfall water and fine sand was carried across the track. The observation of several tadpoles in the shallow pools on the down-side of the wash away across the track indicated that some tadpole had swum or been carried across the track when flows were higher than at the time of inspection.

When first found on the 24th April the tadpoles were 9.5 mm in body length (Gosner development stage 27) which indicates that they were relatively early in growth and most likely the outcome of a breeding event associated with the rainfall that occurred in early April 2013 (rainfall total of 87.6 mm on the 3rd to 5th). The body size accords with that expected from measurements of growth obtained at two field locations (Stauber 2006).

Only one size class of tadpoles occurred and this is interpreted to indicate that all individuals were from a single breeding event. It is not known whether the tadpoles are from one or more pairs, but it is likely that it was only one pair. The number of tadpoles was estimated by counting the number in the pond area and in two sections of the gutter. In total there were estimated to be 150 tadpoles. Tadpoles of the common eastern froglet were also found in the gutter and small pools.

The progression of the tadpoles and condition of the habitat were monitored for 6 weeks following their detection. The pond and drainage remained charged throughout this period despite the absence of any significant rainfall for a period of about 4 weeks. Seepage into the pond and drain was sufficient to keep all the areas where the tadpoles were observed full with water, although the overflow across the track gradually reduced and the small pools on the down side of the track where several tadpoles had been observed on the first occasion were no longer present on the 25/5/2013. After 32 days the tadpoles had progressed significantly in growth to 15.6 mm body length, and the estimated number was only slightly less than when they were first counted.

We surveyed the identified breeding site after the significant rainfall event in late May (70.2 mm on the 23rd to 25th), and then again in early June (8th) to ascertain whether a breeding event occurred, but there was no evidence of adult male calling or of a new group of tadpoles.

Red Crowned Toadlet

After significant rainfall in late January and again in early April and late May adult males were heard calling from several sites and searches for tadpoles along drainage lines and soaks led to the detection of other breeding sites (Table 1 and Figure 1). Adults and tadpoles of the RCT were detected in 13 locations (Table 1). Only four of these was on the subject site (i.e. within the subject site boundary) and all other locations were within the offset site boundary (Figure 1).

Table 1. Locations where RCT were detected in auditory surveys.

Red-crowned Toadlet	Latitude			Longitude		
Western escarpment	33	43	18.726	151	11	42.104
	33	43	23.67	151	11	51.27
	33	43	19.72	151	11	58.03
Upland Coastal Swamp	33	43	43.43	151	12	16.7
	33	43	42.91	151	12	18.26
	33	43	41.89	151	12	18.64
	33	43	42.04	151	12	18.66
	33	43	42.78	151	12	19.04
Rock Shelf, northern escarpment	33	43	28.46	151	12	12.6
Rock shelf near Garigal Trk	33	43	29.22	151	12	21.96
	33	43	20.06	151	12	31.53
	33	43	34.34	151	12	47.5
Plateau, human made trench	33	43	34.19	151	11	59.4
Giant Burrowing Frog						
Garrigal Track	33	43	13.09	151	11	54.54

The majority of locations are associated with seepages sites and small ephemeral drainages at the edge and downslope from the escarpment. No locations were found lower in the valley. Three breeding locations were detected within the subject site. Detection was made by AS, ASRs and tadpole collection. Tadpoles were collected at four locations where calling was not detected, and positive identification was made by reference to the key characteristic in Anstis (2002).

Discussion

Giant Burrowing Frog

Intensive and extensive surveys of habitat at the subject site and in the study area resulted in the detection of one confirmed breeding site of the GBF. The breeding site is more than 300 m outside the subject site and occurs lower in the valley at an altitude of 91 m, whereas the plateau is between 155 and 162 m in altitude. Surveys included targeted searches of likely breeding areas along drainage lines and direct evidence of breeding, as determined by the occurrence of tadpoles, was detected in only the one location. There was no evidence of a breeding location on the subject site or in the escarpment area downslope from the escarpment.

Habitat searches in the heath and woodland habitats on the plateau for foraging and sheltering adults and juveniles did not result in the detection of any frogs. Surveys were conducted under suitable weather conditions, at an appropriate time of the year and with suitable intensity to detect adults in these habitats. Non detection indicates that GBF are not common in the habitats on the plateau. It is not possible to say that non-detection means that GBF do not use habitat on the plateau for sheltering

(burrowing) and foraging but it is possible to say that the density of frogs must be low if none are detected in intensive surveys.

Confirmation of GBF breeding location: The confirmed breeding location of the GBF is in a small soak and drainage that occurs next to the Heath Track in Garigal National Park (33°43' 13.09S 151°11' 54.54E, see Figure 1). Tadpoles of the GBF were first observed in a small pool, drainage gutter and small pools during a nocturnal survey on the 24th of April. Tadpoles were positively identified by the distinctive mouth parts and body features as described by Anstis (2002). However, the tadpoles were at an early stage of development and they were not strongly pigmented as indicated in the description of Anstis (2002). Comparisons were made with tadpoles of the stripped marsh frog and common eastern froglet that were found in numerous locations at the study site, and it was evident that they were not of either of these two species. To confirm the identification as the GBF one tadpole was collected and examined by Marion Anstis who provided an independent identification. With respect to the lack of characteristic pigmentation she considered that this was possibly because the tadpoles were in an early development stage.

Comparisons of the body measurements of the tadpoles taken at the time they were found and then again after six weeks with those recorded for two field clutches by Stauber (2006) indicates that the egg clutch from which they were hatched was deposited after the rainfall event of early April when 72.6 mm of rain fell over a three day period. If this rain event, or that in late January, were triggers for breeding of the GBF in other habitats in the study area and subject site it would be expected that tadpoles would be observed in suitable habitat. There was no evidence of tadpoles in targeted surveys of ephemeral and permanent pools along five drainage lines emanating from the plateau area during visual encounter and habitat surveys. The conclusion is that the study area has a low density population of the GBF.

Tadpoles of the GBF grow rapidly and the length of the larval stage is dependent on water temperature, and the larval period for two egg masses in natures extended for about 33 weeks (Stauber 2006). These egg masses were deposited in late February and the larval period extended through the autumn and winter period with metamorphosis occurring in spring (early October), and during this period the water temperature was low throughout winter. Therefore it is likely that tadpoles at the breeding location detected will not metamorphose until November 2013, and the site will need to retain water or be replenished by rainfall until that time.

Distribution and abundance of GBF in the study area and at the subject site.

The outcome from targeted surveys indicates that GBF are not abundant in the study area. Surveys involved several methods known to be effective for detecting the GBF (VES, AS and habitat searches), and the surveys were conducted at the most appropriate season and under favourable weather conditions.

Detection of tadpoles which indicated a breeding location in the Bare Creek catchment on the northern side of the study area provide positive evidence that the species occurs in the study area and also confirms that weather conditions during the survey period were suitable for the detection of the tadpoles and therefore directly breeding habitat. The tadpoles at the breeding site were easy to observe and relatively abundant and there is no reason to believe that if they occurred in the numerous other ephemeral and permanent drainage lines and soaks that were investigated that they would not have been detected. Tadpoles of several common species were routinely detected in searches of the drainage lines and soaks at the site. The most plausible conclusion is that the GBF is not abundant in the study area and that despite the occurrence of several ephemeral drainage lines with isolated pools which are considered to be suitable breeding habitat, within dense heath vegetation communities, they do not support an abundant population. Evidence from several intensive research investigations of the

GBF show that the density of populations of this frog are low and the outcomes of the current surveys are consistent with these studies (Stauber 2006, Penman 2005).

Close attention was directed in targeted habitat searches to the coastal upland swamp EEC community and ephemeral drainage lines below the escarpment and at mid-slope in the landscape. The absence of observations of calling or tadpoles is considered to represent a real indication that these sites were not used by the GBF for breeding. For example, the use of an automated sound recording device in the coastal upland swamp provided clear evidence of the occurrence of RCT in this habitat, but there was no evidence of calling by GBF over the six week period of survey. In total this is equivalent to an aural survey of 80 minutes per day for six weeks (i.e. 56 hours of survey). This survey period included a significant rainfall event in late May that resulted in activation of calling of the RCT. However, no breeding of GBFs were observed at the known breeding site at this time. Perhaps this rainfall event was too late in the season to enable GBF breeding. Nonetheless, if breeding had occurred in either of the significant rainfall events in January or April, tadpoles should be in the pools and be relatively easy to detect. Thus it is reasonable to conclude that no breeding occurs in these habitats.

Buffers to protect breeding, foraging and shelter habitats:

Following intensive field investigations the conclusion reached is that GBF do not have breeding habitat on the plateau or upper slopes at the study site. The only identification of breeding habitat is on the lower slope on the northern side of the study site. This breeding location is greater than 300 m from the subject site boundary, but within the offset site boundary (see Figure 1). There is no need to provide a buffer zone around the breeding site because of its distance from any potential impact. Similarly, the distance of 300 m from the subject site boundary provides a buffer for shelter sites and foraging areas for the frog. There are records of GBF dispersing distances of greater than 300 m from a breeding site, but the average distance of dispersal of 66 m derived from four study sites in below 300 m (Stauber 2006).

It is necessary to provide some consideration of the detection of a juvenile GBF on the plateau that was found in a cage trap transect (Figure 6 – Travers, Bushfire and Ecology). There are several possible explanations for this observation. Firstly, it could be that this individual had dispersed away from the identified breeding location on the lower slopes to the north and moved up onto the plateau. This would require a displacement of a minimum distance (straight line distance) of over 350 m. Research investigations indicate that a movement of this distance is within the maximum measured for GBF adults (Stauber 2006, Penman 2005), but is greater than the average distances moved. These research investigations reported mainly on adult movement with only minor observations on juveniles and it is possible that juveniles disperse greater distances since it is well accepted that this is the life stage of dispersal in terrestrial amphibians. Secondly, it is possible that the juvenile dispersed from an undetected breeding location higher up the slope and closer to the plateau. Searches of the drainage lines and seepages on the mid-slope did not result in the detection of any additional breeding sites. Several of the drainages in this area provide habitat that is typical for GBF but no evidence of breeding was found. Thirdly, it is possible that the juvenile was from a breeding location on the plateau. Once again we conducted extensive searches of areas on the plateau and identified only one location with suitable habitat for breeding, which is the 'coastal upland swamp EEC' to the south east of the study site. This landscape is often referred to as a 'hanging swamp' (sensu Chapman and Murphy 1989), which are known to provide breeding and sheltering habitat for GBFs (Stauber 2006). The occurrence of a human made scrape which formed a pond in the 'coastal upland swamp EEC/hanging swamp' was identified as a suitable location for breeding and tadpoles of the GBF. The GBF has been found to use human constructed dams and mitre drains in several locations (Stauber 2006), and the pond was observed to contain crayfish and their burrows, a feature that has been identified at many GBF breeding locations. Furthermore, the bench area surrounding the coastal upland swamp EEC was found to have

ample leaf litter and a soil profile with coarse sandy soil to 0.2 m which in a woodland vegetation community meets the characteristic habitats used by GBF for burrowing. Several field methods were used to assess whether the coastal hanging swamp EEC was habitat for the GBF. Searches for tadpoles were made on numerous occasions (four field surveys at day and night), spotlighting in the wetland area and surrounding habitats, and the placement of a sound recorder for a period of over 40 days.

No evidence was found that GBF use this habitat for breeding, burrowing or foraging. The survey period covered two significant rainfall events that coincide with the known breeding season for the GBF (Penman, Lemckert et al. 2005; Lemckert and Mahony 2008) but no evidence of calling, or reproduction was recorded. At the same time breeding did occur at the study site to the north, and on both occasions that the rainfall was significant the wetland was charged and the human made pool contained water throughout the period (late February to early June).

Targeted searches were conducted in the area of low heath vegetation on the plateau at the location where the juvenile GBF was found in a trap line survey (see Travers Bushfire and Ecology 2013). There were no semi-permanent or permanent ponds in this area that would support tadpoles of the GBF, and it is evident that the juvenile found could not be from a local breeding area. The soil in the low heath vegetation community at the location is sandy and up to 0.2 m in some areas and is considered to be suitable for burrowing by GBF. The soils at the location sit on top of a relatively flat sandstone ridge with a slight basin depression that forms a depauperate hanging swamp which can be identified by the growth of reeds and sundews where water is retained. After heavy rainfall water seeps from the edge of the heath and this site provides suitable burrowing and foraging habitat for GBF, but is a relatively small area of low heath in the context of the extent of this vegetation community at mid-slope outside of the subject site.

Movement:

GBF are terrestrial frogs that spend the majority of their life in habitats away from those where breeding occurs. The distance that GBFs move away from breeding sites and the continuity of habitat around breeding sites are significant factors in conserving populations of this frog.

The identified breeding habitat in the study area is greater than 300 m away from the boundary of the subject site and it is most likely that few dispersing adults or juveniles will be impacted by development of the natural habitats on the plateau. GBFs have been recorded to move distances greater than 300 m, however the average distance is 66 m (Stauber 2006). Movement of individual GBFs have been investigated in several studies (Penman 2005; Stauber 2006) although these studies have used different methods they provide valuable information on habitat use of the GBF. The first approach used a repeated survey method with marked individuals of three independent populations located in the Sydney Basin (Stauber 2006). The mean distance move by adult males between captures was 93 m (range of 13 to 663 m). However one animal moved 663 m and if this animal is removed from the analysis the mean distance moved decreases considerably to 66 m. When the location of captures were considered in the context of habitat features, the majority of frogs (90%) were located within 160 m of a creek and males were found to move further than females. In the second study, which was conducted on the south coast of NSW, frogs were fitted with radio-transmitters and ‘tracked’ over a period of six months in an open forest habitat (Penman 2005). Adults were found to have ‘home ranges’ and displacement from one period to another was minimal. The frogs foraged in a ‘home range’ that did not overlap with neighbours and on many occasions the adult returned to a burrowing site. These home ranges were up to 300 m away from the known breeding location. Both studies indicate that outside of the breeding season adult GBFs may be up to 300 m away from the breeding site and move within a home range area. The great majority of the mid-slope landscape in the study area which is outside the

development zone provides for a large area of habitat for foraging and sheltering by the GBF population, and thus to support the local viable population.

The isolation of the identified breeding habitat in the study area means that it is unlikely that development on the plateau breaks a movement corridor between habitats used by GBFs. While it is possible GBFs could move from the valley and mid-slope area up onto the plateau and across to the valley on the other side it is not likely that many individuals would do this. Firstly, this would require an individual to move up to three times greater than the average measured (Stauber 2006; Penman 2005), and secondly the number of individuals would be low since the density of individuals per hectare measured by Stauber (2006) and Penman (2005) is very low. Visual encounter surveys conducted in the study area at times of suitable weather failed to record adult or juvenile GBFs and serve to strengthen the argument that they are not abundant at the study site.

Viable Population

There is no evidence from the targeted field surveys for the GBF that the proposed development of the subject site (=residential zone) will impact on a local viable population. Targeted surveys of potential breeding habitat on the plateau area, which broadly coincides with the subject site, failed to find any evidence of breeding by GBF. Furthermore, at the locations where potential breeding habitat was identified during preliminary habitat assessments there was no breeding detected after heavy seasonal rainfall. Positive identification of a breeding site of the GBF outside the subject site following a significant rainfall event in early April (87 mm on 3rd to 6th April) confirms that the rains provided a suitable trigger for breeding at this time. Intensive searches of soaks and drainages on the plateau and upper slopes did not result in the detection of breeding sites and indicates that the area does not support a large GBF population, and that these drainages are not used for breeding sites. An alternative explanation is that suitable habitat is restricted to the site found.

The distance of the GBF breeding site from the subject site boundary is considerable (> 300 m) and it is not likely individuals from the breeding site will disperse to habitat on the subject site and if individuals do move this distance it would only be a small proportion of the population. Thus it is not likely that development of the subject site will remove important foraging and burrowing sites for the local population of GBFs.

Similarly, the distance between the identified breeding location and the plateau is such that it is unlikely that the plateau is part of a corridor of movement for the GBFs, and thus that development of the plateau area would not impact on the local viable population by breaking a movement corridor.
It is unlikely that development of the subject site would impact on the hydrology of the identified GBF breeding site, because of its distance from the subject site and the large catchment area for infiltration that supports the hydrology of the breeding site are to the east and outside the area of impact of the subject site (see Figure 1 showing contours). Water that flows into the breeding site comes from a large seepage zone that is associated with a rock shelf. It appears that the rock shelf is an impervious layer and that water that has infiltrated the upper layers of rock and soil are expressed as a soak where this layer is exposed. The slope above the rock shelf is not steep and supports a large area of short and tall heath vegetation communities. Observations of the GBF breeding site over a period of six weeks showed that it was being supported by the seepage of water over this period, and the water level in the breeding area did not reduce. There was an observable reduction in flow out of the system across the track six weeks after the rainfall event that is consider to have triggered breeding, however the pond, drainage and pools occupied by the GBF tadpoles remained fully charged. A significant rainfall event in May (71 mm over 23rd to 25th May) increased the flow through the system and water was again passing through the system and overflowing across the track. Tadpoles of the GBF were observed to grow by 50% in size in this period and if we accept the minimum time for field development to metamorphosis as

being 33 to 37 weeks (~ 8 months) (Stauber 2006) then the system would need to retain water and be replenished until the end of November 2013 for successful metamorphosis to occur.

During field surveys at the subject site repeated observations of several ephemeral soaks were made and it was notable that many ceased to flow and dried gradually after the heavy rainfall event in early April, and it is clear that many would not support the long period required for successful completion of the larval period of the GBF. Locations that did contain pools that were sufficiently large to be classed as semi-permanent were found along the drainage lines and these were thoroughly searched, without success, for tadpoles of the GBF.

Red-crowned Toadlet

Habitats associated with the escarpment at the study site provide important breeding habitat for the RCT. These sites are generally below the plateau and are associated with the exposed sandstone and rock benches and small hanging valleys. The majority of these identified breeding habitats are outside the boundary of the subject site and would not be directly impacted by the removal of habitat on the plateau. The greatest potential impacts of the proposal on the RCT will be from changes to the hydrology of the breeding sites and to a lesser extent from the removal of terrestrial habitat used for foraging and shelter.

Most of the breeding sites are found in soaks and small ephemeral pools that form where water seeps out when it encounters the impervious base rock layers beneath the soil which is on top of the plateau. These sites are usually at the edge of the escarpment and there are typically fissures in the rocks and the formation of small hanging gullies with ephemeral pools. After periods of heavy rainfall the soils on the upper surface of the plateau becomes saturated and the ground water reaches the relatively impervious layer of the base rock from where it seeps out at the edges and is directed to the gullies.

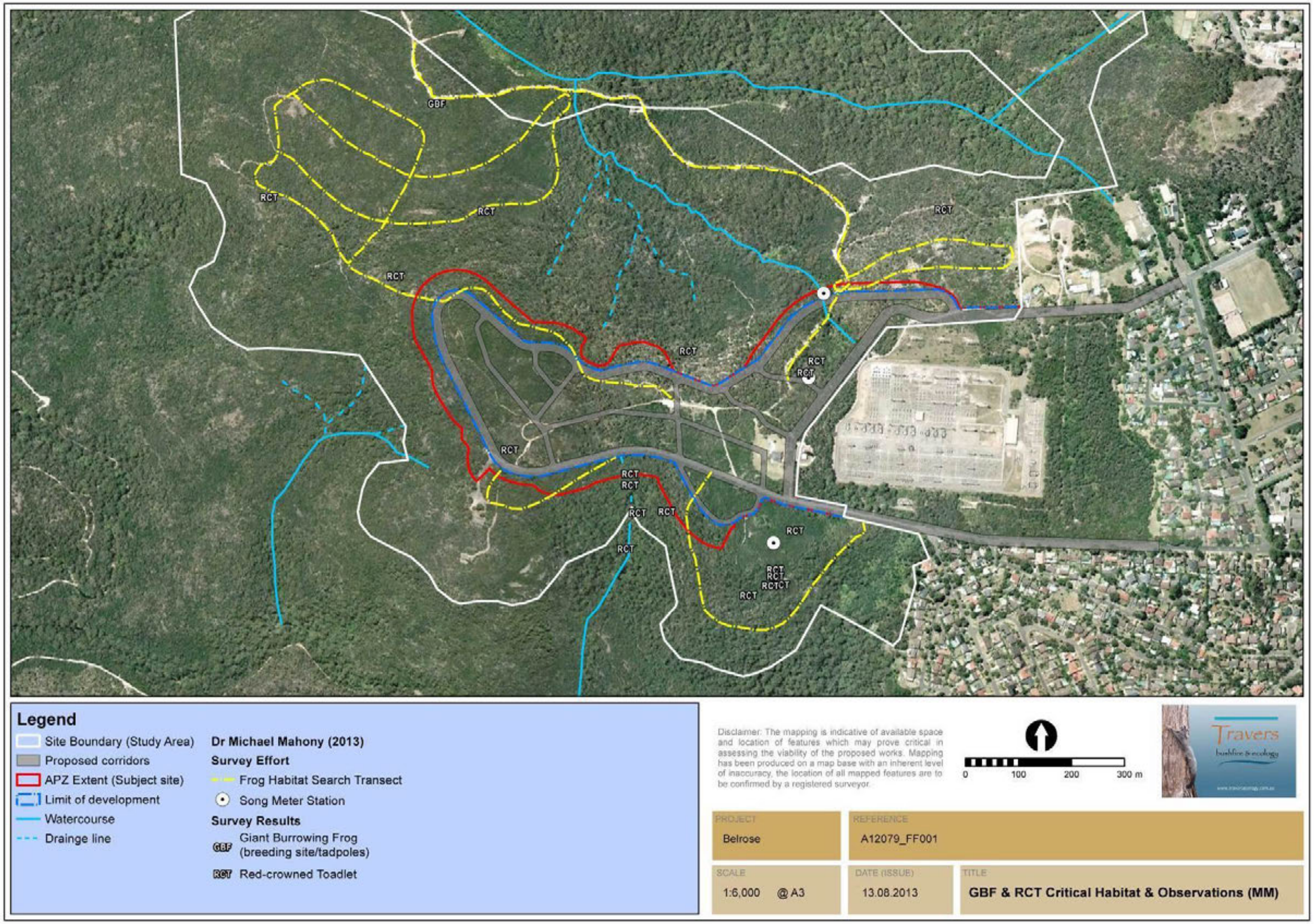
Alterations to the hydrology of these small soaks and ephemeral pools will most likely impact on the breeding habitat of the RCT. Prevention of impact to these areas will require particular emphasis to the hydro-period and volume of water that flows in these sites. These two features are determined by the infiltration of rainwater into the soils on the upper layer of the plateau, the rate of discharge, and the occurrence of replenishing rains. Discharge of water from the upper soil layers is a slow process which maintains the small soaks for sufficient time to enable growth and development of the tadpoles of the RCT to metamorphosis. Measurements of the hydro-period of a series of known breeding sites revealed only a moderate probability for the successful completion of the life cycle in these ephemeral pools. Thumm (2005) hypothesised that the long breeding season and repeated egg deposition observed in the RCT was an adaptation to deal with ephemeral nature of these breeding sites. While it may seem that this situation could be remedied by the provision of additional water to these sites this often results in the invasion of competitive species such as the common eastern froglet and exclusion of the RCT.

Another identified negative outcome of developments in the landscape above the ephemeral soaks used by RCTs is the addition of nutrients to discharged water that results in a change to the productivity of the ephemeral pools (Thumm and Mahony 1999). Nutrients produce a cascade effect which begins with the invasion of weeds which results in increased trapping of sediments, which then encourages competitive species, and eventually renders the ephemeral pools unsuitable for the RCT.

Development of the plateau area will remove habitat that is used by the RCT for foraging and shelter but this is not likely to affect the status of the local population since there is a large and continuous area of habitat that includes all of the escarpment and mid-slope areas in the study site. The majority of identified breeding sites are at the edge of the escarpment and downslope from the escarpment in the mid-slope area and it is most likely that adults and juveniles utilize habitat in this area to forage and

shelter. It is likely that RCTs would move onto the plateau to forage and seek shelter, but this is not the only terrestrial habitat that is available to them. RCTs are capable of moving distances of greater than 100 m between breeding sites (Stauber 2006) and they are occasionally found foraging up to 50 m away from breeding sites (Thumm 2005). However, Stauber (2006) found a high level of fidelity to a breeding site and the mean distance moved was less than 10 m over a 12 month period. Thus protection of the considerable area of RCT habitat below the escarpment and at mid-slope should protect the local viable population.

There is no evidence from the field survey that removal of habitat on the plateau will break a corridor that connects habitats used by the RCT. The majority of breeding sites were at the edge or below the escarpment and movement among breeding sites is likely to at this level and not across the plateau.


GBF
RCT
Legend
Site Boundary (Study Area)
Proposed corridors
APZ Extent (Subject site)
Limit of development
Watercourse
Drainge line
Dr Michael Mahony (2013)
Survey Effort
Frog Habitat Search Transect
Song Meter Station
Survey Results
Giant Burrowing Frog (breeding site/tadpoles)
Red-crowned Toadlet
Disclaimer: The mapping is indicative of available space and location of features which may prove critical in assessing the viability of the proposed works. Mapping has been produced on a map base with an inherent level of inaccuracy, the location of all mapped features are to be confirmed by a registered surveyor.
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Travers
bushfire & ecology
PROJECT
Belrose
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SCALE
1:6,000 @ A3
DATE (ISSUE)
13.08.2013
TITLE
GBF & RCT Critical Habitat & Observations (MM)

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Eastern Pygmy Possum Specialist Report

A7

Preliminary Report on Habitat of the Eastern Pygmy-possum

on Land near Ralston Ave, Belrose

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8 August 2013

Background

This report was requested by *Travers bushfire and ecology*. It considers issues relating to the presence of the eastern pygmy-possum (*Cercartetus nanus*) on lands located off Ralston Avenue at Belrose, on the northern edge of Sydney, approximately 15 km north of the Sydney CBD. There is a proposal to develop a portion of land in this area for residential development. The total area to be impacted as a result of the proposed residential development, associated asset protection zones and proposed road extensions is 25 ha.

In order to consider the potential impact of the proposed development on the eastern pygmy-possum the following instructions were provided in a brief to me:

1. Identify habitat areas suitable for breeding and foraging and whether any important habitat may be affected.

2. Identify potential significance of impact on Eastern Pygmy Possum.

3. Whether is there is adequate separation or buffer between the proposed residential zone and important habitat areas.

4. Whether the planning proposal is likely to result in significant movement or connectivity restriction on the local population.

5. Prepare a plan showing important habitat areas, distinguishing between potential breeding and foraging areas.

6. Make recommendations for any survey that may be required to identify important habitat areas

This report provides a preliminary response to these questions.

Habitat near Ralston Ave, Belrose

The habitat within the proposed development area includes short and tall heath, coastal upland swamp, low open forest, open forest, sandstone gully forest and riparian woodland/forest. All of these habitats contain species of banksia, eucalyptus, corymbia and angophora (*Travers bushfire and ecology* 2013) that form important components of the diet of the eastern pygmy-

possum (see Tulloch 2004; Rueegger 2011; Goldingay unpublished data). Indeed, banksias which are an important source of nectar and pollen are abundant and widespread across the tall heath and the low open forest habitats (see below).

Evaluation

1. Identify habitat areas suitable for breeding and foraging and whether any important habitat may be affected.

   Foraging habitat

   The diet of the eastern pygmy-possum consists predominantly of nectar and pollen, but insects are also included and may be important when nectar and pollen are absent or less abundant (Turner 1984; Huang et al 1987; van Tets and Whelan 1997). The eastern pygmy-possum occurs in a broad range of habitats from heathland to rainforest (Bowen and Goldingay 2000; Harris and Goldingay 2005a; Tulloch and Dickman 2006; Harris et al. 2007a). Its foraging habitat most commonly contains species of banksia. Two species that are particularly important for nectar feeding are *Banksia ericifolia* and *B. serrata* (Harris 2010; Rueegger 2011; Goldingay, Harris and Rueegger unpublished data).

   Banksia ericifolia appears to be particularly important when present and regulates breeding activity in Royal National Park (Goldingay and Rueegger unpublished data). This species is abundant in tall heath in the area of the proposed development. It also occurs in the low heath, the low open forest and the open forest. Other species of banksia and mytaceace will also be important for nectar and pollen when they are in flower. Therefore, basically all vegetation communities in the proposed development and the offset lands will provide foraging habitat for the eastern pygmy-possum. The main point of interest is that the tall heathland with higher densities of various banksia species will be most influential and is likely to drive breeding in the local population.

   Breeding habitat

   Despite the eastern pygmy-possum using a wide range of different shelter types for nesting (Tulloch 2004; Goldingay 2011) it now appears that females are quite selective of the sites they use for breeding (Rueegger et al. 2012). Tree hollows are likely to be favoured such that a local shortage may limit the local population size of this species.

   Within Royal National Park we recorded 19 tree hollows used by 8 pygmy-possums (Rueegger 2011). Four of these pygmy-possums were males and some of the females were not breeding at the time of study so the following records represent trees hollows used for shelter as well as those used for breeding. The majority of hollows (13) were in live trees and the majority (12) were hollows in the trunk. The most commonly used tree species (8 records) were the red bloodwood (*E. gummifera*), followed by the Sydney peppermint (*E. piperita*) and *B. serrata.* The diameter at breast height of these trees averaged 36.9 ± 6.3 (SE) cm (11-90 cm). The entrances to hollows ranged from 0.5 to 9 m above the ground (mean 2.7 ± 0.5 m). Entrances to hollows averaged 3.8 (± 0.4) cm (range 2-7 cm) in the horizontal dimension and 5.1 (± 0.3) cm (range 3-8 cm) in the vertical dimension. The depth of these hollows averaged 27.6 ± 7.3 cm (range 6-125 cm) from the entrance. Radio-tracking of the eastern pygmy-possum has also been conducted by Harris (2010) in Royal National Park and Barren Grounds Nature Reserve. These studies show that eastern pygmy-possums use tree hollows within a range of tree species based on what is available, they

select hollows with a small entrance (our nest boxes had entrances of ~2.5 x 4.5 cm) and their hollows are commonly close to the ground (~3 m). Hollows with a large chamber relative to the size of one pygmy-possum, which can be difficult to determine, will be required for breeding.

An inspection was made on 6 August 2013 of the proposed development area. This revealed that many scribbly gums (*E. haemastoma*) within the low open forest contained small hollows with an entrance of 2-5 cm diameter. An eastern pygmy-possum was previously recorded in one such hollow but this was vacant when inspected on 6 August 2013. However, a hollow was found that contained a recently abandoned leaf nest of a type characteristic of the eastern pygmy-possum (see Rueegger et al. 2012).

An inspection was made of trees (particularly scribbly gums) within the offset lands on 7 August 2013. Relatively few of these trees contained hollows. It is not known whether this is indicative of this area or due to biased sampling.

Will important habitat be affected?

Important areas of foraging habitat and breeding habitat (as described above) will be affected by the proposed development.

2. Identify potential significance of impact on Eastern Pygmy Possum

Impacts on the eastern pygmy-possum from the proposed residential development could be direct and indirect. The loss of habitat from clearing for the residential development would have a direct impact (see below). The most serious indirect impact from the development would be if residents in the area keep house cats. There are many reports in the literature of domestic cats preying on the eastern pygmy-possum (Harris and Goldingay 2005a; Harris et al. 2007b, 2008). The full impact of this is currently unknown but is likely to be substantial. Moreover, domestic cats are likely to contribute to a local feral cat population. This indirect impact of the development could be removed by proposing that cat ownership be disallowed in the residential development.

Foraging habitat for the eastern pygmy-possum appears to encompass almost all vegetation communities in the study area (proposed residential area, APZ and Offset lands) with the exception of the modified community (community E) and possibly the riparian woodland-forest (not examined). The most important community would be the Tall Heath (community B) due to the high density of *B. ericifolia* and presence of other banksia species. The vegetation mapping conducted by *Travers bushfire and ecology* (2013) suggests that there would be a loss of 6.9 ha of Tall Heath from the proposed residential area and APZ. In contrast, the Offset lands contain 20.1 ha of this habitat.

Breeding habitat could be found in several vegetation communities where trees occur but the brief examination of the area bounded by the proposed residential area and APZ suggest that scribbly gums within the low open forest may be the primary source of tree hollows to be used for breeding. At this point it is unknown whether the low open forest in the Offset lands is equivalent in tree hollow density to that in the proposed residential and APZ areas. However, in terms of the areas of this community in each zone, vegetation mapping by *Travers bushfire and ecology* (2013) suggests that there are 9.0 ha of Low Open Forest in the proposed residential area and APZ area, compared to 38.8 ha in the Offset lands.

It is difficult to estimate the overall impact of the proposed development on the local population of the eastern pygmy-possum because population studies on this species are difficult to conduct and none with sufficient detail has been published. The impact of the loss of 6.9 ha of high quality foraging habitat (Tall Heath) may be sustainable when offset by 20.1 ha in the Offset Lands. The loss of breeding habitat if defined by the Low Open Forest in the development area (9.0 ha) may be sustainable if offset by 38.8 ha of Low Open Forest in the Offset Lands and it provides equivalent breeding habitat. Further surveys (see question 6 below) are required to determine the adequacy of the offset.

Another key point with having confidence that the proposal will not have a significant impact on the local population of the eastern pygmy-possum is knowing whether there are opportunities for individuals to disperse east and west across the Forest Way between the adjoining National Parks. This could be achieved if culverts are present under this road enabling dispersal movement. This should be investigated. If none are present rope-bridges (e.g. Goldingay et al. 2013) could also be useful for this species. Ultimately broader connectivity will provide greater confidence that the loss of habitat will not threaten a local population (e.g. Taylor and Goldingay 2012).

3. Whether is there is adequate separation or buffer between the proposed residential zone and important habitat areas.
   As stated above, most vegetation communities appear to offer foraging habitat. This habitat abuts the proposed APZ area so there is no separation. Based on very preliminary observations the Low Open Forest appears to have the most potential for providing breeding habitat. This community also abuts the APZ area so again there is no separation of important habitat areas from the proposed residential zone.

4. Whether the planning proposal is likely to result in significant movement or connectivity restriction on the local population.

   Foraging habitat for the eastern pygmy-possum occurs all around the proposed development site. Therefore, if the development proceeded there would be some localised restriction to the movement by individuals but the movement of pygmy-possums would not be significantly restricted due to the broad extent of open forest and other vegetation communities to the west of the site. Eastern pygmy-possums are highly mobile animals moving as much as 500 m in a night (unpublished data). Therefore, the spatial location of the proposed development will not pose a particular restriction on movements by the local population.

5. Prepare a plan showing important habitat areas, distinguishing between potential breeding and foraging areas.

   I would argue that all habitats across the development site and the Offset Lands contain foraging habitat. I would suggest that the Tall Heath provides the most important foraging habitat due to the higher density of *B. ericifolia* in that community compared to other communities. Therefore, the existing vegetation map can be used to represent the different foraging areas.

   As for potential breeding habitat, the one recent breeding hollow that was discovered on 6 August 2013 was in an *Angophora crassifolia* which is apparently common in the Low Open Forest. Furthermore, the tree species in which hollows were most frequently observed was the scribbly gum and this species is most common in the Low Open Forest also.

Therefore, the existing vegetation map can be used to represent the different breeding areas with that vegetation mapped as Low Open Forest offering the best breeding habitat.

6. Make recommendations for any survey that may be required to identify important habitat areas.

   The eastern pygmy-possum can be a difficult animal to conduct surveys for (Bowen and Goldingay 2000; Harris and Goldingay 2005a, b; Harris et al. 2007a, b). The published literature for this species is now quite detailed and enables many conclusions to be reached based on just a few observations such as the two for the study area (an animal in a short tree hollow and a leaf nest in another tree hollow). Therefore, further surveys of the study area to detect this species are not warranted. However, what is required is more detailed information on the distribution and abundance of tree hollows that potentially provide breeding sites for the eastern pygmy-possum. This would provide more confidence in determining whether the Offset Lands provide important areas of breeding habitat in comparison to what may be lost in the development area.

   Conducting a survey for tree hollows that may be suitable for the eastern pygmy-possum requires that special attention be given to the hollow preferences of this species. A survey that simply documents the abundance of tree hollows will not be adequate. Someone with specialist knowledge of tree hollows used by eastern pygmy-possums would be desirable. The survey should attempt to quantify the abundance of these specific tree hollows in the different vegetation communities in the development zone and the Offset Lands. Replicate quadrats will be required in the different vegetation communities. This might be supplemented with some opportunistic assessment in case suitable tree hollows are scarce and quadrats produce few data.

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Examination of the amount of preferred habitat of the Eastern Pygmy-possum on Land near Ralston Ave, Belrose (FINAL REPORT)

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Introduction

This report was requested by *Travers bushfire and ecology*. It considers issues relating to the presence of the eastern pygmy-possum (*Cercartetus nanus*) on lands located off Ralston Avenue at Belrose, approximately 15 km north of the Sydney CBD. There is a proposal to develop a portion of land in this area for a residential development (see *Travers bushfire and ecology* 2013). The land proposed for development (including asset protection zone) amounts to approximately 21 ha while a further 92 ha surrounding the proposed development site is available to offset the proposal (*Travers bushfire and ecology* 2013). These areas as well as the remaining 25 ha of additional habitat below powerline easements can be referred to collectively as the study area.

This report reviews investigations conducted concerning the suitability of the habitat for the eastern pygmy-possum (EPP) on the proposed development and offset site and considers the potential impact on the local population of the EPP of the proposed development.

Investigations

A number of investigations have been conducted by *Travers bushfire and ecology*. For the EPP this has mostly involved assessing habitat suitability and documenting tree hollows. Female EPPs build nests from various native plant species using fresh leaf material (Ward 1990; Rueegger et al. 2012). This distinguishes EPP nests from other small mammals such as the brown antechinus which builds nests mostly from dead eucalypt leaves (Goldingay personal observations). Viewing cavities within tree hollows with a videoscope has allowed the identification of some EPP nests within the study area. Searching of tree hollows has also led to the discovery of some EPP present within a hollow. Together with some earlier records, the presence of the EPP has now been documented at 5 locations within the development site and 3 locations in the offset area (*Travers bushfire and ecology* 2015).

Sixteen quadrats measuring 20 m by 200 m were scored for vegetation throughout the study area: 3 were along areas mapped as Low Open Forest and Open Forest communities within the subject site (development area) and 13 quadrats in the remaining lands of the study area within Low Open Forest, Open Forest and Sandstone Gully Forest community. Tree hollows with entrances of 4-6 cm diameter were documented as suitable for EPP and those in a broader range 3-8 cm diameter also considered if a suitable cavity was present. Further tree hollow

assessment occurred amounting to 36 x 0.2-ha quadrats placed within Low Open Forest across the study area.

Potential habitat has been identified based on where the EPP records occur in the study area as well as being informed by studies on EPP in Coastal Sandstone Plateau Heath and Coastal Sandstone Ridgetop Woodland in Royal National Park (Rueegger et al. 2012) and Coastal Sandstone Plateau Heath and Budderoo-Morton Plateau Forest in Barren Grounds Nature Reserve (Harris et al. 2014), using vegetation communities identified by Tozer at al. (2010). Information on the relative use of different broad habitat types has also been derived from Tulloch and Dickman (2006). Indeed, the vegetation mapping by Tozer at al. (2010) for the study area at Belrose shows extensive areas of Coastal Sandstone Plateau Heath and Coastal Sandstone Ridgetop Woodland as well as Coastal Sandstone Gully Forest.

The study area was visited on 18 September 2015 with Corey Mead from *Travers bushfire and ecology*. The aim of this site inspection was to examine the habitat present and review a habitat suitability map for the EPP that had been generated. An inspection of the proposed development area had also been conducted on 6 August 2013.

EPP habitat at Ralston Ave

The vegetation communities on the proposed development site and the offset area have been mapped by *Travers bushfire and ecology.* Nine different plant communities were identified extending in structure from short heath through to sandstone gully forest and riparian woodland/forest. The EPP is known to use a very broad range of macrohabitats (Tulloch and Dickman 2006) so potentially it could use or traverse all macrohabitats in the study area. The habitats of particular importance are those in which certain species of banksia dominate because they provide an important winter food source (Ward 1990; Bladon et al. 2002; Tulloch 2004; Rueegger et al. 2012). One limitation on habitat quality is the availability of shelter sites. Although the EPP may use a range of different shelter types, from the skirts of grass trees and bird nests through to tree hollows, it appears that it is the tree hollows that are required for breeding (Tulloch 2004; Harris 2008; Rueegger et al. 2012). In particular, tree cavities of sufficient size (>5 cm diameter) appear critical for a female pygmy-possum to raise a litter. Therefore, habitat quality needs to be assessed based on both the abundance of food plants and the abundance of tree cavities.

The study area contains food plants in the form of banksias or eucalypts, angophoras or bloodwoods throughout virtually all vegetation types. This means that all of the study area except those areas cleared, managed, landscaped or weedy, offers at least low quality habitat for the EPP. Tree cavities are not particularly abundant in the study area but are more abundant in habitat containing scribbly gum (*Eucalyptus haemastoma*). Only 47% of 36 x 0.2-ha quadrats across the Low Open Forest in the study area contained 2 or more hollows. The habitat type found to provide food plants and tree cavities in the study area is that identified as Low Open forest in mapping by *Travers bushfire and ecology* (2015). This vegetation type aligns with what is designated as Sydney North Exposed Sandstone Woodland in the Sydney Metro vegetation mapping (see *Travers bushfire and ecology* 2015).

Although the whole study area can be identified as potentially suitable to the EPP, there is value in trying to identify different levels of suitability (i.e. low, medium and high habitat quality).

EPP density and habitat quality

The density of the EPP is difficult to estimate. Published accounts of local population size have probably not accounted for the total area used by individuals so have overestimated density (Harris et al. 2014). Ward and Turner (2008) suggest that densities may vary from around 14-20 per ha in coastal banksia woodland in Victoria to 2.5 per ha in rainforest with a banksia understorey in north-east New South Wales. The former estimate is based on a study area of 2.4 ha (Ward 1990) and the latter a study area of 4 ha (Bladon et al. 2002). Detailed investigation into the home ranges of EPP in New South Wales has revealed that home ranges are typically 3-7 ha in area (Law et al. 2013), and this is likely to hold true elsewhere because all studies report overnight movements of up to 300-500 m (Ward 1990; Bladon et al. 2002; Tulloch & Dickman 2006; Law et al. 2013). Thus, estimates of density are based on study areas that are too small (i.e. potentially smaller than a single home range). Furthermore, EPP can produce several litters in a year and young become independent within 65 days (Ward 1990; Goldingay et al. 2014). This can lead to the inclusion of juvenile individuals within density estimates, even though these individuals will disperse soon after independence and therefore should not be considered part of the local population.

I have been investigating EPP habitat use and density in Royal National Park (NP) on a 9 ha study grid. This area typifies what I would regard as high quality pygmy-possum habitat. I captured 27 adult pygmy-possums (18 females) within this grid over a 3-month period (May-Aug 2015) during the flowering of *Banksia ericifolia*, the main food plant in the study area. The area sampled by this grid will be greater than 9 ha because animals captured on the periphery will range outside the grid. A buffer strip needs to be placed around this grid. A common approach is to add a strip equal to the radius of a species' home range, assuming the home range is approximately circular in shape. Law et al. (2013) estimated mean home range size for males and females to be 3.1 ha. Thus, a 100-m buffer can be applied giving the sample area of my study grid as 25 ha. Therefore, the density on this grid is estimated to be 1.1 adult pygmy-possums per ha. This is likely to be an overestimate because animals may move outside the grid on a seasonal basis. For example, captures on the grid declined to 1 individual in October 2015, which is consistent with other studies documenting a dramatic decline in captures in spring (Harris et al. 2014).

I have quantified the abundance of tree hollows across this study grid. Circular plots of 20-m radius (i.e. 0.13 ha) were searched for tree hollows across the 16 grid points in the study area (i.e. total search area of 2.01 ha). Trees in the study area are relatively short (<7 m) and narrow stemmed so that few if any hollows high up were missed. Some trees were climbed to check for hollows. This survey detected 25 hollows within the 2.01 ha survey area, giving a density of 12.4 tree hollows per ha. Only 50% of plots had hollows. Logs on the ground were not assessed for hollows but few logs were present. The study area was subject to intense wildfires in 1994 and 2001. Given that 32 nest boxes were added to the study area that has a sample area of 25 ha, the density of nest sites was 12.4 hollows per ha plus 1.3 nest boxes per ha, to give a total of 13.7 cavities per ha. This can be regarded as indicating high quality pygmy-possum habitat. The value to pygmy-possums from the nest boxes may be overstated because some were used by brown antechinuses. Of the 25 hollows recorded in the study area, only about 3 (12%) were large enough to provide a nesting cavity.

Law et al. (2013) identified the den sites of pygmy-possums in McPherson State Forest on the NSW central coast. Pygmy-possums used tree hollows (41% of dens), stumps (12%), logs on the ground (30%) and nest boxes (9%). Law et al. (2013) recorded that hollow-bearing trees occurred at a density of 40-70 per ha, and hollow-bearing logs at a density of 107-340 per ha. This study area obviously reflects a very high quality site. These totals are based on hollow dimensions that would fit an EPP (entrance 4 cm diameter, depth >5 cm). What isn't known is what percentage would be suitable as maternity nests.

Based on the above information in Royal NP we can attempt to characterise the quality of habitat in the study area at Belrose. The vegetation types at Belrose are equivalent to those in Royal NP so food plant abundance is suitable for habitat to be scored higher than low quality. Tree hollows have been scored in 36 x 0.2-ha quadrats across the study area (*Travers bushfire and ecology* 2015). This has allowed habitat quality to be categorised as low, medium and high based on hollow abundance per ha and vegetation type. Low Open Forest is habitat containing both scribbly gum which contain tree hollows more frequently than other trees, and *B. ericifolia* which is a primary food plant. Therefore, Low Open Forest can be regarded as habitat that is of higher quality than other vegetation communities in which either tree hollows or food plants may be scarce. Low Open Forest was divided into medium and high habitat quality based on tree hollow abundance, with medium habitat quality being where quadrats scored <15 hollows per ha and high habitat quality being where quadrats scored ≥15 hollows per ha. This value is approximately equivalent to that above in Royal NP where 14 cavities per ha appears to reflect high quality habitat.

In summary, all native plant communities in the study area provide at least low quality habitat for EPP. The plant community that provides a high abundance of EPP food plants and tree hollows for nesting is the Low Open Forest. Using a tree hollow abundance the Low Open Forest can be classed as medium (<15 hollows per ha) or high (≥15 hollows per ha) quality habitat for EPP.

Potential impact from the residential development on the EPP

In order to consider the potential impact of the proposed development on the EPP the following questions are addressed:

1. *Whether the proposed development site is important to the survival of the population and which parts of the landscape are likely to be more important for breeding purposes.*

The EPP has been detected at several locations across the proposed development site. Habitat has been mapped across this site which has revealed a diversity of food plants as well as an abundance of one in particular, *B. ericifolia*, which is known to be of great importance to the EPP in NSW (Tulloch and Dickman 2006; Rueegger et al. 2012; Harris et al. 2014). EPPs also require tree hollows so habitats offering both in close proximity are likely to be of high importance. Within the study the habitat in which food and shelter are best represented occurs within habitat containing *E. haemastoma*. This has been mapped as Low Open Forest. So clearly the development site is important to the EPP but the local population of the EPP would not be restricted to the development site (see below).

2. *Whether there is adequate habitat surrounding the proposed residential zone to support a viable population.*

The term 'viable' has been narrowly defined by DECC (2007) for assessment of impact under the NSW *Threatened Species Conservation Act* 1995 as "the capacity to successfully complete each stage of the life cycle under normal conditions". DECC (2007) has also defined a 'local population' of a fauna species to "comprises those individuals known or likely to occur in the study area, as well as any individuals occurring in adjoining areas (contiguous or otherwise) that are known or likely to utilise habitats in the study area".

In the case of the EPP at Belrose, given that habitat is continuous between the study area and Garigal National Park (Garigal NP), the local population encompasses those individuals within the study areas as well as those within Garigal NP. Whether this local population remains viable would simply amount to whether any individuals across the broader area could complete their lifecycle of breeding, rearing of young, dispersal of young and then the maturation of those young to breeding age.

Habitat mapping conducted by *Travers bushfire and ecology* has revealed that the subject site contains 8.4 ha of Low Open Forest. Of this 37.5% (3.1 ha) can be classed as high quality EPP habitat (≥15 hollows per ha) from the quadrat data. Habitat mapping shows there are 38.5 ha of Low Open Forest in the Offset site. Of this 20% can be classed as high quality EPP habitat from the quadrat data. The broader study area contains 46.9 ha of Low Open Forest. The Sydney North Exposed Sandstone Woodland (Sydney Metro Veg mapping 2013) aligns at least partly with what *Travers bushfire and ecology* have mapped as Low Open Forest. The broader study area contains 61.4 ha of Sydney North Exposed Sandstone Woodland. Thus, if we assume that Sydney North Exposed Sandstone Woodland contains Low Open Forest and other plant communities, we can conclude more generally that 76.4% (46.9/61.4) of the Sydney North Exposed Sandstone Woodland contains Low Open Forest, and representing either medium or high quality EPP habitat.

Within the 1001 ha of Garigal NP adjoining the study area, mapping reveals there are 288.1 ha of Sydney North Exposed Sandstone Woodland. Assuming that 76.4% of this would contain Low Open Forest there would be 219.0 ha of either medium or high EPP habitat. Given we have two estimates for what percentage would be high quality EPP habitat from above (20% or 37.5%), this would suggest there might be somewhere between 44 ha and 82 ha of high quality EPP habitat in Garigal NP.

In summary, the subject site is estimated to contain 8.4 ha of medium or high EPP habitat. The retained lands is estimated to contain 38.5 ha of medium or high EPP habitat. Garigal NP is estimated to contain 219.0 ha of medium or high EPP habitat. It would appear there would be adequate habitat within Garigal NP and the offset site to support a viable local population based on the definitions given by DECC (2007).

3. *Whether the planning proposal is likely to result in a movement or connectivity restriction of importance to the local population.*

Given that the study area is continuous with Garigal NP and that the eastern end of the subject site is bounded by Forest Way and associated human developments, there does not appear to be

any concern that development of the subject site would impede movement or connectivity for the local EPP population.

4. *The expected impacts of the proposed rezoning and the degree of importance.*

The proposed development would remove 21 ha of EPP habitat including 3.1 ha of high quality habitat and 5.3 ha of medium quality habitat. The density of EPP in low or medium quality habitat has not been estimated but would be less than in high quality habitat. To enable a comparison of the relative number of EPP that might be present in different areas I make the assumption that the density of EPP in medium quality habitat is half of that in high quality habitat and in low quality habitat it is half again (i.e. one quarter of that in high quality habitat).

EPP density in high quality habitat has been estimated as 1.1 EPP per ha (see above) so the density in medium quality habitat is assumed to be 0.6 EPP per ha and in low quality habitat 0.3 EPP per ha. These density values can be combined with the estimated area of each habitat class to estimate the number of EPP that may be present (Table 1). These values refer to adult individuals.

This analysis with several simplifying assumptions suggests there might be 11 individual EPPs present on the subject site. This compares to about 51 EPPs on the offset site and 388 in Garigal NP. Based on detailed habitat assessments in the subject site and the retained lands it would appear the subject site contains approximately 21% of the total number of EPP in the study area. The number is not insubstantial and requires some mitigation for the development to proceed.

Table 1. Relative comparison of the number of EPP present based on several assumptions.

	Habitat quality			
	low	medium	high	total
Area of habitat				
Subject site	12.6	5.3	3.1	21.0 ha
Retained lands	78.5	30.8	7.7	117 ha
Garigal NP	781.7	175.0	44.0	1001 ha
EPP density	0.3	0.6	1.1	
Number of EPP				
Subject site	3.8	3.2	3.4	10.4
Offset site	23.6	18.5	8.5	50.6
Garigal NP	234.5	105.0	48.4	387.9

5. *Mitigation measures that can be implemented to mitigate the expected impacts.*

The limiting factor for EPP in the study does not appear to be food plants but the availability of tree hollows and particularly those suitable for breeding. Given that EPP will readily use nest boxes in areas where tree hollows are scarce (Rueegger et al. 2012), the addition of nest boxes would be an effective means of mitigating the impacts of the development. The tree hollow survey suggested a lower abundance of hollows in the offset area compared to the subject site.

I would recommend installing nest boxes throughout the offset area at a density of 1 per ha. The most appropriate design for breeding females is given in Rueegger et al. (2012). These boxes would require monitoring approximately once per year for a period of 3 years.

There is concern that house cats may prey on EPP. Therefore, the keeping of cats should be banned from the residential development if it goes ahead.

The local population of EPP in Garigal NP would benefit from having more secure connectivity with the other portion of Garigal NP to the north-east and with Ku-ring-gai Chase NP to the north. This would maintain gene flow which may be disrupted for arboreal mammals where housing and major roads subdivide populations (e.g. Goldingay et al. 2013). This would also allow the movement of individuals which might boost the local EPP population should there be a wildfire in Garigal NP.

Conclusions

A residential development is proposed for a 21 ha area with demonstrated occurrence of the vulnerable eastern pygmy-possum. An adjoining area of 92 ha has been proposed to offset the loss of habitat in the subject site and a further 25 ha of habitat will be available below powerline easements. Investigations have been conducted to determine the relative quality of habitat in these areas as well as to understand how much suitable habitat is present in the adjoining Garigal National Park. It is estimated that 8.4 ha medium-high quality EPP habitat occur in the subject site and 38.5 ha in the retained lands. The density of tree hollows in the subject site is higher than in the retained lands so direct comparison of areas of habitat may not reveal the full impact of any loss. Several simplifying assumptions were made about the density of EPP in different classes of habitat quality. This suggests there could be 11 EPP in the subject site compared to 51 in the offset area. Areas of suitable habitat (even of low quality) in Garigal NP could support a local population of at least several hundred EPPs.

Appropriate caution is needed to address the impacts of the residential development should it go ahead. This would include the installation of nest boxes through the offset area to increase habitat quality, the banning of house cats from the residential area, and measures implemented to increase connectivity of habitat across both Mona Vale Road and Forest Way, to ensure connectivity of Garigal NP with other reserves.

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