# 4. METHODS

## 4.1 Timing

Surveys were conducted during two time periods to obtain a good understanding of the bird species that may utilise the study area, and to document changes in habitat use between seasons. A spring survey was conducted over five days, from the 23rd of October to the 27th of October 2000. This time period coincided with a quarter moon phase. The lunar conditions experienced during the survey were adequate for sampling nocturnal birds.

A summer survey was conducted over six days, and four nights. The survey was originally scheduled to commence on the 31st of January 2001, however persistent rain meant that the survey was postponed. Surveys were conducted between the 4th and 6th and 15th and 17th of February 2001. Surveys were conducted during the first and last quarter moon phases.

## 4.2 Weather conditions

### 4.2.1 Spring survey

The spring survey was conducted during mainly fine weather. Although rain and storms occurred on each night of the survey the days were mostly fine with light winds and warm sunny conditions (Table 2a, Appendix 2).

### 4.2.2 Summer survey

Weather conditions were variable during the summer survey. Initial surveys from the 4th to the 6th of February were conducted in fine conditions following a prolonged period of heavy rain. Surveys between the 15th and 17th of February were conducted during mixed weather conditions. Days were characterised by heavy cloud cover and light showers, whilst nights were mostly fine with calm conditions (Table 2b, Appendix 2).

## 4.3 Terrestrial bird surveys

During both the spring and summer surveys a comprehensive assessment was conducted of all terrestrial habitats in the study area. Both surveys included targeted searches for legislatively protected species[2], and general surveys for all bird species.

A variety of methods were employed to survey the terrestrial bird community. The terrestrial bird survey included a combination of methods specified by the NSW National Parks and Wildlife Service (1999), and standard procedures that targeted specific groups of birds. Terrestrial surveys included a general quantitative and qualitative assessment of species richness and relative abundance, within the major habitat types, and targeted surveys for threatened species in selected habitats. Nomenclature used throughout the report follows Christidis and Boles (1994).

[2] Legislatively protected species include any species listed on the state or commonwealth legislation or international agreements. Legislatively protected species are also referred to as threatened species.

### 4.3.1 Habitat assessment

Prior to the commencement of bird surveys a baseline assessment of habitat types present within the study area was conducted. This assessment involved a brief perusal of the entire study area, with notes taken on each of the different habitat types. By identify the major habitat types present within the study area bird surveys could follow a stratified sampling design, and there was a greater likelihood that all habitat types would be adequately sampled.

After the initial site inspection a more detailed assessment of habitat types was conducted. This assessment involved gathering a range of standard data on bird habitat within each of the delineated habitat types. Information on habitats and a map showing the location of each habitat type within the study area is provided in the results.

### 4.3.2 Point Counts

To obtain some indication of the relative abundance of birds within different habitats in the study area replicate point counts were conducted in each habitat type. Point counts provide a rapid means of obtaining accurate data on the relative abundance of birds within specific habitats (Bibby *et al.* 1992). In the present case point counts were deemed to be superior to transects as the density of the vegetation in a number of habitats can greatly affect the ability to detect birds whilst moving along a transect. The use of point counts during the present study also provided data that were comparable to that collected during surveys along the southern part of the C4 alignment (Sandpiper Ecological Surveys 2001).

Point count surveys consisted of three point counts along replicate 200 m transects. Each point was separated by 100 m. Five minutes was spent at each point recording the number of birds and species present within a 30 m radius of the observer. Birds were identified through direct observation and call. To reduce the impact of disturbance two minutes were spent waiting at each point prior to the commencement of each five-minute observation period (Bibby *et al.* 1992). Each point count site was regarded as a replicate.

A total of 27 point count sites were sampled during the spring survey, with 18 sampled during the summer survey (Tables 3 & 4, Figure 2). Each point was surveyed on two non-consecutive mornings during each time period (i.e. spring and summer) by the same observer. The habitats sampled included, dry open forest, moist regrowth, swamp forest, and regrowth rainforest. Point counts were not conducted in disturbed land due to the limited extent of these habitats, and the difficulty associated with establishing replicate transects. Each transect was surveyed during favourable weather conditions. Point counts were conducted between 6.00 and 9.00 am (Daylight Savings Time).

Although point count surveys focussed on birds within a 30 m radius of the observer all species outside of this area were recorded as being present. Bird species recorded during a slow traverse between point count locations (i.e. between 0 and 100 m along a transect) were also recorded to provide an indication of species richness. The data gathered during the slow traverse were analogous with the data gathered using the area search technique described below.

### 4.3.3 Area search

Area searches were used to obtain information on the species richness of birds within each of the habitats in the study area. The data collected during each area search consisted only of the number of species present within a particular habitat. Area searches were conducted between 6.00am and 10.30 am, and involved a 30 to 60 minute meandering traverse by one observer. During a traverse the number of species present within each habitat was recorded by either sight or call.

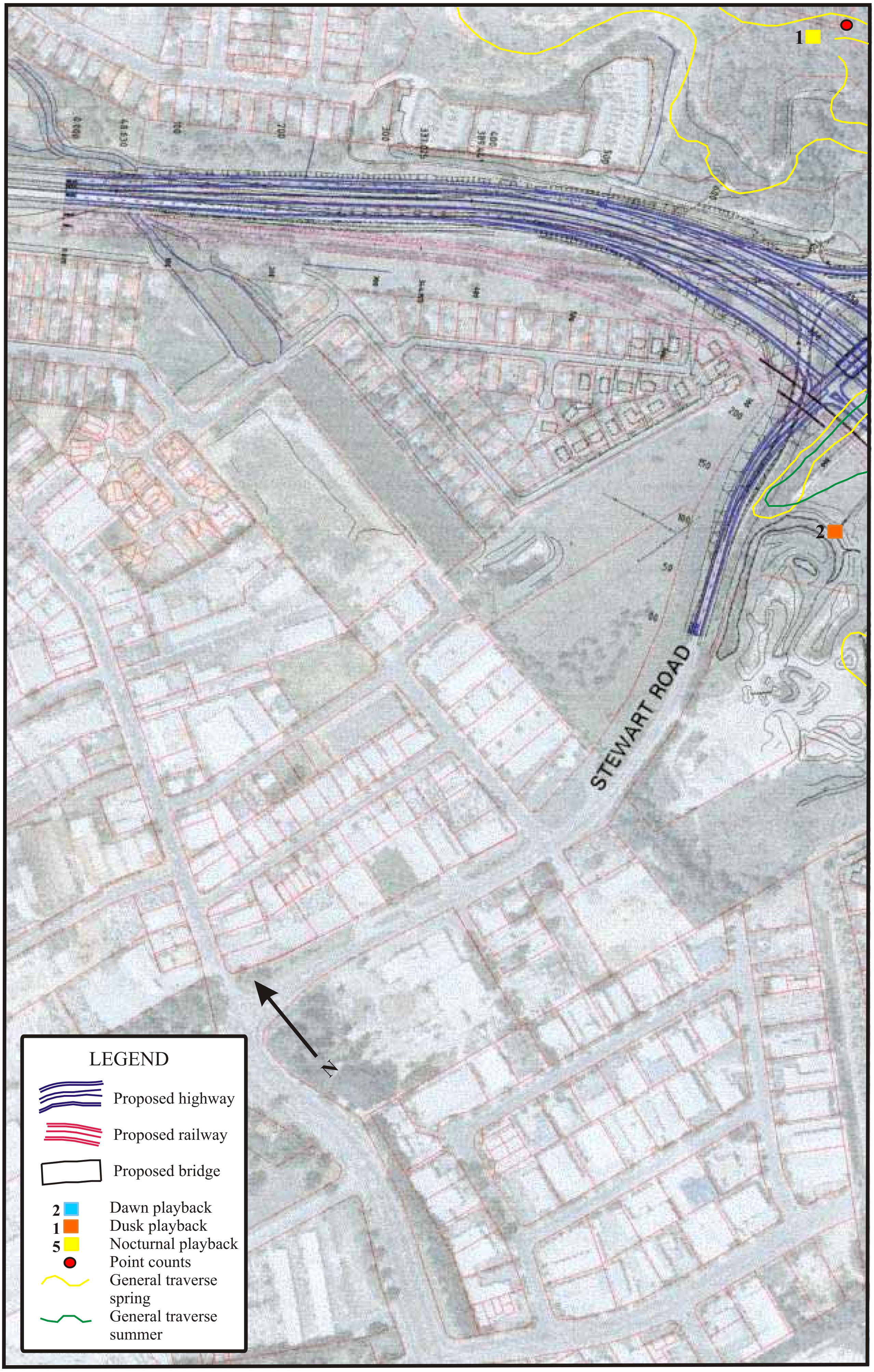


*Figure 2*: Location of survey sites within the study area for the northern section of the proposed Tugun Bypass.

Repeated area searches were conducted in each of the major habitat types present in the study area (Figure 3). Repeat surveys were generally conducted in the same vicinity as the initial survey however, rarely did repeat surveys follow the same route (Figure 2). A total of 19 area searches were conducted within five habitats during spring, with 17 searches conducted in five habitats during summer (Tables 3 & 4). Almost 20 hours were spent conducting area searches during the summer and spring surveys.

### 4.3.4 General traverse

General traverses were conducted in the late afternoon (i.e. between 3.00 and 7.30 pm), and consisted of walk transects through the study area. The objective of general traverses was to survey small habitats and to search for fauna features, such as evidence of foraging or roost sites. General traverses were conducted within four areas, north of existing highway, quarry, sewage treatment works and Woodgee Hill/Hidden Valley (Figure 2).

*Table 3*: Summary of the survey effort expended during the spring survey of diurnal terrestrial birds for the proposed Tugun Bypass, Boyd Street to Stewart Road. * includes time taken during point counts; repeats = number of repeated surveys on each transect, traver = traverse.

| Habitat | Point Count | | | Area Search* | | | General Traverse | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. points | No repeats | Time (mins) | No. traver | No repeats | Time (mins) | No. traver | No repeats | Time (mins) |
| Dry open forest | 12 | 2 | 120 | 9 | 1 | 328 | 3 | | 210 |
| Regrowth rainforest | 3 | 2 | 30 | 3 | 1 | 108 | 2 | | 80 |
| Moist regrowth | 3 | 2 | 30 | 1 | 2 | 50 | 0 | | 0 |
| Swamp forest | 6 | 2 | 60 | 4 | 1 | 118 | 0 | | 0 |
| Disturbed land | 3 | 2 | 30 | 2 | 1 | 56 | 1 | | 30 |
| Woodland | - | - | - | - | - | - | 1 | | 30 |

*Table 4*: Summary of the survey effort expended during the summer survey of diurnal terrestrial birds for the proposed Tugun Bypass, Boyd Street to Stewart Road. * includes time taken during point count surveys. Abbreviations are the same as Table 1.

| Habitat | Point Count | | | Area Search* | | | General Traverse | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. points | No repeats | Time (mins) | No. traver | No repeats | Time (mins) | No. traver | No repeats | Time (mins) |
| Dry open forest | 6 | 2@3 | 45 | 6 | 1 | 185 | 3 | 1 | 175 |
| Regrowth rainforest | 3 | 2 | 30 | 4 | 1 | 175 | 2 | 1 | 165 |
| Moist regrowth | 3 | 2 | 30 | 2 | 2 | 60 | 1 | 1 | 20 |
| Swamp forest | 6 | 2 | 60 | 4 | 1 | 106 | 0 | 0 | 0 |
| Disturbed land | - | - | - | 1 | 1 | 10 | 2 | 1 | 110 |
| Woodland | - | - | - | - | - | - | 1 | | 60 |

### 4.3.5 Playback

***Nocturnal playback***

Nocturnal playback was conducted during both the spring and summer surveys. The species targeted during the survey included masked owl (*Tyto novaehollandiae*), barking owl (*Ninox connivens*), powerful owl (*Ninox strenua*), grass owl (*Tyto capensis*), barn owl (*Tyto alba*), sooty owl (*Tyto tenebricosa*), and marbled frogmouth (*Podargus ocellatus*). During both spring and summer playback for masked, barking and powerful owls was conducted at three sites, whilst playback for grass owls was conducted at one additional site (Figure 2, Table 5). The survey site for grass owl is located immediately adjacent to site 2 (sth side of highway).

Data for a fourth site Boyd Street was collected during previous surveys (Sandpiper Ecological Surveys 2001), however, it has been included here because it covers habitat present within this study area. Playback was conducted at a sixth site (Hidden Valley) to target marbled frogmouth.

Playback was conducted over two non-consecutive nights at each site during each survey period. The exception to this was the southern side of the highway, which was sampled on only one occasion during the spring survey due to the onset of poor survey conditions, and the north side of the highway which was sampled only during spring.

Surveys commenced at least 30 minutes after dark (i.e. at about 9.00pm DST), and were conducted by two observers spaced about 200 m apart. Upon arrival at a site 10 minutes was spent listening for owl calls. After this period the calls of each species (in the order powerful, masked, barking, sooty and grass owl) were broadcast through a 10-watt megaphone for a period of five minutes, with a two minute gap between calls. The final call was followed by a 10 minute listening period, which was inturn followed by a brief (approximately 200 m) spotlight traverse in the vicinity of the playback site. The objective of the spotlight survey was to detect owls that may have approached the playback site without responding to the broadcast (NPWS 1999).

***Dusk playback***

Dusk playback targeted bitterns, crakes, rails, and bush-hen and was conducted at two sites (Figure 2, Table 6). Playback for Australasian bittern and Lewins rail was conducted at one site, whilst playback for black bittern and bush-hen was conducted at both sites (Figure 2). The method used was the same as that described above for nocturnal playback. Dusk surveys commenced one-hour prior to dusk, and generally continued for approximately 30 minutes after sunset. This time was selected as it represents a period of known activity for bitterns, crakes and rails. Two observers were used during the dusk surveys, with a distance of approximately 100-150 m between observers.

***Dawn playback***

Dawn playback was conducted at two sites, Hidden Valley and 'east slope' (Table 5). Calls of three species of fruit-dove and white-eared monarch were broadcast at each site. The methods used during the surveys were the same as those described above for nocturnal and dusk playback. Dawn playback was conducted between 6.00 am and 9.00 am (DST).

*Table 5*: Nocturnal broadcast sites sampled during the summer and autumn surveys for the proposed Tugun Bypass. Site numbers correspond to those shown on Figure 3. PO = powerful owl, MO = masked owl, BO = barking owl, GO = grass owl; SO = sooty owl; MF = marbled frogmouth; ** surveys conducted at this site in summer and Autumn 2000 during surveys for southern part of the alignment refer to Sandpiper Ecological Surveys (2001) for specific details; * calls played only during summer survey. Site numbers correspond to those listed on Figure 2.

| Site | Location | Habitats sampled | Calls played | Number of surveys | |
|---|---|---|---|---|---|
| | | | | Spring | Summer |
| 1 | Nth side of highway | Dry open forest | PO, MO, BO | 2 | 0 |
| 2 | Sth side of highway | Dry open forest, regrowth dry open forest, disturbed grassland | PO, MO, BO, GO, BaO* | 1 | 2 |
| 3 | Woodgee Hill | Dry open forest, regrowth rainforest | PO, MO, BO, SO*; BaO* | 2 | 2 |
| 4 | Boyd Street** (NW corner in SES 2001) | Swamp forest, woodland, dry open forest | PO, MO, BO | 2** | 2** |
| 5 | Pacific Beach | Disturbed grassland | GO | 0 | 1 |
| 6 | Hidden Valley | Regrowth rainforest | MF | 0 | 2 |

*Table 6:* Dusk broadcast sites sampled during the spring and summer surveys for the proposed Tugun Bypass. Site numbers correspond to those listed on Figure 2. AB = Australasian bittern, BB = black bittern, BH = bush-hen, LR = Lewins Rail.

| Site | Location | Habitats sampled | Calls played | Number of surveys | |
|---|---|---|---|---|---|
| | | | | Spring | Summer |
| 1 | Hidden Valley | Small dam/creekline | BH, BB | 1 | 2 |
| 2 | Grassland | Grassland and phragmites | BH, BB, AB, LR | 1 | 2 |

*Table 7:* Dawn broadcast sites sampled during the spring and summer surveys for the proposed Tugun Bypass. Site numbers correspond to those listed on Figure 2. RCF = rose-crowned fruit-dove, WF = wompoo fruit-dove, SF = superb fruit-dove, WEM = white-eared monarch.

| Site | Location | Habitats sampled | Calls played | Number of surveys | |
|---|---|---|---|---|---|
| | | | | Spring | Summer |
| 1 | Hidden Valley | Rainforest Gully & slopes | RCF, WF, SF, WEM | 1 | 2 |
| 2 | East Slope | Moist regrowth in gully | RCF, WF, SF, WEM | 1 | 2 |

#### 4.4.6 Dusk listening

Dusk listening represents an effective way of gathering information on the occurrence of nocturnal and crepuscular birds, and can provide valuable information on the location of diurnal roost sites (NPWS 1999). The basic method employed during dusk listening was to approach a site immediately prior to dusk, and sit quietly at that site for a period of approximately 30 minutes listening for calls of threatened birds. During spring, dusk listening was conducted on two nights at each of two sites, *Stewart Road* and *Hidden Valley*. During autumn dusk listening was conducted on one night at three sites, *Stewart Road*, *Hidden Valley,* and *Boyd Street*.

#### 4.3.7 Bird movements

Information on bird movements was obtained using two methods. The first method involved the opportunistic recording of bird movements whilst conducting other activities. The second method involved recording all bird movements across the proposed alignment at a set location. One observer was positioned at the quarry and recorded all bird movements during three, two hour periods. The survey periods were 7.00-9.00am (DST), 11.00-1.00pm (DST), and 5.00pm-7.00pm (DST). Data collected from all observations included the species of bird, number of individuals, direction of flight, and height above the ground. Most opportunistic records were obtained from open habitats in the vicinity of the quarry.

#### 4.3.8 Nest searches

During the area searches and general traverses specific attention was focussed on searching for raptor nests. Any large stick nests recorded during the survey were noted and observed throughout the survey in an attempt to determine if they were used by raptors.

#### 4.3.9 Opportunistic

All records of birds made whilst moving around the study area were recorded, and the habitat type used was noted. Opportunistic records have been included into the general bird lists for each habitat type.

# 5. RESULTS AND DISCUSSION

## 5.1 Habitat assessment

Six habitat types were identified within the study area (Table 8, Figure 3). A brief discussion of the major features of each habitat type is provided below.

### 5.1.1 Regrowth rainforest

Regrowth rainforest was restricted to Hidden Valley. Rainforest habitat was quite extensive within the valley, extending to the top of the western slope, and almost to the top of the eastern slope (Figure 3). This habitat has been previously cleared, and consisted primarily of regrowth vegetation that is greater than 25 years old. No recent evidence of fire, logging or grazing was recorded in regrowth rainforest, although weed invasion was regarded as moderate, with lantana (*Lantana camara*) recorded on both slopes. Understorey vegetation cover was typical of rainforest habitats, being dominated by leaf litter. Ground vegetation consisted of a mix of ferns and regrowth rainforest shrubs. No large hollows were recorded in the rainforest regrowth, and small hollows were uncommon. Epiphytes and fleshy fruits occurred throughout the habitat type. Approximately 0.67 ha of regrowth rainforest habitat would be removed.

### 5.1.2 Moist regrowth

Moist regrowth forest was recorded in two gullies, one adjacent to the existing Pacific Highway near Stewart Road, and the other on the eastern slope heading towards Boyd Street (Figure 3). Both sites were dominated by cheese tree (*Glochidion* spp.) with emergent rainforest species. Both sites appear to have been previously cleared, although there was no recent evidence of grazing or fire. Weeds, in particular lantana were recorded at both sites. A small amount of mistletoe, epiphytes and acacia was recorded in moist regrowth, with abundant fruits and flowers. Fleshy fruits included cheese tree, and bangalow palms (*Archontophoenix cunninghamiana*). No obvious midstorey was evident in this habitat type. Canopy height was estimated at 15 m.

### 5.1.3 Dry open forest

Dry open forest was the most extensive habitat type recorded within the study area, covering much of the eastern slope of Woodgee Hill, and much of the habitat in the vicinity of the quarry and Stewart Road. The isolated block of vegetation on the northern side of the highway was also dominated by dry open forest, with small pockets of moist forest (Figure 3). Due to the extent of dry open forest in the study area the habitat components were assessed at three locations. All of the dry open forest in the study area is fairly mature apart from a small patch of habitat on the southern side of the quarry, which consists of immature forest.

Dry open forest has been previously logged, and recent (3-5 yrs) evidence of fires, grazing and weed invasion was recorded (Table 8). Understorey vegetation cover was moderate ranging from 45 to 60%, with about 30% litter cover. Large and small hollows and mistletoe was sparsely distributed throughout the habitat. *Acacia* spp. and *Allocasuarina* spp. were fairly common in the midstratum at one site, on the eastern slope of Woodgee Hill. Overstorey vegetation was dominated by blackbutt (*Eucalyptus pilularis*), with small-fruited grey gum (*E. propinqua*) and pink bloodwood (*Corymbia intermedia)* as co-dominants. Overstorey vegetation ranged in height from 20-30 m. Midstorey vegetation varied considerably throughout the study area (Table 8). Approximately 7.34 ha of dry open forest habitat would be removed.

### 5.1.4 Disturbed land

Disturbed land occurred throughout the study area. The major areas of disturbed land include grassy habitat in the vicinity of the disused quarry, and Stewart Road, near Boyd Street, and in the vicinity of the rubbish tip and sewage works (Figure 3). Disturbed land had a simplified structure consisting primarily of tall grassland with occasional shrubs. Ponds with dense aquatic vegetation were recorded at the sewage treatment works. No hollows, flowers or fleshy fruits were recorded in disturbed habitat. Approximately 24.85 ha of disturbed land would be removed.

### 5.1.5 Swamp forest

Swamp forest habitat was restricted to low-lying land surrounding a small drainage line at the southern end of the study area near the Boyd Street interchange (Figure 3). Broad-leaved paperbark (*Melaleuca quinqunervia)* and swamp mahogany (*E. robusta*) dominated the swamp forest, although in some instances the habitat was dominated by only one of these species. A mix of coast banksia (*Banksia integrifolia*), and cheese tree (*Glochidion* spp.) dominated the midstratum, whilst *Blechnum spp.,* and *Lygodium microphyllum* dominated the understorey.

Waterbodies within swamp forest habitat appear suitable for crakes, rails and bitterns. It is likely that much of the swamp forest habitat becomes inundated after prolonged rainfall. Swamp forest habitat also has a number of additional features important for birds, including a high density of flowering trees and shrubs (paperbark and banksia), and a low density of small and large hollows. Swamp forest habitat has suffered only minor disturbance. Approximately 2.28 ha of swamp forest habitat would be removed.

### 5.1.6 Woodland

Dry woodland is restricted to the southern end of the study area in the vicinity of the Boyd Street interchange (Figure 3). This habitat type is situated on slightly elevated sandy soils adjacent to swamp forest. This habitat type was dominated by scribbly gum (*Eucalyptus signata*) and pink bloodwood (*Corymbia intermedia*), with a dense heathy understorey. *Acacia* spp., and *Allocasuarina* spp. occur within the midstratum.

Dry woodland has a number of features important for birds, including occasional large (> 15 cm diameter) basal hollows suitable for owls, and several small (5-15 cm diameter) hollows. The habitat is also characterised by dense mid-stratum and ground vegetation suitable for small passerines. There are considerable food resources available within the woodland habitat, including flowering and fruiting *Banksias*, *Allocasuarinas*, and mistletoe. Approximately 0.54 ha of woodland habitat would be removed.

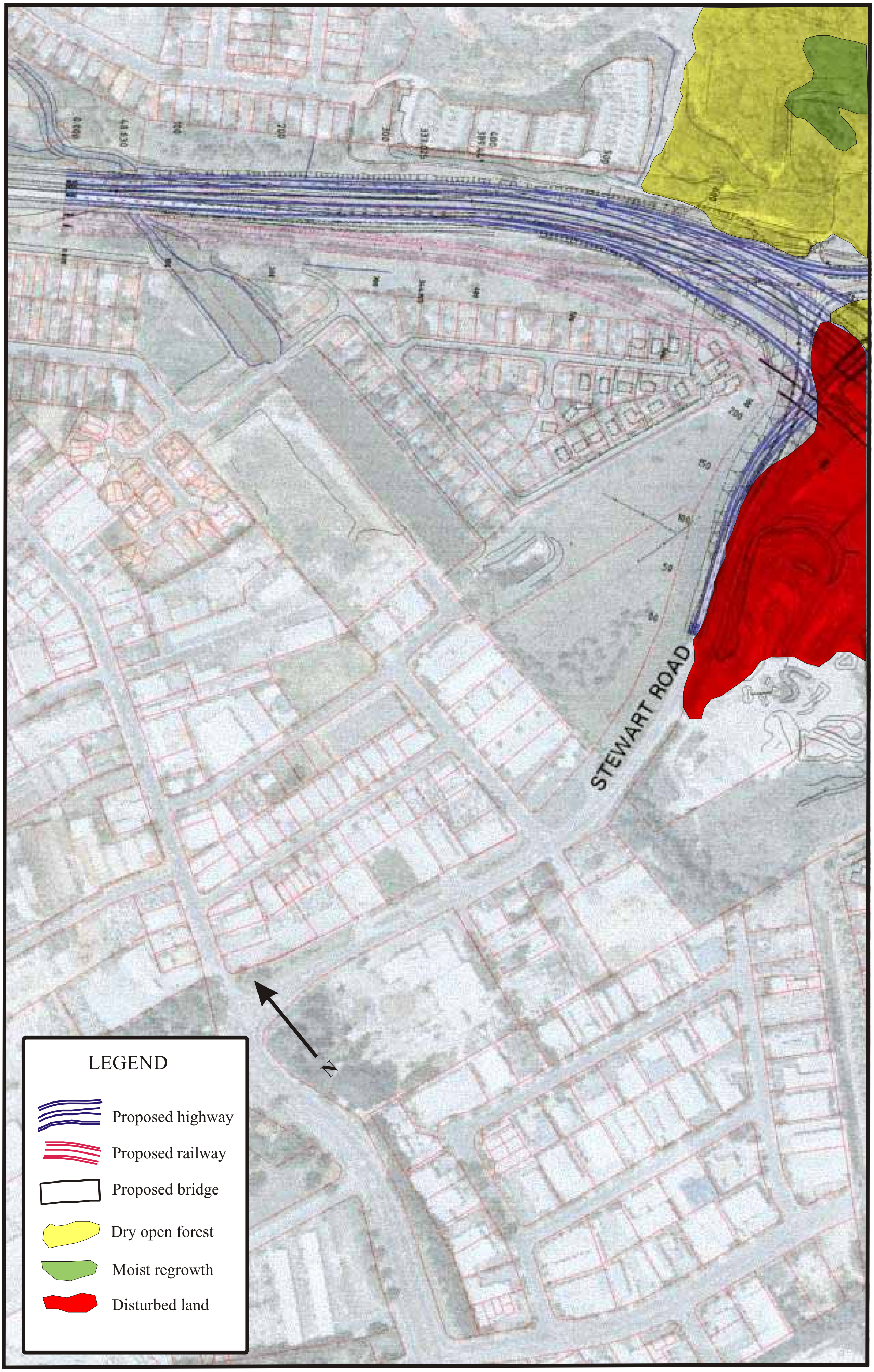


*Figure 3*: Habitat types recorded within the study area, and the location where species listed on the *QNCWR 1994* and the NSW *TSC Act 1995* were recorded.

*Table 8:* Characteristics of major terrestrial habitat types identified within the study area. ** = site previously slashed; LH = large hollow, SH = small hollow, M = mistletoe, Ep = epiphytes, FF = fleshy fruits, Fl = flowers, Ac = *Acacia* spp., Ba = *Banksia* spp., Al = *Allocasuarina* spp.

| Habitat Type | Topographic position | Disturbance History | | | | Soil | | Ground Layer (% cover) | | | | Litter depth | Humus depth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fire | Logging | Grazing | Weeds | Depth | Type | Vegt | Soil | Log | Litter | | |
| Regrowth Rainforest | Lower slope, gully | Ne, >5yr | Ne, >25yr | Ne, >10yr | Mod. | deep | loam | 15 | 10 | 10 | 65 | 2-10cm | 0-2cm |
| Moist regrowth | Open depression/gully | Ne >5yrs | Severe 15yrs | Ne | Mod. | deep | loam | 60 | 10 | 10 | 20 | 2-10cm | 0-2cm |
| Dry open forest 1 | Upper slope/ridge | Mod, 3-5yr | Severe, 20+yr | Mod, 3-5yr | Mod. | shallow | Cl/loam | 45 | 10 | 15 | 30 | 2-10cm | 0-2cm |
| Dry open forest 2 | Upper slope/ridge | Light 5-10 yr | Mod 15-20yr | nil | light | shallow | Cl/loam | 45 | 15 | 10 | 30 | >10 cm | 0-2cm |
| Dry open forest 3 | Crest/hillcrest | Mod 3-5yrs | Mod 20 yrs | Ne | severe | shallow | Cl/loam | 60 | 5 | 5 | 30 | 2-10 cm | 0-2cm |
| Disturbed land | mixed | Mod 3yrs | cleared | Ne | severe | shallow | clay | 85 | 5 | 5 | 5 | 0-2cm | 0-2cm |
| Swamp Forest | Flat, plain | 5 years (mod) | none | 5 years (light) | light | shallow | loam | 90 | 0 | 5 | 5 | 0-2cm | 2-10cm |
| Dry Open Woodland | Flat, plain | <10 years (mod) | < 15 yrs (light) | nil | nil | shallow | loam | 70 | 10 | 10 | 10 | 0-2cm | 0-2cm |

*Table 8:* cont

| Habitat Type | Stand Description (% of trees) | | | | | | | | | Stags >10 cm dbh/ 20x20m | Shrub Growth form | Ground growth form | Dominant midstorey & (height m) | Dominant overstorey & (height m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LH | SH | M | Ep | FF | Fl | Ac | Ba | Al | | | | | |
| Regrowth rainforest | 0 | <5% | <5% | 5-25% | 5-25% | 5% | 0 | 0 | 0 | 0 | mesic | fern | *Archontopheonix cunninghami* to 15 m | Mixed rainforest species to 25 m |
| Moist regrowth | 0 | 0 | <5% | 5% | 5-25% | 5-25% | 5% | 0 | 0 | 0 | mesic | fern | No obvious midstorey | *Glochidion* spp., Cinnamomum camphora, mixed rainforest to 15m |
| Dry open forest 1 | 0 | <5% | <5% | 0 | 0 | 0 | 5-25% | 0 | 5-25% | 0 | mixed | Herb/grass | *Eucalyptus tereticornis* *Lophostemon confertus* *Allocasuarina* spp to 15 m | *Eucalyptus pilularis* to 20-25m |
| Dry open forest 2 | 0 | 5% | <5% | 0 | 0 | 5-25% | 5% | 0 | <5% | 0 | mixed | Herb/grass | *Eucalyptus* spp *Endiandra spp.* to 7m | *E. pilularis* *E. propinqua* to 25 m |
| Dry open forest 3 | <5% | 5% | 5% | 0 | 0 | 0 | 0 | 0 | 0 | 1 | mixed | Tussock grass | *Endiandra spp.* to 10 m | *E. pilularis*, *C. intermedia* to 30 m |
| Disturbed land | 0 | 0 | 0 | 0 | 0 | 0 | <5% | 0 | 0 | 0 | heathy | grass | *Acacia* spp. to 4 m | None |
| Swamp Forest | 5 | <5 | 5 | 0 | 5 | 5 | 5 | 25-50 | 0 | 1-2 | heathy | sedge | *Dodenaea* spp (2-3) *Glochidion* spp. (4-6) *Banksia robor* (1-2) | *Eucalyptus robusta* (20-25) *Melaleuca quinqunervia* (25-30) |
| Dry Open Woodland | 5 | 5-25 | 5 | <5 | <5 | 5- 25 | 25- 50 | 5-25 | 5-25 | 1-2 | heathy | Fern/sedge | *Acacia* sp (4-8) | *Eucalyptus signata* (15-20) *Corymbia gummifera* (15-20) |

## 5.2 Species richness

A total of 125 species of bird were recorded in the study area during the spring and summer surveys (Table 3a & 3b Appendix 3). Ninety-eight species were recorded during the spring survey, with 108 species recorded during the summer survey (Table 3a & 3b Appendix 3). Eighty species were recorded during both surveys, with 17 species recorded in spring but not summer, and 28 species recorded in summer but not spring.

Ten of the 28 species recorded in summer but not spring were waterbirds, with eight of these species recorded at the sewage treatment works, which were not sampled during the spring survey. Birds recorded in spring but not summer included three species of cuckoo (brush, little bronze & horsefields bronze), and two species of monarch (white-eared and spectacled). Black-faced monarchs were recorded during both surveys. The species of raptor using the study area also varied between the surveys. Pacific bazas and black-shouldered kites were recorded during both surveys, whilst whistling kites, brahminy kites and brown goshawks were recorded during spring only, and white-bellied sea-eagle and peregrine falcon were recorded during summer only. Barn owl and tawny frogmouth were recorded during summer only.

Fewer species of bird were recorded in each habitat type during the summer survey (Table 9). During spring each species used an average of 2.8 habitats, whilst during summer each bird used an average of 2.2 habitats. This result is surprising given that a greater number of species were recorded in summer. The result suggests that birds used a greater range of habitats during the spring survey. A direct comparison between the two surveys is not possible due to differences in survey effort, although a greater survey effort in woodland, rainforest, moist regrowth and disturbed land resulted in fewer species during summer. The observed result may be due to changes in food availability between spring and summer. Increased food availability in summer may have enabled birds to concentrate foraging activities in fewer habitats. The result may also be due to the poor weather conditions that were experienced immediately prior to the commencement of surveys in summer.

*Table 9:* Number of species of bird recorded in each habitat type during the spring and summer bird surveys. Also shown is the total survey effort for each habitat. Sp = species; EF = survey effort in minutes. Survey effort does not include the time spent conducting dawn, dusk and nocturnal playback.

| Time of survey | Woodland | | Swamp Forest | | Regrowth Rainforest | | Moist regrowth | | Disturbed land | | Dry Open Forest | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sp | Ef | Sp | Ef | Sp | Ef | Sp | Ef | Sp | Ef | Sp | Ef |
| Spring | 25 | 30 | 48 | 118 | 44 | 188 | 21 | 50 | 60 | 86 | 80 | 538 |
| Summer | 17 | 60 | 37 | 106 | 39 | 340 | 19 | 80 | 55 | 120 | 67 | 360 |

## 5.4 Bird density

The number of species recorded in each habitat type during point counts provided a similar result to the compilation of species records (section 5.3). A greater number of species were recorded in all habitats during spring than in summer. The most pronounced difference was in swamp forest where species richness declined from 38 in spring to 25 in summer (Table 10). The trend observed for species richness was not fully supported by the density estimates. Density was lower in summer in rainforest and moist regrowth, but greater in swamp forest and dry open forest. In dry open forest density increased from 24.71 birds/ha in spring to 43.61 birds/ha in summer. A substantial decline in density was recorded during summer in moist regrowth (Table 10).

A small number of species contributed greatly to bird density. These species included rainbow and scaly-breasted lorikeet, brown thornbill, silvereye, Torresian crow, and silvereye.

*Table 10:* Density of birds/ha in four of the major habitat types recorded in the study area. Spr = spring; sum = summer.

| Common Name | Regrowth Rainforest | | Moist Regrowth | | Swamp Forest | | Dry Open Forest | |
|---|---|---|---|---|---|---|---|---|
| | Spr | Sum | Spr | Sum | Spr | Sum | Spr | Sum |
| Australian Brush-turkey | | | 1.17 | | | | | |
| Australian White Ibis | | | | | 0.59 | | 0.39 | |
| Pacific Baza | | | | | 0.29 | | | 0.39 |
| Brahminy Kite | | | | | 0.29 | | | |
| Lewins Rail | | | | | | | | |
| Spotted Turtle-Dove | | | 2.34 | | 0.59 | | | |
| Brown Cuckoo-Dove | | | | | | | 0.2 | |
| Crested Pigeon | | | | | 0.59 | | | |
| Peaceful Dove | | | | | | 0.39 | | |
| Galah | 7.67 | | | | 0.59 | | | |
| Long-billed Corella | | | | | | | 0.39 | |
| Sulphur-crested Cockatoo | | | | | | | 0.2 | |
| Australian King Parrot | | | | | 0.89 | | 0.39 | |
| Rainbow Lorikeet | | 4.72 | | | 3.84 | 6.69 | 7.08 | 6.69 |
| Scaly-breasted Lorikeet | | | 2.34 | | 2.07 | 2.36 | 3.93 | 2.36 |
| Pheasant Coucal | | | | | | | | |
| Laughing Kookaburra | | 1.17 | | | 0.29 | 0.79 | 0.2 | 0.79 |
| Sacred Kingfisher | | | | 1.18 | 11.18 | | 0.29 | |
| Rainbow Bee-eater | | | | | 0.89 | | | |
| Dollarbird | 1.18 | | | | | | 0.79 | |
| Superb Fairy-wren | | | | | 2.36 | | 0.39 | |
| Varigated Fairy-wren | | | | | 1.77 | | | |
| Red-Backed Fairy-wren | | | | | 0.29 | | | |
| Spotted Pardalote | | | | | 1.48 | 0.79 | | 0.79 |
| Striated Pardalote | | | | | | | 0.59 | |
| White-browed Scrubwren | 1.18 | | | | 0.29 | 1.97 | | 1.97 |
| Large-billed Scrubwren | 2.36 | 2.36 | | | | 1.17 | | 1.17 |
| Brown Gerygone | | | | | 0.89 | | | |
| Brown Thornbill | 2.36 | 2.36 | 5.9 | 2.36 | 0.89 | 4.33 | | 4.33 |
| Noisy Friarbird | | | | | 0.29 | 0.79 | 0.59 | 0.79 |
| Noisy Miner | | | | 2.36 | | 1.57 | 1.38 | 1.57 |
| Lewins Honeyeater | 1.18 | 2.36 | 1.17 | 2.12 | 0.29 | 1.97 | 0.79 | 1.97 |
| White-naped Honeyeater | | | | | | | 0.79 | |
| Brown Honeyeater | | | | | 0.29 | | | |
| White-cheeked Honeyeater | | | | | 0.29 | | 0.2 | |
| Eastern Spinebill | | 1.17 | | | | | 0.2 | |
| Eastern Yellow Robin | | | | 1.17 | | | 0.2 | |
| Eastern Whipbird | 2.36 | 5.9 | 2.34 | 2.36 | 2.36 | 2.75 | 0.79 | 2.36 |
| Golden Whistler | | | 9.4 | | | | | 0.39 |
| Rufous Whistler | 0.17 | | | 2.36 | 1.17 | | | |
| Little Shrike-thrush | 1.77 | 1.17 | | 1.17 | | | | 0.39 |
| Grey Shrike-thrush | | | | | 1.17 | 0.39 | | |
| Black-faced Monarch | 4.13 | | 3.54 | | | 0.39 | | 0.39 |
| Spectacled Monarch | 1.18 | | 5.9 | | | | | |
| White-eared Monarch | | | 2.34 | | | | | |
| Leaden Flycatcher | 1.77 | | 1.17 | | 0.89 | | | |
| Magpie-lark | | | | | | | 0.2 | |
| Grey Fantail | | 1.17 | | | | 0.39 | | 0.39 |

*Table 10:* cont.

| Common Name | Regrowth Rainforest | | Moist Regrowth | | Swamp Forest | | Dry Open Forest | |
|---|---|---|---|---|---|---|---|---|
| | Spr | Sum | Spr | Sum | Spr | Sum | Spr | Sum |
| Spangled Drongo | 0.17 | | 4.72 | 5.9 | 0.29 | 2.75 | | 1.57 |
| Black-faced Cuckoo-shrike | | | 1.17 | 1.17 | 1.17 | | 0.2 | |
| Cicadabird | | | | 1.17 | 0.29 | | 0.2 | 1.17 |
| Varied Triller | 1.77 | 3.54 | | | | 0.79 | 0.39 | 0.39 |
| Olive-backed Oriole | 1.18 | | | | 0.29 | | | |
| Figbird | | | 1.17 | 5.31 | 0.29 | | 0.2 | 0.39 |
| White-breasted Woodswallow | | | | | | | 0.2 | |
| Grey Butcherbird | | | | | | 1.17 | | |
| Pied Butcherbird | | | | | | 0.79 | 0.39 | 0.39 |
| Australian Magpie | | | | | | 0.39 | | 0.39 |
| Pied Currawong | | | | | | | 0.39 | 1.17 |
| Torresian Crow | | | | | 1.48 | 7.87 | 1.38 | 0.39 |
| Richards Pipit | | | | | | 0.39 | | |
| Red-browed Finch | | | | | 0.54 | 1.97 | | 3.54 |
| Mistletoebird | 0.17 | | | | 0.54 | | 0.2 | |
| Fairy Martin | | | | | 6.49 | | 0.79 | |
| Golden-headed Cisticola | | | | | 0.29 | | | |
| Silvereye | 5.31 | 2.36 | 9.44 | 1.18 | 2.34 | 2.75 | 0.98 | 7.47 |
| Unidentified spp. | | | | | | 0.79 | 0.2 | |
| Number of species | 17 | 11 | 15 | 13 | 38 | 25 | 33 | 26 |
| Total density/ha | 35.91 | 28.28 | 54.11 | 29.81 | 41.42 | 46.4 | 24.71 | 43.61 |

# 5.5 Playback

## 5.5.1 Nocturnal playback

Two species of bird were recorded during nocturnal playback, with one additional species (masked owl) recorded at site 4 during playback conducted for previous surveys (Table 11). The two species recorded during the present survey were the barn owl and tawny frogmouth, both of which were recorded in dry open forest at Woodgee Hill (Figure 2).

*Table 11:* Species of bird recorded during nocturnal playback at six sites within the study area. U = unconfirmed; C = confirmed. MO = masked owl, ON = owlet nightjar, WN = white-throated nightjar, SB = southern boobook, TF = tawny frogmouth, GO = grass owl; ** species recorded during previous surveys. Site numbers correspond to numbers on Figure 4.

| Site | Habitat | No. Surveys | | Species recorded | | Habitat where species recorded |
|---|---|---|---|---|---|---|
| | | Spring | Summer | Spring | Summer | |
| 1 | Dry open forest | 2 | 0 | nil | nil | - |
| 2 | Dry open forest, regrowth dry open forest, disturbed grassland | 1 | 2 | nil | nil | - |
| 3 | Dry open forest, regrowth rainforest | 2 | 2 | nil | barn owl, tawny frogmouth | Dry open forest |
| 4 | Swamp forest, woodland, dry open forest | 2** | 2** | masked owl** | | Woodland |
| 5 | Disturbed grassland | 0 | 1 | - | nil | - |
| 6 | Rainforest regrowth | 0 | 2 | - | nil | - |

### 5.5.2 Dusk playback

One target species was recorded during dusk playback (Table 12). A pair of bush-hens responded to playback from a small dam in Hidden Valley. The behaviour displayed by the birds was indicative of nesting (Marchant & Higgins 1993).

*Table 12:* Results of dusk playback conducted at two sites in the study area.

| Site | Habitat | No. Surveys | | Species recorded | | Habitat where species recorded |
|---|---|---|---|---|---|---|
| | | Spring | Summer | Spring | Summer | |
| 1 | Small dam/creekline | 1 | 2 | nil | Bush-hen | Small dam/rainforest |
| 2 | Grassland and phragmites | 1 | 2 | nil | nil | - |

### 5.5.3 Dawn playback

Three species of fruit-dove were recorded during dawn playback in Hidden Valley, although the record of the superb fruit-dove requires confirmation (Table 13). Rose-crowned fruit-doves responded to playback on three occasions, with individuals recorded along the length of the creek within the valley. Wompoo fruit-doves were recorded on one occasion, adjacent to the proposed highway alignment.

*Table 13:* Results of dawn playback conducted at two sites in the study area. RCF = rose-crowned fruit-dove, WF = wompoo fruit-dove, SF = superb fruit-dove, * = tentative record.

| Site | Habitat | No. Surveys | | Species recorded | | Habitat where species recorded |
|---|---|---|---|---|---|---|
| | | Spring | Summer | Spring | Summer | |
| 1 | Rainforest Gully & slopes | 1 | 2 | nil | RCF, WF, SF* | Regrowth rainforest |
| 2 | Moist regrowth in gully | 1 | 2 | nil | nil | - |

## 5.6 Bird flight heights and movements

A number of species of bird were recorded flying across the proposed alignment, with individuals recorded flying in all compass directions. There was a general trend of birds moving in a northwest to southeast direction, suggesting movement to, and from habitats within and surrounding Currumbin Bird Sanctuary. However, do distinct dawn or dusk movement was recorded, although previous observations suggest that such a movement may exist. Lorikeets were often recorded flying in all directions around the study area throughout the day. Casual observation indicated that a number of waterbirds (egrets, ibis and spoonbills) move towards Currumbin at dusk. A similar movement away from Currumbin is anticipated to occur at dawn.

Comparison of flight heights indicated that most species and individuals were flying well above the ground level (Table 14). However, it must be considered that the results represent only a small timeframe and provide only an indication of flight heights. More intensive observations would be required to provide conclusive evidence of the risk posed by the proposed highway. The range of flight heights (last column in Table 14) shows that a number of species come fairly close to the ground and could be subject to road strike. Lorikeets may be particularly vulnerable in this sense as they often fly at rapid speeds between clumps of trees.

*Table 14:* Results of observations on bird flight height conducted at the 'quarry' to obtain baseline information on the road strike risk posed by the highway on avifauna. SD = standard deviation.

| Species/Group | No. Flocks | Average Flock Size (no. ind) | Average Flight Height (m) | SD – Flight Height (m) | Flight Height Range (m) |
|---|---|---|---|---|---|
| Ibis | 21 | 2.7 | 67.1 | 25.3 | 20 - 100 |
| Egrets | 8 | 1.4 | 57.5 | 19.8 | 30 - 80 |
| Parrots | 11 | 4.4 | 58.6 | 45.2 | 10 - 150 |
| Crows | 6 | 3.3 | 61.7 | 21.4 | 30 - 80 |
| Others | 7 | 6.0 | 62.8 | 24.3 | 30-100 |

## 5.7 Legislatively protected species recorded during the field survey

### 5.7.1 Species recorded in Queensland

Lewins rail was the only legislatively protected species recorded in the Queensland section of the study area. This species is listed as rare under Schedule 4 of the *QNCWR 1994*. One Lewins rail was recorded in disturbed grassland habitat near Stewart Road during the spring field survey (Figure 3). This species was not detected in the same site during the summer survey despite targeted searches, including the use of playback. The habitat in which the species was recorded is regarded as marginal, although the site provides the dense vegetation preferred by this species it lacks areas of permanent water that may be used for foraging. One additional species listed on the *QNCWR 1994* that was recorded in the NSW section of the study area but which may also utilise habitats in Qld. is the glossy black-cockatoo.

### 5.7.2 Species recorded in NSW

Two species listed on the NSW *TSC Act 1995* were recorded in the NSW section of the study area, whilst unconfirmed records of an additional two species have been obtained from this area during previous surveys. The species recorded during the present field survey were the bush-hen and glossy black-cockatoo both of which were recorded in the vicinity of the Boyd Street interchange. Unconfirmed records of black bittern and masked owl were obtained from the same area during previous surveys (Sandpiper Ecological Surveys 2001).

Glossy black-cockatoos were recorded foraging on black she oak (*Allocasuarina littoralis*) to the south of Boyd Street. It is considered likely that this species could also forage on *A. torulosa* present on the eastern slope of Woodgee Hill. It is considered likely that masked owls would forage over the entire study area, using habitat in both Qld and NSW. Masked owls have been recorded from the immediate vicinity of the study area (Parker 2000). In NSW black bittern and bush-hen are most likely restricted to swamp forest habitat along the small drainage line that runs parallel to the proposed carriageway.

Seven species listed by NPWS (1999) as being of conservation significance were also recorded. These species included: brahminy kite, forest kingfisher, little bronze-cuckoo, little shrike-thrush, Pacific Baza, and peregrine falcon.

**5.7.3 Species recorded in Queensland that are listed on the NSW TSC Act (1995).**

Five species recorded only in the Qld. section of the study area are listed on the NSW *TSC Act 1995*. These species are not covered by the relevant Qld legislation but warrant consideration due to the close proximity of the study area to NSW, and the current and predicted disturbance to habitat used by these species in NSW, immediately south of the study area. These species include rose-crowned, wompoo, and superb fruit-doves, white-eared monarch, and bush-hen. The fruit-doves and the bush-hen were all recorded using habitats in Hidden Valley, whilst the rose-crowned fruit-dove and white-eared monarch were recorded using moist regrowth near Stewart Road.

# 6. LIKELIHOOD OF OCCURRENCE OF LEGISLATIVELY PROTECTED SPECIES

To determine which legislatively protected species may be affected by the proposal an assessment of the likelihood of occurrence of each species has been conducted (Table 15). This assessment is based on the results of bird surveys, and the habitat assessment conducted during the field investigations. The column headings *Likelihood of Occurrence in Qld* and *Likelihood of Occurrence in NSW* refer to the likelihood to which each species could be expected to occur in either the Qld or NSW sections of the study area.

The assessment identified 15 species that require consideration during the impact assessment process. Potentially affected species include three species (square-tailed kite, glossy black-cockatoo, and marbled frogmouth) listed in both NSW and Qld, two species (grey goshawk, and Lewins Rail) listed only in Qld, five species listed only in NSW (bush-hen, black bittern, rose-crowned fruit-dove, masked owl, and white-eared monarch), and five species (white-bellied sea-eagle, oriental cuckoo, rainbow bee-eater, white-throated needletail and fork-tailed swift) listed on JAMBA and CAMBA.

*Table 15:* Assessment of the likelihood of occurrence of legislatively protected species in the study area.

| Common Name | Listed in Qld | Likelihood of Occurrence in Qld | Listed in NSW | Likelihood of Occurrence in NSW | Notes | Species requiring consideration |
|---|---|---|---|---|---|---|
| Wedge-tailed Shearwater | No | Unlikely | No | Unlikely | This species is a pelagic seabird. No habitat occurs in the study area. | No |
| Sooty Shearwater | No | Unlikely | No | Unlikely | This species is a pelagic seabird. No habitat occurs in the study area. | No |
| Black-necked Stork | Yes | Unlikely | Yes | Unlikely | No habitat for this species occurs in the study area. | No |
| Cattle Egret | No | Confirmed | No | Confirmed | Listed on JAMBA & CAMBA. Very common in the locality & recorded from the study area. The project poses no threat to this species. | No |
| Great Egret | No | Confirmed | No | Confirmed | Listed on JAMBA & CAMBA. Common in the locality & recorded from the study area. The project poses no threat to this species. | No |
| Osprey | No | Unlikely | Yes | Unlikely | No habitat for this species occurs in the study area. | No |
| White-bellied Sea-Eagle | No | Unlikely | No | Confirmed | Listed on CAMBA. Habitat in NSW may represent marginal quality foraging habitat for this species | Yes |
| Square-tailed Kite | Yes | Possible | Yes | Possible | Suitable habitat exists in the form of dry open forest. Recorded previously south of the study area. The large home range of this species means that they may utilise the study area. | Yes |
| Grey Goshawk | Yes | Likely | No | Likely | Suitable habitat exists in the form of regrowth rainforest. Although not recorded, it is likely that this species may utilise Hidden Valley. | Yes |
| Bush-hen | No | Confirmed | Yes | Possible | Confirmed record from Hidden Valley, with unconfirmed record from near Stewart Road, and near the Boyd Street Interchange. | Yes |

*Table 14:* cont.

| Common Name | Listed in Qld | Likelihood of Occurrence in Qld | Listed in NSW | Likelihood of Occurrence in NSW | Notes | Species requiring consideration |
|---|---|---|---|---|---|---|
| Black Bittern | No | Unlikely | Yes | Possible | Unconfirmed record from near the Boyd Street interchange, no suitable habitat occurs in Qld. Section. | Yes |
| Lewins Rail | Yes | Confirmed | No | Likely | Confirmed record from disturbed grassland near Stewart Road during spring no evidence of birds obtained during summer. Potential habitat occurs in the NSW section. | Yes |
| Lathams Snipe | No | Unlikely | No | Unlikely | Listed on JAMBA & CAMBA. Habitats in the study area are unsuitable for this species. | No |
| South Polar Skua | No | Unlikely | No | Unlikely | Listed on JAMBA. This species is a pelagic seabird and would not use habitats in the study area | No |
| Common Tern | No | Unlikely | No | Unlikely | Listed on JAMBA & CAMBA. This species would not utilise habitats in the study area. | No |
| Little Tern | Yes | Unlikely | Yes | Unlikely | Also listed on the *ESP Act 1992*. No habitat occurs in the study area for this species. | No |
| Common Noddy | No | Unlikely | No | Unlikely | Listed on JAMBA & CAMBA. No habitat occurs in the study area for this species. | No |
| Glossy Black-Cockatoo | Yes | Likely | Yes | Confirmed | Confirmed record from just south of the study area, suitable habitat exists on the eastern slope of Woodgee Hill in both Qld and NSW. | Yes |
| Rose-crowned Fruit-Dove | No | Confirmed | Yes | Likely | Confirmed records from near Stewart Road and in Hidden Valley also may utilise moist regrowth on the eastern slope of Woodgee Hill. | Yes |
| Superb Fruit-Dove | No | Possible | Yes | Unlikely | Tentative record from Hidden Valley, no other suitable habitat in the study area. | No |
| Wompoo Fruit-Dove | No | Confirmed | Yes | Unlikely | Confirmed record from Hidden Valley, southwest of the proposed alignment. No suitable habitat elsewhere in the study area. | No |

*Table 14:* cont.

| Common Name | Listed in Qld | Likelihood of Occurrence in Qld | Listed in NSW | Likelihood of Occurrence in NSW | Notes | Species requiring consideration |
|---|---|---|---|---|---|---|
| Powerful Owl | Yes | Unlikely | Yes | Unlikely | No evidence that this species uses the study area. Food, hollows and habitat area may be limiting factors. | No |
| Barking Owl | No | Unlikely | Yes | Unlikely | No evidence that this species uses the study area. | No |
| Sooty Owl | Yes | Unlikely | Yes | Unlikely | No evidence that this species uses the study area, the extent of habitat in Hidden Valley is considered too small to support the species. | No |
| Masked Owl | No | Likely | Yes | Confirmed | Known to utilise habitats in NSW, also likely to forage within Qld, limited roosting habitat in the study area. | Yes |
| Marbled Frogmouth | Yes | Possible | Yes | Unlikely | Potential habitat exists in Hidden Valley, although the extent of habitat may be a limiting factor. No suitable habitat exists in NSW. | Yes |
| Oriental Cuckoo | No | Possible | No | Possible | Listed on JAMBA & CAMBA. This species could utilise habitats in the study area. | Yes |
| Collared Kingfisher | No | Unlikely | Yes | Unlikely | No suitable habitat exists in the study area for this species. | No |
| White-throated Needletail | No | Confirmed | No | Confirmed | Listed on JAMBA & CAMBA. This species could utilise habitats in the study area. | Yes |
| Fork-tailed Swift | No | Confirmed | No | Confirmed | Listed on JAMBA & CAMBA. This species could utilise habitats in the study area. | Yes |
| Rainbow Bee-eater | No | Confirmed | No | Confirmed | Listed on JAMBA. This species could utilise habitats in the study area. | Yes |
| Southern Emu-wren | Yes | Unlikely | No | Unlikely | No suitable habitat exists in the study area for this species. | No |
| White-eared Monarch | No | Confirmed | Yes | Possible | Recorded from moist regrowth near Stewart Road, also likely to utilise habitat in Hidden Valley. May also utilise moist regrowth in NSW, but no confirmed records. | Yes |

# 7. IMPACT OF THE PROPOSAL ON BIRDS

Eight factors have been identified that may affect birds within the study area. These factors include: vegetation removal; habitat fragmentation; edge effects; barrier effects; road strike; disturbance effects; altered hydrological regimes; and pollution of wetlands. A brief summary of the predicted impacts of each of the eight factors is provided below.

## 7.1 Vegetation removal

The proposal would remove a relatively small area of vegetation. The most recent estimate of the area of habitat to be removed from the Queensland section of the proposed alignment is 13.4 ha. The most extensive area of vegetation removal would occur on the eastern slope of Woodgee Hill, with a considerable area of vegetation removed from a large cut on the crest of the hill (Figure 2). Swamp forest and disturbed vegetation would be removed in the vicinity of the Boyd Street Interchange, with swamp forest and woodland habitat removed from the lower slope of Woodgee Hill.

A bridge would span Hidden Valley reducing the extent to which regrowth rainforest habitat would be cleared. There would however, be some removal of rainforest vegetation during bridge construction. The bridge would initially consist of a single two-lane structure, however, this would be duplicated for the four-lane stage of the project. There would be a three-metre gap between the two bridges. Each bridge would be positioned on two piers. During construction a 15 x 5 m area would be disturbed around each pier, and a 5m wide access track would need to be constructed to the valley floor. The access track would be constructed from the quarry side of the valley. Vegetation removal to the north of Woodgee Hill is restricted primarily to disturbed land, although the edge of dry open forest and disturbed habitat would be removed. No moist regrowth habitat would be affected by the proposal.

The impacts associated with habitat removal would vary considerably between species, and depend largely on the type and extent of the habitat removed. Vegetation removal would result in the loss of roosting, foraging and breeding habitat for a number of bird species, including some species listed on the *QNCWR 1994*, and the NSW *TSC Act 1995*. Vegetation removal would affect known habitat for Lewin's rail and potential habitat for glossy black-cockatoo. Although no evidence of glossy black-cockatoos was recorded in the immediate vicinity of the proposed road corridor potential foraging and roosting habitat does occur, and birds were recorded foraging in black oak to the south of the proposed Boyd Street interchange.

The impact of habitat removal on highly mobile species, such as the masked owl, or nomadic species that follow fruiting trees such as the fruit-doves are difficult to predict. Masked owls occupy large home ranges and often forage in open habitats or along the edge of open and forested habitats (Debus & Rose 1994; Kavanagh & Murray 1996), and therefore may be less affected by the loss of a small area of habitat. It is unlikely that roosting or breeding habitat for masked owls would be affected by the proposal. No habitat for rose-crowned, wompoo or superb fruit-doves would be removed by that part of the alignment, which occurs in NSW. A small area of potential habitat for oriental cuckoo, and known habitat for rainbow bee-eater would be removed. This would not affect local populations of these species. Vegetation removal may cause a very slight reduction in the quality of foraging habitat for white-throated needletail and fork-tailed swift through a reduction in insects.

## 7.2 Habitat fragmentation and isolation

The proposal would not fragment habitats that are not already partially isolated. The position of the alignment on the northern edge of Woodgee Hill greatly reduces the extent of fragmentation in this area, although a small linear fragment of habitat would become isolated on the northern side of the alignment at Woodgee Hill. Habitat fragmentation in this area is unlikely to have a substantial effect on threatened species.

The block of council owned dry open and moist regrowth forest on the southern side of the existing highway near Stewart Road would suffer increased isolation, with major roads on two sides and urban development on two sides. This block of vegetation is already partially isolated by the existing highway, urban development and disturbed land. Forest birds using the block would already need to cross either the existing highway or disturbed grassland to move north, or utilise the thin strip of dry open forest on the western slope of Tugun Heights to move south. Forest birds moving in a southerly direction would need to cross the proposed highway to reach Hidden Valley and habitats further south. The area of disturbed grassland near Stewart Road is already isolated from similar habitat types, and the proposal would not lead to further isolation.

## 7.3 Edge effects

Edge effects can have a significant impact on bird communities, and the significance of these effects should not be underestimated (Laurance 1997). The impact of edge effects varies between species and habitats, and the magnitude of effects would depend on the size of the remnant, with small remnants affected to a greater degree than larger ones (Young & Mitchell 1994). Edge effects may be divided into three groups (Murcia 1995):

- abiotic (changes in physical environment);
- direct biological (changes in the distribution and abundance of species); and
- indirect biological (changes in species interactions).

Edge effects generally lead to a change in forest structure along the exposed edge, and provide the opportunity for increased access by predators, such as foxes and cats. In previously undisturbed habitat the change in forest structure associated with edge creation can lead to a change in the bird community. In general terms the edge environment becomes unsuitable for species that prefer forested habitats (Baker *et al.* 1998). Edge habitats may be colonised by "edge preferring" species, although the overall species richness may be reduced (Sisk & Margules 1993). The occurrence of edge specialists such as the noisy miner can have a further impact on forest bird communities through disturbance and competitive displacement (Bennett 1999).

Baker *et al.* (1998) in a study on the impact of powerline easements on forest birds found a significant difference in species richness between edge and interior habitats, and a difference in the species using the two habitats. One of the major impacts associated with edge effects on birds is nest predation, which is generally considered to be higher near the edge (Marini *et al.* 1995; Gardner 1998), although there is contrary evidence regarding the influence of edges on nest predation (Taylor & Ford 1998; Lindenmayer *et al.* 1999).

A precise definition of the area of forest likely to be affected by edge effects is lacking, and the impact of edge effects would vary between habitats, and species. The influence of newly created forest edges on small, fragmented remnants, such as those that occur in the study area, is also difficult to assess. These habitats already appear to be heavily affected by edge effects, and may represent *'edge-modified'* habitats. A number of previous activities have resulted in the development of edge effects throughout the study area. These activities include powerline easements, roads and tracks, quarry operation, and the general encroachment of urban development.

The current proposal would create a new forest/road edge in a number of places. In most cases the proposed alignment is situated near the existing forest edge, or in areas already disturbed. A new forest edge would be created along the northern edge of the eastern slope of Woodgee Hill, however, this edge is situated close to the existing edge in habitat that is regarded as reasonably edge effected.

Edge effects are often most pronounced in forested habitats that have a closed structure, with rainforest habitat particularly affected. Edge effects are not likely to have a significant affect on rainforest habitat in Hidden Valley. Habitat in this area has been previously disturbed, and is currently edge affected. A small area of habitat in Hidden Valley would be subject to a greater degree of shading from the proposed bridge. The increased shading may in the long-term cause a slight change in plant species composition in the vicinity of the bridge, as shade tolerant species replace shade intolerant species. This is unlikely however, to alter the rainforest structure of habitat in Hidden Valley, or affect a substantial area of habitat used by species listed on the QNCWR, JAMBA or CAMBA.

It is considered unlikely that edge effects associated with the proposal would have a substantial impact on the birds in the study area. This conclusion is based on the disturbed nature of much of the habitat present, and the tolerance of many of the species present to edge effects.

## 7.4 Barrier effects

Roads represent major barriers to fauna movement (Andrews 1990; Bennett 1991, 1999). The impact of barrier effects would vary considerably between different groups of fauna. Barrier effects would be most significant for small mammals and cover dependent species, including some birds (Burnett 1992; Goosem 1997). Some species of bird may avoid roads altogether, whilst others may attempt to cross and be struck by cars (Goosem 1997). Barrier effects are likely to be most pronounced in areas where roads cut historical movement corridors. Attempts by fauna to continue using these corridors can result in direct mortality, whilst avoidance of the road may reduce genetic exchange or totally disrupt a species life cycle by prohibiting access to breeding or non-breeding areas. Birds may be less affected by barrier effects than other groups of fauna as they have the ability to fly over the barrier.

The current proposal would create only a minor barrier effect. The effect is considered as minor as much of the habitat affected by the proposal is disturbed and fragmented, or is situated near the edge of the vegetation, and there would be little need for birds to cross the barrier created by the highway. Barrier effects would have the greatest impact on cover dependent species, or small species that are incapable of traversing large gaps. Most of the birds recorded in the study area are readily capable of traversing large gaps. The construction of a bridge at Hidden Valley would create an initial minor barrier effect, however, the location of the bridge (at the end of the habitat) and the limited extent of disturbance mean that birds would most likely readily habituate to its presence.

On a larger scale the proposed highway may represent a barrier to birds moving between wetlands to the north and south of the study area, and in particular for birds moving, to and from the Currumbin Bird Sanctuary. Observations of bird movements conducting during the field survey indicate that a range of species readily traverse the gap created by the quarry, and the existing Pacific Highway. It is considered unlikely that the proposal would represent a barrier to birds moving between habitats to the north and south of the study area.

## 7.5 Road strike

Mortality associated with the construction of roads can have a detrimental effect on species trying to maintain historic movement patterns and thus local populations. The impact of road strike is not limited to any one fauna group with documented impacts recorded on frogs (Fahrig *et al.* 1995), ground mammals (Clarke *et al.* 1998), nocturnal birds (Debus & Rose 1994), and koalas (Prevett 1991). A recent compilation of road-kills from 22 road segments in NSW recorded road mortality in a range of vertebrate groups including small mammals, reptiles and birds (Cooper 1998). Goosem (1997) also recorded mortality from each of the vertebrate groups during her study. Mortality of wildlife occurs when animals are trying to cross the road, or when they are using the roadside to forage (Bennett 1991).

The opportunity for birds to be struck by vehicles is present along most roads. In the present case it is likely that an increase in road strike would occur during the initial stages of road operation, prior to birds habituating to the presence of the road. The extent of road strike is often dependent on the extent to which important bird habitats become isolated, and the type of habitats that become isolated. In the present case habitat isolation is regarded as minimal, and the slight increase in isolation is unlikely to cause a substantial increase in road strike.

The proposal could cause an increase in the incidence of road strike for birds moving between habitats to the north and south of the study area, in particular birds moving to, and from Currumbin Bird Sanctuary. Observations conducted during the field survey indicate that this would occur, although most individuals traverse the alignment at a considerable height. Some road strike is inevitable, however, it is unlikely that in the long-term the extent of road strike would be greater than that associated with the existing highway.

## 7.6 Disturbance effects

There are numerous forms of disturbance associated with highways, including noise, movement, and a general avoidance of the road structure (Andrews 1990). Disturbance effects stem primarily from highway operation, although disturbance would also occur during construction. The disturbance effects of primary concern in the present context include noise and movement. Unfortunately the impact of disturbance effects is difficult to determine, and quantitative studies on Australian fauna are lacking. Zande *et al.* (1980) provide evidence to show that increased traffic density caused a reduction in the density of meadow birds, and Madsen (1985) found that even roads with low traffic volumes inhibited habitat utilisation by geese, in Europe.

Both noise and disturbance effects already exist in close proximity to the proposed alignment. Jets taking-off and landing at Coolangatta Airport, vehicles using the existing Pacific Highway, and motorbikes using the quarry already create considerable noise and movement disturbance for birds.

The current proposal would cause an increase in noise and movement disturbance, however in most cases disturbance would be concentrated along the edge of existing habitats and would therefore have less of an impact on birds. Disturbance effects may be most pronounced at Hidden Valley, an area that, currently receives only limited disturbance. Increased disturbance in Hidden Valley may affect the quality of habitat for grey goshawk, bush-hen, and rose-crowned and wompoo fruit-doves. Hidden Valley most likely represents an important habitat for individuals that also utilise habitats in NSW. Detrimental impacts at Hidden Valley may in turn affect the use of habitats in NSW.

The construction of a bridge at Hidden Valley would most likely reduce the quality of habitat for bush-hens. Impacts on fruit-doves may be less distinct and may be limited to a slight reduction in the area of habitat utilised. Birds may avoid foraging in the area immediately surrounding the bridge.

Lewins rail using disturbed grassland near Stewarts Road would also suffer from a slight increase in disturbance, although it is unlikely to further reduce the quality of habitat for this species.

## 7.7 Altered hydrological regimes

The proposal represents a significant engineering task, and impacts on existing hydrological regimes are likely to be associated with any project of this scale. The proposed alignment crosses at least one drainage line (Hidden Valley), and is situated within the catchment of a second drainage line in the vicinity of the Boyd Street interchange. The impact of the bridge on the small creek in Hidden Valley is undetermined. Impacts may occur through the construction of bridge pylons, and through runoff from the bridge. Given the location of the bridge near the lower end of the valley impacts on birds and bird habitats are regarded as minor.

Based on current topography runoff from the highway may flow (or be channelled) directly into swamp forest habitat on the southern side of the border. Increased runoff into this area may have a detrimental affect on potential habitat for bush-hens and black bittern. During dry periods this may prove beneficial by providing increased freshwater inputs, however, during storm events or minor floods detrimental impacts may occur as the area of foraging and roosting habitat is reduced. An increased frequency of inundation associated with increased rates of runoff may also prove detrimental.

## 7.8 Wetland contamination

Associated with the potential changes to the hydrology of drainage lines in the study area is the potential increase in pollution of aquatic habitats. Pollution would occur during both the construction and operational phases of the project. Pollution during the construction phase would include inputs of sediment washed from the road surface, whilst operational impacts would include the input of pollutants from the road surface. Pollution of wetlands from the exposure of acid sulphate soils may also occur in the vicinity of the Boyd Street interchange. Contamination of wetlands in the vicinity of Boyd Street may reduce the quality of habitat for bush-hen and black bittern. In addition to ‘normal’ runoff from the road surface accidents on the highway would pose an increased risk of wetland contamination.

## 7.9 Contribution of impacts to threatening processes acting within the locality

A number of threatening processes are already acting within the locality. Of concern is habitat removal and fragmentation associated with developments along the Tweed Coast, and at Cobaki Lakes immediately to the south of the alignment. This development is increasing the degree of isolation experienced by habitats in the study area. In the present case the assessment of impacts is hampered by the fact that the alignment crosses between NSW and Queensland. Given the close proximity of habitats it is likely that threatened species from NSW would most likely utilise habitats in both states, and due consideration must be given regarding habitat use in the locality as opposed to habitat use within each state.

# 8. SUMMARY OF IMPACTS

## 8.1 Background

Impacts on species listed on the NSW *TSC Act 1995*, and the *QNCWR 1994* are summarised in Table 16. Included within the table are species listed on both the Queensland and NSW legislation. Although most of the study area occurs within Queensland consideration of species protected under NSW legislation is warranted. There are two reasons for this. Firstly, the proposal would affect habitats in NSW, through changes in hydrology and pollution of wetlands. Secondly, it is highly likely that species listed on one states legislation but not the other utilise habitats across the border. For example, Lewins rail are not listed on the NSW *TSC Act 1995* but are listed on the *QNCWR 1994*. Impacts on this species in NSW could affect the local population in Queensland.

A cumulative approach to the assessment of impacts may be warranted due to the nature of the proposal and the close proximity of habitats affected. When viewed separately impacts on habitats in NSW or Qld may not be regarded as significant however, when viewed cumulatively impacts in one state may affect the viability of the local population in the other state.

The magnitude of impacts shown in Table 16 has been assessed only for the section of highway addressed in this report (i.e. between Boyd Street and Stewart Road). An indication of the overall affect of the proposal is provided in the final column of the table. The magnitude of impacts have been assessed using a subjective scale, none, minor, moderate and major. A brief definition of each level of impact is provided below:

- None – this impact is considered unlikely to affect the subject species.
- Low local– this impact would have some affect on habitats used by the subject species, however it is considered likely that the species would readily tolerate the anticipated level of impact, or that the anticipated level of impact would only affect part of the habitat used by this species.
- High local – it is considered likely that the impact would render a considerable area of the habitat used by this species in the locality as unsuitable or would pose a definite risk of road strike or create a barrier effect.
- Low regional – it is considered highly likely that an area of known habitat would be detrimentally affected by the proposal, and become unsuitable for use by the subject species. The area of habitat affected is regarded as important in a regional context.

## 8.2 Impacts on legislatively protected species

### 8.2.1 Species protected in Queensland

Impacts on species listed under the QNCWR are in general regarded as minor, although the cumulative effect of impacts on grey goshawks is of some concern. Impacts would be restricted to the removal of a small area of known habitat for Lewins rail, and potential habitat for glossy black-cockatoo and grey goshawk. The proposal would not increase the risk of road strike or create a barrier effect or disturbance effects for glossy black-cockatoos. However, Lewins rail habitat in the vicinity of Stewart Road would suffer increased disturbance effects, and individuals may suffer a slight increase in the risk of road strike. A small area of Lewins rail habitat would also be removed. The absence of suitable habitat on both sides of the proposed alignment may reduce the risk of road strike and the barrier effect associated with the proposal.

Grey goshawks using Hidden Valley and moving between this site and northern habitats may suffer a slight increase in the risk of road strike. Although the risk may decline as birds habituate to the road. Due to its location within, or immediately above the canopy the bridge over Hidden Valley may pose some risk of road-strike. A small area of goshawk habitat in Hidden Valley would be directly affected by habitat disturbance (during construction), edge effects and disturbance effects that may reduce the suitability of part of the habitat for this species.

Square-tailed kites would not be substantially affected by the proposal. This species prefers foraging in forested habitats, and if present in the study area is most likely to utilise dry open forest on the eastern slope of Woodgee Hill or contiguous habitat on the southern side of the disused quarry and Hidden Valley. The predicted use of this habitat is based on the fact that it is linked to known square-tailed kite habitat to the south of the study area. It is undetermined if clearing associated with the Cobaki Lakes development may have already disrupted the movement corridors for square-tailed kites.

The proposal would remove a small area of low quality potential foraging habitat along the northern edge of the existing vegetation boundary. Other impacts would include an increase in disturbance effects into potential foraging habitat. The cumulative impact of the proposal on square-tailed kites is regarded as minor.

### 8.2.2 Species protected in New South Wales

A small number of species listed on the *TSC Act 1995* are known to utilise habitats in the study area that occur within NSW, whilst a number of other listed species were recorded using habitats in Queensland. Species recorded or considered likely to utilise habitats in the NSW section of the study area include the glossy black-cockatoo, masked owl, bush-hen and possibly the black bittern. Superb, rose-crowned, and wompoo fruit-doves, white-eared monarch and bush-hen were recorded using habitats within the Qld section of the study area. It is also likely that masked owls would utilise habitats in Qld.

The proposal would not remove known habitat for any threatened species within the NSW section of the study area, however off-site impacts may occur. These impacts include disturbance effects, altered hydrological regimes, and wetland contamination. The proposal could also pose a risk of road strike to birds that reside primarily in NSW but utilise habitats in Qld for foraging.

*Table 16:* Summary of the potential impacts of the proposal on subject species.

| Species | Status | Impacts | | | | | | | | Discussion of Impact |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Vegetation Removal | Habitat Isolation | Edge Effects | Barrier Effects | Road Strike | Disturbance Effects | Hydrology | Wetland Pollution | |
| Black Bittern | NSW TSC Act | None | None | None | None | None | None | high local | high local | Overall the proposal would have a minor impact on potential black bittern habitat in the vicinity of the Boyd Street interchange. |
| White-bellied Sea-Eagle | CAMBA | low local | None | None | None | None | None | None | None | Habitats on the eastern slope of Woodgee Hill may be used on an occasional basis by the subject species. This habitat is regarded as of marginal quality. Use of the habitat may decline with the construction of Cobaki Lakes. |
| Square-tailed Kite | NSW TSC Act | low local | none | none | none | none | none | none | none | If present in the study area this species would most likely utilise habitats on Woodgee Hill. The location of the proposed highway near the northern edge of the vegetation would minimise impacts on this species. |
| Grey Goshawk | QNCWR | low local | low local | low local | low local | low local | low local | none | none | This species may suffer a range of impacts, all of which are considered as minor. Grey goshawk may utilise habitats in Hidden Valley, although individuals may move between this site and habitats in the vicinity of Currumbin. |
| Bush-hen | NSW TSC Act | None | None | **Low regional** | None | None | **Low regional** | high local | high local | The proposal may displace bush-hens currently breeding in Hidden Valley. This raises additional concerns regarding the long-term security of this species in the locality. |
| Lewins Rail | QNCWR | low local | low local | high local | low local | None | high local | high local | high local | Proposal would have a minor impact on Lewins rail habitat that is of marginal quality. A considerable area of suitable habitat for this species would be affected to the south of the study area. |
| Masked Owl | NSW TSC Act | low local | low local | None | None | low local | None | None | None | Impacts are regarded as minor. The proposal would remove a small area of potential foraging habitat, and cause a slight increase in the risk of road strike. |
| Marbled Frogmouth | NSW TSC Act QNCWR | low local | None | low local | None | low local | low local | low local | low local | Impacts on marbled frogmouth are regarded as minor. Habitat affected by the proposal is largely unsuitable for this species. Potential habitat would suffer increased disturbance affects, and edge effects through bridge construction & highway operation. |
| Glossy Black-Cockatoo | NSW TSC Act QNCWR | low local | None | None | None | None | None | None | None | Impacts are regarded as minor. The proposal would remove a small area of potential foraging habitat for this species. Cumulative impacts are also regarded as minor. |

*Table 16:* cont.

| Species | Status | Impacts | | | | | | | | Discussion of Impact |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Vegetation Removal | Habitat Isolation | Edge Effects | Barrier Effects | Road Strike | Disturbance Effects | Hydrology | Wetland Pollution | |
| Rose-Crowned Fruit-Dove | NSW TSC Act | None | low local | high local | low local | low local | high local | None | None | Impacts are regarded as moderate. The proposal would reduce the quality of a small area of habitat in Hidden Valley, and create a barrier between habitats, increasing the risk of road strike. Habitat for this species would be affected to the south of the study area. |
| Oriental Cuckoo | JAMBA CAMBA | low local | None | None | None | None | None | None | None | Oriental cuckoos are only likely to utilise the subject site on a very occasional basis, if at all. Vegetation removal would have a very minor impact on this species. |
| White-throated Needletail | JAMBA CAMBA | None | None | None | None | low local | None | None | None | White-throated needletail's regularly traverse the subject site whilst foraging. This species is not known to roost in the study area, but forages on the wing above the study area. Individuals were regularly recorded foraging above the quarry. The proposal could lead to a slight reduction in food availability, and individuals would be at a very slight risk of road strike. |
| Fork-tailed Swift | JAMBA CAMBA | None | None | None | None | low local | None | None | None | Fork-tailed swifts occasionally traverse the subject site whilst foraging. This species is not known to roost in the study area, but forages on the wing above the study area. Individuals were regularly recorded foraging above the quarry. The proposal could lead to a slight reduction in food availability, and individuals would be at a very slight risk of road strike. |
| Rainbow Bee-eater | JAMBA CAMBA | low local | None | None | None | low local | None | None | None | Impacts on rainbow bee-eaters would be very minor. The proposal would remove a small area of habitat for this species, and individuals would suffer an increased risk of road strike, during the early stages of highway operation. The magnitude of impacts would not affect the viability of the local rainbow bee-eater population. |
| White-eared Monarch | NSW TSC Act | None | low local | high local | low local | low local | high local | none | none | Impacts are regarded as minor. The quality of a small area of habitat in Hidden Valley would be reduced, and the species would suffer an increased risk of road strike, and possibly some barrier effect. The species would not be significantly affected by impacts to the south of the study area. |

The proposal could have moderate impacts on bush-hen and black bittern habitat in the vicinity of the Boyd Street interchange. Habitat in this area would be affected by increased water inputs from the highway, and possibly from pollution through sediment deposition during construction, and chemicals washed from the road surface during operation. Impacts on both bush-hens and black bitterns may be reduced through the provision of appropriate mitigation measures.

Impacts on glossy black-cockatoo habitat in NSW would be limited to disturbance effects, which in the present context are regarded as minor. Cockatoos would not suffer an increased risk of road strike or any impacts associated with barrier effects. Potential habitat for masked owls would also be affected by disturbance effects, and this species may attempt to forage along the edge of the highway, possibly leading to an increased risk of road strike. Although masked owls are known to utilise road edges for foraging it is likely that the presence of street lights and heavy traffic volumes would frighten birds from the highway thereby reducing the risk of road strike. The proposal may reduce the area of foraging habitat available to masked owls in the Qld section of the study area, and disrupt normal foraging routes.

The proposal would also reduce the quality of a small area of foraging habitat in Hidden Valley for fruit-doves and white-eared monarchs. None of these species are listed on the *QNCWR 1994*, however, they are listed on the NSW *TSC Act 1995*, and it is likely that the same individuals would utilise habitats on both sides of the border. Rose-crowned fruit-doves may also suffer a slight increase in the risk of road strike, and the highway may pose a slight barrier to movement between foraging habitats. No foraging habitat for fruit-doves would be removed by the proposal.

### 8.2.3 Species covered by international agreements

The proposal would have minor impacts on five species listed on international migratory bird agreements. Impacts would stem primarily from the loss of a small area of foraging habitat. No known nest sites would be affected, although rainbow bee-eaters may nest in the study area. The area of foraging habitat affected is regarded as minor, and unlikely to affect local populations of any of the listed species. White-bellied sea-eagle and oriental cuckoo may utilise the study area on only an occasional basis.

# 9. MITIGATION MEASURES

The construction of a four-lane highway between Stewart Road and the Boyd Street Interchange would not have a major impact on birds. Overall the impacts are regarded as minor. However, hydrological, edge and disturbance effects have the potential to be moderate to major. To ensure that potential impacts are minimised, a range of mitigation measures have been recommended. These measures are detailed below.

- Where possible place sediment ponds, spoil dumps, and work depots in either disturbed land, or in small habitat fragments created through vegetation clearing. Avoid removing additional vegetation to site these facilities.

- Control runoff into Hidden Valley and swamp forest habitat in NSW. Preferably channel all runoff away from these areas.

- Revegetate sediment ponds, particularly if a pond is positioned in disturbed grassland near Stewart Road. A pond in this area should be revegetated with dense grasses to provide potential habitat for Lewins rail.

- Where appropriate revegetate the disturbed road edge to reduce edge effects. Revegetation is primarily warranted on the southern side of the alignment on the eastern slope of Woodgee Hill. It is essential that revegetation should replace a similar density of vegetation to that removed to avoid excessive shading, and the creation of additional edge effects.

- Assess the potential impact of shading on vegetation in Hidden Valley. To minimise the risk of plant dieback and weed invasion it may be appropriate to plant the shade-affected area with shade tolerant species.

- Minimise disturbance during the construction of the road to the base of the bridge in Hidden Valley. Ideally this road should commence at the quarry. Additional impacts would occur if the road is placed on the opposite side of the valley.

- During construction of the bridge and associated infrastructure minimise impacts on the small dam/pond utilised by bush-hens. It appears as though this pond is outside the construction footprint. However, the location of the pond should be clearly marked and all attempts made to avoid it.

- During the construction of the bridge in Hidden Valley all attempts should be made to minimise the removal of known food trees for fruit-doves, particularly Bangalow Palms.

- Time construction activities outside of the breeding season for legislatively protected species. Ideally vegetation removal and construction in Hidden Valley should be conducted during late autumn, winter and spring, which is outside the breeding season for bush-hens. This time period would however, coincide with the period when fruit-doves are more likely to utilise habitats in the valley.

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# APPENDIX ONE

## SPECIES RECORDED PREVIOUSLY FROM THE LOCALITY

*Table 1a:* Species of bird recorded previously from the locality. Wildnet = the data base of the Queensland National Parks and Wildlife Service; Cob. Lakes = records obtained during surveys of the Cobaki Lakes Development; Q = listed on the *QNCWR 1994*; N = listed on the NSW *TSC Act 1995*; J = listed on JAMBA; C = listed on CAMBA.

| *Species Name* | Common Name | Wildnet | Cob. Lakes |
|---|---|---|---|
| *Alectura lathami* | Australian Brush-turkey | | x |
| *Coturnix pectoralis* | Stubble Quail | | x |
| *Coturnix chinensis* | King Quail | x | |
| *Chenonetta jubata* | Australian Wood Duck | x | x |
| *Anas superciliosa* | Pacific Black Duck | | x |
| *Tachybaptus novaehollandiae* | Australasian Grebe | x | |
| *Daption capense* | Cape Petrel | x | |
| *Pterodroma macroptera* | Great-winged Petrel | x | |
| *Macronectes giganteus* | Southern Giant Petrel | x | |
| *Pterodroma arminjoniana* | Herald Petrel | x | |
| *Pterodroma leucoptera* | Gould's Petrel | x | |
| *Pchyptila desolata* | Antarctic Prion | x | |
| *Pachyptila belcheri* | Slender-billed Prion | x | |
| *Pachyptila turtur* | Fairy Prion | x | |
| ***Puffinus pacificus*** | **Wedge-tailed Shearwater (J)** | **x** | |
| ***Puffinus griseus*** | **Sooty Shearwater (J, C)** | **x** | |
| *Puffinus gavia* | Fluttering Shearwater | x | |
| *Morus serrator* | Australasian Gannet | x | |
| *Anhinger melanogaster* | Darter | x | |
| *Phalacrocorax varius* | Pied Cormorant | x | |
| *Phalacrocorax sulcirostris* | Little Black Cormorant | x | |
| *Pelecanus conspicillatus* | Australian Pelican | x | |
| *Egretta novaehollandiae* | White-faced Heron | | x |
| *Ardea intermedia* | Intermediate Egret | | x |
| ***Ardea ibis*** | **Cattle Egret (J, C)** | **x** | **x** |
| *Butorides striatus* | Striated Heron | x | |
| ***Ixobrychus flavicollis*** | **Black Bittern (N)** | **x** | |
| *Threskiornis spinicollis* | Straw-necked Ibis | | x |
| *Threskiornis molucca* | Australian White Ibis | | x |
| *Platalea regia* | Royal Spoonbill | x | |
| ***Ephippiorhynchus asiaticus*** | **Black-necked Stork (Q, N)** | | **x** |
| ***Pandion haliaetus*** | **Osprey (N)** | **x** | **x** |
| *Aviceda subcristata* | Pacific Baza | x | |
| *Elanus axillaris* | Black-shouldered Kite | x | |
| *Haliaster sphenurus* | Whistling Kite | x | x |
| ***Haliaeetus leucogaster*** | **White-bellied Sea-Eagle (C)** | | **x** |
| *Accipiter fasciatus* | Brown Goshawk | x | |
| ***Accipiter novaehollandiae*** | **Grey Goshawk (Q)** | | |
| *Falco berigora* | Brown Falcon | | x |
| *Falco longipennis* | Australian Hobby | x | |
| *Falco peregrinus* | Peregrine Falcon | x | |
| *Falco cenchroides* | Nankeen Kestrel | x | |
| *Gallirallus philippensis* | Buff-banded Rail | x | |
| ***Rallus pectoralis*** | **Lewins Rail (Q)** | **x** | |
| ***Amaurornis olivaceus*** | **Bush-hen (N)** | **x** | |
| *Porphyrio porphyrio* | Purple Swamphen | x | |
| *Gallinula tenebrosa* | Dusky Moorhen | x | |
| *Turnix varia* | Painted Button-quail | x | |

*Table 1a:* cont.

| *Species Name* | Common Name | Wildnet | Cob. Lakes |
|---|---|---|---|
| ***Gallinago hardwickii*** | **Latham's Snipe (J, C)** | **x** | |
| ***Haematopus longirostris*** | **Pied Oystercatcher (N)** | **x** | |
| *Charadrius ruficapillus* | Red-capped Plover | x | |
| *Vanellus miles* | Masked Lapwing | x | x |
| ***Catharacta maccormicki*** | **South Polar Skua (J)** | **x** | |
| *Larus novaehollandiae* | Silver Gull | x | |
| *Sterna nilotica* | Gull-billed Tern | x | |
| *Sterna bergii* | Crested Tern | x | |
| *Sterna striata* | White-fronted Tern | x | |
| ***Sterna hirundo*** | **Common Tern (J, C)** | **x** | |
| *Gygis alba* | White Tern | x | |
| ***Sterna albifrons*** | **Little Tern (Q, N, J, C)** | **x** | |
| *Sterna fuscata* | Sooty Tern | x | |
| ***Anous stolidus*** | **Common Noddy (J, C)** | **x** | |
| *Columba leucomela* | White-headed Pigeon | | x |
| *Macropygia aboinensis* | Brown Cuckoo-Dove | x | x |
| *Chalcophaps indica* | Emerald Dove | | x |
| *Ocyphaps lophotes* | Crested Pigeon | x | x |
| *Geopelia humeralis* | Bar Shouldered-Dove | | x |
| *leucosarcia melanoleuca* | Wonga Pigeon | x | |
| ***Ptilinopus regina*** | **Rose-Crowned Fruit-Dove (N)** | **x** | |
| *Lopholaimus antarcticus* | Topknot Pigeon | | x |
| *Calyptorhynchus funereus* | Yellow-tailed Black-Cockatoo | | x |
| *Cacatua galerita* | Sulphur-crested Cockatoo | | x |
| *Alisterus scapularis* | Australian King Parrot | | x |
| *Trichoglossus haematodus* | Rainbow Lorikeet | x | x |
| *Trichoglossus chlorolepidotus* | Scaly-breasted Lorikeet | x | x |
| *Glossopsitta pusilla* | Little Lorikeet | x | |
| *Platycerus eximus* | Eastern Rosella | x | x |
| *Platycerus adscitus* | Pale-headed Rosella | x | x |
| ***Cuculus saturatus*** | **Oriental Cuckoo (J, C)** | **x** | |
| *Cacomantis variolosus* | Brush Cuckoo | x | |
| *Cacomantis flabelliformis* | Fan-tailed Cuckoo | x | x |
| *Eudynamys scolopacea* | Common Koel | x | x |
| *Centropus phasianinus* | Pheasant Coucal | x | x |
| ***Ninox strenua*** | **Powerful Owl (Q, N)** | | **x** |
| ***Ninox connivens*** | **Barking Owl (N)** | **x** | |
| *Ninox novaeseelandiae* | Southern Boobook | x | x |
| ***Tyto tenebricosa*** | **Sooty Owl (Q, N)** | **x** | |
| ***Tyoto novaehollandiae*** | **Masked Owl (N)** | **x** | **x** |
| *Tyto alba* | Barn Owl | x | |
| ***Tyto capensis*** | **Grass Owl (N)** | **x** | |
| *Podargus strigoides* | Tawny Frogmouth | x | x |
| *Eurostopodus mystacalis* | White-throated Nightjar | x | |
| *Aegotheles cristatus* | Australian Owlet Nightjar | | x |
| ***Hirundapus caudacutus*** | **White-throated Needletail (J, C)** | **x** | **x** |
| *Alcedo azurea* | Azure Kingfisher | x | |
| *Dacelo novaeguineae* | Laughing Kookaburra | x | x |
| *Todiramphus sanctus* | Sacred Kingfisher | x | |
| ***Todiramphus chloris*** | **Collared Kingfisher (N)** | **x** | |
| *Todiramphus macleayi* | Forest Kingfisher | x | |
| *Eurystomus orientalis* | Dollarbird | x | |
| *Pitta versicolor* | Noisy Pitta | x | |

*Table 1a:* cont.

| *Species Name* | Common Name | Wildnet | Cob. Lakes |
|---|---|---|---|
| *Malurus cyaneus* | Superb Fairy-wren | | x |
| *Pardalotus striatus* | Striated Pardalote | x | x |
| *Sericornis frontalis* | White-browed Scrubwren | | x |
| *Gerygone olivacea* | White-throated Gerygone | | x |
| *Acanthiza lineata* | Striated Thornbill | | x |
| *Plectorhyncha lanceolata* | Striped Honeyeater | | x |
| *Philemon corniculatus* | Noisy Friarbird | x | x |
| *Manorina melanocephala* | Noisy Miner | x | x |
| *Meliphaga lewinii* | Lewins Honeyeater | | x |
| *Lichenostomus chrysops* | Yellow-faced Honeyeater | | x |
| *Melithreptus albogularis* | White-throated Honeyeater | | x |
| *Lichmera indistincta* | Brown Honeyeater | x | |
| *Eopsaltria australis* | Eastern Yellow Robin | | x |
| *Psophodes olivaceus* | Eastern Whipbird | | x |
| *Pachycephala pectoralis* | Golden Whistler | | x |
| *Colluricincla harmonica* | Grey Shrike-thrush | | x |
| *Monarcha melanopsis* | Black-faced Monarch | x | x |
| *Myiagra rubecula* | Leaden Flycatcher | | x |
| *Grallina cyanoleuca* | Magpie-lark | x | x |
| *Rhipidura fuliginosa* | Grey Fantail | | x |
| *Rhipidura leucophrys* | Willie Wagtail | | x |
| *Dicrurus bracteatus* | Spangled Drongo | | x |
| *Coracina novaehollandiae* | Black-faced Cuckoo-shrike | x | x |
| *Coracina tenuirostris* | Cicadabird | | x |
| *Lalage leucomela* | Varied Triller | x | |
| *Oriolus sagittatus* | Olive-backed Oriole | | x |
| *Sphecotheres viridis* | Figbird | x | x |
| *Cracticus torquatus* | Grey Butcherbird | x | x |
| *Cracticus nigrogularis* | Pied Butcherbird | x | x |
| *Gymnorhina tibicen* | Australian Magpie | x | x |
| *Strepera grucelena* | Pied Currawong | x | x |
| *Corvus orru* | Torresian Crow | x | x |
| *Sericulus chrysocephalus* | Regent Bowerbird | x | |
| *Neochima temporalis* | Red-browed Finch | | x |
| *Dicaeum hirundinaceum* | Mistletoebird | | x |
| *Hirundo neoxena* | Welcome Swallow | | x |
| *Acrocephalus stentoreus* | Clamorous Reed-Warbler | x | |
| *Megalurus timoriensis* | Tawny Grassbird | | x |
| *Cristicola exilis* | Golden-headed Cisticola | x | x |
| *Zosterops lateralis* | Silvereye | x | |
| *Zoothera lunulata* | Bassian Thrush | x | |
| *Sturnus vulgaris* | Common Starling | | x |

# APPENDIX TWO

## WEATHER CONDITIONS

*Table 2a:* Weather variables recorded at day and night during the spring survey. Night weather variables were measured only when nocturnal surveys were conducted. P = rain not recorded during the survey but recorded during previous 24 hours; nr = variable not recorded; - = no survey conducted; light – wind moves small branches; mod = wind moves large branches.

| Date | Cloud Cover % | | Wind Direction | | Wind Speed | | Rainfall | | Air Temperature | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Day | Night | Day | Night | Day | Night | Day | Night | Day | Night |
| 24 | 5 | 80 | NE | nr | Nil | Mod. | P | P | 18 | 21 |
| 25 | 100 | - | NE | - | Light | - | P | - | 20 | - |
| 26 | 10 | 100 | NE | nr | Nil | Light | P | P | 18 | 19 |
| 27 | 25 | - | NE | - | Light | - | P | - | 21 | - |

*Table 2b:* Weather conditions experienced during the summer bird survey. Abbreviations are the same as those listed in Table 2a.

| Date | Cloud Cover % | | Wind Direction | | Wind Speed | | Rainfall | | Air Temperature | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Day | Night | Day | Night | Day | Night | Day | Night | Day | Night |
| 4 | 100 | 75 | nr | nr | nil | nil | P | P | 21 | 22 |
| 5 | 20 | nr | nr | nr | nil | nil | nil | nil | 20 | 23 |
| 6 | 25 | - | nr | - | nil | - | nil | - | 18 | - |
| 15 | 15 | - | nr | - | nil | - | nil | - | 19 | - |
| 16 | 100 | 50 | nr | nr | nil | mod | light | light | 19 | 20 |
| 17 | 100 | - | nr | - | nil | - | light | - | 17 | - |

# APPENDIX THREE

## SPECIES OF BIRD RECORDED DURING THE FIELD SURVEY

*Table 3a:* Species of bird recorded in five habitat types present within the study area during the spring survey. SF = swamp forest; Dist = disturbed grassland; DOF = dry open forest; W = woodland; RF = rainforest regrowth; MR = moist regrowth; J = JAMBA, C = CAMBA; Q = QNCWR 1994; N = NSW TSC Act 1995; CS = species of conservation significance (NPWS 1999).

| *Species Name* | Common Name | SF | Dist | DOF | W | RF | MR | No. habitats |
|---|---|---|---|---|---|---|---|---|
| *Alectura lathami* | Australian Brush Turkey | | | x | | x | x | 3 |
| *Chenonetta jubata* | Australian Wood Duck | | | x | | | | 1 |
| *Anas superciliosa* | Pacific Black Duck | | x | x | | x | | 3 |
| *Phalacrocorax melanoleucos* | Little Pied Cormorant | | | x | | | | 1 |
| *Phalacrocorax sulcirostris* | Little Black Cormorant | | | x | | | | 1 |
| *Ardea ibis* | Cattle Egret (J, C) | | | x | | | | 1 |
| *Threskiornis molucca* | Australian White Ibis | x | x | x | x | x | | 5 |
| *Aviceda subcristata* | Pacific Baza (CS) | x | x | x | | x | | 4 |
| *Elanus axillaris* | Black-shouldered Kite | | x | | | | | 1 |
| *Haliaster sphenurus* | Whistling Kite | | | x | | | | 1 |
| *Haliaster indus* | Brahminy Kite (CS) | x | | | | | | 1 |
| *Accipiter fasciatus* | Brown Goshawk | | | x | | | | 1 |
| *Rallus pectoralis* | Lewins Rail (Q) | | x | | | | | 1 |
| *Porphyrio porphyrio* | Purple Swamphen | | x | | | | | 1 |
| *Streptopelia chinensis* | Spotted Turtle-Dove | x | x | x | | | x | 4 |
| *Columba leucomela* | White-headed Pigeon | | | x | | | | 1 |
| *Macropygia aboinensis* | Brown Cuckoo-Dove | | | x | | x | | 2 |
| *Chalcophaps indica* | Emerald Dove | | x | x | x | x | | 4 |
| *Ocyphaps lophotes* | Crested Pigeon | x | x | x | | | | 3 |
| *Geopelia humeralis* | Bar Shouldered-Dove | x | | x | | | | 2 |
| *Calyptorhynchus funereus* | Yellow-tailed Black-cockatoo | | x | x | | | | 2 |
| *Cacatua roseicapilla* | Galah | x | x | x | x | x | | 5 |
| *Cacatua tenuirostris* | Long-billed Corella | | x | x | | | | 2 |
| *Cacatua galerita* | Sulphur-crested Cockatoo | x | x | x | | x | | 4 |
| *Alisterus scapularis* | Australian King Parrot | x | | x | | x | | 3 |
| *Trichoglossus haematodus* | Rainbow Lorikeet | x | x | x | x | x | | 5 |
| *Trichoglossus chlorolepidotus* | Scaly-breasted Lorikeet | x | x | x | x | x | x | 6 |
| *Platycerus adscitus* | Pale-headed Rosella | | | x | | | | 1 |
| *Platycerus eximius* | Eastern Rosella | | | | | x | | 1 |
| *Cacomantis variolosus* | Brush Cuckoo | | | x | | x | | 2 |
| *Cacomantis flabelliformis* | Fan-tailed Cuckoo | | x | x | | x | | 3 |
| *Chrysococcyx basalis* | Horsfield's Bronze-Cuckoo | | | x | | | | 1 |
| *Chrysococcyx minutillus* | Little Bronze-Cuckoo (CS) | | | x | | | | 1 |
| *Eudynamys scolopacea* | Common Koel | | x | x | | x | | 3 |
| *Scythrops novaehollandiae* | Channel-billed Cuckoo | | | x | | x | | 2 |
| *Centropus phasianinus* | Pheasant Coucal | | x | x | | x | | 3 |
| *Hirundapus caudacutus* | White-throated Needletail (J,C) | x | x | x | | | | 3 |
| *Apus pacificus* | Fork-tailed Swift (J, C) | | x | | | | | 1 |
| *Dacelo novaeguineae* | Laughing Kookaburra | x | x | x | x | x | | 5 |
| *Todiramphus sanctus* | Sacred Kingfisher | x | x | x | x | x | x | 6 |
| *Merops ornatus* | Rainbow Bee-eater (J) | x | x | x | x | x | | 5 |
| *Eurystomus orientalis* | Dollarbird | x | x | x | x | x | | 5 |
| *Malurus cyaneus* | Superb Fairy-wren | x | x | x | | | | 3 |
| *Malurus lamberti* | Varigated Fairy-wren | x | x | x | | | | 3 |
| *Malurus melanoc ephalus* | Red-backed Fairy-wren | x | | x | | | | 2 |
| *Pardalotus punctatus* | Spotted Pardalote | x | | x | x | | | 3 |
| *Pardalotus striatus* | Striated Pardalote | | x | x | x | | | 3 |
| *Sericornis frontalis* | White-browed Scrubwren | x | x | x | | x | x | 5 |
| *Sericornis magnirostris* | Large-billed Scrubwren | | | | | x | | 1 |

*Table 3a:* cont.

| *Species Name* | Common Name | SF | Dist | DOF | W | RF | MR | No. habitats |
|---|---|---|---|---|---|---|---|---|
| *Gerygone mouki* | Brown Gerygone | x | | | | | | 1 |
| *Gerygone olivacea* | White-throated Gerygone | | | x | | | | 1 |
| *Acanthiza pusila* | Brown Thornbill | x | | x | | x | x | 4 |
| *Philemon corniculatus* | Noisy Friarbird | x | x | x | x | | | 4 |
| *Plectorhyncha lanceolata* | Striped Honeyeater | | | x | | | | 1 |
| *Entomyzon cyanotis* | Blue-faced Honeyeater | | x | | | | | 1 |
| *Manorina melanocephala* | Noisy Miner | | x | x | x | | | 3 |
| *Meliphaga lewinii* | Lewins Honeyeater | x | x | x | | x | x | 5 |
| *Lichmera indistincta* | Brown Honeyeater | x | x | x | | | | 3 |
| *Philidonyris nigra* | White-cheeked Honeyeater | x | x | x | | | | 3 |
| *Acanthorhynchus tenuirostris* | Eastern Spinebill | x | x | x | | x | | 4 |
| *Myzomela sanguinolenta* | Scarlet Honeyeater | | | x | | x | | 2 |
| *Eopsaltria australis* | Eastern Yellow Robin | | | x | | x | x | 3 |
| *Psophodes olivaceus* | Eastern Whipbird | x | x | x | x | x | x | 6 |
| *Pachycephala pectoralis* | Golden Whistler | | | | | x | x | 2 |
| *Pachycephala rufiventris* | Rufous Whistler | x | x | x | x | | | 4 |
| *Colluricincla megarhyncha* | Little Shrike-thrush (CS) | | | | | x | | 1 |
| *Colluricincla harmonica* | Grey Shrike-thrush | x | x | x | x | x | | 5 |
| *Monarcha melanopsis* | Black-faced Monarch | | | | | x | x | 2 |
| *Monarcha trivirgatus* | Spectacled Monarch | | | | | x | x | 2 |
| *Monarcha leucotis* | White-eared Monarch (N) | | | | | | x | 1 |
| *Myiagra rubecula* | Leaden Flycatcher | x | x | x | x | x | x | 6 |
| *Grallina cyanoleuca* | Magpie-lark | | x | x | x | | | 3 |
| *Rhipidura fuliginosa* | Grey Fantail | x | | x | x | | | 3 |
| *Rhipidura  leucophrys* | Willie Wagtail | | x | x | | | | 2 |
| *Dicrurus bracteatus* | Spangled Drongo | x | x | x | x | x | x | 6 |
| *Coracina novaehollandiae* | Black-faced Cuckoo-shrike | x | x | x | x | | x | 5 |
| *Coracina tenuirostris* | Cicadabird | x | | x | | x | x | 4 |
| *Lalage leucomela* | Varied Triller | x | x | x | | x | | 4 |
| *Oriolus sagittatus* | Olive-backed Oriole | x | x | x | | x | x | 5 |
| *Sphecotheres viridis* | Figbird | x | x | x | x | x | x | 6 |
| *Artamus leucorynchus* | White-breasted Woodswallow | | | x | | | | 1 |
| *Cracticus torquatus* | Grey Butcherbird | x | | x | x | | x | 4 |
| *Cracticus nigrogularis* | Pied Butcherbird | x | x | x | | | | 3 |
| *Gymnorhina tibicen* | Australian Magpie | x | x | x | | | | 3 |
| *Strepera grucelena* | Pied Currawong | x | x | x | x | x | | 5 |
| *Corvus orru* | Torresian Crow | x | x | x | x | x | | 5 |
| *Ptilonorhynchus violaceus* | Satin Bowerbird | | | x | | | | 1 |
| *Passer domesticus* | House Sparrow | | x | | | | | 1 |
| *Taeniopygia bichenovii* | Double-barred Finch | | x | x | | | | 2 |
| *Neochima temporalis* | Red-browed Finch | x | x | x | | | | 3 |
| *Dicaeum hirundinaceum* | Misletoebird | x | x | x | | x | | 4 |
| *Hirundo ariel* | Fairy Martin | x | x | x | | | | 3 |
| *Acrocephalus stentoreus* | Clamorous Reed-Warbler | | x | | | | | 1 |
| *Megalurus timoriensis* | Tawny Grassbird | | x | x | | | | 2 |
| *Cristicola exilis* | Golden-headed Cisticola | | x | | | | | 1 |
| *Zosterops lateralis* | Silvereye | x | x | x | | x | x | 5 |
| *Acridotheres tristis* | Common Myna | | x | | | | | 1 |
| | Unidentified spp. | | | x | | | | 1 |
| **Number of Species** | | **48** | **60** | **80** | **25** | **44** | **21** | |

*Table 3b:* Species of bird recorded in five habitat types present within the study area during the summer survey. SF = swamp forest; Dist = disturbed grassland; DOF = dry open forest; W = woodland; RF = rainforest regrowth; MR = moist regrowth; J = JAMBA, C = CAMBA; Q = QNCWR 1994; N = NSW TSC Act 1995; CS = species of conservation significance (NPWS 1999).

| *Species Name* | Common Name | SF | Dist | DOF | W | RF | MR | No. Habitats |
|---|---|---|---|---|---|---|---|---|
| *Alectura lathami* | Australian Brush Turkey | | | | | x | | 1 |
| *Coturnix ypsilophora* | Brown Quail | x | x | | | | | 2 |
| *Dendrocygna arcuata* | Wandering Whistling-Duck | | x | | | | | 1 |
| *Chenonetta jubata* | Australian Wood Duck | | x | | | | | 1 |
| *Anas superciliosa* | Pacific Black Duck | | x | x | | x | | 3 |
| *Anas castanea* | Chestnut Teal | | x | | | | | 1 |
| *Tachybaptus novaehollandiae* | Australasian Grebe | | x | | | | | 1 |
| *Phalacrocorax melanoleucos* | Little Pied Cormorant | | x | | | | | 1 |
| *Egretta novaehollandiae* | White-faced Heron | | x | | | | | 1 |
| *Egretta ibis* | Cattle Egret (J, C) | | x | | | | | 1 |
| *Threskiornis molucca* | Australian White Ibis | x | x | x | | x | | 4 |
| *Platalea regia* | Royal Spoonbill | | x | x | | | | 2 |
| *Aviceda subcristata* | Pacific Baza (CS) | | | x | | x | | 2 |
| *Elanus axillaris* | Black-shouldered Kite | | x | | | | | 1 |
| *Haliaeetus leucogaster* | White-bellied Sea-Eagle (C) | | x | | | | | 1 |
| *Falco peregrinus* | Peregrine Falcon (CS) | | | x | x | | | 2 |
| *Gallirallus philippensis* | Buff-banded Rail | | x | | | | | 1 |
| *Amaurornis olivaceus* | Bush-hen (N) | | | | | x | | 1 |
| *Elseyornis melanops* | Black-fronted Dotterel | | x | | | | | 1 |
| *Venellus miles* | Masked Lapwing | | x | | | | | 1 |
| *Porphyrio porphyrio* | Purple Swamphen | | x | | | | | 1 |
| *Gallinula tenebrosa* | Dusky Moorhen | | x | | | | | 1 |
| *Streptopelia chinensis* | Spotted Turtle-Dove | x | x | x | | | | 3 |
| *Columba leucomela* | White-headed Pigeon | | | | | x | | 1 |
| *Macropygia aboinensis* | Brown Cuckoo-Dove | | | x | | x | | 2 |
| *Chalcophaps indica* | Emerald Dove | | | x | | x | | 2 |
| *Ocyphaps lophotes* | Crested Pigeon | | x | x | | | | 2 |
| *Geopelia striata* | Peaceful Dove | x | x | | x | | | 3 |
| *Geopelia humeralis* | Bar-shouldered Dove | | | | x | x | | 2 |
| *Ptilinopus superbus* | Superb Fruit-Dove (N) | | | | | x | | 1 |
| *Ptilinopus regina* | Rose-Crowned Fruit-Dove (N) | | | | | x | x | 2 |
| *Ptilinopus magnificus* | Wompoo Fruit-Dove (N) | | | | | x | | 1 |
| *Cacatua roseicapilla* | Galah | | x | | | | | 1 |
| *Cacatua galerita* | Sulphur-crested Cockatoo | | x | x | | x | | 3 |
| *Calyptorhynchus lathami* | Glossy Black-Cockatoo (N, Q) | | | | x | | | 1 |
| *Alisterus scapularis* | Australian King Parrot | | | x | | | | 1 |
| *Trichoglossus haematodus* | Rainbow Lorikeet | x | x | x | | x | | 4 |
| *Trichoglossus chlorolepidotus* | Scaly-breasted Lorikeet | x | x | x | | x | | 4 |
| *Platycerus adscitus* | Pale-headed Rosella | | x | x | | | | 2 |
| *Platycerus eximius* | Eastern Rosella | | x | x | | | | 2 |
| *Cacomantis flabelliformis* | Fan-tailed Cuckoo | x | | x | x | | | 3 |
| *Chrysococcyx lucidus* | Shinning Bronze-Cuckoo | | | | | x | | 1 |
| *Eudynamys scolopacea* | Common Koel | | x | x | | x | | 3 |
| *Scythrops novaehollandiae* | Channel-billed Cuckoo | | x | x | | | | 2 |
| *Centropus phasianinus* | Pheasant Coucal | x | x | x | | | x | 4 |
| *Tyto alba* | Barn Owl | | | x | | | | 1 |
| *Podargus strigoides* | Tawny Frogmouth | | | x | | x | | 2 |
| *Hirundapus caudacutus* | White-throated Needletail (J,C) | x | | x | | | | 2 |
| *Dacelo novaeguineae* | Laughing Kookaburra | | x | x | | x | | 3 |

*Table 3b:* cont.

| *Species Name* | Common Name | SF | Dist | DOF | W | RF | MR | No. Habitats |
|---|---|---|---|---|---|---|---|---|
| *Todiramphus macleayi* | Forest Kingfisher (CS) | | | x | | | | 1 |
| *Todiramphus sanctus* | Sacred Kingfisher | x | x | x | | | x | 4 |
| *Merops ornatus* | Rainbow Bee-eater (J) | x | | x | | | | 2 |
| *Eurystomus orientalis* | Dollarbird | | x | x | | | | 2 |
| *Malurus cyaneus* | Superb Fairy-wren | | x | x | | | | 2 |
| *Malurus lamberti* | Varigated Fairy-wren | | x | x | | | | 2 |
| *Malurus melanoc ephalus* | Red-backed Fairy-wren | x | x | x | | | | 3 |
| *Pardalotus punctatus* | Spotted Pardalote | x | | x | | | | 2 |
| *Pardalotus striatus* | Striated Pardalote | | | x | | | | 1 |
| *Sericornis frontalis* | White-browed Scrubwren | | | x | | x | x | 3 |
| *Sericornis magnirostris* | Large-billed Scrubwren | | | x | | x | | 2 |
| *Gerygone olivacea* | White-throated Gerygone | x | | x | | | | 2 |
| *Acanthiza pusila* | Brown Thornbill | | | x | | x | x | 3 |
| *Anthochaera chrysoptera* | Little Wattlebird | x | | | x | | | 2 |
| *Philemon corniculatus* | Noisy Friarbird | | x | x | x | | | 3 |
| *Plectorhyncha lanceolata* | Striped Honeyeater | | | x | | | | 1 |
| *Manorina melanocephala* | Noisy Miner | x | x | x | | | x | 4 |
| *Meliphaga lewinii* | Lewins Honeyeater | x | x | x | | x | x | 5 |
| *Melithreptus albogularis* | White-throated Honeyeater | | | x | x | | | 2 |
| *Melithreptus lunatus* | White-naped Honeyeater | | | x | | | | 1 |
| *Lichmera indistincta* | Brown Honeyeater | x | x | x | x | | | 4 |
| *Philidonyris nigra* | White-cheeked Honeyeater | x | x | | x | | | 3 |
| *Acanthorhynchus tenuirostris* | Eastern Spinebill | | | x | | x | x | 3 |
| *Eopsaltria australis* | Eastern Yellow Robin | | | x | x | x | x | 4 |
| *Psophodes olivaceus* | Eastern Whipbird | x | | x | | x | x | 4 |
| *Pachycephala pectoralis* | Golden Whistler | | | x | | x | | 2 |
| *Pachycephala rufiventris* | Rufous Whistler | | | x | x | | | 2 |
| *Colluricincla megarhyncha* | Little Shrike-thrush (CS) | | | x | | x | x | 3 |
| *Colluricincla harmonica* | Grey Shrike-thrush | x | | | x | | | 2 |
| *Monarcha melanopsis* | Black-faced Monarch | | | x | | | | 1 |
| *Myiagra rubecula* | Leaden Flycatcher | | | x | x | | | 2 |
| *Grallina cyanoleuca* | Magpie-lark | x | x | x | | | | 3 |
| *Rhipidura fuliginosa* | Grey Fantail | x | | x | x | x | | 4 |
| *Rhipidura leucophrys* | Willie Wagtail | x | x | | | | | 2 |
| *Dicrurus bracteatus* | Spangled Drongo | x | x | x | | x | x | 5 |
| *Coracina novaehollandiae* | Black-faced Cuckoo-shrike | | x | x | | | x | 3 |
| *Coracina tenuirostris* | Cicadabird | x | | x | | x | x | 4 |
| *Lalage leucomela* | Varied Triller | x | | x | | x | | 3 |
| *Oriolus sagittatus* | Olive-backed Oriole | | x | x | | x | x | 4 |
| *Sphecotheres viridis* | Figbird | | x | x | | x | x | 4 |
| *Cracticus torquatus* | Grey Butcherbird | x | | x | | | | 2 |
| *Cracticus nigrogularis* | Pied Butcherbird | x | x | x | | | | 3 |
| *Gymnorhina tibicen* | Australian Magpie | x | x | x | | x | x | 5 |
| *Strepera grucelena* | Pied Currawong | | x | x | | x | x | 4 |
| *Corvus orru* | Torresian Crow | x | x | x | | x | | 4 |
| *Ptilonorhynchus violaceus* | Satin Bowerbird | | | | x | x | | 2 |
| *Anthus novaeseelandiae* | Richard's Pipit | x | x | | | | | 2 |
| *Taeniopygia bichenovii* | Double-barred Finch | | x | | | | | 1 |
| *Neochima temporalis* | Red-browed Finch | x | x | x | x | | | 4 |
| *Lonchura castaneothorax* | Chestnut-breasted Mannikin | | x | x | | | | 2 |
| *Passer domesticus* | House Sparrow | | x | | | | | 1 |
| *Dicaeum hirundinaceum* | Mistletoebird | | x | x | | | | 2 |
| *Hirundo ariel* | Fairy Martin | x | x | | | | | 2 |

*Table 3b:* cont.

| *Species Name* | Common Name | SF | Dist | DOF | W | RF | MR | No. Habitats |
|---|---|---|---|---|---|---|---|---|
| *Megalurus timoriensis* | Tawny Grassbird | | x | | | | | 1 |
| *Acrocephalus atentoreus* | Clamorous Reed Warbler | | x | | | | | 1 |
| *Cristicola exilis* | Golden-Headed Cisticola | x | x | | | | | 2 |
| *Zosterops lateralis* | Silvereye | x | x | x | | x | x | 5 |
| *Sturnus vulgaris* | Common Starling | x | x | | | | | 2 |
| *Acridotheres tristis* | Common Myna | | x | | | | | 1 |
| **Number of species** | | **37** | **53** | **67** | **17** | **39** | **19** | |

# Appendix C

*Survey of Reptiles, Amphibians and Mammals Inhabiting Coastal Lowland Areas Associated with the Proposed Tugun Bypass* (Hero et *al.* 2000)

# Survey for Reptiles, Amphibians and Mammals inhabiting coastal lowland areas associated with the proposed Tugun by-pass.

## Final Report

JEAN-MARC HERO [A], STEVE PHILLIPS [A, B] and LUKE SHOO [A]

[A] *Griffith University Centre for Coastal Management, School of Environmental and Applied Sciences, Griffith University Gold Coast, PMB 50 Gold Coast MC, Queensland 4127 Australia*

[B] *Biolink (ESAM) Pty. Ltd., PO Box 196 Uki NSW 2484*

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# CONTENTS

# EXECUTIVE SUMMARY

This report relates to the proposed Tugun bypass, a transport corridor which traverses the Queensland/NSW State border between Tweed Heads and Tugun. As a component of investigations related to an assessment of potential environmental impact of road and rail construction in this area, a survey of reptile, amphibian and mammal communities inhabiting coastal lowlands between the Coolangatta Airport and Cobaki Broadwater was initiated in January 2000.

Survey methodology involved the use of standardised techniques for censusing vertebrate populations including the use of Elliot traps, dry pitfalling, hair tubes, spotlighting, harp traps, mist netting and bat detectors, visual and acoustic surveys. Faecal material from predators, were also collected and analysed for the presence of identifiable fauna remains. Records from a variety of other sources including the QEPA 'Wildnet', NSWNPWS 'Wildlife Atlas' and Queensland Museum databases augmented the fieldwork results.

A total of 19 species of amphibians, 24 species of reptiles and 32 species of mammals are either known or considered likely to occur in the study area on the basis of the survey results and database records. Of the known species, 9 are currently listed as 'Vulnerable' for the purposes of the NSW *Threatened Species Conservation Act 1995* - the Wallum Froglet *Crinia tinnula*, Wallum Sedge Frog *Litoria olongburensis*, Planigale *Planigale maculata*, Squirrel Glider *Petaurus norfolcensis*, Blossom bat *Syconycteris australis*, Black Flying-fox *Pteropus alecto*, Little Bent-wing bat *Miniopterus australis*, Eastern Long-eared Bat *Nyctophilus bifax* and Large-footed Myotis *Myotis adversus*. The presence of an additional 3 'Vulnerable' species - the Yellow-bellied Sheathtail bat *Saccolaimus flaviventris*, White-crowned Snake *Cacophis harrietae* and Potoroo *Potorous tridactylus* is possible on the basis of historical records. Historical records also exist for a fourth additional 'Vulnerable' species - the Koala *Phascolarctos cinereus*, but our survey data strongly suggests that this species is locally extinct in the study area.

The results of the survey raise a number of matters relating to alignment of road and rail links within the transport corridor. Additional to the loss of foraging and/or roosting habitat for threatened bat species, viable populations of *L. olongburensis* and *P. maculata* inhabiting a site west of the existing runway will potentially be threatened. Further, a small and localised area of high amphibian biodiversity will also be threatened by roadworks and associated infrastructure at the southern end of the transport corridor. In order to ameliorate such impacts, this report recommends that the proposed alignment of road and rail links within the transport corridor be re-evaluated. Issues of compensatory habitat and the need to re-establish habitat links within the study area also discussed.

The extent of impacts upon threatened species known to occur in the area are sufficient to warrant a Species Impact Statement in accordance with Division 2 (Part 6) of the NSW *Environmental Planning & Assessment Act* 1979. Furthermore the potential impacts on the nationally listed Wallum Sedgefrog (*L. olongburensis*) population must be considered for referral under provisions of the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*.

## INTRODUCTION

A new transport corridor has been proposed (hereafter referred to as the Tugun by-pass) to accommodate road and rail links between Tugun Heights in Queensland and Tweed Heads, New South Wales [option C4, Route Selection Report: Connell Wagner (1999)]. The proposed deviation of the Pacific Highway is between the Stewart Road intersection (Qld.) and the northern end of the Kennedy Drive Interchange (NSW). A rail corridor adjacent to the highway deviation is also proposed. The NSW section of the proposed by-pass has been declared a State Significant Development under the *Environmental Planning and Assessment Act 1979* .

The principle objective of the survey described herein was to obtain information on the presence and distribution of amphibians, reptiles and mammals within the general area of the transport corridor. Of particular interest was the presence of fauna species currently listed as threatened (Endangered or Vulnerable) in the current schedules (updated 21 July 2000) of the NSW Government's *Threatened Species Conservation Act 1995* (hereafter referred to as the TSC Act), the Commonwealth Government's *Environment Protection and Biodiversity Conservation Act 1999*, and to a lesser degree (given that only approx. 350m of the corridor is located in Queensland), the Queensland Government's *Nature Conservation (Wildlife) Regulation 1994*. This fauna study thus forms part of a formal environmental impact assessment being undertaken on behalf of the proponent, Queensland Department of Main Roads.

## STUDY AREA

The study area constituted a relatively small area of land located to the west of the Pacific Highway between Tweed Heads in far north-eastern New South Wales and Tugun in south-eastern Queensland (Fig.1). The area is bounded by the Coolangatta Airport precinct, Cobaki Broadwater and the urban environment of Tweed Heads West to the south, with the northern boundary loosely defined as coastal lowlands (quaternary sand deposits) towards the base of Mt. Woodgee in Queensland. Sand mining has occurred over some of the land in question and the area in general remains extensively dissected by a network of vehicle tracks.

**Fig. 1**. **Study area (yellow boundary) showing location and alignment of the proposed Tugun bypass (C4 option) as presented by Connell Wagner (1999). Queensland / New South Wales border is represented by a broken red line.**

## SURVEY METHODOLOGY

For broader censusing purposes, the study area was divided into a number of survey 'precincts'. The boundaries of these precincts, along with locations for each of the primary field sites detailed below, are shown in Fig 2.

### a) Primary Field Sites

Six primary field sites considered representative of vegetation communities in the study area were selected. Three of these sites sampled communities largely dominated by Swamp Mahogany *E. robusta*, while two sampled drier heathland communities (typically dominated by Scribbly Gum *E. signata* and *Banksia* spp.) at more elevated sites. The sixth site was located within a small area of rainforest. Field sampling was undertaken between January and July 2000 with peak sampling activities timed to coincide with periods of minimal lunar illumination (mammals), rain events (amphibians) and other temporal and/or climatological considerations.

Each primary field site was subjected to the following sampling strategy:
Linear transects comprising 25 Type A Elliot traps placed approximately 10 - 15m apart were established, each trap baited with a mixture of rolled oats, peanut butter and honey. In close proximity, a dry pitfall line consisting of 5 x 20 litre plastic buckets located approximately 5m apart and connected by a 300mm high polythene dampcourse drift fence was also established. Elliot traps and pitfall lines were maintained for a minimum of four nights. Additionally, three linear transects comprising a series of six hair tubes (opening size 100mm x 80mm) located approximately 20 - 25 metres apart were placed perpendicular to established trap lines at selected sites (Fig. 3). Hair tubes were alternatively baited with either sardines or a mixture of rolled oats, peanut butter, honey and pistachio essence, and were left in the field for 10 nights. A summary of survey effort is presented below (Table 1).


**Fig. 2**. **Survey precincts (dotted lines) within the study area. Numbers correspond to survey sites mentioned in the text (Tables 2-4). Numbers 1-6 also detail specific locations of primary field sites established for purposes of the field survey.**

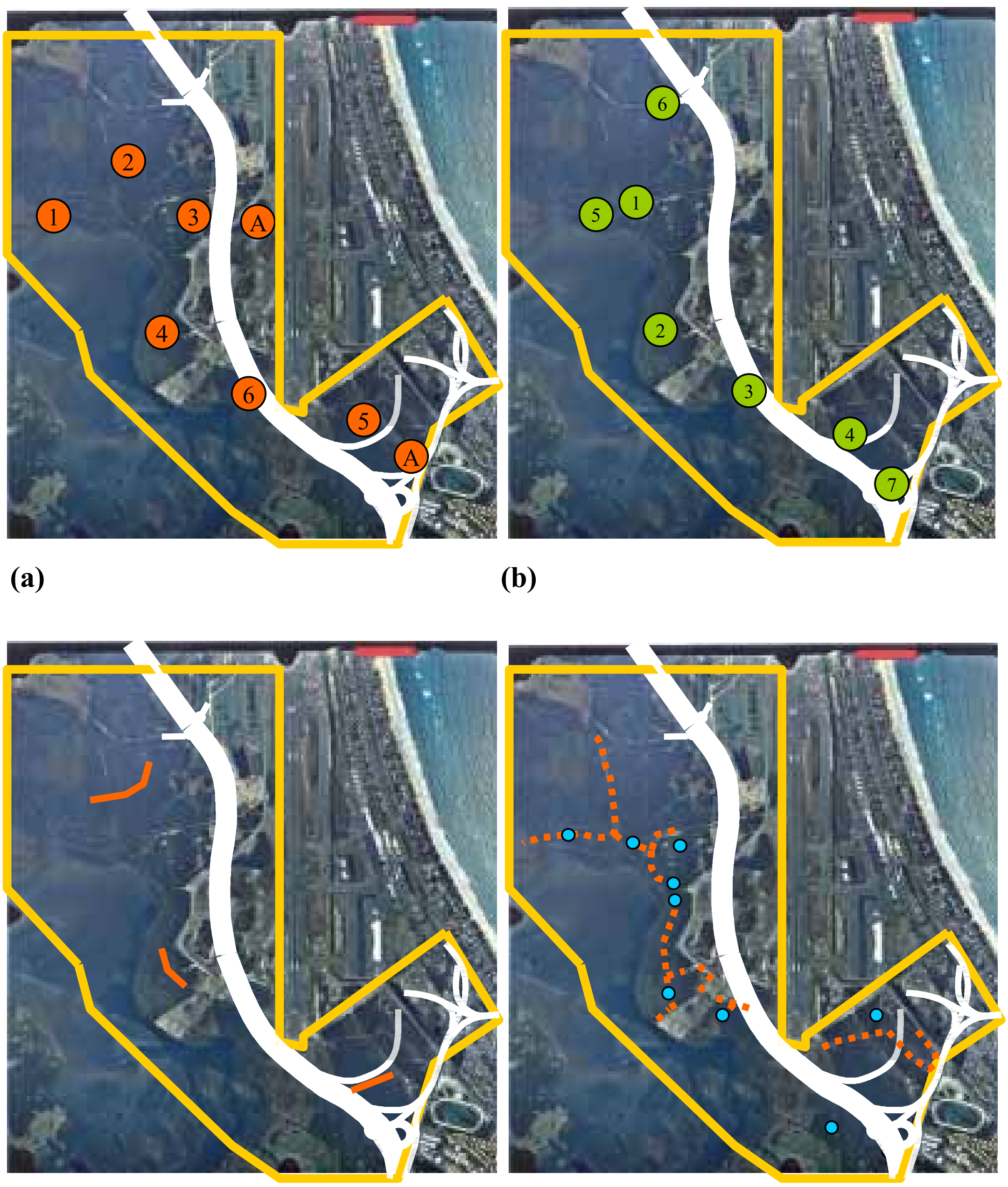


**Fig 3 (a-d). Location of various census points and other sampling traverses undertaken during the course of the survey [a- location of pitfall and small mammal traplines (A = Ancillary trap sites); b - location of Koala SPOT assessments; c - location of hair tube transects; d - locations of harp traps (blue circle), Anabat and spotlighting transects].**

**Table 1**. Summary of survey methods and effort used to detect fauna in this study.

| Taxon/methods | Nocturnal search | Diurnal search | Pitfall trap | Elliot trap (type A) | Hair-tube trap | Spotlight | Predator Scat search | Spot assess-ment | Harp trap | Anabat |
|---|---|---|---|---|---|---|---|---|---|---|
| Amphibians | √ | √ | √ | | | | | | | |
| Reptiles | √ | √ | √ | | | | | | | |
| Terrestrial & arboreal mammals | | | √ | √ | √ | √ | √ | √ | | |
| Microchirpoterans | | | | | | | | | √ | √ |
| Trap nights | | | 195 | 685 | 180 | | | | 18 | |
| Search hours | 20 | 18 | | | | 24 | 12 | | | 14 |
| No. of assessments | | | | | | | 48 | 7 | | |

***Tugun Fauna Survey***

**i) Amphibians**

Diurnal and nocturnal foot-based visual and acoustic surveys were undertaken in all suitable habitats throughout the area, with survey effort intensified during periodic heavy rainfall events over the course of the study. Surveys included searches along roads and tracks in addition to intensive searches at ponds, swamps and watercourses within the study area. Playback methods were not considered suitable for detecting frog species found in coastal habitats. Search effort (in terms of time) was equally distributed throughout the study area for a total of approximately 38 person hours.

**ii) Reptiles**

Diurnal and nocturnal foot based visual surveys were undertaken in all habitat types throughout the study area. Surveys included searches along roads and tracks in addition to intensive searches around potential shelter sites. Search effort (in terms of time) was equally distributed throughout the study area for a total of approximately 38 person hours .

**iii) Terrestrial and Arboreal Mammals**

Opportunistic observations of both native and introduced mammal species (including the presence of diagnostic faecal material) were recorded throughout the survey. Tree trapping was also undertaken on an *ad hoc* basis. Where circumstances permitted, Type A Elliot traps baited with a mixture of rolled oats, peanut butter and honey were secured to horizontal branches of suitable trees (predominantly *Banksia* spp.) at heights of between 1 - 2 metres off the ground. Branches in front of each trap were sprayed with a mixture of honey and water on a daily basis and maintained for four consecutive nights.

Spotlighting

Spotlighting for arboreal mammals was undertaken using both vehicle and foot-based searches (see Fig. 3). Vehicle-based spotlighting employed a driver and at least one observer using a single, hand held 100w spotlight. Foot-based transects employed two 'Faunatech' 55w hand held spotlights. Search effort (in terms of time) was equally distributed throughout the study area for a total of 24 person hours.

**iv) Microchirpoterans**

Field censusing for microchiropteran bats primarily involved the deployment of three "Harp Traps" which were strategically located in likely "flyways" throughout the study area, including suitable localities along vehicle tracks and across creeks. Each of the three traps were maintained for 2 consecutive nights at each of nine locations. A hand held Anabat detector (Titley Electronics) was also used to record calls using the 'walking detection' method described by de Oliveira (1998). Search effort (in terms of time) focussed on likely peak activity periods (2 - 3 hours after sunset) and was equally distributed throughout the study area (see Fig. 3). Fourteen walk/search hours were completed.

### b) Supplementary Sampling

Ancillary pit fall lines were established at two additional sites during the course of the survey (see Fig. 3). At one of these - a small vegetation remnant inside the airport boundary fence - a further 10 Elliot traps were also deployed. In keeping with the approach outlined above, these traplines were also maintained for a minimum of four nights.

Mistnetting

Two 18m mist nets (mesh size 20mm x 20mm) were deployed proximal to flowering *Banksia integrifolia* specifically to sample for Queensland Blossom Bats. Fifty four metre/hrs were completed over two nights during July.

Predator scats

Systematic searches for predator scats were undertaken throughout the study area using teams of at least 2 people walking alongside each other on either side of established vehicle tracks. Predator scats were also collected whenever they were encountered opportunistically. Scat (and hair tube) analysis was undertaken by Ms. Michiala Bowen.

Koala Spot Assessments

Seven *post hoc* assessments using the approach of Phillips and Callaghan (1995) were undertaken in areas of suitable habitat (Swamp Mahogany forest) in order to further sample for the presence of koalas. These assessments were generally preceded by a broader search for evidence of koala activity (faecal pellets, scratch marks) in the general area of the selected site (see Fig. 3).

### c) Literature reviews and fauna database searches

Survey work was augmented by examination and/or review of prior field studies in the area, including relevant environmental studies maintained in the Tweed Shire Council's Development Services Library. Additionally, amphibian, reptile and mammal records covering an area of approximately 100km$^2$ surrounding the study area were obtained from the Qld. EPA "Wildnet" and NSW NPWS's "Wildlife Atlas" databases respectively. Queensland Museum (QM) records were also obtained.

## SURVEY RESULTS

Collectively, fifty six species of reptiles, amphibians and small mammals (including 7 introduced species) are known to occur in the study area, comprising 16 species of amphibians, 13 species of reptiles and 27 species of mammals. Records for a further 3 species of amphibians, 11 species of reptiles and 8 species of small mammal in the general area were obtained from the 'Wildnet', 'Wildlife Atlas' and QM databases. Collective data (Tables 2, 3 & 4) thus suggest a minimum of 78 species in the study area, 12 of which (2 amphibians, 1 reptile and 10 mammals) are currently listed as 'Vulnerable' for the purposes of the TSC Act. A more detailed discussion of the results for each of the major groups is provided below.

### a) Amphibians

Spotlighting and acoustic surveys revealed a high amphibian diversity in the study area. The results of the survey program have established the presence of at least 16 species of amphibians (Table 2). Records for a further 2 species in the general area were obtained as a consequence of "Wildlife Atlas", "Wildnet" and QM database searches. An unconfirmed record for a third species (Freycinet's Frog *L. freycineti*) reported by WBM (1991) has also been included.

One hundred and ninety five (195) pitfall trap nights were completed. Six species of amphibians – the Cane Toad *B. marinus*, Clicking Froglet *C. signifera*, Wallum Froglet *C. tinnula*, Ornate Burrowing Frog *L. ornatus*, Striped Marsh Frog *L. peronii* and Scarlet-sided Pobblebonk *L. terraereginae* were captured in pit fall traps.

Two species currently listed as 'Vulnerable' for the purposes of the TSC Act - *Crinia tinnula* and *Litoria olongburensis* were recorded during the survey, the former species being widespread and abundant throughout the study area (Fig. 4). In contrast and apart from an incidental recording of one individual of *L. olongburensis* in an adjacent area of swamp (despite ideal sampling conditions during the course of the study ~ warm nights, during and following heavy rainfall events), *L. olongburensis* remains known from only one site within the study area (Fig. 4), the location of which will be directly impacted by construction of road and rail links (based on the preferred by-pass alignment) within the transport corridor.

**Table 2.** Amphibian species encountered either on or in close proximity to lands associated with the proposed Tugun by-pass (Site numbers refer to those detailed in Fig. 2). Note: the table includes 3 additional species not encountered but recorded in the data base searches.

| Species/Site No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | NSW | EA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Family: Bufonidae** | | | | | | | | | | | | | | |
| *Bufo marinus** | O,T, W | O,T, W | O,W | O,T, W | O,T | T | | | | | W | W | | |
| **Family: Hylidae** | | | | | | | | | | | | | | |
| *Litoria caerulea* | | O | W | W | W | W | W | | | | O,W | W | | |
| *L. dentata* | | W | | O | | | | | | | O,W | | | |
| *L. fallax* | | W | W | W | W | W | W | | W | W | W | W | | |
| *L. freycineti* [4] | | | | | | | | | | | | | | |
| *L. gracilenta* | | O,W | W | O,W | O,W | W | W | | | | O,W | W | | |
| *L. nasuta* | | W | O,W | W | W | W | W | W | W | W | W | W | | |
| *L. olongburensis* | | | | | W | O,W | | | | | | | **V** | **V** |
| *L. peronii* | | | | | O,W | | | | | | | | | |
| *L. rubella* | | | | | | | | | | | O,W | | | |
| *L. tyleri* | | O,W | | W | W | | | | | W | | | | |
| **Family: Myobatrachidae** | | | | | | | | | | | | | | |
| *A. brevis* [3] | | | | | | | | | | | | | | |
| *Crinia parinsignifera* | | | W | | W | | W | | | | W | W | | |
| *C. signifera* | T | | W | | W | | W | | W | W | | W | | |
| *C. tinnula* (V) | T,W | T | W | W | W | O,T, W | W | W | W | W | W | W | **V** | |
| *Limnodynastes ornatus* | | | O | | T | | | | | | O | | | |
| *L. peronii* | O,T | T,W | O,T, W | | W | T | W | W | W | W | W | W | | |
| *L. terraereginae* | O,W | T | W | O,T, W | O,T, W | O,T | W | W | | W | W | W | | |
| *Pseudophyrne* spp [1] | | | | | | | | | | | | | | |

**Code:** T = trapped; O = observed; W = heard; * = introduced species; V = Vulnerable species for purposes of **NSW** *Threatened Species Conservation Act* 1995 and **EA** the Commonwealth = *Environment Protection & Biodiversity Act* 2000. 1 = NPWS 'Wildlife Atlas' record; 2 = QEPA 'Wildnet' record; 3 = Queensland Museum record; 4 = WBM Oceanics (1991).


**Fig. 4. Locations of threatened species recorded during the course of the survey (Ct = *C. tinnula*, Lo = *L. olongburensis*, Ma = *M. australis*, Mad = *M. adversus,* Nb = *N. bifax*, Pm = *P. maculata*, Pa = *P. alecto*, Sa =** S. australis, **Pn** = P. norfolcensis, **Pt** = *P. tridactylus*)**.**

**b) Reptiles**

The results of the survey have confirmed the presence of at least 13 species of reptiles within the study area (Table 3). Three of these - *L. delicata*, *C. virgatus* and *S. equalis* - were collected by pit fall traps, the remainder obtained during diurnal and/or nocturnal searches. Records for an additional 11 species in the general area were obtained as a consequence of "Wildlife Atlas", "Wildnet" and QM database searches. We consider that one of these latter records - the Hooded scaly-foot *Pygopus nigriceps* - is anomalous, our reasoning based on the fact that the species is mostly restricted to sub-humid and arid regions throughout much of Australia, excluding cool moist south-east, south-west, Nullarbor Plain and (notably) most areas east of the Great Dividing Range (Wilson and Knowles 1988)

No threatened reptile species were detected during the course of the survey. However, the QEPA and QM database searches both provided records for the White-crowned Snake *Cacophis harrietae*, a species that is currently listed as 'Vulnerable' for the purposes of the TSC Act. While we are confident that this species does not actually occur within the immediate study area, its potential presence cannot be entirely discounted with confidence.

**Table 3.** Reptile species occurring either on or in close proximity to lands associated with the proposed Tugun by-pass (Site numbers refer to those detailed in Fig. 2). Note: the table includes 11 additional species not encountered but recorded in the data base searches.

| Species/Site No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Family: Agamidae** | | | | | | | |
| *Physignathus lesueurii* | | | O | | | | |
| *Pogona barbata* | | | O | O | O | O | O |
| **Family: Boidae** | | | | | | | |
| *Morelia spilotes* [2] | | | | | | | |
| **Family: Colubridae** | | | | | | | |
| *Bioga irregularis* [2 3] | | | | | | | |
| *Dendrelaphis punctulata* | | O | O | | | | |
| *Tropidonophus mairii* [3] | | | | | | | |
| **Family: Elapidae** | | | | | | | |
| *Acanthophis antarcticus* [2 3] | | | | | | | |
| *Cacophis harriettae* (V) [2 3] | | | | | | | |
| *C. krefftii* [2 3] | | | | | | | |
| *Demansia psammophis* | | O | | | | | |
| *Hemiaspis signata* [3] | | | | | | | |
| *Pseudonaja textilis* [3] | | | | | | | |
| *Rhinoplocephalus nigrescens* | O | | | O | | | |
| *Tropidechis carinatus* | | O | | | | | |
| *Vermicella annulata* [3] | | | | | | | |
| **Family: Pygopodidae** | | | | | | | |
| *Lialis burtonis* [2 3] | | | | | | | |
| *Pygopus lepidopodus* | O | | | | | | |
| **Family: Scincidae** | | | | | | | |
| *Cryptoblepharus virgatus* | | T | O | O | | | O |
| *Ctenotus arcanus* | O | | O | | | | |
| *C. robustus* | O | | O | | | | |
| *Eulamprus martini* [3] | | | | | | | |
| *Lampropholis delicata* | O | O | O,T | O | O | O,T | O,T |
| *Saiphos equalis* | O | | O,T | | | | |
| **Family Varanidae** | | | | | | | |
| *Varanus varius* | O | O | O | O | | | |

**<u>Code:</u>** T = trapped; O = observed; * = introduced species; V = Vulnerable species for purposes of NSW *Threatened Species Conservation Act* 1995; 1 = NPWS 'Wildlife Atlas' record; 2 = QEPA 'Wildnet' record; 3 = Queensland Museum record.

**c) Mammals**

The results of the survey have confirmed the presence of at least 23 species of native mammals within the study area (Table 4). Reliable records for a further 8 native species in the general area of the transport corridor were obtained as a consequence of "Wildlife Atlas" and "Wildnet" database searches.

Six hundred and eighty five trap nights (665 ground-based, 20 tree-based) were completed. Four species of native small mammal - the Grassland Melomys *M. burtoni*, Bush Rat *R. fuscipes*, Eastern Swamp Rat *R. lutreolus* and Yellow-footed Antechinus *A. flavipes* were captured in Elliot traps. On the basis of the trapping program *M. burtoni* was the most abundant small mammal in the study area. Conversely, *R. fuscipes* was the least common, being represented by the capture of a single individual at Site 4.

Pit fall trapping (195 trap nights) yielded a single individual of the introduced *M. domesticus*, a single sub-adult *A. flavipes* and several *P. maculata*, the latter notable not only because of its status as a 'Vulnerable' species for the purposes of the TSC Act, but also because all captures were obtained from the one area (Site 6) the location of which will potentially be impacted by construction of road and rail links (based on the preferred alignment) within the transport corridor (Fig. 4).

Scant samples of mammalian hair were found in only three of the eighteen hair tubes, providing evidence of investigation by *Rattus* sp., *Mus domesticus* and a species of bandicoot.

Analysis of predator scats (n = 48) revealed a diversity of prey items (Appendix 3) while also establishing the presence of two additional species, the Northern Brown Bandicoot *I. macrourus* and Eastern Water Rat *Hydromys chrysogaster*, which had not been detected during the course of the survey.

Notwithstanding the presence of Squirrel Gliders *Petaurus norfolcencis* in the mature Scribbly Gum forest in the vicinity of Site 1, spotlighting results suggested both a low density and depauperate community of arboreal marsupials. The absence of koala sightings is also a notable outcome from the spotlighting results which, coupled with no evidence of koala activity from the seven SPOT assessments (Table 5), support a conclusion that the study area no longer supports a resident koala population (see species account).

In contrast to the above, the study area clearly supports a rich and diverse community of microchiropteran bats, the results (Table 4) exceeding expectations for the associated trapping effort (18 Harp Trap nights). Of the three 'Vulnerable' microchiropteran species captured, *N. bifax* was the most widespread. Indeed, *N. bifax* was the most commonly captured bat species on the site, suggesting that the study area supports a significant population of this particular species.

**Table 4.** Mammal species occurring either on or in close proximity to lands associated with the proposed Tugun by-pass (Site numbers refer to those detailed in Fig. 2). Note: the table includes 8 additional species not encountered but recorded in the data base searches.

| Species/Site No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NSW | EA |
|---|---|---|---|---|---|---|---|---|---|
| **Family: Canidae** | | | | | | | | | |
| Dog/Fox* | S | S | O | S | S | S | | | |
| **Family: Dasyuridae** | | | | | | | | | |
| *Antechinus flavipes* | T | T | T | | | | | | |
| *Planigale maculata* | | | | | | T | | **V** | |
| *Sminthopsis murina* [1] | | | | | | | | | |
| **Family: Emballonuridae** | | | | | | | | | |
| *Saccolaimus flaviventris* [1, 2] | | | | | | | | **V** | |
| **Family: Felidae** | | | | | | | | | |
| *Felis catus** | | S | | S | | | | | |
| **Family: Leporidae** | | | | | | | | | |
| *Lepus capensis** | | | O | O | | | | | |
| *Oryctolagus cuniculus** | | | P | | | | | | |
| **Family: Macropodidae** | | | | | | | | | |
| *Wallabia bicolor* | O | O,P | O, P | O | O | O | | | |
| *Macropus rufogrisea* [2] | | | | | | | | | |
| **Family: Molossidae** | | | | | | | | | |
| *Nyctinomus australis* [2, 3] | | | | | | | | | |
| **Family: Muridae** | | | | | | | | | |
| *Hydromys chrysogaster* | P | | | | | | | | |
| *Melomys burtoni* | T | P,T | T | P,H | T | T | | | |
| *Mus domesticus** | | | H | | T | | P,T | | |
| *Rattus fuscipes* | | | | T | | | | | |
| *R. lutreolus* | P,T | | P | | T | | T | | |
| *R. rattus** | | | H | | | | T | | |
| **Family: Peramelidae** | | | | | | | | | |
| *Isoodon macrourus* | | | P | P | | | | | |
| *Perameles nasuta* | | | P,O | P | | | | | |
| **Family: Petauridae** | | | | | | | | | |
| *P. breviceps* [2, 3] | | | | | | | | | |
| *P. norfolcensis* | O | | | | | | | **V** | |
| **Family: Phalangeridae** | | | | | | | | | |
| *Trichosurus caninus* | O | | | | | | | | |
| **Family: Phascolarctidae** | | | | | | | | | |
| *Phascolarctos cinereus* [1,2, 3] | | | | | | | | **V** | |
| **Family: Potoroidae** | | | | | | | | | |
| *Potorous tridactylus* [1] | | | | | | | | **V** | **V** |
| **Family: Pteropodidae** | | | | | | | | | |
| *Pteropus alecto* | O | O | | O | | | O | **V** | |
| *P. poliocephalus* | O | | | P,O | | | | | |

**Table 4 (cont).** Mammal species occurring either on or in close proximity to lands associated with the proposed Tugun by-pass (Site numbers refer to those detailed in Fig. 2).

| Species/Site No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NSW | EA |
|---|---|---|---|---|---|---|---|---|---|
| *Syconycteris australis* | | | | T | | | | **V** | |
| **Family: Tachyglossidae** | | | | | | | | | |
| *Tachyglossus aculeatus* | | | S, P | | | | | | |
| **Family: Vespertilionidae** | | | | | | | | | |
| *Chalinolobus morio* | T | | T | | | | | | |
| *Miniopterus australis* | $A^{P}$ | | | T | A | | | **V** | |
| *Myotus adversus* | | | | T | | | | **V** | |
| *Nyctophilus bifax* | T | | T | T | | | | **V** | |
| *N. gouldii* | T | | | | | | | | |
| *Scotorepens* sp1 [1] | | | | | | $A^{P}$ | $A^{P}$ | | |
| *Vespedalus pumilus* | T | | T | T | | | | | |

**<u>Table 4 Code:</u>** T = trapped; O = observed; S = scat; P = predator scat; A = Anabat ($^{P}$ = probable); H = hair tube; * = introduced species; V = Vulnerable species for purposes of **NSW**, *Threatened Species Conservation Act* 1995 and **EA** the Commonwealth = *Environment Protection & Biodiversity Act* 2000.1 = NPWS 'Wildlife Atlas' record; 2 = QEPA 'Wildnet' record; 3 = Queensland Museum record.

**Table 5.** Results of seven SPOT assessments from areas of primary koala habitat throughout the study area. Numbers indicate the number of live stems sampled at each location (E. rob = *E. robusta*; E. sig = *E. signata*; E. ter = *E. tereticornis*; M. qui = *M. quinquenervia*). Note that no evidence of koala activity was detected.

| SPOT No. | Easting | Northing | E. rob. | E. sig. | E. ter. | M. qui. | Others |
|---|---|---|---|---|---|---|---|
| **1** | $^{5}$48800 | $^{68}$84150 | 16 | - | - | 2 | 7 |
| **2** | $^{5}$49150 | $^{68}$83400 | - | - | 8 | - | 17 |
| **3** | $^{5}$49950 | $^{68}$83200 | 12 | - | - | 7 | 6 |
| **4** | $^{5}$50450 | $^{68}$83250 | 16 | 5 | - | 1 | 3 |
| **5** | $^{5}$48600 | $^{68}$84050 | - | 4 | 6 | 3 | 12 |
| **6** | $^{5}$48100 | $^{68}$84700 | 21 | - | - | 4 | - |
| **7** | $^{5}$51000 | $^{68}$83100 | 15 | - | - | 6 | 4 |
| **Total No.** | | | **80** | **9** | **14** | **23** | **49** |

## DISCUSSION

The survey results demonstrate that the study area has a high diversity of vertebrate fauna with correspondingly high numbers of amphibians and small mammals, although reptiles and arboreal mammals appear to be poorly represented. A number of these species are currently listed as threatened in accord with provisions of the TSC Act and are discussed in more detail below.

### 1. Amphibians

The study area supports a substantial number of amphibian species (Table 2) which reflect a diversity representative of amphibian communities encountered in the coastal lowland habitats of south-eastern Queensland and north-eastern New South Wales. The diversity of breeding habitats available to amphibians in the area is likely to be a major factor contributing to the richness of frog species recorded. Two frog species encountered in the area are currently listed as 'Vulnerable' (Wallum Froglet – *Crinia tinnula* and the Wallum Sedgefrog – *Litoria olongburensis*); both belonging to a group known as the “wallum” or “acid” frogs as they are generally restricted to low nutrient soils associated with acidic waters (pH less than 5) found on the coastal lowlands and sand islands in south-eastern Queensland and northern New South Wales, with mainland populations at high risk from continuing loss of habitat through clearing for agriculture, pine plantations, housing and infrastructure such as canal developments, drainage projects and transport corridors (Hines *et al*. 1999, Hero *et al*. 2000). The potential for localised extinction of populations due to habitat loss and/or fragmentation is a particular concern arising from this study. Furthermore, protection of the water quality and the maintenance of appropriate pH levels is critical to the survival of these species (Hero *et al*. 2000, E. Meyer unpub. data). It should be noted that nothing is known about the movement patterns, home range or population dynamics of these “wallum” frog species.

### Amphibian Biodiversity Hotspot

Eleven species of frog were encountered in a single wetland habitat in the north-eastern corner of survey precinct 5 (see Fig. 2). This unusually high concentration of species was probably due to the extensive flooding over an area surrounding a deeper semi-permanent pond. This area contained the highest diversity of amphibians and as such we consider it to be an important site for biodiversity in the local area.

**Wallum Froglet** (*Crinia tinnula*)

The Wallum Froglet is an "Acid Frog", reliant upon water with low pH in coastal areas from Fraser Island (Ingram and Corben, 1975) to near Wyong on the central coast of NSW (NSWNPWS, 1999). The Wallum froglet is described as being "…restricted to acid paperbark swamps in the Wallum country" (Robinson, 1993) but has also been recorded in coastal open woodland with heath understory (Hero *et al*. 2000). The nearest records of *C. tinnula* populations are 30-40 km south in the Pottsville - Hastings Point area (Phillips *et al*. 1995) and 25 km to the north at Southport (Hero *et al.* 2000).

*Crinia tinnula* breed in lentic waters < 1.5m deep within the pH range 3.0 - 5.2 (E. Meyer unpub. data). The Beeping Froglet (*C. parinsignifera*) replaces *C. tinnula* at sites with waters of pH 5.0 and above (E. Meyer unpub. data). At other sites where *C. tinnula* and *C. parinsignifera* occur together (Karawatha Forest, Capalaba and Caboolture) *C. tinnula* are found in areas of low pH, while *C. parinsignifera* occur in adjacent waterbodies with higher pH (E. Meyer unpub. data).

In this study Wallum Froglets were recorded throughout the study area (Table 2). However populations appear to be localised and there is some evidence, based on work on other *Crinia* species, that fidelity to breeding sites is maintained. The small size of this species does not suggest extensive movement and, because of this, it must be assumed that most populations are distinct (although some migration is expected between them). Calling males were encountered at many ponds associated with heath vegetation, water depths usually less than 0.5m, and water pH ranging from 3.84 – 5.18. This falls within the range reported for this species (see above). Changes to pond hydrology that will increase water pH is likely to have a negative impact on the survival and persistence of *C. tinnula* populations in the area.

**Wallum Sedge Frog** (*Litoria olongburensis*)

In common with *C. tinnula*, the Wallum Sedge Frog is restricted to "Wallum" habitats in coastal south-eastern Queensland and north-eastern New South Wales from Fraser Island (Ingram and Corben, 1975) to the Coffs Harbour area (NSWNPWS 1999) and is one of several frog species which breed in water of low pH (Ingram and Corben, 1975). The nearest mainland records of *Litoria olongburensis* are 30-40 km south in the Pottsville - Hastings Point area (Phillips *et al.* 1995) and over 100 km to the north in the Beerwah region (Hines *et al.* 1999).

*Litoria olongburensis* are known to breed in waters with a pH range between 3.4 and 4.5, and in deeper water amongst sedges (*Baumea* spp. and the like) and/or ferns such as *Blechnum indicum* (E. Meyer unpub. data). *Litoria olongburensis* tadpoles usually overwinter, emerging as metamorphs in Spring, suggesting that deeper semi-permanent ponds are necessary for breeding success in this species and that ephemeral shallow ponds are unsuitable for successful reproduction (E. Meyer unpub. data). *Litoria olongburensis* is ecologically similar to *L. fallax.* At other sites where *L. olongburensis* and *L. fallax* occur in symaptry, *L. olongburensis* are found in areas of low pH, while *L. fallax* occur in adjacent waterbodies with higher pH (E. Meyer unpub. data).

We found a small aggregation of calling male *L. olongburensis* in a pond on the north eastern corner of site 6. This pond is on the ecotone of the forest / cleared grassland habitats at the end of the runway. Significantly, this pond had the lowest pH recorded in the area (pH values at this site ranged between 3.84 and 3.91, while pH at other sites ranged from 4.16 – 5.18), values which fall within the known range for this species (see above).

A single call sequence from *L. olongburensis* was also heard during daylight hours on the 31st of January 2000 in the Amphibian Biodiversity Hotspot (see preceding section on page 21) within site 5. However, when we returned that night there were large choruses of *L. fallax* and no *L. olongburensis* were heard or seen. The single individual recorded at the site does not appear to represent a viable population of this species; furthermore the high pH (5.18) and the presence of *L. fallax* in large numbers, also suggests site 5 is unsuitable for *L. olongburensis*.

**Freycinet's Frog** (*Litoria freycineti*)

Freycinet's Frog is a medium sized (ca 45mm) 'tree frog' distributed along the eastern coast of Australia from the south-eastern corner of Queensland to the south coast of New South Wales (Robinson 1993).

Little is known about the ecology of *L freycineti*. In common with *C. tinnula* and *L. olongburensis*, the species is often associated with 'wallum' type habitats. Unlisted but uncommon in New South Wales, the species has been reported from the Pottsville area (Gilmore and Associates 1986) some 30km to the south of the study area. It was also recorded in the Tweed coastal lowlands by Denny (1994). Despite the fact that *L. freycineti* was recorded in the study area by WBM Oceanics (1991), the species has thus far not been recorded during the course of the present study despite ideal sampling conditions.

Threats to *L. freycineti* populations, should the species occur in the study area, will arise as a consequence of habitat destruction and/or modification associated with roadworks.

### 2. Reptiles

**White-crowned Snake** (*Cacophis harrietae*)
*Cacophis harrietae* is a small to medium sized [< 400mm - Shine (1991)] venomous snake with a fragmented distribution along the eastern coast of Australia from near Atherton in north-eastern Queensland to the Coffs Harbour area on the north coast of NSW (NSWNPWS 1999).

The species has been recorded from a variety of habitat types throughout its range in eastern Australia and pertinent aspects of its ecology have been detailed in a threatened species profile prepared by the NSWNPWS (NSWNPWS 1999). No White-crowned Snakes have thus far been recorded during the course of the fauna survey. However, both the QEPA 'Wildnet' and QM database searches provided records for this species from areas immediately to the north of the study area and because of this, the potential for this species to occur within the study area cannot be discounted.

Key factors working to reduce populations of *C. harrietae* are difficult to isolate. Threats to the species appear to be primarily associated with a reduction in the amount of suitable habitat due to land clearing, modification by grazing, road construction and overly frequent fire regimes; predation by domestic animals is also known (NSWNPWS 1999).

### 3. Mammals

**Common Planigale** (*Planigale maculata*)
*Planigale maculata* is a small (6 - 35gms) carnivorous marsupial distributed along the eastern seaboard of Australia from Cape York to the Hunter River Valley on the central coast of NSW (Strahan 1995).

The regional distribution and abundance of *P. maculata* is difficult to ascertain with confidence. Because of its small size and cryptic nature the species is not always detected nor readily censused by conventional survey methodology. Locally, the species is known from other areas of the Tweed Coast (Phillips *et al.* 1995) and from further to the south (Milledge 1991). A single record from an area to the north of the study area was also obtained from the Queensland Museum database.

There is no information on the movement patterns, home range requirements or other aspects of population dynamics for *P. maculata*. The small size of this species does not suggest extensive movement and because of this, it must be assumed that most populations will be localised. Pit fall trapping associated with the current survey resulted in three captures (at least two individuals), all of which were from the same locality - Site 6 - which will be potentially impacted by roadworks associated with construction of the proposed by-pass.

Threats to the species primarily relate to loss and/or modification of habitat. Predation by feral and domestic animals is also known.

**Long-nosed Potoroo** (*Potorous tridactylus*)

The long-nosed Potoroo has a patchy and extremely localised distribution along the east coast of Australia from south-eastern Queensland to Victoria and Tasmania. Preferred habitat for the species appears to be areas of coastal heathlands and both dry and wet sclerophyll forests; a major habitat requirement is relatively thick groundcover (Strahan, 1995; Mason 1997).

A single record for this species were obtained from the NSW NPWS 'Wildlife Atlas' database and the species has a history of controversy towards the northern end of the transport corridor (IPTP 1992; Mason 1993; MPS 1993). The species was recorded by Milledge (1988) within the now Cudgen Nature Reserve to the south and has also been the subject of a detailed population study at Tyagarah Nature Reserve in the Byron Shire (Mason 1997). Suitable habitat for *P. tridactylus* does exist within the study area and the potential for the species to occur in such areas should not be discounted, despite the fact that it has not been detected during the course of the fauna survey.

Major threats to the species include habitat destruction, fragmentation and modification, the latter primarily as a result of excessive fire regimes in areas of otherwise suitable habitat. Motor vehicle fatalities and predation by domestic and feral animals such as dogs and foxes are also known.

**Squirrel Glider** *(Petaurus norfolcensis*)

The Squirrel Glider is the largest of two closely related *Petaurus* species, the other being the Sugar Glider *P. breviceps*; both have potentially extensive and often sympatric distributions in eastern

Australia (Traill and Lill 1997). However, *P. norfolcensis* is by far the rarer of the two and is more restricted in range, preferring dry sclerophyll forests and woodlands (Strahan, 1995).

Records for Squirrel Gliders from areas to the north of the transport corridor were obtained from the QEPA 'Wildnet' and QM database searches. Within the study area, three individuals were observed in the mature Scribbly Gum forest near Site 1 during spotlighting transects. Major threats to *P. norfolcensis* populations are the clearing of vegetation which potentially provides essential habitat components, particularly older stands of drier sclerophyll forest with a prevalence of hollow bearing trees. Domestic animals, particularly cats, also represent a major threat while motor vehicle kills have been observed.

**Koala** (*Phascolarctos cinereus*)
The koala - Australia's largest arboreal marsupial - is an obligate folivore which feeds primarily on the genus *Eucalyptus*. Its distribution in eastern Australia extends from far north-eastern Qld. to the Eyre Peninsula in South Australia (Strahan 1995). Often regarded as solitary animals, koalas actually live in well defined social hierarchies comprised of overlapping home range areas. Breeding activity is usually presided over by an alpha-male whose home range area will overlap that of several females. As a general rule, long term (ie many years) occupation of the same home range area is demonstrated by adult koalas in a stable breeding aggregation.

No evidence of koalas was found during the course of the current survey. Current Wildlife Atlas records for the general area are old (ca 1986), consistent with a view that this species is gradually disappearing from the Tweed Coast and proximal areas of south-eastern Queensland. However, recent studies have confirmed the persistence of a small population in the vicinity of the proposed Piggabeen Rd. bypass and associated lands on the southern edge of the Cobaki Broadwater (Parker 1999; Phillips unpub. data).

Loss of habitat, road mortalities, predation by foxes and feral dogs, and fire all threaten koala populations. While fire is a natural component of many Australian ecosystems, the frequency of fire events has increased with European occupation and in many areas, the timing of such events exceeds the ability of many koala populations to recover adequate population levels. Unfortunately, many contemporary declines are masked by the relative longevity of the species, with time periods of 16-20 years now being associated with localised extinction events (Phillips 2000a). It should be noted that the stands of Swamp Mahogany forest present in the study area constitute an extensive area of what would otherwise be primary koala habitat (Phillips and Callaghan 1996; Phillips *et al*. 2000; Phillips 2000b). Thus the significance of this area in terms of its longer term potential to assist recovery actions for koalas in the Tweed area should not be overlooked.

**Queensland Blossom Bat** (*Syconycteris australis*)

The Queensland Blossom Bat is the smallest member of the Megachiropteran group and occurs from New Guinea to coastal eastern Australia. In New South Wales its occurrences are localised and restricted to a narrow coastal strip of approximately 600km from the Qld/NSW border to south of the Manning River (Law 1992). The species appears to be solitary by nature and the protection offered by dense foliage in rainforest, adjacent wet sclerophyll forests and paperbark swamps is used for daytime roosting, the evenings spent foraging in adjoining coastal heathland (Law 1993; Strahan 1995). The species has been observed hovering in front of, or feeding on, the blossoms of paperbark, bottlebrushes, banksias, bloodwoods and cultivated bananas (Strahan 1995). Locally, the species is known from the Round Mountain area, including Pottsville and Taggets Hill to the south (Denny 1994; Phillips *et al*. 1995).

Habitat destruction and modification arising from coastal developments, weed infestation and altered fire regimes constitute major threats to the Queensland Blossom Bat. There is a significant threat to the major winter food source, *Banksia integrifolia*, considered to be of crucial importance because of its lengthy flowering period (Law 1993). Many areas of *B. integrifolia* heathland are in senescence due to germination and recruitment suppression by weed infestations (Dodkin and Gilmore 1985; Law 1992). The low level flying behaviour of the species also possibly predisposes it to collisions with motor vehicles and potential predation by introduced animals such as foxes and cats.

**Black Flying-fox** (*Pteropus alecto*)

The Black Flying-fox is the largest of the native Australian megachiropterans. Distributed around the northern periphery of the Australian continent, the species reaches the southern limit of it's known geographical range in north-eastern New South Wales (Strahan, 1995). The species is a permanent resident in the Tweed area with a long established camp on a mangrove island in the Tweed Estuary Nature Reserve immediately to the south of the study area.

Preferred food of *P. alecto* includes the blossoms of eucalypts, paperbarks and turpentines (Strahan, 1995). Apart from general information pertaining to the fact that groups of *P. alecto* are known to travel as far as 50km from their camp to feed on preferred trees (Strahan 1995), there is no published information regarding known dispersal or movement patterns. Within the study area, *P. alecto* was observed feeding in several localities, specifically in association with flowering individuals of Pink Bloodwood *Corymbia intermedia*. It must be assumed that other tree species in the study area, particularly *Eucalyptus* spp. and *Melaleuca* spp. will be equally important over the course of a given year.

Environmental pressures affecting *P. alecto* primarily relate to the ongoing clearing and fragmentation of roosting and foraging habitat. Deliberate disturbance of camp sites and poorly regulated persecution by humans further contribute to potential threats to this species.

**Yellow-bellied Sheathtail-bat** (*Saccolaimus flaviventris*)

The Yellow-bellied Sheathtail-bat is sparsely but widely distributed throughout its known range in southern Australia (Strahan, 1995), an assessment confirmed by surveys over three years using electronic call detection during the NPWS North East Fauna Survey (Parnaby, pers. comm.). As a consequence, few records exist from north-eastern NSW. Single records for this species within the general area of the transport corridor were obtained from the QEPA 'Wildnet' and NSW NPWS 'Wildlife Atlas' databases respectively.

Little is known about the ecological requirements of this species. It is a fast and high flying species which roosts in tree hollows and appears to forage in open habitats above the forest canopy. Although recorded from a wide range of forest types similar to those that occur in the study area, there are no detailed studies of the ecological requirements of the species, and its preferred foraging habitat remains unknown. Hollows in mature eucalypts are likely to represent critical habitat components in the study area, but other critical habitat components, if present, are unlikely to be identifiable given current limitations on our knowledge.

Likely threats to *S. flaviventris* include the loss of foraging and roosting habitat either directly through clearing or indirectly through forest fragmentation.

**Little bent-wing Bat** (*Miniopterus australis*)

The Little Bentwing-bat occurs from Cape York in eastern Queensland, south to northern NSW as far south as Kempsey area. In NSW the species appears mainly restricted to sub-tropical coastal lowlands (Dwyer, 1968) and has been recorded elsewhere in the Tweed Shire (Denny 1994; Phillips *et al.* 1995). The species is present in low numbers in caves in NSW (Dwyer 1968) and is highly vulnerable as populations concentrate in very few maternity caves. Two individuals of *M. australis* were trapped at Sites 1 and 4 during the course of the current fauna survey.

Most roost sites of this species are located in or close to areas of dense vegetation (Dwyer, 1968). Within the study area, critical habitat can be considered to be foraging areas and any roost sites in disused mines (if they occur). Although regarded as a cave roosting species, *M. australis* has been recorded as roosting in tree hollows and it is possible that the species roosts at some time in tree hollows within the study area.

Threats to the species arise from disturbance to overwintering and/or maternity caves, in addition to the loss of foraging and/or roosting habitat associated with tree clearing and forest fragmentation.

**Large-footed Myotis** *(Myotis adversus)*

The Large-footed Myotis remains comparatively rare within its limited range around the northern and eastern periphery of the Australian continent (Strahan 1995). A single specimen was trapped at Site 4 during the course of the current fauna survey while calls recorded along a small watercourse in the vicinity of the proposed southern interchange may also prove to be attributable to this species.

This specialised bat forages over the surface of creeks and reservoirs for invertebrates and small fish and is thought to snare the latter with its enlarged hind feet (Robson, 1984). It roosts in caves and mine tunnels but has also been found roosting under bridges. Critical habitat within the study area is likely to be roost sites (mines, caves and (sometimes) road underpasses) and foraging habitat which includes the resource of small fish and other invertebrate fauna. The species appears to be intimately associated with streams and lakes and does not appear to have been captured away from such areas. It is reasonable to assume that movements occur along waterways.

Major threats to the species are human disturbance from visitation to cave roosts, and destruction of foraging habitat – riparian vegetation, creeks and other water bodies. Potential impacts to the aquatic food resource (small fish and invertebrates) could arise from acidification, siltation and pollution of the foraging habitat. Predation pressures are poorly known.

**Eastern Long-eared Bat** (*Nyctophilus bifax)*

The distribution of the Eastern Long-eared Bat in eastern Australia ranges from Cape York to north-eastern NSW (Parnaby, 1987). In northern NSW the species is usually found at near-coastal localities and has been recorded as far south as Coffs Harbour. Further records are available from the Pottsville area and Taggets Hill to the south (Denny, 1994; Phillips *et al*. 1995). The species was relatively abundant within the study area (trapped at five of the nine locations sampled), a result which suggests the presence of a significant population in the study area.

In Queensland *N. bifax* is found in a range of habitats (Allison, 1989), but NSW records appear to be primarily associated with rainforest or wet sclerophyll forest (Lunney *et al.* 1996) who concluded that the proximity of a range of roost types in rainforest, including dense vegetation and hollows in mature trees are likely to be critical for the survival of this species.

Major threats to the species in NSW appear to be destruction, modification (eg logging, weed invasion and urban encroachment) and fragmentation of rainforest habitat. Lunney *et al.* (1996) suggest that any alternation to the canopy of rainforest which destabilises the subcanopy microclimate is also likely to have a deleterious impact on this species.

## Preliminary Assessment of Likely Impacts

### General

The results of the survey have established that the study area has considerable conservation value. Construction of the by-pass along the currently preferred alignment will result in the loss or isolation of a number of key habitats in the area. A further factor that must be considered is the potential impacts of the proposed tunnel on existing hydrological regimes, specifically the flow of underground water and water-table levels below the critical vegetation alliances found throughout the area.

Our concerns with regard to threatened species and the maintenance of biodiversity in the general area are presented in the form of five key areas (Fig. 5) which, ideally, should be protected from further disturbance, rehabilitated where appropriate and measures taken to maintain connectivity with adjacent habitats.

Area A - the Amphibian Biodiversity Hot Spot within survey precinct 5,
Area B – an area of mature *E. robusta* forest adjoining a *Blechnum indicum*/*Banksia robur* wetland in the south-eastern corner of survey precinct 5,
Area C - the *L. olongburensis* and *P. maculata* populations inhabiting Site 6,
Area D – numerous fragmented populations of Wallum Froglets (*Crinia tinnula*), and
Area E– potential *P. tridactylus* habitat in the north-eastern corner of survey precinct 2.

Additional to the above, alignment of the bypass as currently proposed will result in the loss and/or isolation of Wallum Froglet habitat within survey precincts 3, 5, 6, 7, 8, 11 and 12 (Fig. 2). These threats arise from the draining and/or filling of wetlands, particularly those with chemically suitable breeding sites (water bodies with low pH) and their associated vegetation (frog habitat). Habitat degradation constitutes a further threatening process because chemically suitable water bodies occur in close proximity which will potentially affected by changes to the water table. In the absence of appropriate mitigation measures, mortalities from motor vehicles will also occur because some populations will occur in close proximity to the proposed highway.

Each of these areas are discussed in detail below:-

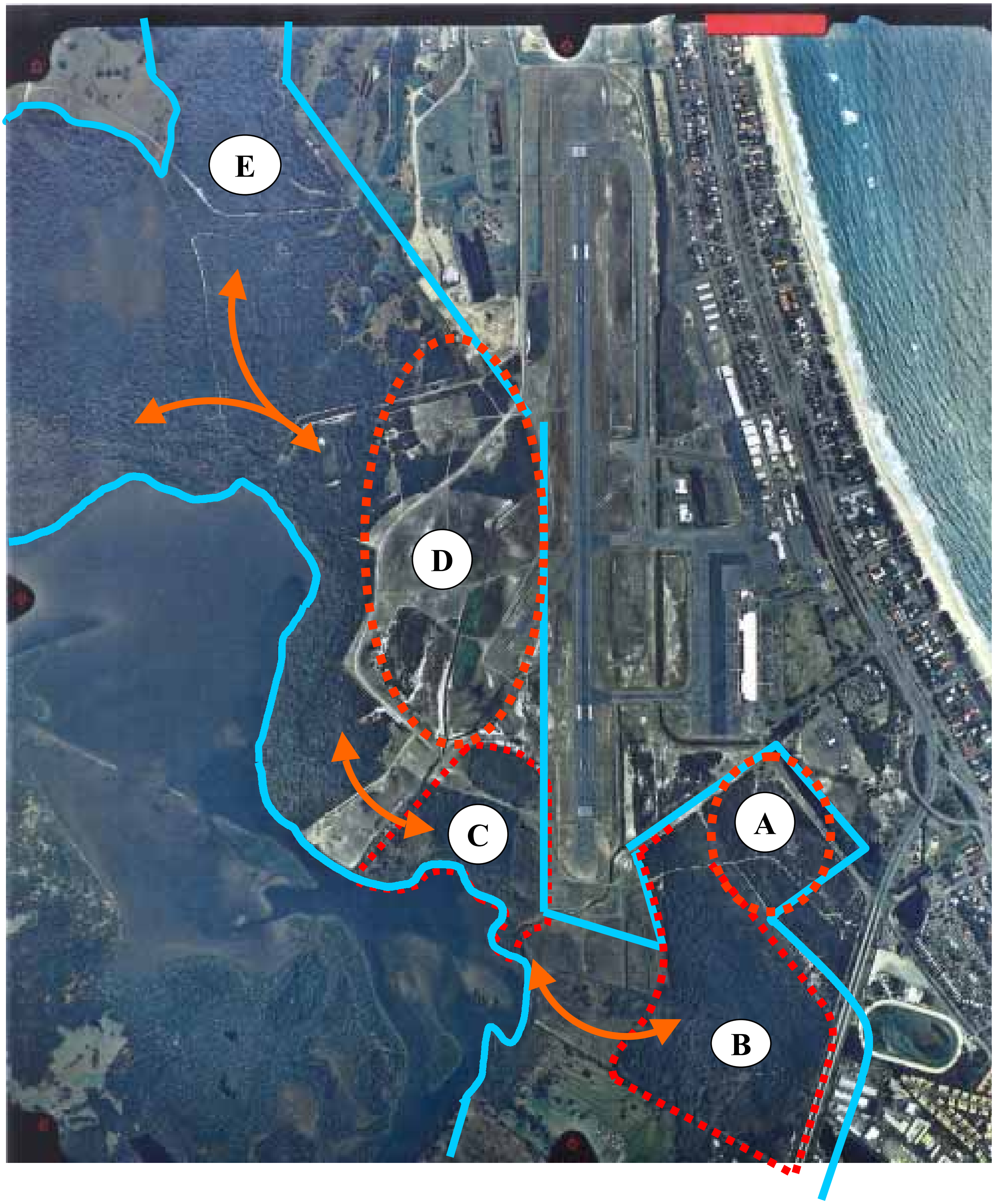


**Fig. 5. Constraints map. Significant habitat areas (dotted lines) referred to in the text are indicated. Blue line marks boundary of a proposed conservation area. Orange arrows indicate linkages necessary to allow for fauna movements and habitat continuity.**

Each of these areas are discussed in detail below:-

**Areas A and B: interchange construction at southern end of the transport corridor.**

The removal of native vegetation from survey precinct 5 will result in the loss of a large area of relatively undisturbed areas of "wallum" habitat. This area also includes Broad-leafed Paperbark (*Melaleuca quinquenervia*) forest, communities of Swamp Mahogany (*E. robusta*), scattered individuals and stands of Pink Bloodwood (*Corymbia intermedia*), Scribbly gum (*E. signata*) and associated areas of both wet and dry heathland. A significant stand of *Blechnum indicum*/*Banksia robur* wetland is also present.

The threats to the amphibian biodiversity hotspot will primarily arise from the draining and/or filling of the wetland in the construction of the rail link and roundabouts required connecting the by-pass to the existing highway. Habitat degradation constitutes a further threatening process where chemically suitable water bodies (low pH) occur in close proximity to roadworks and will potentially be affected by changes to the water table. Furthermore the proposed roadworks would isolate the frog hotspot from the surrounding vegetation that is likely to be important habitat for juveniles and non-breeding adults. In the absence of appropriate mitigation measures, mortalities from motor vehicles will also occur where populations are in close proximity to the proposed by-pass.

The above areas are also considered to provide foraging habitat for the threatened bat species *Pteropus alecto*, *Syconycteris australis*, *Myotis adversus*, *Nyctophilus bifax* and *Miniopterus australis*. The significance of habitat loss for these five species is difficult to quantify. For *P. alecto* at least, the removal of this vegetation is considered to constitute an immediate loss of important food resources, more so given the following:

a) the known importance of the above mentioned tree species in the diet of this species,
b) their relatively sedentary foraging patterns (Strahan 1995),
c) demonstrated use of these tree species in the study area over the course of the study to date, and
d) the close proximity of a known *P. alecto* camp in the Tweed Estuary Nature Reserve.

Additional to the loss of likely foraging habitat for *S. australis*, *M. adversus*, *N. bifax* and *M. australis* will be the loss of roosting opportunities.

**Area C: road construction towards the southern end of the transport corridor.**

Adoption of the preferred alignment for the proposed by-pass will destroy the pond that supports the only population of Wallum Sedge Frogs encountered in this study. Habitat degradation constitutes a further threatening process where chemically suitable water bodies (low pH) occur in close proximity to roadworks and will potentially be affected by changes to the water table. This particular area is known to also support a population of the *Planigale maculata*, noteworthy because it is also the only site within the transport corridor where this species has been recorded to date. As a consequence, and also because of the relatively small size of this forest patch, the resident *P. maculata* population is deemed to be threatened with localised extinction should roadworks occur in this area.

**Area D: fragmented heathland habitats surrounded by disturbed areas.**

This area contains numerous populations of the Wallum Froglet, *Crinia tinnula,* constituting perhaps the largest mainland populations for this species. Threats to these habitats will primarily arise from the draining and/or filling of the wetland in the construction of the road/rail link. Habitat degradation constitutes a further threatening process where chemically suitable water bodies (low pH) occur in close proximity to roadworks and will potentially be affected by changes to the water table. Furthermore the proposed roadworks would isolate populations on either side of the highway. In the absence of appropriate mitigation measures, mortalities from motor vehicles will also occur. Realigning the proposed highway to avoid remaining patches of heath habitats and constructing underpasses for frog fauna could mitigate some of these impacts.

**Area E: interchange construction at the northern end of the transport corridor.**

In NSW, the northern end of the transport corridor traverses an area formerly considered to support a population of the threatened species *Potorous tridactylus*. Notwithstanding the fact that the species was not recorded by the survey , the precautionary principle suggests a conservative approach should be adopted, more so given records for this species from the NSW Wildlife Atlas database that are located immediately to the south (within 1 - 2 km) of the transport corridor (see also Mason 1993). Thus it should be considered that roadworks towards the northern end of the transport corridor have the potential to directly impact upon this species due to loss of habitat in the first instance, followed by a clear threat to longer term population viability brought about by road mortalities in the absence of appropriate mitigation measures.

## Summary of Potential Impacts

Areas of native vegetation immediately adjacent to the transport corridor for the proposed Tugun by-pass support diverse communities of amphibians, reptiles and mammals. Twelve species are listed as 'Vulnerable' for the purposes of the NSW *Threatened Species Conservation Act 1995,* two of which are similarly listed for purposes of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

Construction of the proposed by-pass along its currently preferred route will result in

- direct impacts to populations of at least three 'Vulnerable' species - *Crinia tinnula*, *Litoria olongburensis* and *Planigale maculata* (species impact statements required)
- localised extinction of populations of two of these species - *Litoria olongburensis* and *Planigale maculata* (in the absence of appropriate mitigative measures).
- indirect impacts, primarily associated with the loss of food resources and roosting opportunities, are also forseen for *P. alecto, S. australis* and each of the three microchiropterans; *M. adversus*, *M. australis* and *N. bifax*. The longer term implications of the indirect impacts are difficult to predict with certainty but are considered significant.

## Legislative Implications.

Notwithstanding the potential for ameliorative measures (see below) to mitigate some of the preceding impacts, a consideration of issues in the context of section 5A of the NSW *Environmental Planning & Assessment Act* 1979 could only conclude that the extent of impacts upon threatened species known to occur in the area are sufficient to warrant a Species Impact Statement in accordance with Division 2 (Part 6) of the Act. Furthermore the potential impacts on the nationally listed Wallum Sedgefrog (*L. olongburensis*) population must be considered for referral under provisions of the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999.*

## Amelioration of Likely Impacts

Appropriate measures must be applied to conserve biodiversity values. The loss of foraging and/or roosting habitat for threatened mammals and amphibian species that are utilising the study area might best be ameliorated by the following:

a) a reappraisal of the location and/or configuration of the proposed southern interchange with a view to minimising habitat loss by re-siting the interchange to the area of highest disturbance (*ie* avoiding areas A, B & C in figure 5),

b) initiating and sponsoring the rapid rehabilitation of currently cleared areas located between the transport corridor and the Cobaki broadwater with a view to the medium and longer-term provision of suitable compensatory habitat (Figure 5),
c) provide alternative breeding habitat for the endangered Wallum Sedgefrog (*Litoria olongburensis*) adjacent to survey precinct 5, 6 & 8 by construction of artificial ponds,
d) creation of a wildlife corridor over the highway (*ie* extending the underground tunnel to the southeast) at the southern end of the bypass. The corridor would link important habitats on the eastern side at the southern end of the runway (Fig. 5 areas A & B) with less disturbed areas of "wallum" west of the runway(Fig. 5 area C),
e) in association with b) above, creation of a corridor linking the least disturbed areas of "wallum" habitat in the south-eastern corner of survey precinct 5 through the southern portion of survey precinct 9 to join up with survey precinct 6 (Fig. 2).

The immediate threat posed by road construction to the ongoing viability of the *L. olongburensis* and *P. maculata* populations at Site 6 are best ameliorated by a realignment of road and rail links to avoid this area. Additional protection will be provided by rehabilitation of survey precinct 8 and restoring a link between it and survey precinct 6. In this instance survey precinct 8 would act as a buffer to mitigate any potential impacts of road and rail construction on survey precinct 6.

The threats posed to the assumed population of *P. tridactylus* inhabiting the northern end of the transport corridor by construction of road and rail links might best be ameliorated by one or both of the following:
a) a minor realignment of the proposed road and rail links to the east to minimise disturbance and habitat loss in this area,
b) elevation of the road alignment through this area such that provision can be made for the installation of one or more road underpasses (Reinforced Concrete Box Culverts) of a size and design standard to be determined in accordance with perceived requirements for this particular species.

Subject to the need to make variable provisions for fauna movements (including larger mammals such as *W. bicolor* and *P. tridactylus*) towards the northern and southern ends of the transport corridor, fauna exclusion fencing will ultimately be required along the entire length of the proposed route.

## Additional Information to Complete a Species Impact Statement.

The proposed bypass is expected to cause localised extinction of known populations of two listed species - *Litoria olongburensis* and *Planigale maculata*, and fragmentation and localised extinction of sub-populations of the Wallum Froglet (*C. tinnula*). We recommend the following studies be undertaken to:
1) provide more information on the status of the populations of these species found in the area, and,
2) assess the potential ameliorative measures that can be applied to avoid the impacts of the bypass on these species.

Specifically we recommend the following,

for the Wallum Sedgefrog (*L. olongburensis*):
1. survey the known population to estimate the population size
2. initiate targeted surveys to detect additional populations if present
3. study the breeding habitat requirements of this species at this, other sites in the region, to quantify the pond characteristics necessary to construct artificial breeding sites in areas adjacent to the known population.

for the Wallum Froglet (*C. tinnula*):
1. examine the potential for movement of froglets between sub-populations in fragmented heath patches
2. investigate the potential for movement of froglets through highway underpasses

and, for the Planigale (*Planigale maculata*):
1. survey the known population to estimate the population size
2. initiate targeted surveys to detect additional populations if present.

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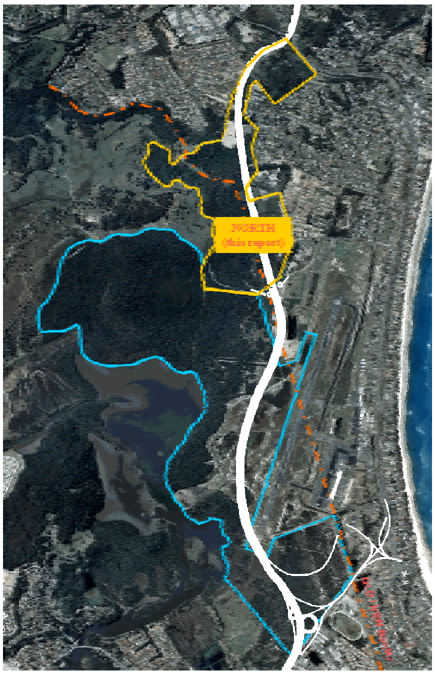
# Appendix D

*Survey for Reptiles, Amphibians and Mammals Inhabiting the Northern Section of the Proposed Tugun Bypass* (Hero *et al*. 2001a)

# Survey for Reptiles, Amphibians and Mammals inhabiting the northern section of the proposed Tugun by-pass.



# Final Report

**JEAN-MARC HERO [A], STEVE PHILLIPS [A, B] and LUKE SHOO [A]**

[A] *School of Environmental and Applied Sciences,*
*Griffith University Gold Coast, PMB 50 Gold Coast MC, Queensland 9726, Australia*
[B] *Biolink Pty. Ltd., PO Box 196 Uki NSW 2484*

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# CONTENTS

# EXECUTIVE SUMMARY

This report relates to the proposed Tugun bypass, a transport corridor which traverses the Queensland/NSW State border between Tweed Heads and Tugun. As a component of investigations related to an assessment of the potential environmental impact of road and rail construction in this area, a survey of reptile, amphibian and mammal communities inhabiting the northern section of the proposed route between Boyd Street (NSW) and the Stewart Road intersection (Qld) was undertaken between October 2000 and February 2001.

Survey methodology involved the use of standardised techniques for censusing vertebrate populations including the use of elliot traps, dry pitfalls, hair tubes, spotlighting, mist netting and bat detectors, visual and acoustic surveys. Faecal material from predators were also collected and analysed for the presence of identifiable fauna remains. Records from a variety of other sources augmented the fieldwork results.

A total of 19 species of amphibians, 29 species of reptiles and 34 species of mammals are either known or considered likely to occur in the study area on the basis of the survey results and database/literature records. However, the greater proportion of forested lands surveyed for this study exhibit varying degrees of disturbance and/or modification as a consequence of human activities; this consideration is likely to preclude the presence of several threatened species already known to occur along or in close proximity to the transport corridor. Paradoxically, a small area of sub-tropical rainforest in the study area is deemed to be of considerable scientific and conservation value because of the vertebrate fauna it supports.

Of the known species, the Long-nosed Potoroo *Potorous tridactylus* and the Wallum Froglet *Crinia tinnula* are currently listed as Vulnerable for purposes of both the NSW Government's *Threatened Species Conservation Act 1995* and the Queensland Government's *Nature Conservation (Wildlife) Regulation 1994*. The Potoroo is also listed as a Vulnerable species for purposes of the Commonwealth Government's *Environment Protection and Biodiversity Conservation Act 1999*. The habitat being utilised by both species will be impacted by the proposed alignment. In order to ameliorate such impacts, this report recommends that the alignment of road and rail links within the transport corridor between the Boyd Street extension and the southern flank of Woodgee Hill be re-evaluated for the purposes of maximising habitat retention. The need to maintain habitat links within the study area is also discussed. Establishment of a small working group to address issues associated with recovery and future management of threatened species such as *P. tridactylus, C. tinnula* and *L. olongburensis* along the proposed route is recommended.

# INTRODUCTION

A new transport corridor has been proposed (hereafter referred to as the Tugun by-pass) to accommodate road and rail links between Tugun Heights in Queensland and Tweed Heads, New South Wales [option C4, Route Selection Report: Connell Wagner (1999)]. The proposed deviation of the Pacific Highway is between the Stewart Road intersection (Qld.) and the northern end of the Kennedy Drive interchange (NSW). A rail corridor adjacent to the highway deviation is also proposed. The NSW section of the proposed by-pass has been declared a State Significant Development under the *Environmental Planning and Assessment Act 1979* .

The principle objective of the survey described herein was to obtain information on the presence and distribution of amphibians, reptiles and mammals within the general area of the northern section of the transport corridor. Of particular interest was the presence of fauna species currently listed as threatened (Endangered or Vulnerable) in the current schedules of the NSW Government's *Threatened Species Conservation Act 1995* (hereafter referred to as the TSC Act), the Commonwealth Government's *Environment Protection and Biodiversity Conservation Act 1999*, and the Queensland Government's *Nature Conservation (Wildlife) Regulation 1994*. Coupled with earlier work by *Hero et al*. (2000a), this study thus forms part of a formal environmental impact assessment being undertaken by PPK Environment and Infrastructure on behalf of the proponent, Queensland Department of Main Roads.

# STUDY AREA

The study area comprised a relatively small area of land located to the north of recent roadworks undertaken for purposes of the Cobaki Lakes residential development in NSW, and Stewart Road in Queensland (Fig.1). Within this area Woodgee Hill (99m asl) constitutes an extreme outlier of the McPherson Range, to which it is connected by small, linear strip of forest to the south-west. For the most part, the area is bounded by residential environments of Tugun Heights and Currumbin Waters to the east and west respectively. Vegetation communities of the study area comprise a small area of lowland sub-tropical rainforest, dry sclerophyll forest and heathland/swamp-forest communities.


**Fig. 1 Study area (blue boundary) showing location and alignment of the proposed Tugun bypass (C4 Option) as presented by Connell Wagner (1999).**

# METHODOLOGY

For broader censusing purposes, the study area was divided into four survey 'precincts'. The boundaries of these precincts, along with locations for each of the primary field sites detailed below, are shown in Fig 2.

## a) Primary Field Sites

Four primary field sites considered representative of vegetation communities in the study area were sampled. Two sites were located in dry sclerophyll communities variously dominated by Blackbutt *Eucalyptus pilularis*, Grey Gum *E. propinqua*, Northern Grey Ironbark *E. siderophloia*, Tallowwood *E. microcorys*, Spotted Gum *Corymbia maculata* and Brush Box *Lophostemon confertus*. The remaining two comprised a small area of wet heath/lowland swamp forest variously dominated by Swamp Mahogany *E. robusta*, Red Mahogany *E. resinifera* and Broad-leaved Paperbark *Melaleuca quinquenervia* with localised occurences of Scribbly Gum *E. signata*; and a small area of lowland sub-tropical rainforest, the central feature of which is a Bangalow Palm forest located on the drainage line on the northern side of Woodgee Hill. Field sampling was undertaken between October 2000 and February 2001 with peak sampling activities timed to coincide with periods of minimal lunar illumination (mammals), rain events (amphibians) and other temporal and/or climatological considerations.

Each primary field site was subjected to the following sampling strategy:
Linear transects comprising 25 Type A Elliot traps placed approximately 10 - 15m apart were established, each trap baited with a mixture of rolled oats, peanut butter and honey. In close proximity, a dry pitfall line consisting of 5 x 20 litre plastic buckets located approximately 5 - 6m apart and connected by a 300mm high polythene dampcourse drift fence was also established. Elliot traps and pitfall lines were maintained for four consecutive nights. Additionally, three linear transects comprising a series of six hair tubes (opening size 100mm x 80mm) located approximately 20 - 25 metres apart were placed close to established trap lines at three sites (Fig. 3). Hair tubes were baited with a mixture of rolled oats, peanut butter, honey and pistachio essence, and were left in the field for a minimum of 10 nights. A summary of the survey effort is presented below (Table 1).


**Fig. 2 Survey precincts (dotted lines) within the study area. Numbers correspond to survey sites mentioned in the text (Tables 2-4). Numbers 1-4 also detail specific locations of primary field sites established for the purposes of the field survey.**

**Table 1.** Summary of survey methods and effort used to detect fauna in this study

| Taxon/methods | Nocturnal search | Diurnal search | Pitfall trap | Elliot trap (type A) | Hair-tube trap | Cage trap | Spotlight | Predator scat search | Spot assess-ment | Mist net | Anabat |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amphibians | √ | √ | √ | | | | | | | | |
| Reptiles | √ | √ | √ | | | | | | | | |
| Terrestrial & arboreal mammals | | | √ | √ | √ | √ | √ | √ | √ | | |
| Microchirpoterans | | | | | | | | | | √ | √ |
| Trap nights | | | 100 | 400 | 180 | 40 | | | | | |
| Search hours | 17.5 | 23.5 | | | | | 7.5 | | | 60mh | 6.45 |
| No. of assessments | | | | | | | | | 4 | | |

**i) Amphibians**

Diurnal and nocturnal foot-based visual and acoustic surveys were undertaken in all suitable habitats throughout the area, with effort intensified during periodic heavy rainfall events over the course of the study. Surveys included searches along roads and tracks in addition to intensive searches at ponds, swamps and watercourses. Playback methods were not considered suitable for detecting frog species found in coastal habitats. Search effort (in terms of time) was equally distributed throughout the study area for a total of approximately 41 person hours.

**ii) Reptiles**

Diurnal and nocturnal foot based visual surveys were undertaken in all habitat types throughout the study area. Surveys included searches along roads and tracks in addition to intensive searches around potential shelter sites. Search effort (in terms of time) was equally distributed throughout the study area for a total of approximately 41 person hours .

**iii) Terrestrial and Arboreal Mammals**

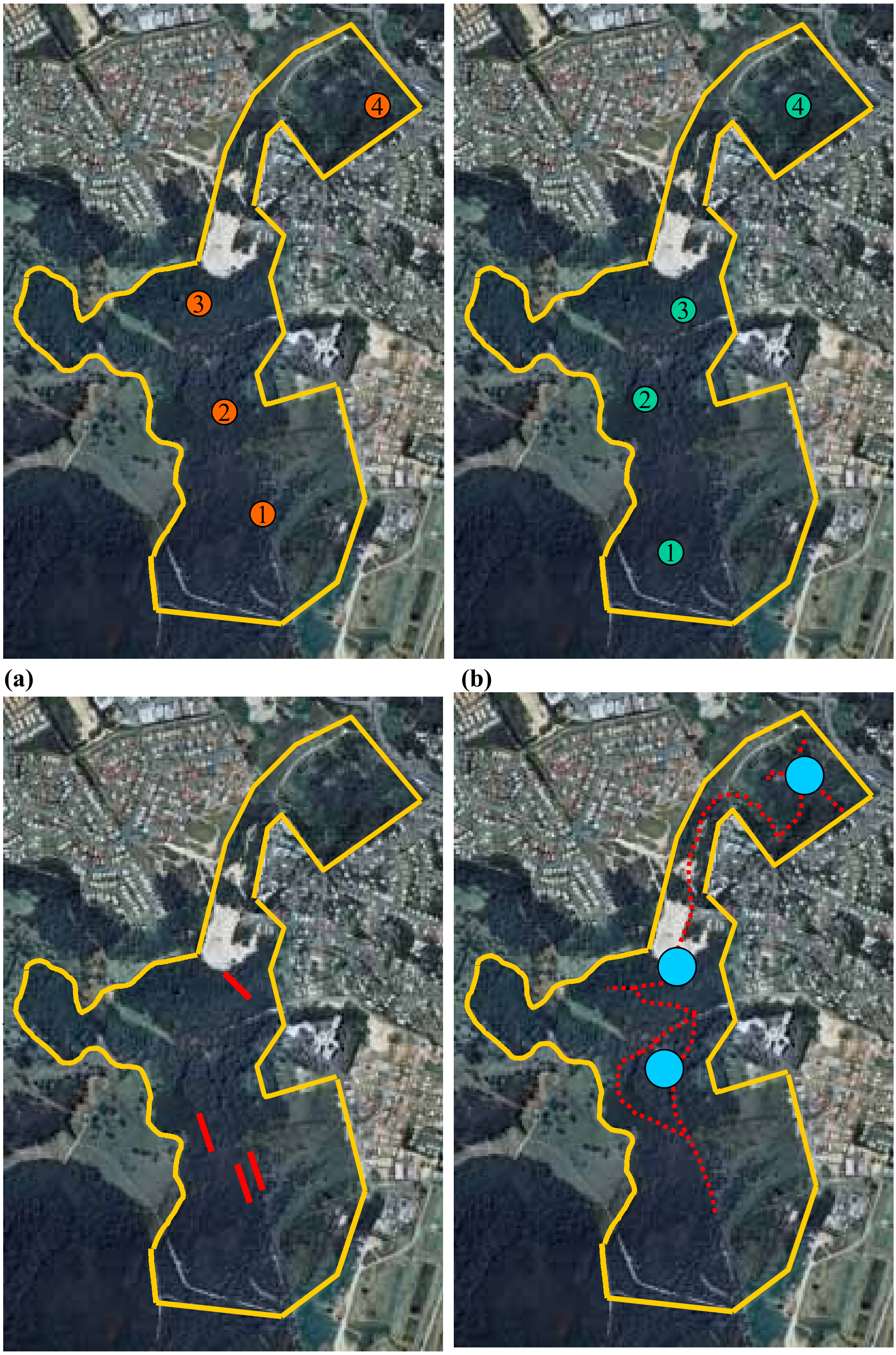
Opportunistic observations of both native and introduced mammal species (including the presence of diagnostic faecal material) were recorded throughout the survey.

Spotlighting

Spotlighting for arboreal mammals was undertaken on foot using a hand-held 100w spotlight. Each of the survey precincts were dissected by numerous vehicle and/or walking tracks which facilitated broad coverage during spotlighting sessions. Search effort (in terms of time) was equally distributed throughout the study area for a total of 7.5 hours.

**iv) Microchirpoterans**

Field censusing for microchiropteran bats primarily involved the use of bat detectors, with some mist netting (see below). An Anabat detector (Titley Electronics) was used to record calls using both stationary sampling stations and the 'walking detection' method described by de Oliveira (1998). Search effort (in terms of time) focussed on likely peak activity periods (2 - 3 hours after sunset) and was equally distributed throughout the study area (see Fig. 3). Six hours and forty five minutes of sampling time was accumulated. Tape analysis was undertaken by Dr. H. E. Parnaby. Harp Traps were not deployed given the lack of suitable locations and security issues associated with high levels of human use in most areas. This decision was assisted by the knowledge that a number of microchiropteran bat surveys had already been undertaken in the immediate area (see Parker 1999).



(a) (b)

(c) (d)

**Fig 3 (a-d). Location of various census points and other sampling traverses undertaken during the course of the survey [a - location of pitfall and small mammal traplines; b - location of Koala SPOT assessments; c - location of hair tube transects; d - location of  Anabat (blue circles) and spotlighting transects.**

**b) Supplementary Sampling**

Mistnetting

Two 20m mist nets (mesh size 20mm x 20mm) were deployed across the drainage line in the small pocket of sub-tropical rainforest below Woodgee Hill. Nets were unfurled shortly after dusk and monitored at 15min intervals for 1 ½ hours on each of two nights during December for a total of 60m/hrs of sampling.

Cage trapping

Cage trapping for Potoroos was undertaken in the area of wet heath/lowland swamp forest located between the Boyd Street extension and the base of Woodgee Hill following the tentative sighting of a Potoroo on 31st October. Ten cage traps were arranged in two lines of 5 traps approximately 25m apart on either side of the NSW/Qld border. Traps were baited with a mixture of rolled oats, peanut butter, honey and pistachio essence and were maintained for four consecutive nights.

Predator scats

Predator scats were also collected whenever they were encountered opportunistically. Scat (and hair tube) analysis was undertaken by Ms. Michiala Bowen.

Koala Spot Assessments

Four *post hoc* assessments using the approach of Phillips and Callaghan (1995) were undertaken in areas containing known food trees (Swamp Mahogany, Tallowwood and Grey Gum) in order to further sample for the presence of koalas. These assessments were generally preceded by a broader search for evidence of koala activity (faecal pellets, scratch marks) in the general area.

**c) Literature reviews and fauna database searches**

Survey work was augmented by examination and/or review of prior field studies in the area, including the related study by Hero *et al.* (2000a) and the Cobaki Lakes SIS (Parker 1999). Additionally, amphibian, reptile and mammal records covering an area of approximately 100km$^2$ surrounding the study area were obtained from the Qld. EPA "Wildnet" and NSW NPWS's "Wildlife Atlas" databases respectively. Queensland Museum (QM) records were also obtained.

# RESULTS

## a) Amphibians

The results of the survey program have established the presence of 13 species of amphibians within the study area (Table 2). Reliable records for an additional 6 native species in the general area of the transport corridor were obtained from related studies by Hero *et al.* (2000a), WBM Oceanics (1991), Parker (1999) and from Queensland Museum records.

One hundred (100) pitfall trap nights were completed. Three species of amphibians – the Cane Toad *B. marinus*, Striped-marsh Frog *Limnodynastes peronii* and Wallum Froglet *C. tinnula* were captured in pit fall traps. One species currently listed as 'Vulnerable' for the purposes of the *NSW Threatened Species Conservation Act 1995* and the Queensland *Nature Conservation (Wildlife) Regulation 1994* - *Crinia tinnula* was recorded during the survey. The species was recorded in both New South Wales and Queensland and was abundant throughout the lowlands of the study area.

## b) Reptiles

The results of the survey have confirmed the presence of 10 species of reptiles within the study area (Table 3). Three of these - *Rhinoplocephalus nigrescens*, *Lampropholis delicata* and *Saproscincus challengeri* - were collected by pit fall traps, the remainder obtained during diurnal and/or nocturnal searches. No threatened reptile species were detected during the course of the survey. Reliable records for an additional 19 native species in the general area of the transport corridor were obtained from the related study by Hero *et al.* (2000a) and as a consequence of "Wildnet" and Queensland Museum database searches.

**Table 2.** Amphibian species encountered either on or in close proximity to lands associated with the proposed Tugun by-pass (Site numbers refer to those detailed in Fig. 2). Note: table includes 6 additional species not encountered by the current survey but otherwise recorded by earlier surveys and data base and/or literature searches.

| Species/Site No. | 1 | 2 | 3 | 4 | QLD | NSW | EA |
|---|---|---|---|---|---|---|---|
| **Family: Bufonidae** | | | | | | | |
| *Bufo marinus** | O | | | T | | | |
| | | | | | | | |
| **Family: Hylidae** | | | | | | | |
| *Litoria caerulea* | W | | | | | | |
| *L. dentata* [3] | | | | | | | |
| *L. fallax* | O,W | | O,W | | | | |
| *L. freycineti* [2] | | | | | V | | |
| *L. gracilenta* | W | | | | | | |
| *L. nasuta* | W | | | | | | |
| *L. olongburensis* [3] | | | | | V | V | V |
| *L. peronii* | W | | O,W | | | | |
| *L. rubella*[3] | | | | | | | |
| *L. tyleri* | W | | O,W | | | | |
| | | | | | | | |
| **Family: Myobatrachidae** | | | | | | | |
| *Adelotus brevis* [1] | | | | | | | |
| *Crinia parinsignifera* | O,W | | | | | | |
| *C. signifera* | W | | W | | | | |
| *C. tinnula* | W | T | | | V | V | |
| *Limnodynastes ornatus* [3] | | | | | | | |
| *L. peronii* | T,W | T | T,W | T | | | |
| *L. terraereginae* | O,W | | | | | | |
| *Pseudophyrne raveni* | W | | | | | | |

**Table 2 Code:** T = trapped; O = observed; W = heard; * = introduced species; V = Vulnerable species for purposes of **NSW** *Threatened Species Conservation Act* 1995, **QLD** *Nature Conservation (Wildlife) Regulation 1994* and **EA** the Commonwealth = *Environment Protection & Biodiversity Act* 2000. [1 = Queensland Museum record; 2 = WBM Oceanics (1991); and 3 = Hero *et al.* (2000a)].

**Table 3.** Reptile species encountered either on or in close proximity to lands associated with the proposed Tugun by-pass (site numbers refer to those detailed in Fig. 2). Note: table includes 19 additional species not encountered by the current survey but otherwise recorded by earlier surveys and data base and/or literature searches.

| Species/Site No. | 1 | 2 | 3 | 4 | NSW |
|---|---|---|---|---|---|
| **Family: Agamidae** | | | | | |
| *Physignathus lesueurii* [3] | | | | | |
| *Pogona barbata* | | O | | O | |
| | | | | | |
| **Family: Boidae** | | | | | |
| *Morelia spilotes* [1] | | | | | |
| | | | | | |
| **Family: Colubridae** | | | | | |
| *Bioga irregularis* [1, 2] | | | | | |
| *Dendrelaphis punctulata* | | O | | | |
| *Tropidonophus mairii* [2] | | | | | |
| | | | | | |
| **Family: Elapidae** | | | | | |
| *Acanthophis antarcticus* [1, 2] | | | | | |
| *Cacophis harriettae* [1, 2] | | | | | V |
| *C. krefftii* [1, 2] | | | | | |
| *Demansia psammophis* [3] | | | | | |
| *Hemiaspis signata* | O | | | | |
| *Pseudonaja textilis* [2] | | | | | |
| *Rhinoplocephalus nigrescens* | | T | | | |
| *Tropidechis carinatus* [3] | | | | | |
| *Vermicella annulata* [2] | | | | | |
| | | | | | |
| **Family: Pygopodidae** | | | | | |
| *Lialis burtonis* [1, 2] | | | | | |
| *Pygopus lepidopodus*[3] | | | | | |
| | | | | | |
| **Family: Scincidae** | | | | | |
| *Anomalopus verreauxii* [4] | | | | | |
| *Cryptoblepharus virgatus* [3] | | | | | |
| *Ctenotus arcanus* [3] | | | | | |
| *C. robustus* [3] | | | | | |
| *Eulamprus martini* [4] | | | | | |
| *E. murrayi* | | | O | | |
| *Hemisphaeriodon gerrardii* | | O | | | |
| *Lampropholis delicata* | O,T | O | O | O,T | |
| *Saiphos equalis* | O | O | | | |
| *Saproscincus challengeri* | | | O,T | | |
| *Tiliqua scincoides* | | O | | | |
| | | | | | |
| **Family Varanidae** | | | | | |
| *Varanus varius* [3] | | | | | |

**Table 3 Code:** T = trapped; O = observed; V = Vulnerable species for purposes of NSW *Threatened Species Conservation Act* 1995; [1 = QEPA 'Wildnet' record; 2 = Queensland Museum record; 3 = Hero *et al*. (2000a); 4 = additional records for the southern section of the study area *post* Hero *et al*. (2000a)].

**c) Mammals**

The results of the survey have confirmed the presence of at least 14 species of native mammals within the study area (Table 4). Reliable records for an additional 20 native species in the general area of the transport corridor were obtained from the related study by Hero *et al.* (2000a), Parker (1999) and as a consequence of "Wildlife Atlas", "Wildnet" and Queensland Museum database searches.

Four hundred trap nights were completed. Four species of native small mammal - the Grassland Melomys *M. burtoni*, Bush Rat *R. fuscipes*, Eastern Swamp Rat *R. lutreolus* and Yellow-footed Antechinus *A. flavipes* were captured. Although restricted to only two survey precincts – and in contrast to the results from the related study by Hero *et al*. (2000a) – the Bush Rat was the most abundant ground-dwelling small mammal in the study area. Pit fall trapping (100 trap nights) resulted in the capture of two Common Planigales *P. maculata* at one site, thus providing a second locality record for this species as a consequence of this study.

Fourteen samples of mammalian hair were obtained from hair tubes, providing evidence of investigation by Swamp Wallaby *W. bicolor* (2), Long-nosed Potoroo *P. tridactylus* (2), House Mouse *M. domesticus* (1), *Rattus* sp.(4), Rodent sp. (2) and *Trichosurus* sp. (3). Analysis of predator scats revealed a diversity of prey items consistent with that recorded in the related study by Hero *et al*. (2000a).

Spotlighting results suggested both a low density and depauperate community of arboreal marsupials, with Sugar Gliders *Petaurus breviceps* and Short-eared Mountain Possums *Trichosurus caninus* being the only two species recorded. The absence of koala sightings is also a notable outcome from the spotlighting results which, coupled with no evidence of koala activity from the four SPOT assessments (Table 5), support the conclusion reached earlier by Hero *et al.* (2000a) that the study area no longer supports a resident koala population. Northern Brown Bandicoots *Isoodon macrourus*, Swamp Wallabies and Grey-headed Flying foxes *Pteropus poliocephalus* were also observed during spotlighting sessions. The Little Bent-winged Bat *Miniopteris australis* was the only species positively identified from Anabat call sequences recorded in the study area.

**Table 4.** Mammal species occurring either on or in close proximity to lands associated with the proposed Tugun by-pass (Site numbers refer to those detailed in Fig. 2). Note: table includes 20 additional species not encountered by the current survey but otherwise recorded by earlier surveys and data base and/or literature searches.

| Species/Site No. | 1 | 2 | 3 | 4 | NSW | QLD | COM |
|---|---|---|---|---|---|---|---|
| **Family: Canidae** | | | | | | | |
| Dog/Fox[#] | S | S | S | S | | | |
| **Family: Dasyuridae** | | | | | | | |
| *Antechinus flavipes* | T | T | | | | | |
| *Planigale maculata* | | | | T | * | | |
| *Sminthopsis murina* [1] | | | | | | | |
| **Family: Emballonuridae** | | | | | | | |
| *Saccolaimus flaviventris* [1,2,4] | | | | | * | | |
| **Family: Felidae** | | | | | | | |
| *Felis catus*[#] | | | | | | | |
| **Family: Leporidae** | | | | | | | |
| *Lepus capensis*[#] | | O | | | | | |
| *Oryctolagus cuniculus*[#] | | | | | | | |
| **Family: Macropodidae** | | | | | | | |
| *Wallabia bicolor* | O,H | O,H | O | O | | | |
| *Macropus rufogrisea* [2] | | | | | | | |
| **Family: Molossidae** | | | | | | | |
| *Nyctinomus australis* [2, 3,4] | | | | | | | |
| *Mormopterus* sp.[4] | | | | | | | |
| **Family: Muridae** | | | | | | | |
| *Hydromys chrysogaster* [5] | | | | | | | |
| *Melomys burtoni* | T | T | | | | | |
| *Mus domesticus*[#] | | T,H | | | | | |
| *Rattus fuscipes* | | T | T | | | | |
| *R. lutreolus* | T | | | | | | |
| *R. rattus*[#] | T | | | | | | |
| **Family: Peramelidae** | | | | | | | |
| *Isoodon macrourus* | | | O | | | | |
| *Perameles nasuta* [5] | | | | | | | |
| **Family: Petauridae** | | | | | | | |
| *Petaurus breviceps* | O | O | | O | | | |
| *P. norfolcensis* [5] | | | | | * | | |
| *Petauroides volans* [4] | | | | | | | |
| **Family: Phalangeridae** | | | | | | | |
| *Trichosurus caninus* | H | O,H | H | | | | |
| **Family: Phascolarctidae** | | | | | | | |
| *Phascolarctos cinereus* [1,2, 3] | | | | | * | | |
| **Family: Potoroidae** | | | | | | | |
| *Potorous tridactylus* | O,H | | | | * | * | * |
| **Family: Pteropodidae** | | | | | | | |
| *Pteropus alecto* [5] | | | | | * | | |
| *P. poliocephalus* | | | O | O | * | | |
| *Syconycteris australis* [5] | | | | | * | | |
| **Family: Tachyglossidae** | | | | | | | |
| *Tachyglossus aculeatus* [5] | | | | | | | |
| **Family: Vespertilionidae** | | | | | | | |
| *Chalinolobus morio* [5] | | | | | | | |
| *Miniopteris australis* | | A | A | A | * | | |
| *Myotis adversus* [5] | | | | | * | | |
| *Nyctophilus bifax* [5] | | | | | * | | |

*Continued →*

**Table 4 (cont).** Mammal species occurring either on or in close proximity to lands associated with the proposed Tugun by-pass (Site numbers refer to those detailed in Fig. 2).

| Species/Site No. | 1 | 2 | 3 | 4 | NSW | QLD | COM |
|---|---|---|---|---|---|---|---|
| *N. gouldii* [5] | | | | | | | |
| *Scotorepens orion* [5] | | | | | | | |
| *S.* sp1 [1] | | | | | | | |
| *Vespedalus pumilus* [5] | | | | | | | |

**Table 4 Code:** T = trapped; O = observed; S = scat; P = predator scat; A = Anabat; H = hair tube; # = introduced species; * = Vulnerable species for purposes of *Threatened Species Conservation Act* 1995 (NSW) and/or Qld *Nature Conservation (Wildlife) Regulation 1994* (Qld.) and/or the Commonwealth Governments = *Environment Protection & Biodiversity Act* 2000 [1 = NPWS 'Wildlife Atlas' record; 2 = QEPA 'Wildnet' record; 3 = Queensland Museum record; 4 = Parker (1999); 5 = Hero *et al.* (2000a)].

**Table 5.** Results of four SAT plots from areas of suitable koala habitat within the study area. Numbers indicate the number of live stems of known food tree species sampled at each location (Erob = *E. robusta*; Emic = *E. microcorys*; Epro = *E. propinqua*); non food trees are listed as "Misc.". Note that no evidence of koala activity was detected.

| SPOT No. | Easting | Northing | Erob | Emic | Epro | Misc. |
|---|---|---|---|---|---|---|
| **8** | $^{5}48125$ | $^{68}84871$ | 7 | - | - | 18 |
| **9** | $^{5}47639$ | $^{68}84889$ | - | 8 | 11 | 6 |
| **10** | $^{5}47596$ | $^{68}85323$ | - | 3 | 1 | 21 |
| **11** | $^{5}47257$ | $^{68}86106$ | - | - | 6 | 19 |
| **Total No.** | | | **7** | **11** | **18** | **64** |

**DISCUSSION**

The survey results suggest that the study area has a generally lower diversity of vertebrate fauna than that reported in the related study of lands to the south by Hero *et al*. (2000a). There are several possible reasons for this:

Parts of the study area have been extensively disturbed by human activities. Survey precincts 3 and 4 in particular, are extensively dissected by tracks which are utilised on a regular basis for trail bike riding and other human related activities. The proximity of urban environments further predisposes these areas to predation by domestic animals such as dogs and cats. There is also a paucity of hollow bearing trees, indicating a measure of historical disturbance for either logging or agriculture.

Notwithstanding these considerations, a number of issues are forthcoming:

The area of dry sclerophyll forest on the southern flank of Woodgee Hill (precinct 2) constitutes an important link between the coastal lowland communities to the south and elevated portions of the McPherson Range to the north-west (Fig. 4). Though degraded, the longer-term role of this area as wildlife habitat, both in terms of its ability to support wildlife populations and to facilitate the movement of species from coastal lowlands to more elevated portions of the McPherson Range should not be understated. It should also be noted that one Wallum Froglet was caught in a pitfall trap on the ridge at least one hundred metres from the nearest calling site in the lowland swamp to the south (precinct 1).

The area of lowland sub-tropical rainforest (precinct 3) represents an extreme eastern outlier of potential bio-geographic importance, evidenced by the presence of relic populations of species such as *Saproscincus challengeri*, *Eulamprus murrayi*, and – to a lesser extent - the resident population of Bush Rats. While none of these species are formally listed as threatened, their presence in this area is of interest because of its potential further assist an understanding of evolutionary and biogeographic processes in eastern Australia. From this perspective, the site should be recognised as one of national importance. During the course of the survey, this area was also being utilised as a day-time camp by a small group (15 – 20 individuals) of Grey-headed Flying-foxes, a species recently listed on a provisional basis for purposes of the NSW TSC Act.

**Fig. 4 Linkages necessary to allow fauna movements and habitat continuity.**

Though degraded, the northern ridge (precinct 4) is noteworthy as it supports a population of the Common Planigale (listed as Vulnerable in NSW*)*. While the distribution and abundance of Common Planigales in the local area is difficult to ascertain with confidence, surveys within the study area (Parker 1999) and related areas to the south (Hero *et al*. 2000a) support a conclusion of local rarity and population patchiness.

**Threatened Species**

Two of the wildlife species recorded during the survey are currently listed as threatened in accord with NSW, Qld. and – in one instance –Commonwealth legislation. These are discussed in more detail below. Details relating to other threatened species known to occur along the proposed route of the by-pass are contained in the related study by Hero *et al*. (2000a).

**1. Wallum Froglet (*Crinia tinnula*)**

The Wallum Froglet (*Crinia tinnula*) is currently listed as 'Vulnerable' for the purposes of the NSW Government's *Threatened Species Conservation Act 1995* and the Queensland Government's *Nature Conservation (Wildlife) Regulation 1994*. Furthermore, this species was proposed for listing in February 2001 as "Vulnerable" for the purposes of both the IUCN Red List of Threatened Species™ and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (J.-M. Hero pers. comm.).

The Wallum Froglet belongs to a group known as the "wallum" or "acid" frogs as they are generally restricted to low nutrient soils associated with acidic waters (pH less than 5) of the coastal lowlands and sand islands in south-eastern Queensland and northern New South Wales, with mainland populations at high risk from continuing loss of habitat through clearing for agriculture, pine plantations, housing and infrastructure such as canal developments, drainage projects and transport corridors (Hines *et al*. 1999, Hero *et al*. 2000b). The Wallum froglet is described as being "…restricted to acid paperbark swamps in the Wallum country" (Robinson, 1993) but has also been recorded in coastal open woodland with heath understory (Hero *et al*. 2000b). The nearest records of *C. tinnula* populations are 30-40 km south in the Pottsville - Hastings Point area (Phillips *et al*. 1995) and 25 km to the north at Southport (Hero *et al.* 2000b).

The potential for localised extinction of Wallum Froglet populations due to habitat loss and/or fragmentation is a particular concern arising from this study. Furthermore, protection of the water quality and the maintenance of appropriate pH levels is critical to the survival of these species (Hero *et al*. 2000b, E. Meyer unpub. data). *Crinia tinnula* breed in lentic waters < 1.5m deep within the pH range 3.0 - 5.2 (E. Meyer unpub. data). The Beeping Froglet (*C. parinsignifera*) replaces *C. tinnula* at sites with waters of pH 5.0 and above (E. Meyer unpub. data). At other sites where *C. tinnula* and *C. parinsignifera* occur together (Karawatha Forest, Capalaba and Caboolture) *C. tinnula* are found in areas of low pH, while *C. parinsignifera* occur in adjacent waterbodies with higher pH (E. Meyer unpub. data). It should be noted that nothing is known about the movement patterns, home range or population dynamics of this “wallum” frog species.

In this study Wallum Froglets were recorded throughout the drainage lines that run through precincts 1 and 2 (Woodgee Hill - Table **2**). Populations appear to be spread throughout this drainage and extend into the larger populations in NSW south of the Boyd Street interchange. As there is some evidence, based on work on other *Crinia* species, that fidelity to breeding sites is maintained the importance of maintaining the connection between these populations may be critical for the long term survival of these populations. The small size of this species does not suggest extensive movement and, because of this, it must be assumed that most populations are distinct (although some migration is expected between them). Calling males were encountered throughout the heath vegetation in the central drainage, water depths usually less than 0.5m. Water pH ranged from 3.84 – 5.18 falling within the range reported for this species (see above). Changes to the hydrology of the swamp area that will increase water pH is likely to have a negative impact on the survival and persistence of *C. tinnula* populations in the area.

The population of *Crinia tinnula* is spread throughout the entire Tugun study area and is of considerable size (estimated to be in excess of 10,000 individuals). As such this is the largest known population south of Brisbane - and the second largest mainland population (after Cooloola N. P.).

Participants at a recent IUCN Threatened Frog Workshop (February 2001) felt that due to the difficulty in assessing populations more objective measures were needed to assess frog species under the EPBC Act. It was suggested that the sixth criteria in the Administrative Guidelines, referring to availability and quality of habitat, was best suited to this and have drafted the following 'rule':

*An action has, will have or is likely to have a significant impact on a vulnerable species if it does, will or is likely to modify, destroy, remove, isolate or decrease the known occupied habitat of a vulnerable frog species by 0.5% or more.*

For frogs, the known occupied habitat should be considered to be the area of occupancy for each species as specified in the IUCN Red List of Threatened Species™ criterion (Hilton-Taylor 2000). Using this guideline the population of Wallum Froglets found along the proposed Tugun bypass represents a substantial part of the mainland populations (>0.5%) and should be considered as an "important population" and hence nationally significant under the EPBC Act.

2. **Long-nosed Potoroo (*Potorous tridactylus*)**

The Long-nosed Potoroo has a patchy and extremely localised distribution along the east coast of Australia from south-eastern Queensland to Victoria and Tasmania. Preferred habitat for the species appears to be areas of coastal heathlands and both dry and wet sclerophyll forests; a major habitat requirement is relatively thick groundcover (Strahan, 1995; Mason 1997).

Prior to this study, a single Potoroo record for the study area was obtained from the NSW NPWS 'Wildlife Atlas' database and the species has a history of controversy towards the northern end of the transport corridor (IPTP 1992; Mason 1993; MPS 1993). The persistence of what appears to be a small and localised population has been confirmed however, with two sightings (1 tentative, the other positive) made during the course of the current survey from an area straddling the NSW/Qld border between the access road to the Cobaki Lakes development site and the southern flank of Woodgee Hill. The species was also recorded from hair tube samples from the same area. Potoroos have also been recorded by Milledge (1988) within the now Cudgen Nature Reserve to the south and have been the subject of a detailed population study at Tyagarah Nature Reserve in the Byron Shire (Mason 1997). In Queensland, Potoroos are poorly known and restricted in their distribution to the extreme south-eastern corner of the state.

Major threats to Potoroos arise from habitat destruction, fragmentation and modification, the latter primarily as a result of excessive fire regimes in areas of otherwise suitable habitat. Motor vehicle fatalities and predation by domestic and feral animals such as dogs and foxes are also known. The persistence of this small population considerably enhances the conservation value of Survey precincts 1 and 2; the population is perceived to be disjunct and at the extreme northern limit of its distribution in NSW, and at the extreme southern limit of its distribution in Queensland where it is also listed as a threatened species. Given its further status as a threatened species for purposes of the Commonwealth's *EPBC Act 1999*, the area of habitat currently being utilised by the population should be considered as one of national importance, more so because it represents one of the few remaining coastal populations. It should also be recognised that much of the area to the south (Hero *et al*., 2000a) supports habitat that is potentially suitable for Potoroos. With diligent care and an appropriate management regime – this population could, theoretically at least, be successfully managed and recovered to more viable population levels.

## Preliminary Assessment of Likely Impacts

### General

Considered in the context of the earlier study by Hero *et al*. (2000a), the results of this survey contribute further to a notion that the area proposed to be traversed by the refined C4 alignment has considerable conservation value. Figure 4 outlines the linkages believed to be necessary to allow fauna movements and habitat continuity that will facilitate the preservation and maintenance of biodiversity in the area.

Construction of the by-pass along the currently preferred alignment from the Boyd Street extension north will result in impacts upon a number of key habitats in the area. Our concerns with regard to threatened species and the maintenance of biodiversity in general are presented in the form of two key areas which, ideally, should be protected from further disturbance.

Area A (Precinct 1) – coastal lowlands to the south of Woodgee Hill which provide habitat for the Long-nosed Potoroo and the Wallum Froglet.
Area B (Precinct 3) – sub-tropical rainforest community occupying northern slopes of Woodgee Hill and associated drainage line.

Alignment of the bypass as currently proposed will result in the loss of habitat considered essential to buffering the remaining Potoroo and Wallum Froglet habitat within survey precincts 1 and 2. Encroachment of the proposed bypass into this already narrow corridor of vegetation is likely to heighten the potential for negative impact on both these species. Edge effects from the Cobaki Lakes development to the west and the Pacific Beach residential development to the east, along with threats arising from the now fragmented nature of the habitat (Boyd Street to the south) will be exacerbated by any further disturbances in close proximity to precincts 1 and 2. Direct threats arise from habitat removal and the draining and/or filling of wetlands, and – in the case of the Wallum Froglet - especially those with chemically suitable breeding sites (water bodies with low pH) and their associated vegetation. Habitat degradation constitutes a further threatening process because chemically suitable water bodies occur in close proximity which will potentially affected by changes to the water table. In the absence of appropriate mitigation measures, mortalities from motor vehicles will also occur because populations of both species occur in close proximity to the proposed highway.

As mentioned earlier, the sub-tropical rainforest remnant represents an extreme eastern outlier of biogeographical importance. This habitat should be protected from further disturbances arising from the Tugun by-pass proposal and indeed, any other activity with the potential to result in a negative impact. The extent of buffering vegetation should be maximised and the drainage line protected from sedimentation arising from erosion. Given the lack of connecting habitat of this type, the long term persistence of viable populations of species such as *S. challengeri* will be singularly dependent on effective management and protection of this important rainforest remnant.

## Summary of Potential Impacts

In the northern section, areas of native vegetation immediately adjacent to the transport corridor for the proposed Tugun by-pass support diverse communities of amphibians, reptiles and mammals.

Construction of the proposed by-pass along its currently preferred route will result in

- direct impacts to populations of the 'Vulnerable' Wallum Froglet,
- direct impacts to habitat buffering and/or being utilised by a State and Nationally listed Long-nosed Potoroo, the consequences of which in association with other factors, may lead to localised extinction of the population - in the absence of an assertive management and recovery program.

## Legislative Implications.

Notwithstanding the potential for ameliorative measures (see below) to mitigate some of the preceding impacts, a consideration of issues in the context of section 5A of the NSW *Environmental Planning & Assessment Act* 1979 could only conclude that the extent of impacts upon threatened species known to occur in the area are sufficient to warrant a Species Impact Statement in accordance with Division 2 (Part 6) of the Act. Furthermore, the potential impacts on the Potoroo and the recent nomination of the Wallum Froglet as "Vulnerable" under provisions of the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* should also be considered.

## Amelioration of Likely Impacts

In addition to the direct impacts of habitat destruction, the resulting highway will isolate and fragment existing populations of threatened species. Indeed, circumstances surrounding the identification of Long-nosed Potoroo habitat for the purposes of ameliorating impacts associated with the proposed Tugun by-pass highlight a key issue associated with threatened species management in Australia. The removal of a small area of arguably peripheral Potoroo habitat required for road construction in this instance does not in itself appear a major threat. However, the action must be assessed in the context of recent developments in the area, each of which has been singularly adopted and/or approved with little regard for cumulative impact; a circumstance directly analogous to Stankey's (1985) '*tyranny of small decisions*'. From the perspective of Potoroos at least, assertive planning and associated actions which might reverse the otherwise predictable outcome from this history of poor decision making would be most desirable. Because of this and with regard to issues arising from the the earlier work by Hero *et al*. (2000), we propose the establishment and sponsorship of a Threatened species Management/Recovery Working Group as a key ameliorative measure arising from a consideration of impacts associated with the by-pass proposal. The primary task of this group will be to ensure the recovery and long-term survival of species such as the Long-nosed Potoroo, Common Planigale (NSW), Wallum Froglet and Wallum Sedge Frog, based on the simple premise that, at any point in time, there must be no demonstrable nett loss of individuals and/or populations of threatened species arising from activities associated with construction of the Tugun by-pass. In order to achieve a meaningful outcome, the working group should ideally be comprised of representatives from State and National Conservation Agencies, Gold Coast Airport Limited, relevant landholders and the scientific community.

Subject to the formation of this working group we propose the following ameliorative measures for consideration:

1. Threats posed by construction of road and rail links to the population of Wallum Froglets inhabiting the northern end of the transport corridor might best be ameliorated by the following:

a) realignment of the proposed road and rail links to the east by re-siting the road onto the cleared land east of the existing "wallum" swamp in order to minimise disturbance and habitat loss in Survey precinct 1,

b) construction and maintenance of a frog exclusion fence along the western edge of the highway from the dry ridge on the northern end to the Boyd street interchange,

c) creation of frog corridors under the western side of the Boyd Street interchange to link the populations north and south of the interchange,

d) creation of frog corridors under the highway at several locations south of the Boyd street interchange to link important habitats on the eastern side at the southern end of the runway with less disturbed areas of “wallum” west of the runway (see also Hero *et al*. 2000a). It should be noted that these "frog corridors" should simultaneously act as barriers to large mammals (*i.e.* potoroos and wallabies) that should be excluded from the restricted airport management lands east of the runway,

e) construction and maintenance of frog exclusion fences along the eastern and western sides of the highway south of the Boyd street interchange.

2. Threats posed to the population of Long-nosed Potoroos inhabiting the northern end of the transport corridor by construction of road and rail links might best be ameliorated by the following:

a) as detailed above, a maximal realignment of the proposed road and rail links to the east to minimise disturbance and habitat loss in the area of Survey precincts 1 and 2,

b) making specific provision for Long-nosed Potoroo movements between the northern and southern ends of the transport corridor as part of a review of ameliorative measures currently proposed to cater for this species as a consequence of the adjoining Cobaki Lakes development and associated Boyd Street extension (we note that destruction of Potoroo habitat will also be required for purposes of constructing the proposed Boyd Street overpass). Potoroo movement will be best facilitated by a combination of wildlife exclusion fencing and the strategic placement of underpasses, the latter to adopt the following minimum spacing and dimensions:

1. where distance of under-road traverse is less than 35m – min 2.1m x 1.5m RCBCs at 50m intervals,
2. where distance of under-road traverse is greater than 35m but less than 65m – min 3.0m x 3.0m RCBCs at 75m intervals, and
3. where distance of under-road traverse is greater than 65m but less than 85m – min 4.2m x 3.6m RCBCs at 50m intervals.

Further measures associated with meaningful management of the Potoroo population will also require development of effective monitoring, predator control and fire management strategies if the resident population is to be effectively recovered.

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# Appendix E

*Supplementary Surveys of Common Planigales, Eastern Long-eared Bat and Wallum Sedge Frogs within the Proposed Tugun Bypass* (Hero *et al.* 2001b)

# Supplementary Surveys of Planigales, Eastern Long-eared Bat and Wallum Sedge Frogs within the proposed Tugun By-pass.

**Jean-Marc Hero, Steve Phillips and Luke Shoo**

School of Environmental and Applied Sciences, Griffith University Gold Coast
PMB 50, Gold Coast MC, Queensland 9726 Australia.

## Attached are 2 separate reports:

1. **Surveys of the Wallum Sedge Frog inhabiting coastal lowland areas associated with the proposed Tugun by-pass.**

2. **Supplementary studies associated with the proposed Tugun by-pass**

   **I – Additional elliot trapping and hair-tube sampling**

   **II – Eastern Long-eared Bat *Nyctophilus bifax***

   **III – Common Planigale *Planigale maculata***

## Final Reports

## June 2001

***Revised* 21 August, 2001**

# Surveys of the Wallum Sedge Frog

# inhabiting coastal lowland areas

# associated with the proposed Tugun by-pass

**Jean-Marc Hero, Luke Shoo and Steve Phillips**

School of Environmental and Applied Sciences, Griffith University Gold Coast

PMB 50, Gold Coast MC, Queensland 9726 Australia.

## Final Report

## 22 May 2001

## *Revised* 21 August, 2001 & 15 November 2001

## 1.0 Summary

Supplementary surveys have contributed to understanding the distribution and abundance of the **Wallum Sedge-frog** (*L. olongburensis*) within the proposed Tugun by-pass corridor. Six localities are known to be occupied by the species however population estimates at these sites are indicative only and restricted to the maximum number of individuals recorded during a single survey. The small numbers of individuals recorded suggest these sub-populations (frogs at each pond site) are connected, and collectively they form a single metapopulation. These sub-populations exchange migrants and are subject to local extinction and recolonization. Connectivity and hence the long-term survival of this metapopulation may be threatened by the proposed by-pass. A number of ameliorative measures are proposed to reduce the likely impacts if the by-pass proceeds.

## 2.0 Introduction

The Wallum Sedgefrog (*Litoria olongburensis*) is currently listed as vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, Queensland *Nature Conservation (Wildlife) Regulation 1994* and New South Wales *Threatened Species Conservation Act* 1995. *Litoria olongburensis* occurs along coastal south-eastern Queensland and north-eastern New South Wales and is distributed from Fraser Island south to Woolgoolga near Coffs Harbour (Liem & Ingram 1977, Hines *et al*. 1999). *Litoria olongburensis* inhabits coastal lowlands and sand islands where there are low nutrient soils or deep sands (Hines *et al*. 1999). Vegetation types typical of these environments include heathland, Melaleuca swamp, sedgeland and Banksia woodland (Hines *et al*. 1999). It occurs in low pH waters characteristic of wallum environments, along flowing creeks, in marshy or swampy habitats (usually temporary or semi-permanent) and their connecting channels, and coastal freshwater lakes, including perched lakes with deep water (often permanent) (Liem & Ingram 1977; James 1996; Ehmann 1997). The species is often found amongst emergent vegetation and reeds (Liem & Ingram 1977; Emnann 1997). Ingram and Corben (1975) termed *L. olongburensis*, along with *L. cooloolensis*, *L. freycineti* and *Crinia tinnula*, an 'acid' frog as this species is confined to sandy heaths and their acidic water. Non breeding habitat is not known.

Hero *et al.* (2000) recorded the species from two locations within an area of coastal lowland north of Cobaki Broadwater at Coolangatta, north-eastern NSW, between January and March 2000. The first record pertained to an aggregation of calling male **Wallum Sedge-frogs** in a pond adjacent to a forest fragment, survey precinct 6 (Hero *et al.* 2000) (Fig. 1 pond site 1). Consistent with observations of Liem and Ingram (1977), individuals were scattered amongst emergent vegetation in low pH water (ranged between 3.84-3.91). Another ‘acid’ frog, *Crinia tinnula*, was also recorded in the immediate area but was noticeably more widespread and not restricted to deeper water of the **Wallum Sedge-frog** pond. The second record related to a single call sequence heard during daylight hours in January 2000 from an ephemeral swamp, survey precinct 5 (Hero *et al.* 2000) (Fig. 1 pond site 2). Further attempts to locate the species at this location were unsuccessful. Large choruses of *L. fallax* had subsequently been recorded without detecting *L. olongburensis*. The single individual recorded at the site was not thought to be indicative of a population of this species; furthermore the high pH (5.18), limited hydroperiod of the waterbody (time that the pond contains water), and the presence of *L. fallax* in large numbers supported this conclusion.

In order to better understand the distribution and population size of **Wallum Sedge-frogs** within the coastal lowlands of the study area, and hence develop a better understanding of impacts associated with the proposed Tugun by-pass, supplementary surveys were undertaken for the species. This included (a) systematic surveys to estimate the likely population size of **Wallum Sedge-frogs** at the known pond location (pond site 1) and (b) additional surveys throughout adjacent areas to detect additional populations of the species. Two additional sub-populations of **Wallum Sedge-frogs** (see Fig. 1) were provided by Ben Lewis (BSc, Hons) during bird surveys in the area (during the field work for the bird report prepared by D. Rohweder). Ben Lewis has extensive experience with this species throughout northern NSW.

## 3.0 Methods

A minimum of five non-consecutive day/nights of surveying was proposed to estimate the likely population size of **Wallum Sedge-frogs** at the known pond location. Each survey consisted of an assessment of the condition of the waterbody (temperature, depth and pH) followed by a half-hour visual and acoustic census of the population. Surveys were conducted under varying climatic conditions - note several visits in November 2000 found few individuals and no calling activity. Additional surveys throughout adjacent areas (Table 1) primarily focused on locating potential breeding sites that would be suitable for larval development of the species (ie. long hydroperiod, low pH). Nocturnal and diurnal surveys were then undertaken at these locations.


**Fig. 1**. Numbers 1-6 identify pond sites occupied by *L. olongburensis* during visual and acoustic surveys, the size of each circle represents the area with breeding pond habitat. Numbers correspond to pond sites 1 - 4 identified in our surveys, ponds 5 and 6 are records reported by Ben Lewis.

## 4.0 Results

**4.1 Population size of Wallum Sedge-frogs at pond site 1** (Fig. 1)

*Litoria olongburensis* was recorded on six of the twelve surveys undertaken between November 2000 and March 2001 (Table 2). Surveys that failed to locate the species corresponded to a period of low rainfall and declining water level at the pond. On occasions when the species was recorded, numbers were consistently low with a maximum of 6 individuals being recorded on a single visit. The pH of the waterbody was consistent with previous observations and remained relatively stable throughout the survey period, ranging between 3.77 and 4.2.

**4.2. Supplementary surveys to locate additional populations of *L. olongburensis***

Supplementary surveys have increased the number of localities known to be occupied by **Wallum Sedge-frogs** and have contributed to the understanding of the distribution of the species throughout the study area. Six potential breeding ponds have been identified and are listed in Table 3, plotted in Figure 1 and described in detail below.

**Pond Site 1** (Fig. 1)

Refers to the original location first recorded by Hero *et al.* 2000 in survey precinct 6 (see also section 4.1 of this report). This pond site is a large sand based depression with tannin stained waters and emergent sedges. A combination of low pH (3.84-4.2), deep water (maximum 500mm) and long hydroperiod suggest that the locality is suitable for the species. Although not permanent, the waterbody appears to retain water for extended periods of time (ie. possibly several months under suitable conditions). While a maximum of six individuals was recorded in systematic surveys between November 2000 and March 2001, qualitative observations during January 2000 suggest that this is an underestimate (even if only calling males are considered). Tadpoles have also been recorded indicating that breeding occurs at this locality. Other species recorded include *Crinia tinnula*, *Litoria fallax* and *L. nasuta*. Adjacent ponds to the south were found to contain the introduced Mosquito fish (*Gambusia* spp.).

**Pond Site 2** (Fig. 1)

Refers to the locality of an incidental record of a single call sequence heard during daylight hours in January 2000 in the Amphibian Biodiversity Hotspot within precinct 5 (Hero *et al.* 2000). An extensive, ephemeral sand based waterbody. Opportunistic visits to the locality suggest that the site is dry for extensive periods of time. However, following heavy rainfall in February and March 2001, the site was inundated with water and measured up to 370mm in depth during surveys. pH was lower than previous estimates (5.18, Hero *et al*. 2000) and ranged between 4.4 and 5.2. Large numbers of **Wallum Sedge-frogs** were heard calling suggesting that the site is well utilised by the species (Table 2). Other species recorded include *Crinia parinsignifera*, *C. signifera*, *C. tinnula*, *Limnodynastes peronii*, *L. terraereginae*, *Litoria caerulea*, *L. fallax*, *L. gracilenta*, *L. nasuta*, *L. peronii*, *L. tyleri* and *Bufo marinus*.

**Pond Site 3** (Fig. 1)

A previously undescribed locality from the southeastern corner of survey precinct 4 (refer to Hero *et. al.* 2000). While, during periods of low rainfall, water in the crescent shaped drainage line is restricted, under suitable conditions the drainage line may form an extensive waterbody between the existing access road and the rainforest reserve. Although limited during dry periods, water has been observed at this locality during all surveys. The pH of the waterbody ranged between 3.5 and 4.3 with a maximum depth of 730mm. *Litoria olongburensis* was first recorded at the locality on 6-12-00 and has subsequently been revisited on numerous occasions. The species was recorded on four of the eight surveys undertaken between November 2000 and March 2001. On occasions when the species was recorded, numbers were typically low, however nine individuals were recorded on 19-02-01 following rain. Tadpoles of the species have also been recorded indicating that breeding occurs at this locality. Other species recorded include *Crinia signifera*, *C. tinnula*, *Limnodynastes ornatus*, *Litoria fallax*, *L. nasuta* and *Bufo marinus*

**Pond Site 4** (Fig. 1)

A previously undescribed locality from the eastern edge of survey precinct 8 (refer to Hero *et. al.* 2000). Limited information is available on this locality. More surveys are needed to assess the distribution of the species within the fragment and to determine whether, like Wallum Froglets (*Crinia tinnula*), **Wallum Sedge-frogs** utilise ephemeral pools, which extend into the adjacent cleared habitat. pH of the waterbody is low, measuring 4.0 to 4.4. The species has only been recorded on one occasion and the record is based on two calling individuals. Other species recorded include *Crinia tinnula*, *C. signifera*, *Litoria fallax*, *Limnodynastes peronii* and *Bufo marinus*.

**Pond Sites 5 and 6 (Ben Lewis pers. comm.)** (see Fig. 1)

Previously undescribed localities from the edge of survey precinct 8 and from within survey precinct 11 respectively (refer to Hero *et al*. 2000). Two to five individuals were heard calling at both locations by Ben Lewis (pers. comm.) during bird surveys associated with the proposed Tugun By-pass in late January 1999. Subsequent surveys by the authors following periods of rain have identified suitable habitat (deep water, low pH) at both locations. These records are of particular interest as pond site 6 represents the second record of **Wallum Sedge-frogs** from survey precinct 8. Furthermore, the detection of **Wallum Sedge-frogs** and Wallum Froglets (*C. signifera*) from pond site 5 increases the number of species recorded within survey precinct 11 to fourteen - equivalent number of species at pond site 2 (*ie.* the biodiversity hotspot described in Hero *et al*., 2000).

Based on the current proposed alignment, site 5 is likely to be destroyed during the construction of the proposed by-pass, and Site 3 will be isolated from other breeding populations -and this is likely to lead to local extinction. Furthermore extreme caution must be applied to adequately protect breeding sites 1, 3 & 6 that are adjacent to the proposed by-pass. Specifically, strict guidelines should be prepared for construction personnel during the construction phase.

**Table 1**: Survey effort to locate additional populations of *L. olongburensis*

| Date | Rain[1] (mm) | Min. air temp (°C) | Max. air temp (°C) | Person hours |
|---|---|---|---|---|
| 29-11-00 | 0 (2) | 20.8 | 28.7 | 5.0 |
| 6-12-00 | 0 (1) | 16.2 | 25.8 | 4.0 |
| 21-12-00 | 0 (2) | 18.5 | 28.3 | 4.0 |
| 24-01-01 | 0 (2) | 22.2 | 27.7 | 5.0 |
| 19-02-01 | 9 (0) | 17.9 | 25.6 | 3.5 |
| 14-03-01 | - (1) | 21.5 | 24.0 | 5.0 |
| Total | | | | 26.5 |

[1] numbers in brackets refer to standard reporting code: 0 = rain during survey; 1 = evidence of rain in last 24 hours; 2 = no evidence of rain in last 24 hours

**Table 2**: Systematic surveys of the original **Wallum Sedge-frog** pond (Fig 1, pond site 1)

| Date | Rain[1] (mm) | Min. air temp (°C) | Max. air temp (°C) | Temp. water (°C) | Depth (mm) | pH | Person hours | Number of individuals |
|---|---|---|---|---|---|---|---|---|
| 1-11-00 | 28 (0) | 15.6 | 23.3 | 20.0 | 500 | - | 1.0 | 1 |
| 6-11-00 | 36 (0) | 16.9 | 26.7 | 21.0 | - | - | 1.0 | 2 |
| 15-11-00 | 43 (0) | 18.2 | 24.3 | 23.0 | 500 | - | 1.0 | 4 |
| 6-12-00 | 0 (1) | 16.2 | 25.8 | 31.0 | 500 | 3.77 | 1.0 | 0 |
| 2-01-01 | 0.4 (1) | 20.8 | 26.6 | 27.0 | 200 | 4.1 | 1.0 | 0 |
| 15-01-01 | 0 (2) | 23.1 | 28.0 | 27.0 | 0 | - | 0.5 | 0 |
| 24-01-01 | 0 (2) | 22.2 | 27.7 | 34.0 | 110 | 3.9 | 0.5 | 0 |
| 30-01-01 | 2 (1) | 23.1 | 28.7 | - | 0 | - | 0.5 | 0 |
| 19-02-01 | 9 (0) | 17.9 | 25.6 | 24.0 | 395 | 4.0 | 0.5 | 6 |
| 22-02-01 | 0 (2) | 24.0 | 24.0 | 28 | 380 | 4.2 | 0.5 | 0 |
| 11-03-01 | - (1) | 22.0 | 22.0 | 26.0 | - | - | 1.0 | 5 |
| 14-03-01 | - (1) | 21.5 | 24.0 | 23.0 | 410 | 4.1 | 0.5 | 2 |
| Total | | | | | | | 8.5 | |

[1] numbers in brackets refer to standard reporting code: 0 = rain during survey; 1 = evidence of rain in last 24 hours; 2 = no evidence of rain in last 24 hours

**Table 3**: Location and maximum number of individuals recorded during visual and acoustic surveys for all known records of *L. olongburensis*

| Pond site | Survey precinct[1] | Easting | Northing | No. of surveys | Max. number of individuals |
|---|---|---|---|---|---|
| 1 | 6 | 549903 | 6883279 | 12 | 6 |
| 2 | 5 | 550550 | 6883550 | 6 | 10 |
| 3 | 4 | 549361 | 6883371 | 8 | 9 |
| 4 | 8 | 549950 | 6883350 | 2 | 2 |
| 5 | 8 | 549750 | 6883400 | 3 | 2-5 |
| 6 | 11 | 549450 | 6883550 | 4 | 2-5 |

[1]refer to Hero *et al.* 2000. Note: grid locations refer to the approximate centre of waterbody only. Records of **Wallum Sedge-frogs** at pond sites 5 and 6 provided by Ben Lewis pers. comm.

## 5.0 Discussion

Supplementary surveys have contributed to understanding the distribution and abundance of **Wallum Sedge-frogs** within the study area. Extensive surveys have detected the species at six localities. One site (5) is likely to be destroyed during the construction of the proposed bypass. Site 3 will be isolated from other breeding populations' -and if they remain in isolation it is likely to lead to local extinction of frogs in that sub-population. The remaining sub-populations (sites 1, 2 4 & 6) will be isolated on the eastern side of the by-pass, defining a reduced metapopulation size that is more susceptible to extinction processes. No alternative breeding sites were detected and due to the high habitat selectivity of this species we expect the likelihood of encountering new sub-populations (if they exist) is minimal.

Population estimates at these sites are low (< 10 calling males), however our estimates are restricted to knowledge of maximum number of individuals recorded during a single survey. Habitat at all localities are characterised by low pH and relatively deep water with some capacity to retain water for longer periods than surrounding ephemeral ponds occupied by *C. tinnula*. Following intense rainfall periods, the species is encountered amongst sedges and emergent vegetation in open areas with limited canopy cover.

Surveys periods that failed to locate the species corresponded to periods of low rainfall and declining water levels at ponds throughout the study area. This is consistent with observations in other parts of the species range where calling activity has been reported during spring, summer and early autumn at night and by day when water levels are rising or ample water is available (Ehmann 1997). It is clear that the number of individuals observed fluctuates throughout the breeding season and is likely to be dependent on factors such as temperature, rainfall and water levels at breeding sites. While systematic surveys were employed to gather information on the likely population size of the species at the original locality, sub-optimal conditions during a number of the surveys meant that few individuals were recorded. Subsequently our estimates may underestimate population size. In the absence of suitable data with which to estimate population size, maximum numbers of individuals recorded during a single survey are our best estimate.

Despite being recorded from Fraser, Bribie, Moreton and North Stradbroke Islands (Liem & Ingram 1977, Hines *et al*. 1999) the nearest mainland records of *Litoria olongburensis* are 30-40 km south in Pottsville – Hastings Point area (Phillips *et al*. 1995) and over 100 km north at Beerwah (Liem & Ingram 1977). While populations of 'acid' frogs on offshore islands appear to be at low risk, mainland populations are at high risk from continuing loss of habitat through clearing for agriculture, pine plantations, housing and infrastructure such as canal development, drainage projects and transport corridors (Hines *et al*. 1999). The apparent isolation of these records from other populations on the mainland makes this location particularly important at the regional scale. If the species is to be conserved in the coastal lowlands of southeastern Queensland and northeastern New South Wales, it is crucial that direct threats such as habitat destruction and indirect threats such as habitat degradation through changes in hydrological regimes are prevented. It should be noted that it is the reality of threats such as these which have prompted authorities to recently recommend the species for listing as "vulnerable" for the purposes of the IUCN Red Data Book (J.-M. Hero pers. comm.).

The proximity of small neighboring breeding populations to each other suggests they act as a metapopulation and the habitat between them is clearly an important part of maintaining links within the metapopulation. This is of particular importance given the potential for the road to act as a barrier to dispersal and the subsequent isolation of one of the largest breeding populations on the western side of the by-pass. Short-term opportunistic movement across areas during wet periods and long-term population dispersal along suitable corridors (coastal swamps and wallum plains) must be considered. While the dispersal abilities and the frequency or likelihood of colonisation events of the species are not known, its use of recently created or rehabilitated sites for reproduction suggests that they are successful colonists provided there is a natural corridor to aid dispersal (James 1996).

## 6.0 Amelioration of Likely Impacts

The low numbers of **Wallum Sedge-frogs** within the area, the fragmented nature of the habitat and the presence of potentially competitive, ecologically similar species such as *Litoria fallax* at all known localities, would suggest that the observed populations may already be under considerable stress. Additional pressure, in the form of removal/isolation of habitat or change in water quality, is also likely to constitute a major threat to the long-term survival of the species within the study area. The extent to which immigration and emigration between ponds plays a role in sustaining the species is unknown**.** However, the small numbers of individuals recorded at each of the 6 ponds suggest they may interact to form a single metapopulation. Thus, in addition to the direct loss of breeding habitat, the isolation of ponds through the construction of the proposed by-pass might in itself be a threatening process. Amelioration and compensatory measures for protection of herpetofauna along the proposed Tugun by-pass are provided in an additional report.

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# Supplementary mammal studies associated with the proposed Tugun by-pass

## I – Additional elliot trapping and hair-tube sampling

## II – Eastern Long-eared Bat *Nyctophilus bifax*

## III – Common Planigale *Planigale maculata*

**Stephen Phillips, Helena Forsman, Jean-Marc Hero and Luke Shoo**

School of Environmental and Applied Sciences
Griffith University Gold Coast
PMB 50 Gold Coast MC, Queensland 9726

## Final Report

## June 2001

## *Revised* 21 August 2001

**Summary**

This report presents the results of three supplementary studies undertaken as a consequence of earlier survey work by Hero *et al.* (2000). In addition to further elliot trapping and hair-tube sampling, studies were initiated to gain a more detailed knowledge of two 'Vulnerable' species - the Eastern Long-eared Bat *(Nyctophilus bifax)* and the Common Planigale *(Planigale maculata)* - in order to better understand the impacts of road construction.

Survey methodology for *N. bifax* involved a localised harp trapping program in a small area of mature *M. quinquenervia* forest, augmented by some mist netting and an independent monitoring of bat activity. Twelve harp trap nights and 80 m/hours of mist netting were undertaken over four consecutive nights. A single *N. bifax* was the only microchiropteran captured. While subsequent radio-tracking of this one animal suggested dispersal from the site, this was not interpreted as indicative of habitat use by the species generally.

Survey methodology for *P. maculata* involved the use of dry pit-fall traps and drift fences within a small habitat isolate. Six trap stations were established and a total of 395 trap nights accumulated over a two week period. Only three *P. maculata* were captured (2 males and 1 female) and there were no recaptures. Captures were localised and a speculalative population estimate of between 16 and 40 animals within the site of interest has been proposed on the basis of the results which were obtained.

The result present a number of problems for consideration. The poor capture success and low bat activity during the survey suggest that use of the mature Melaleuca forest by *N. bifax* may be seasonal. Application of the precautionary approach to habitat modification in this area is recommended, the underlying principle to maximise the retention of mature trees generally. Design constraints proximal to the habitat isolate currently supporting the *P. maculata* population essentially preclude the installation of ameliorative measures such as underpasses. Further, the most likely outcome of road construction in the general area will be isolation of the population, thus creating the potential for a localised

extinction event. The proposed realignment of the route to maximise retention of optimal habitat in this area is endorsed, a trapping program to minimise direct mortalities during vegetation removal and other road construction activities is also recommended.

## Introduction

A new transport corridor has been proposed to accommodate both road and rail links between Tugun Heights in Queensland and Tweed Heads, New South Wales [option C4, Route Selection Report: Connell Wagner (1999)]. The proposed deviation of the Pacific Highway is between the Stewart Road intersection (Qld.) and the northern end of the Kennedy Drive Interchange (NSW). Part of a rail corridor from Robina to the Coolangatta Airport is also included as a part of the proposed extension to rail services.

Fauna survey work for the southern (NSW) component of the proposed Tugun by-pass (Hero *et al*. 2000) identified the presence of several threatened species, among them a population of Common Planigales *P. maculata* inhabiting a habitat isolate which will be directly impacted by road works, and a significant population of Eastern long-eared bats *N. bifax*, some individuals of which were collected from an area of mature *M. quinquenervia* forest which is also likely to be impacted by road works as a consequence of by-pass construction. The principal objectives of this study were to gain a more detailed understanding about certain ecological aspects of the above mentioned species, specifically to develop a population estimate and better understand the distribution of *P. maculata* within the habitat isolate and to further investigate use of the *M. quinquenervia* forest by *N. bifax*.

## Methods

### 1) Additional elliot trapping and hair tube sampling

<u>Study Area/s</u>

Two localities (sites B and D – Fig.1) were selected for sampling. Site B was a grassland/sedgeland community interspersed with scattered Mangroves and saltmarsh.

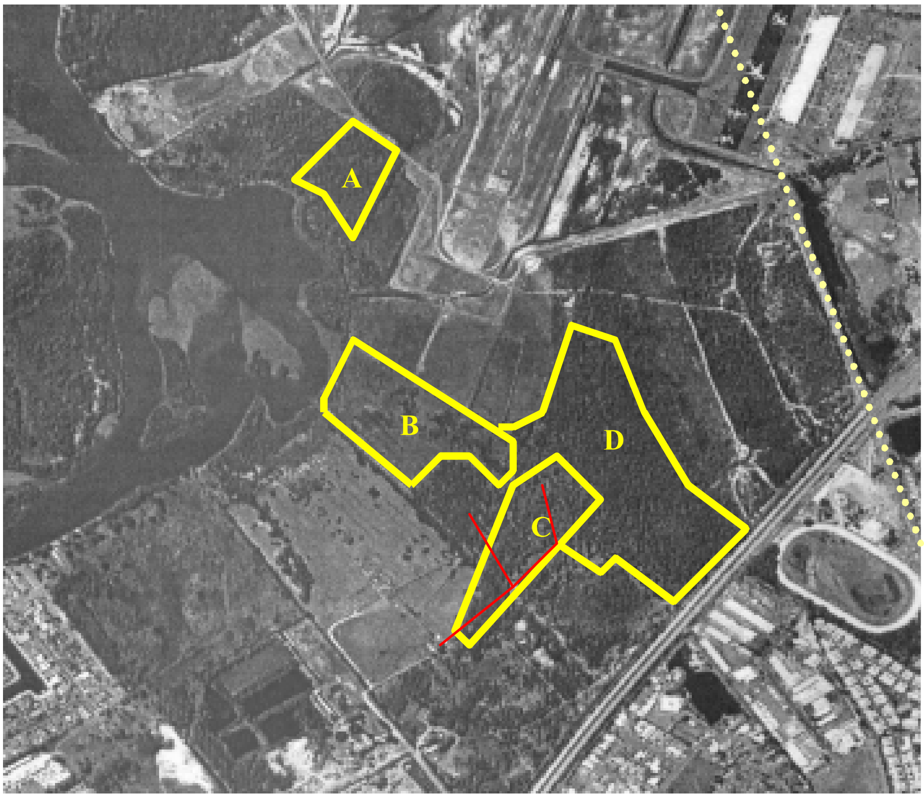


**Fig. 1.** Location of additional trap lines and other supplementary study sites - southern section of C4 alignment. Broken line indicates NSW/Qld. Border (red line indicates spotlighting transect referred to on page 4 of this report).

**A** = Swamp Mahogany (*E. robusta*) forest - *Planigale maculata* population study.
**B** = Sedgeland/Mangrove community - supplementary trapline and hair-tube sampling.
**C** = Mature Broad-leaved Paperbark (*M. quinquenervia*) forest - *Nyctophilus bifax*.
**D** = Swamp Mahogany forest - supplementary trapline and hair-tube sampling.

Site D was an area of Swamp Mahogany (*E. robusta*) Forest with a dense understorey of *Xanthorhea* spp., *Banksia* spp. and *Blechnum sp*.

<u>Elliot traps</u>

Two linear transects comprising 25 Type A Elliot traps placed approximately 10 -15 metres apart were established within each of the above sites. Each trap was baited with a mixture of rolled oats, peanut butter and honey and the line was maintained for four consecutive nights over the period 24/01/01 – 27/01/01. Traps were checked on a daily basis.

<u>Hair tubes</u>

Two transects comprising a series of 15 hair tubes (opening size 100 mm x 80 mm) located approximately 20 - 25 meters apart were placed in close proximity to the elliot trap lines at Sites B and D. A third transect comprising a series of 10 hair tubes was also undertaken within survey precinct 8 (see Hero *et al*. 2000). Hair tubes were baited with a mixture of rolled oats, peanut butter, honey and pistachio essence and left in the field for a minimum of 10 nights.

A small amount of *ad hoc* spotlighting was also undertaken within Area C (Fig. 1).

For mapping purposes, co-ordinates were determined for the ends of each trapline by data averaging to ± 5m using a 12 Parallel Channel GPS Receiver (Garmin 12XL).

**2) Eastern Long- eared Bat** (*Nyctophilus bifax)*

<u>Study Area</u>

The study site (Area C – Fig. 1) was a localised area of mature Broad-leaved Paperbark (*M. quinquenervia*) forest located towards the southern end of the transport corridor.

<u>Methodology</u>

Survey methodology involved deployment of three harp traps at eleven locations within the study area for five consecutive days over the period 23/01/01 to 27/01/01. Traps were placed in perceived "flyways" and monitored hourly from dusk until approx. 2230 hrs each night; they were then left until the following morning when they were again inspected before being moved to a new location. The original *N. bifax* capture site reported by Hero *et al.* (2000) was sampled on the evenings of the 23/01/01 and 26/01/01. On the last evening of the study, two 20m mist nets were also erected in suitable locations and unfurled for a two hour period from 1930hrs to 2200hrs.

A stationary Anabat detector (Titley Electronics) was also used to concurrently monitor bat activity within the study site for the first 45mins following sunset each evening.

Captured *N. bifax* were to be fitted with a LTM single-stage radio transmitter (Titley Electronics) before being released at the point of capture.

For mapping purposes, co-ordinates were determined for each Harp Trap location, and for the centre of each mist net site, by data averaging to ± 5m using a 12 Parallel Channel GPS Receiver (Garmin 12XL).

### 3) Common Planigale *(Planigale maculata)*

Study Area

The study site (Area A – Fig. 1) comprised a remnant stand of Swamp Mahogany Forest located outside the perimeter fence proximal to the south-western corner of the primary runway at Coolangatta Airport.

Methodology

Six trap stations comprising a series of 5 x 20 litre plastic buckets sunk into the ground at 5 – 6 metre intervals and connected by a 30m x 300 mm high polyethylene drift-fence were established over the period 30/01/01 – 31/01/01. Each pitfall bucket contained drainage holes, a small square of styrofoam and minimal shelter. Each of the trap stations was monitored on a once-daily basis (early morning). All animals captured were identified prior to release. Individual *P. maculata* were sexed and marked for recapture purposes by the removal of a small amount of hair from the right hip before being released at the point of capture.

Heavy rain over the period 02/02/01 – 04/02/01 rendered the majority of pitfall buckets inoperative due to flooding and a subsequently elevated water table. For the remainder of the study, a trap was deemed to be functional (in terms of its ability to capture *P. maculata*) only when the water level had fallen to 50% or less of the buckets total volume. Lowering of water table was progressive, with all stations except one achieving a level of operational efficiency by the end of the study.

For mapping purposes, co-ordinates were determined for the central pitfall of each trap station by data averaging to ± 5m using a 12 Parallel Channel GPS Receiver (Garmin 12XL).

**Results**

**1) Additional trapping and hair tube results**

A total of 200 elliot trap nights, 580 hair tube nights and 1.5hrs of spotlighting were accumulated for the purposes of supplementary sampling. Table 1 details the specific locations, dates, effort and the results arising from this component of the program. The Grassland Melomys *Melomys burtoni* and the Eastern Swamp Rat *Rattus lutreolus* were the only native mammal species captured in the elliot traps. *Rattus* sp. were the only mammals positively identified by hair-tube samples. Spotlighting recorded the presence of Short-eared Mountain Possums *T. caninus* and Flying-foxes *Pteropus* sp.

| Site | Easting | Northing | Easting | Northing | 1st date | 2nd date | No. traps | Type | Effort | Result |
|---|---|---|---|---|---|---|---|---|---|---|
| ET12 | 550450 | 6882911 | 550203 | 6882845 | 23/01 | 27/01 | 25 | Elliot | 100 | *M. burtoni* (1), *R. lutreolus* (1) |
| ET13 | 550798 | 6882949 | 550858 | 6883204 | 23/01 | 27/01 | 25 | Elliot | 100 | *M.burtoni* (7), *R. lutreolus* (1) |
| HT7 | 548114 | 6883801 | 547448 | 6883701 | 21/12 | 09/01 | 10 | H/tube | 190 | Unid. small mammal |
| HT8 | 550418 | 6882851 | 550175 | 6882983 | 24/01 | 06/02 | 15 | H/tube | 195 | No hair samples obtained |
| HT9 | 550798 | 6882949 | 550858 | 6883204 | 24/01 | 06/02 | 10 | H/tube | 130 | *Rattus* sp., unid. small mammal |
| HT10 | 550923 | 6883108 | 550759 | 6883067 | 24/01 | 06/02 | 5 | H/tube | 65 | *Rattus* sp., unid. small mammal |
| Misc. | | | | | | | | S/light | 1.5 hrs | *T. caninus*, *Pteropus* sp. |

**Table 1.** Results obtained from supplementary trapping program undertaken in selected areas on lands towards southern end of proposed Tugun by-pass. Dual eastings and northings correspond to respective ends of each trapline.

**2) Eastern Long- eared Bat** (*Nyctophilus bifax)*

Twelve Harp Trap nights and 80metre/hours of mist netting as well as 3 hours Anabat recording were completed. A single male *N. bifax* was the only microchiropteran captured during the course of the survey. The location of each harp trap and the two mist nets are detailed in Table 2, as are the results of concurrently monitored bat activity – measured by the number of bat passes – which occurred during the first 45mins following sunset each evening. This latter result suggests a minimum of bat activity within the study area generally. A call sequence from an Eastern broad-nosed bat *Scotorepens orion* was also identified during subsequent tape analysis.

Consistent with the methodology, the captured *N. bifax* was fitted with a radio-transmitter and released at the point of capture. Subsequent monitoring confirmed the continued presence of this animal within the study area until at least 2230 hrs that evening. The transmitter signal could not be located the following morning despite an intensive vehicle and foot-based search throughout the study area, including forested areas north to Woodgee Hill. The signal could not be detected on subsequent nights, suggesting that the animal had possibly dispersed and/or was no longer foraging in the general area.

| Site | easting | northing | 1st date | 2nd date | No. traps | type | T/nights | result |
|---|---|---|---|---|---|---|---|---|
| Melaleuca Forest | 550826 | 6882911 | 23/01/01 | 24/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550699 | 6882814 | 23/01/01 | 24/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550726 | 6882773 | 23/01/01 | 24/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550835 | 6882914 | 24/01/01 | 25/01/01 | 1 | Harp | 1 | *N. bifax* (1) |
| Melaleuca Forest | 550610 | 6882843 | 24/01/01 | 25/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550525 | 6882774 | 24/01/01 | 25/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550832 | 6882878 | 25/01/01 | 26/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550582 | 6882888 | 25/01/01 | 26/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550690 | 6882771 | 25/01/01 | 26/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550763 | 6882872 | 26/01/01 | 27/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550816 | 6882896 | 26/01/01 | 27/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550699 | 6882814 | 26/01/01 | 27/01/01 | 1 | Harp | 1 | Nil |
| Melaleuca Forest | 550806 | 6882943 | 26/01/01 | 26/01/01 | 1 x 20m | Mist | 40 m/hrs | Nil |
| Melaleuca Forest | 550764 | 6882830 | 26/01/01 | 26/01/01 | 1 x 20m | Mist | 40 m/hrs | Nil |
| Melaleuca Forest | | | 23/01/01 | 26/01/01 | 4 x 45min | A/bat | 3 hrs | 0,0,4,1 passes |

**Table 2:** Details of trap location, effort and results associated with the *N. bifax* study.

### 3) Common Planigale *(Planigale maculata)*

A total of 325 pitfall trap nights were accumulated over a 15 night period from the 30/01/01 – 14/02/01. Three *P. maculata* (2 males and 1 female) were captured, marked and released over the course of the study. The two males were captured from SMF1 on the 01/02/01 and 05/02/01; the female was captured from SMF 4 on the 12/02/01. There were no recaptures. Table 3 details the location, survey dates and trap effort associated with each of the pitfall lines, including those from earlier survey work undertaken by Hero *et al*. (2000; 2001).

| Site | easting | northing | 1st date | 2nd date | No. traps | T/nights |
|---|---|---|---|---|---|---|
| **This study** | | | | | | |
| SMF 1 | 549809 | 6883267 | 30/01/01 | 14/02/01 | 5 | 75 (2) |
| SMF 2 | 549758 | 6883271 | 30/01/01 | 14/02/01 | 5 | 75 |
| SMF 3 | 549741 | 6883239 | 30/01/01 | 14/02/01 | 5 | 75 |
| SMF 4 | 549722 | 6883223 | 30/01/01 | 14/02/01 | 5 | 60 (1) |
| SMF 5 | 549716 | 6883166 | 30/01/01 | 14/02/01 | 5 | 35 |
| SMF 6 | 549754 | 6883170 | 31/01/01 | 14/02/01 | 5 | 5 |
| | | | | | | |
| **Hero *et al*. (2000)** | | | | | | |
| Crinnula | 548019 | 6883768 | 10/01/00 | 17/11/00 | 5 | 25 |
| Lacey | 548390 | 6884116 | 10/01/00 | 17/11/00 | 5 | 25 |
| Tower | 548921 | 6884073 | 10/01/00 | 17/11/00 | 5 | 25 |
| Rainforest | 549147 | 6883211 | 11/01/00 | 17/11/00 | 5 | 25 |
| Gate 9 | 550517 | 6883426 | 11/01/00 | 17/11/00 | 5 | 25 |
| Bus Stop | 549375 | 6884169 | 11/01/00 | 17/11/00 | 5 | 25 |
| SMFa | 549844 | 6883247 | 10/01/00 | 11/01/00 | 5 | 5 (1) |
| SMFb | 549801 | 6883266 | 17/01/00 | 21/01/00 | 5 | 20 (2) |
| Paddler site | 550972 | 6883274 | | | 5 | 20 |
| | | | | | | |
| **Hero *et al*. (2001)** | | | | | | |
| L'land heath | 548169 | 6884822 | 31/10/00 | 05/11/00 | 5 | 25 |
| Billabong ridge | 547725 | 6885203 | 31/10/00 | 05/11/00 | 5 | 25 |
| Hidden Valley | 547436 | 6885268 | 31/10/00 | 05/11/00 | 5 | 25 |
| North Ridge | 547334 | 6886220 | 31/10/00 | 05/11/00 | 5 | 25 (2) |
| | | | | | | |
| **Total effort** | | | **10/01/00** | **14/02/01** | | **620** |

**Table 3:** Details of pit-fall/drift-fence trapline locations, sampling periods, effort and results obtained during supplementary survey work for *P. maculata*. The number of animals captured in each instance is indicated in brackets. Results from earlier surveys (Hero *et al*. 2000, 2001) are included for comparative purposes.

Estimating population size

Both the small number of *P. maculata* captured and the lack of recapture data make any estimate of population size problematical. However, the following information can be determined from the results in Table 3:

(i) there is no relationship between trap effort (no. trap nights) and the number of *P. maculata* captured;
(ii) the number of *P. maculata* captured is remarkably consistent (only 1 – 2 individuals) between each of the 5 sites where the species was captured.

From these observations we speculate that the presence/absence of *P. maculata* in a given area can be readily determined by pitfall trapping and is not associated with trapping effort *per se*. Further, the relatively constant capture rate (1 – 2 animals/trap line) suggests it is potentially a useful indicator of the abundance of this species in areas where it occurs. The lack of recaptures is also a notable outcome of the study and suggests a measure of learned avoidance once an individual has been trapped on one occasion.

For purposes of the discussion that follows it has been assumed that the minimum area sampled by each trapline is approximately 0.045ha, a determination based upon the trapline being centrally located within a rectangle with a width defined by 25% of the length of the drift fence (30m) on either side. If each trapping session is therefore perceived to be an independent event, and it is assumed that all animals within the area sampled by each trapline have been captured, analysis of the data pooled across all sites would suggest an indicative abundance (± SE) of 0.42 ± 0.18 planigales/0.045ha within the study area. Given that the area of interest has an area of approximately 3.0ha, a tentative population estimate of 28 ± 12 planigales could subsequently be proposed. Within this area however, capture data suggests that the population may be restricted to a smaller area (approx 1.0ha) of more elevated land. If this is true, then the data indicates a slightly higher abundance of planigales in this smaller area than the broader data set suggests (0.86 ± 0.34 planigales/0.045ha or 19 ± 7.56 planigales). Regardless, the end result is a conclusion that the resident planigale population within the site in question is both small and vulnerable to disturbance, more so given that factors influencing recruitment to and/or dispersal from this site remain unknown.

Other Fauna

Table 4 details species other than *P. maculata* that were captured during the survey. Of these, the Wallum froglet *C. tinnula* is currently listed in Schedule 2 (Vulnerable Species) for purposes of the NSW *Threatened Species Conservation Act 1995*. Also notable from this data is a single capture of the reduced-limb skink *A. verreauxii*.

| Species/Trapline no. | SMF1 | SMF2 | SMF3 | SMF4 | SMF5 | SMF6 |
|---|---|---|---|---|---|---|
| **1. AMPHIBIANS** | | | | | | |
| **Family: Bufonidae** | | | | | | |
| *Bufo marinus* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Family: Myobatrachdae** | | | | | | |
| *Crinia tinnula* * | ✓ | | ✓ | | | |
| *Lymnodynastes peronii* | | ✓ | ✓ | | ✓ | |
| *L. terraereginae* | ✓ | ✓ | ✓ | ✓ | | |
| **2. REPTILES** | | | | | | |
| **Family: Elapidae** | | | | | | |
| *Hemiaspis signata* | ✓ | | | | | |
| **Family: Scincidae** | | | | | | |
| *Anomalopus verreauxii* | | ✓ | | | | |
| *Lampropholis delicata* | | ✓ | ✓ | ✓ | | |
| *Saiphos equalis* | ✓ | | ✓ | | | |
| **3. MAMMALS** | | | | | | |
| **Family: Muridae** | | | | | | |
| *Melomys burtoni* | | ✓ | | | ✓ | |

**Table 4:** Other fauna captured during pitfall trapping for *P. maculata*.

## Discussion

In general terms, the results of these supplementary studies have contributed further to the knowledge of wildlife species inhabiting the route of the proposed by-pass. Two species not previously recorded in earlier studies – *Anomalopus verreauxii* and

*Scotorepens orion* add further to the known biodiversity of the study area, while additional data relating to the distribution and abundance of threatened species such as *Crinia tinnula*, *Nyctophilus bifax* and *Planigale maculata* have been documented.

At best, the results of the *N. bifax* study are inconclusive. Interestingly, the results contrast with those from the earlier studies (Hero *et al*. 2000) which otherwise concluded that *N. bifax* was one of the more commonly collected species with a relatively widespread distribution within the study area. The reasons for the disparity between the results of this study and the earlier work of Hero *et al*. (2000) is not known. The low capture success coupled with Anabat monitoring does suggest however, that bat activity within the area was minimal, thus pointing to the potential for seasonal variation in the use of this area of habitat. Seasonal changes in roost selection by this species are known to occur (Strahan 1998). However, this information does not address the specific question of how important the localised area of mature *M. quinquenervia* forest might be. In Queensland *N. bifax* is found in a range of habitats (Allison, 1989), but NSW records were considered to be primarily associated with rainforest or wet sclerophyll forest by Lunney *et al.* (1996) who concluded that the proximity of a range of roost types in rainforest, including dense vegetation and hollows in mature trees were likely to be critical for the survival of this species.

Given the limited understanding of the ecology of *N. bifax* and the probability that the results which were obtained potentially indicate some measure of seasonal variation in the use of this area by this species, application of a precautionary approach in this instance would appear warranted, more so given that *N. bifax* was the only microchiropteran bat species captured over the course of the survey. Thus habitat retention in this area should be maximised.

Resolution of the situation created by the presence of the *P. maculata* population is problematical. The small size of this species does not suggest extensive movement and because of this, it was argued by Hero *et al*. (2000) that populations would be localised.

The results from this survey support this notion, more so given that each of the captures within the habitat isolate occured in close proximity (30 – 40m) to each other.

The area in which the *P. maculata* population resides is characterised by a slight rise in elevation, giving a total habitat area of approximately 1.05ha, nearly 20% of which will potentially be lost as a consequence of by-pass construction (K. Brown pers. com). The alignment corridor in the vicinity of the habitat isolate is narrow and design constraints essentially preclude the installation of putative ameliorative measures such as underpasses. However, it has been proposed that loss of the above mentioned area of habitat could be offset by linking it to a smaller patch (≈ 0.38ha) immediately to the north, an area currently under lease to GCAL and separated from the site in question by a service road. Implementation of this approach is contingent upon agreement by GCAL to both conserve the adjacent habitat to the north, and reroute the existing service road. This approach is generally endorsed, as it will theoretically assist in reducing the loss of what appears to be optimal *P. maculata* habitat.

Nothwithstanding the above, an *a priori* issue for consideration is that the most likely outcome of road construction will be isolation of this habitat and its resident *P. maculata* population. Given a population estimate of 16 - 40 individuals, medium to longer-term viability will obviously be contingent upon adequate levels of recruitment being maintained from proximal populations (see Friend 1987). In the context of meta-population dynamics, it is also possible that the population in question is itself a source population from which others gain their own recruits. Because of this, the potential for localised extinction of this population as a direct consequence of habitat fragmentation and isolation will need to be considered as a possible outcome of by-pass construction, together with longer term consequences for the species as a whole within the larger study area.

Because of the above, we are of the opinion that consideration of a short-term capture and captive management option for some of the population may have merit. Given the narrowness of the road corridor, indirect impacts arising from habitat modification and the potential for isolation of the population, the maintenance in captivity of at least some of the population over the period of road construction may ultimately assist longer term management and conservation objectives. To this end, a trapping program to capture and temporarily hold in captivity Planigales that would otherwise be directly impacted by habitat destruction and ensuing road construction activities in this area is recommended. Subsequent management of the captive animals, including identification of a site or sites for re-release, should ideally be determined in consultation with NSW National Parks and Wildlife Service.

A monitoring program to gauge the potential for indirect effects arising from construction of the by-pass is also recommended within the remaining area of known Planigale habitat (including the 0.38ha identified above). For this purpose we propose placement of 25 single, dry-pitfall/drift fence traps distributed through the area, the design of which is detailed in Fig. 2. The monitoring should be initiated prior to the commencement of road construction activities and be undertaken on a twice-yearly basis (Winter/Spring and Summer/Autumn) for a minimum of five years following completion of the by-pass. All traps are to operate simultaneously for a period of 5 consecutive nights for each monitoring period. This monitoring protocol will need to be replicated in any area subsequently chosen as a release site for any Planigales, which have been maintained in captivity in accord with recommendations in the preceding paragraph.

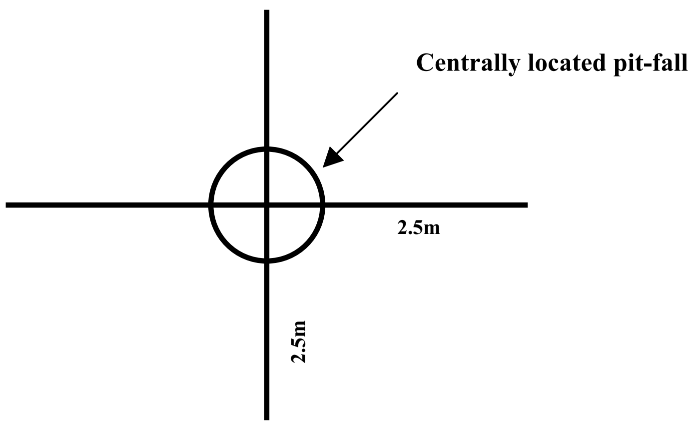


**Fig. 2.** Pit-fall/drift fence configuration for Planigale monitoring program

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# Appendix F

*Amelioration and Monitoring Measures for the Conservation of Herpetofauna Along the Proposed Tugun Bypass* (Hero *et al.* 2001c)

# Amelioration and monitoring measures for the conservation of herpetofauna along the proposed Tugun by-pass.

**Jean-Marc Hero, Luke Shoo and Steve Phillips**

School of Environmental and Applied Sciences

Griffith University Gold Coast

PMB 50, Gold Coast MC,

Queensland 9726

Australia.

## Additional Report

## 21 August, 2001

## Introduction

Two threatened species of amphibian have been located in the path of the proposed by-pass (C4 - P6 Option): *Litoria olongburensis* (Wallum Sedge-frog) and *Crinia tinnula* (Wallum Froglet). Furthermore there is a high diversity of amphibian and reptile species that will also be affected by the by-pass. Herein we identify amelioration measures and monitoring protocols that are required to potentially reduce impacts on the herpetofauna in the area, with particular emphasis on the threatened frog species. These measures are dependent upon funding and collaboration with current landowners, and these issues should be addressed.

In addition to preserving remaining habitat, efforts to conserve populations of reptiles and amphibians in association with the proposed Tugun by-pass should include:

(1) connecting remnant patches of coastal heath on either side of the proposed by-pass
(2) sustaining the existing population of Wallum Sedge-frog through pond restoration and creation of aquatic habitats,
(3) translocation of immediately threatened Wallum Sedge-frogs by the proposed bypass into newly created habitats,
(4) rescue individuals from sites prior to and in the process of construction,
(5) minimising road mortality post-construction, through exclusion fencing and allowing for movement through culverts.

Each of these efforts are considered in detail below, along with the need for an additional measure to (6) monitor and assess the success of such efforts as amelioration/compensatory measures in relation to this and other proposed developments.

## 1. Connecting remnant patches of coastal heath on either side of the proposed by-pass

Existing habitat of coastal heath east of the proposed by-pass is currently fragmented and fauna linkages (i.e. movement) amongst existing fragments is unknown. Further isolation of these fragments on the eastern side of the proposed by-pass will exacerbate the problem of connectivity such that small populations in the remaining fragments may be highly susceptible to local extinction. To maintain the long-term integrity of these small populations we propose that a habitat zone be rehabilitated on the eastern side of the proposed by-pass to connect existing populations. Specifically:

- rehabilitate the cleared land between the existing heath fragments. Initially this could be achieved by stopping the current slashing program maintained by the Gold Coast Airport Limited, allowing natural revegetation,
- rehabilitation of the sand-mined area on the western side of the proposed by-pass,
- naturally vegetating the overpass connecting the east and western sides of the road south of the existing runway and above the proposed tunnel.

## 2. Sustaining the existing population of Wallum Sedge-frog through pond restoration and creation of aquatic habitats

In some instances it may be necessary to rescue and maintain viable amphibian populations, through provision of alternative breeding habitat, where historical breeding sites have been damaged or destroyed (Denton *et al.* 1997). In this regard, pond creation has been targeted at localities where existing populations are endangered by pond loss or where population sizes are small (< 100 adults) (Denton *et al.* 1997). In the absence of detailed information on reproductive success and population size at individual ponds, and levels of movement and genetic structure between ponds, it is difficult to judge the importance of breeding pond density and pond isolation in maintaining overall population size and reducing the probability of local extinction. Nevertheless, where it has been trialed, pond creation has had positive influences on securing and augmenting populations of some species of amphibians such as *Bufo calamita* (Denton *et al.* 1997), *Hyla arborea* (Berninghausen 1995; Meier 1995), *Triturus alpestris* (Mikkelsen 1993), and *Andrias japonicus* (Tochimoto 1995).

Although intuitively obvious, the need to operate within the biological constraints imposed by the species must be emphasised (Dodd and Seigel 1991). Importantly, if prospects for maintaining populations are to be improved, ponds rehabilitated or created need to adequately reflect the needs of the target species. For example, Denton *et al.* (1997) emphasised the importance of creating a network of ponds of varying depths for *B. calamita* to improve the probability that some ponds of suitable depth (deep enough to persist until metamorphosis, but not so deep as to harbour large numbers of predators) are likely to be available every year irrespective of weather conditions. Similarly, in some cases further intervention may be required to remove pollutants or adjust chemical characteristics of waterbodies such as pH (Denton *et al.* 1997).

**Establishment of new ponds to maintain populations of Wallum Sedge-frog**

The long term conservation of Wallum Sedge-frog at Tugun warrants the establishment of new ponds on two counts: firstly the locality supports existing populations which are endangered by pond loss (at least one of five known occupied waterbodies, and other potentially used waterbodies, will be removed and isolated by the proposed highway upgrade C4-P6 option); and secondly, population sizes at known waterbodies are considered to be small (< 10 calling males, Hero *et al*. 2001b). It should also be noted that ponds in which Wallum Sedge-frog are successful in reproducing are also of great importance to most of the other amphibian species in the study area (see data in Hero *et al.* 2001b).

The recovery program for *B. calamita* (Denton *et al.* 1997) in Britain provides a useful model for a number or reasons. Firstly, *B. calamita* has declined as a consequence of habitat loss and the provision of breeding pools has been employed to increase or stabilise populations that have become reliant on one or very few pools at small sites or to promote range expansions in larger areas. Secondly, efforts to enhance populations through the provision of ponds have addressed issues relating to hydroperiod, pH and the persistence of tadpole predators and competitors in semipermanent or ephemeral aquatic environments. While much remains to be learnt about the ecological requirements of Wallum Sedge-frog, some information exists to direct planning and execution of pond construction (Appendix 1).

A network of 10 ponds is proposed to provide enough suitable breeding sites to support Wallum Sedge-frog metapopulations on both sides of the proposed by-pass. The number of ponds proposed is required 1) to provide enough breeding sites on both sides of the bypass to support a metapopulation, 2) safeguard against invasion of fish and, 3) to safeguard against pond that do not succeed (*i.e.* not all ponds may be used at all times). Ponds of varying depths (0.5 - 1.5m) and sizes (10 - 20 m in length, by 5-10 m in width) are proposed. Ponds must be constructed away from permanent waterbodies and drainage lines (*ie*. minimise import of saline water and predatory fish) in open habitats (Fig. 1). Ponds banks should have a gradual slope being deepest in the middle. Pond depth should also be governed by the composition of the substrate such that, if less permeable soil layers are important in maintaining surface waters, ponds are not disrupted by overdeepening during construction. It is envisaged that new ponds would be interspersed with existing breeding ponds known to be occupied by Wallum Sedge-frog, thereby increasing connectivity of aquatic habitats by reducing the average distance between ponds. It is crucial that terrestrial connectivity is maintained among ponds, between ponds is also maintained, and that in the event of road construction appropriate vegetated corridors and underpasses are made available for adult dispersal.


**Fig. 1**. Numbers 1-6 identify pond sites occupied by *L. olongburensis* during visual and acoustic surveys, the size of each circle represents the area with breeding pond habitat. **R** = proposed site for rehabilitation to create a suitable habitat for *L. olongburensis*. **A** = potential sites to create artificial habitats suitable for the translocation of *L. olongburensis*.
Region shaded in blue represents the area proposed for vegetation rehabilitation.

**Rehabilitation of suitable breeding sites currently inhabited by the predatory introduced fish species (*Gambusia affinis*).**

Provision should be made for removing the introduced Mosquito Fish (*Gambusia affinis*) from a pond site within the Airport restricted area – adjacent to pond site 2 (Fig. 1). This pond site is similar in hydrology and water chemistry to ponds where Wallum Sedge-frog have been recorded however the presence of fish probably excludes the species from this pond. Consultation with Gold Coast Airport Limited should also be undertaken to review the current slashing program in this area.

## 3. Translocation of individuals into newly created habitats.

Pond creation needs to be a part of early planning and constructed prior to the by-pass development, for a number of reasons. Firstly, pond placement must consider natural drainage, drainage lines, culverts, and frog fences associated with the by-pass construction. Secondly, new ponds would need to be established prior to the translocation of adults and larvae from sites subject to destruction by the proposal (as mentioned above). Translocation of larvae and adults to newly created ponds is favoured in this instance as (A) it is likely to increase colonisation of newly available breeding habitat, (B) it will avoid impacts on existing ponds (*i.e.* altering species abundance and composition and accidental introduction of novel predators such as fish). While the minimum time necessary for created ponds to stabilise and become suitable for use is unknown, it is reasonable to assume that older established sites are more likely to provide the needs of the species (*eg*. contain mature pond vegetation). Thus, the earlier that ponds are constructed, the better the prospects are likely to be for establishing populations. Denton *et al.* (1997) reported that at all sites subject to pond construction at least one and usually most of the ponds were used by *B. calamita* within 1 or 2 years of their creation. Rates of pond colonisation of Wallum Sedge-frog are currently unknown, however ponds should be constructed 1-2 years prior to road construction to allow for native vegetation to establish in and around the newly established pond sites.

## 4. Rescue of individuals from sites prior to and in the process of construction

While success rates of translocation of herpetofauna are in contention (Dodd and Seigel 1991; Burke 1991), such efforts may be justified where the mortality of individuals is guaranteed through impeding destruction of habitat. Efforts should focus on minimising the scale of translocation such that movement of individuals does not impact on other populations through the transmission of disease (Dodd and Seigel 1991) and mixing of potentially divergent gene pools (Reinert 1991) and to ensure that habitats and conditions at introduction sites closely reflect those from which individuals were removed.

In the event of road construction at Tugun, rescue operations would need to be completed prior to the commencement of works. Exclusion fences would need to be installed such that sufficient time would be made available to remove individuals from within the development area. This could be undertaken in stages if necessary. The drift fence would both serve to delineate the area to be developed and also act as a barrier to minimise subsequent migration into the development area. Removal methods would require a combination of pitfall trapping, dip-netting and active diurnal and nocturnal searches. It is envisaged that once captured, individuals would be immediately transferred to the nearest available habitat (and newly established ponds) outside the development area. Additional consideration will be required, however, where development involves the removal of aquatic habitats. As established in Hero *et al*. 2001b, a significant pond site (sub-population 5) would be removed by the proposal. Importantly, fourteen species of amphibians, including two threatened species *Crinia tinnula* and Wallum Sedge-frog, have been recorded from this location. Two major issues need to be considered in relation to the translocation of amphibians from this and other smaller waterbodies. Firstly, when should rescue operations take place and secondly, where should captured individuals be transferred. Each of these issues are discussed below.

**a) when should rescue operations take place ?**

Most individuals of the subject species call, and hence would be easiest to detect and remove, on wet nights between September and March. However, removal of individuals during this period would disrupt breeding and increase the extent to which the waterbody is being utilised as a reservoir for developing eggs and larvae. It is therefore recommended that rescue operations commence following the first rains in September (*ie.* at the onset of breeding) and continue until such a time that repeated searches yield few or no new individuals. It is important to note that females of the threatened species are rarely reported in herpetological surveys and, whether an artefact of their low delectability or a real reflection of infrequent use of waterbodies, are likely to be under-represented and poorly addressed by the translocation process.

**b) where should captured individuals be transferred ?**

In this instance, translocation should be guided by addressing the needs of those species most threatened by the proposed development and for which habitat requirements are likely to be most specialised. Of the two species dependant on wallum habitats at Tugun, *Crinia tinnula* and *Litoria olongburensis*, the latter species is clearly more restricted. Of the 16 areas surveyed collectively by Hero *et al.* (2000, 2001a, 2001b), Wallum Sedge-frog was only located at 6 sites within 5 areas. These sites coincided with semi-permanent, relatively deep (0.5-1.5m) waterbodies that are sparsely distributed throughout the area. Strategies to deal with the displaced population of Wallum Sedge-frog and populations of other amphibian species are dependent on the creation of new pond habitats (see section 2 above).

## 5. Minimising road mortality through exclusion fencing and allowing for movement through culverts.

In Australia road mortality is a significant mortality factor (Ehmann & Cogger 1985) that must be considered in the management of threatened species. Hels and Buchwald (2001) summarised the destructive potential of roads on populations as: direct, in the sense of actually killing individuals (van Gelder 1973; Cooke 1995; Rosen and Lowe 1994; Drews 1995); and indirect, through the fragmentation of habitat utilised by populations (Mader 1984,1990; Andrews 1990; Reed *et al*. 1996). Thus strategies are required to prevent both mortality of individuals traversing roads and to reduce the extent to which roads function as a barrier to movement. Exclusion fences and under-road culverts have been utilised to address these issues and, more specifically, reduce mortality whilst allowing for movement. Examples of frog exclusion fencing and culvert installation include trials conducted in Denmark (Graff 1996), England (Cooke 1988), Luxembourg (Engel and Bressanutti 1993), Netherlands (Chardon *et al*. 1996), Spain (Yanes *et al*. 1995), and the USA (Piersan 1987). While some culverts have been successful the number of non-functioning tunnel systems predominates (Podloucky, 1989). Furthermore the relationship between culvert length, height and width have not been investigated. Similar to small mammals, the use of tunnels by amphibians is expected to decrease with road width and hence length of the culvert, and to increase with height, width and openness (Yanes *et al*. 1995).

Provision should be made for short and long term movements by re-establishing vegetation corridors between the remnant populations of Wallum Sedge-frog. This would include (1) providing natural substrate in underpasses connecting the east and western sides of the road/rail path from the Boyd Street interchange south, and (2) construction of fencing on both sides of the proposed by-pass to discourage the movement of herpetofauna onto the roadway. Specific to threatened amphibian species, Wallum Sedge Frogs and Wallum Froglets, we propose the following mitigation measures:

A) Creation of under-road culverts under the highway at regular intervals from the Boyd Street interchange south, to link important habitats on the eastern side of the proposed by-pass with less disturbed areas of “wallum” to the west.
   - culverts should be placed at 70-100 m intervals (Anon., 1995) from the Boyd Street interchange south to the commencement of the tunnel approach ramps
   - the size of each culvert should be maximized with recommended minimums of 1m high and 3m wide. We propose the use of three, 1.2metre square box culverts.
   - culverts should have a split level design with the central box culvert placed 50cm lower than the boxes on either side, this will divert water flow through the central culvert during flood periods.
   - culverts should be lined with a natural substrate (earth and humus)
   - culverts should have skylights at mid-point (using maximum dimensions), and slits for light and air whenever practicable (Anon., 1995)
   - culvert tunnels should be set at a gradient to prevent stagnant water collecting,
   - culverts should allow free movement of reptiles, amphibians and small mammals (*eg*. Planigales) however they will require some form of additional exclusion fencing to act as a barrier to large mammals (*i.e.* potoroos and wallabies) that must be excluded from the restricted airport management lands east of the proposed by-pass.

B) Construction and maintenance of frog exclusion fences along the eastern and western sides of the proposed by-pass from the Boyd Street interchange south to the tunnel ramps, these would also guide frogs into the culverts.
   - Fencing could consist of solid overhanging wall measuring at least 400mm high, that would allow surface water flow from the road over the fence and into a drain below.
   - A similar type of fence is shown in Figs 2 & 3. Trials of the proposed exclusion fencing should be undertaken and construction details reviewed as necessary.
   - Runoff from the road should be diverted into holding ponds to prevent chemical contamination of surrounding habitats.

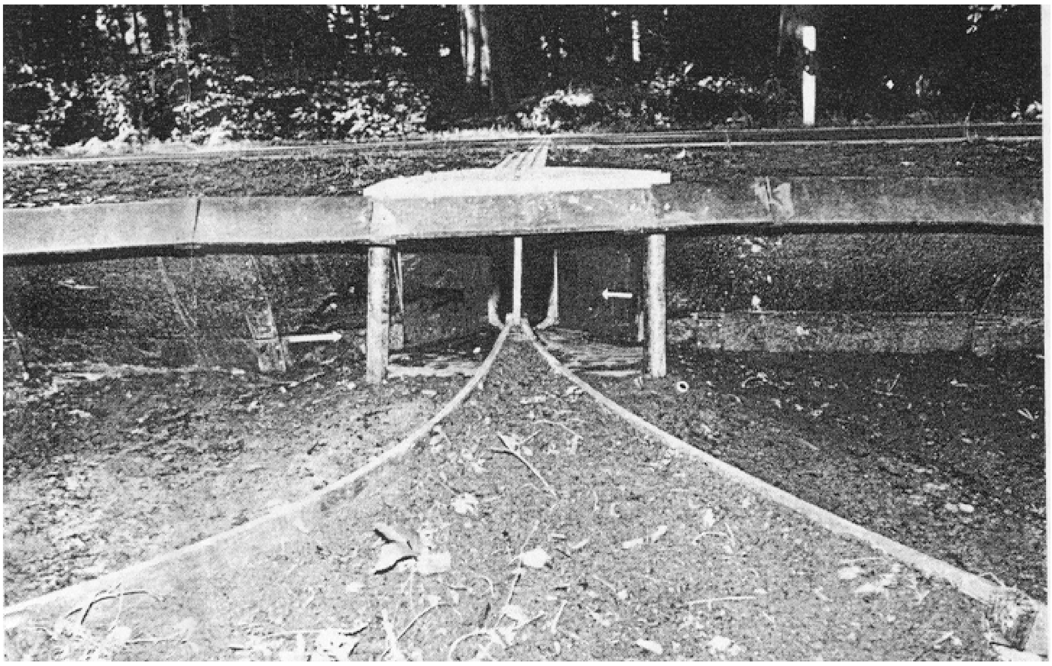

**Figure 2. Photograph of an overhanging fence to stop toads crossing the road and guiding them into culverts (Brehm 1989).**

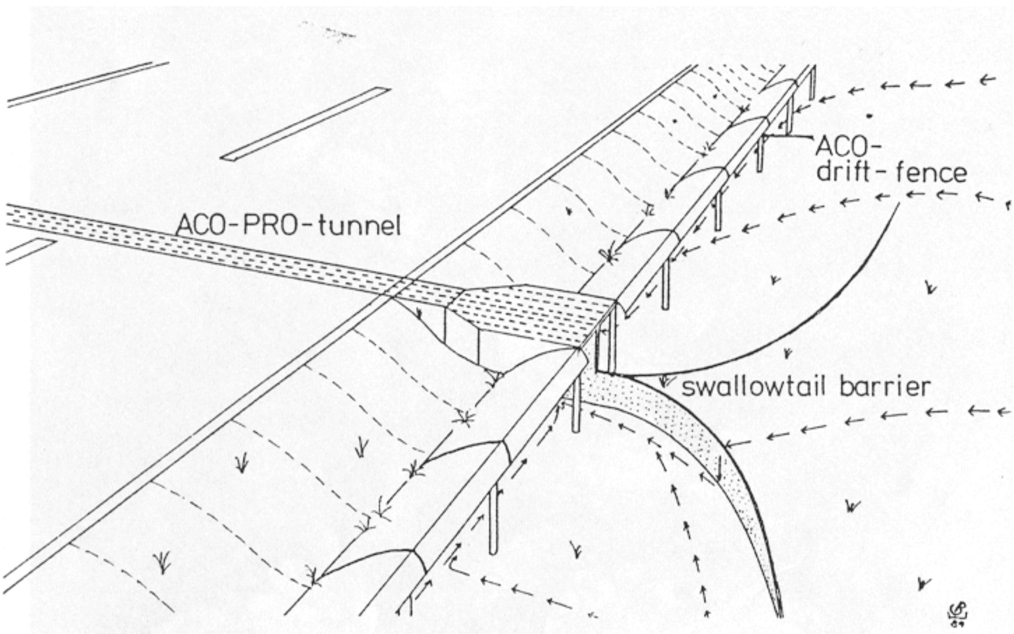


Figure 3. The ACO drift fence with an ACO tunnel, and a special element at the entrance. The 'swallowtail' barrier leads the amphibians to the entrance.

**Figure 3. Demonstration of an overhanging fence to stop toads crossing the road and guiding them into culverts (Brehm 1989). Note in this design the water from the road channels above the overhanging fence.**

# 6. Long-term monitoring

There is a critical lack of information on the long-term success or failure of herpetofauna related translocation programs and actions required to maintain populations of amphibians through the provision of created breeding habitat. This has been further complicated by confusion in the literature concerning what the term 'success' means in the context of such programs (Burke 1991; Dodd and Seigel 1991; Reinert 1991). As the goal of programs is the establishment or enhancement of viable, self sustaining populations (Dodd and Seigel 1991) we follow Griffith *et al.* (1989) in defining success only if evidence of a self sustaining population is established. Given the experimental nature of this proposal (*ie*. we know of no example where the effectiveness of pond creation and under-road culverts has been assessed for any species of reptile or amphibian in Australia) it is important that monitoring work is carried out before, during and after pond construction and installation of exclusion fencing and under-road culverts (Table 1) so that the success of the project can be evaluated. To this end, a funding source should be identified for a minimum of 5-10 years (Podloucky, 1989) so that lessons can be learnt and information can be used to enhance the prospects of this and other similar projects.

**Implementation**

Coordination of activities related to the proposed translocation and population augmentation programs is presented in Table 1. Implementation of each stage will be dependent upon success of the preceding stage, which should be reviewed on an annual basis. For example: road construction (Stage C) should only commence following rehabilitation of surrounding habitat (Stage A), establishment of new pond sites for translocation, and evidence of Wallum Sedge-frog using the new sites (Stage B).

Of the five ameliorative measures considered, none have previously been proven to be effective for herpetofauna of coastal heathland. Below we describe monitoring and experimental design conditions necessary to evaluate the success of the proposed ameliorative measures.

| Stage | Description |
|---|---|
| Stage A: | Initiate revegetation of connecting habitat, construct new frog ponds and remove fish from rehabilitation pond.<br>**Confirm** physical and biological suitability of newly established and rehabilited ponds by **monitoring** hydroperiod, pH and successful breeding and recruitment of indicator amphibian species, with reference and comparison to original ponds. |
| Stage B: | Initiate translocation of displaced amphibians to new ponds. Trial exclusion fences around pond site 5.<br>**Confirm** effectiveness of exclusion fencing and successful breeding and recruitment of frogs in the newly established ponds by **monitoring** movement of hepetofauna into the exclusion area. **Monitor** frogs at newly established and rehabilitated ponds, with reference and comparison to original ponds, |
| Stage C: | Construct exclusion fencing and under-road culverts as part of the by-pass construction phase. Rescue herpetofauna from within the exclusion zone.<br>**Confirm** effectiveness of exclusion fencing and under-road culverts and long-term pond success by **monitoring** movements of herpetofauna into the exclusion area and through the culverts. **Continue monitoring** of hydroperiod, pH and use of new and rehabilitated ponds by amphibians, with reference and comparison to original ponds. |
| Stage D: | Long-term **monitoring** of new, rehabilitated and original pond sites, exclusion fencing and under-road culverts. |

**Table 1: Coordination of activities related to the proposed translocation and population sustainability programs. Implementation of each stage will be dependent upon success of the preceding stage, which should be reviewed on an annual basis.**

(1) **Monitoring connectivity among remnant patches of coastal heath on either side of the proposed by-pass:** comparison of herpetofauna counts between remnant vegetation, rehabilitated vegetation, and vegetation subject to a slashing program

*Crinia tinnula* is likely to be a useful indicator species for assessing temporal changes of fauna use throughout rehabilitating habitat as it is widespread in heath habitats and, under suitable conditions, is readily detected by acoustic surveys. Counts of *C. tinnula* would be undertaken at ten 50 m transects in each of the three vegetation treatments (ie. original, rehabilitated, slashed) on 6 occasions (every second month) each year for 5 years.

Information gathered from the monitoring program would be used to evaluate the success of vegetation rehabilitation and improve understanding of the impact of habitat disturbance on the conservation and distribution a threatened species, *C. tinnula*.

(2) **Monitoring the existing, rehabilitated and newly established populations of Wallum Sedge-frog:** comparison of frog and tadpole counts and physical conditions between original ponds (n=6), a rehabilitated pond (n=1) and created ponds (n=10)

The abundance of adults and larvae of amphibians at individual ponds would be monitored on 12 occasions (once per month) each year for five years. In addition, ten surveys would be undertaken following heavy rain, between September and April each year for five years, to obtain a more rigorous estimate of the abundance of Wallum Sedge-frog in the study area. Observations would initially be undertaken only at original ponds and the proposed rehabilitation pond but later expanded to include new ponds once established. On each occasion, nocturnal visual and acoustic surveys would be supplemented by diurnal surveys employing standard dipnetting methods for larvae. The physical conditions of individual ponds would also be monitored on 12 occasions (once per month) each year for 5 years. Again, observations would initially be undertaken only at original ponds and the proposed rehabilitation pond but later expanded to include new ponds once established. On each occasion, maximum water depth , pH, conductivity and water temperature would be measured.

Information gathered from the monitoring program of adults and larvae would be used to evaluate the success of experimental ponds (*ie*. created ponds and rehabilitation pond) relative to control ponds (*ie*. original ponds) for breeding and maintenance of amphibians with particular emphasis on Wallum Sedge-frog populations. Data from the monitoring program of physical conditions would be used to improve knowledge of the habitat requirements of the individual species and to interpret patterns of success/failure for experimental ponds.

### (3) **Monitoring translocation of individuals into newly created habitats: survival of translocated amphibians**

While an assessment of the survival of all herpetofauna translocated from the area under construction is unlikely to be feasible, at least for amphibian species it may be possible to implement such a project with minimal effort in addition to that already prescribed above. Translocated adults of threatened frog species from pond 5 would be marked prior to introduction to created ponds and their presence would be monitored over time. Such a project would utilise the tendency of amphibians to congregate at breeding sites. Determining persistence of translocated individuals over the study period would require no additional work given that surveys would already be undertaken at ponds.

Information gathered from the monitoring program could be used to assess the benefits of translocation of individuals during rescue operation in this and other projects.

### (4) **rescue individuals from sites prior to and in the process of construction**

Intensive diurnal and nocturnal searches would be undertaken within the proposed development area prior to, and during construction. Consultation with developers would be required such that sufficient notice is given to adequately undertake removal operations. The duration of searches is dependant on the size of the area being developed at any given time, but could be estimated from trials over sample areas. Rescue operations during construction should be prior to major earth works.

Prior to construction a temporary fencing should be constructed on either side of the by-pass footprint, and an extensive pitfall-trapping program should also be initiated within the footprint, at 100 m intervals. All fauna encountered moved into adjacent rehabilitating areas.

Information gathered from these monitoring programs (1-4) could be used to determine when construction should proceed (*ie.* when few or no individuals are recorded on subsequent surveys), evaluate the comprehensiveness of rescue operations to remove herpetofauna from within the development area, and supplement observations relating to the success of exclusion fences to restrict movement of fauna into the development area.

## (5) **monitoring herpetofauna movement pre and post-construction: minimising road mortality through exclusion fencing and allowing for movement through culverts.**

<u>Pre-construction</u>

A trial exclusion fence would be constructed around the perimeter of pond 5 (Fig. 4). Over a period of three months, ten diurnal and nocturnal searches would be undertaken within the exclusion area, and all herpetofauna captured would be marked and removed. Recording the presence of marked individuals during subsequent surveys would assess movement of individuals back into the exclusion area.

Trials of culvert use would be undertaken remotely at existing under-road in similar habitats culverts (where available). 10 days of pitfall trapping would be undertaken at the entrances to ten culverts. A drift fence measuring the width of the culvert would be constructed in a circular arc across the culvert entrance and a 10 L buckets sunk into the ground on both sides of the fence. Pitfalls would be checked each morning. Individuals captured in each bucket would be marked and transferred across the fence.

<u>Post-construction</u>

Diurnal and nocturnal counts of herpetofauna would be undertaken, under a variety of weather conditions, along ten 50 m transects throughout the development area on 10 occasions. Frequency and duration of subsequent surveys would be determined from a review and evaluation of information gathered in initial surveys. Additional surveys could be undertaken along the road following the introduction of vehicular traffic, to assess the effect of road-kill on resident populations of herpetofauna. There may also be potential to extend surveys to include major roads in similar habitats so that a comparison of mortality between roads with and without exclusion fencing could be undertaken.

Ten days of pitfall trapping would be undertaken in spring, summer, autumn and winter at the entrances to each culvert. Frequency and duration of subsequent surveys would be determined from a review and evaluation of information gathered in initial surveys. On each occasion, a drift fence would be constructed in a circular arc across the culvert entrance and a 10 L buckets sunk into the ground on both sides of the fence. Pitfalls would be checked each morning. Individuals captured in each bucket would be marked and transferred across the fence.

Information gathered from the pre and post-construction monitoring program would be used to assess the effectiveness of exclusion fencing in restricting the movement of herpetofauna and the success of culverts in allowing for movement of herpetofauna across the development area. Lessons learnt from pre-construction trials would be used to highlight design features, which need to be re-evaluated and modified prior to construction.

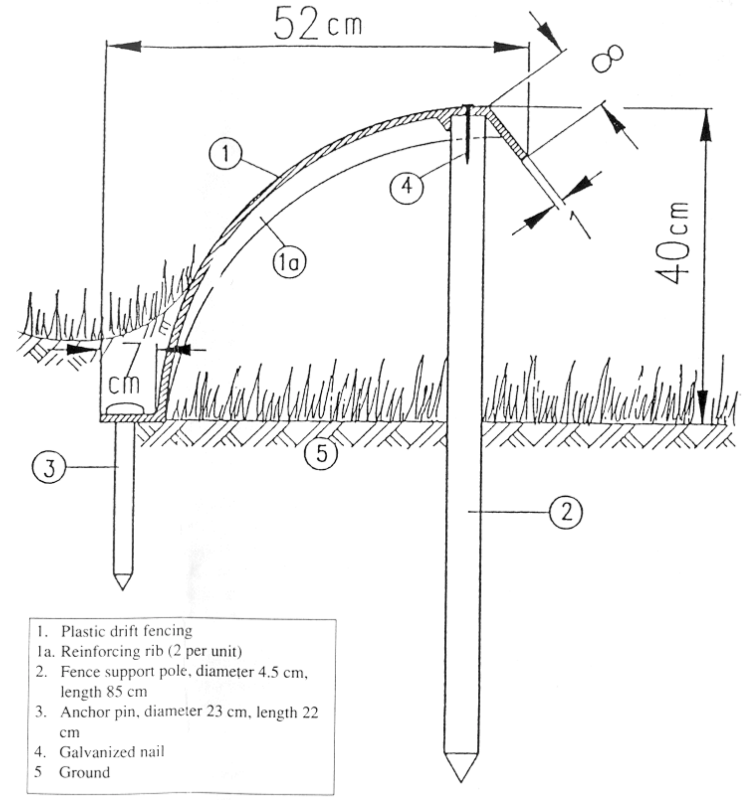


**Figure 4. A temporary drift fence design to exclude frogs from reentering exclusion zones (Brehm 1989).**

## The importance of cooperation and long-term agreement of governing bodies responsible for the management of land within and adjacent to the development area

Central to the process, but not considered previously, is the land tenure associated with the project. Implementation of the program outlined in the above table is dependent upon both funding and collaboration with current landowners. This has important implications for the viability of the proposed mitigation measures. Therefore all objectives and recommendations outlined above are dependent upon cooperation and a long-term agreement for the conservation and expansion of habitats within GCAL/Commonwealth Land and other landholders adjacent to the proposed by-pass.

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## Appendix 1: Information to direct planning and execution of pond construction.

References as cited are: (**1**) Ehmann 1997; (**2**) E. Meyer pers. comm. (**3**) Liem & Ingram 1977; (**4**) James 1996; (**5**) Hero *et al.* 2001b; (**6**) Hines *et al*. 1999.

| Characteristic | Description |
| --- | --- |

| | |
|---|---|
| **Breeding season** | Calling males have been recorded in spring, summer and early autumn at night and by day when swamps were rising or ample water was available (**1**). Wallum Sedge-frogs mainly breeds following heavy rain (**2**). |
| **Larval habitat** | Flowing creeks, in marshy or swampy habitats (usually temporary or semi-permanent) and their connecting channels, and coastal freshwater lakes, including perched lakes with deep water (often permanent) (**1,3,4**) amidst sedges, grasses and/or Bungwell Fern (*Blechnum indicum*) (**2**). Eggs are attached to grasses and sedges and larvae are nektonic in form and dwell amongst reeds and grasses in water (**2**). |
| **Larval period** | Available information suggests several months to more than a year in some cases. May over winter. |
| **Larval predators** | Fish are largely absent from habitat occupied by the species (**2**). |
| **Adult habitat** | During wet periods adults are found clinging to emergent vegetation (grasses, reeds and Bungwall Fern and during dry periods at the base of sedges, grass clumps and/or Bungwall Fern in the same swamps (**2**). Non breeding habitat not known. |
| **Adult movement** | Dispersal abilities and the frequency or likelihood of colonisation events are not known. However, its use of recently created or rehabilitated sites for reproduction suggests that they are quite successful colonists provided there is a natural corridor to aid dispersal (**4**). Dispersal between isolated habitats almost certainly involves short term opportunistic movement across areas during wet periods and long-term population dispersal along suitable corridors (coastal swamps and wallum plains) (**2**). |
| **Hydroperiod** | Variable between years and some water for several months appears to be a minimum. Infrequent pond drying may also be important. |
| **Depth** | 0.5-1.5 m (**2,5**) |
| **Chemistry** | wallum waters in which the species breeds are typically heavily tanin-stained and highly acidic (pH 3.4-4.5) (**2,5**). |
| **Other** | Competition from invading frog species and predation from introduced fish (ie. Mosquito Fish - *Gambusia holbrooki*) have been identified as potentially threatening processes (**1,6**) however remain untested. |

# Appendix G

*The Status and Distribution of the Cobaki Long-nosed Potoroo Population* (Bali *et al.* 2003)

Ecosense Consulting Pty. Ltd.

*2 Chiswick Street, Strathfield South NSW 2136*
*Ph: (02)9642 0298  Fax: (02) 9642 0739*
*ABN 17 073 844 318*
*arbali@optusnet.com.au*


# The Status and Distribution of the Cobaki Long-nosed Potoroo Population

**July 2003**

Prepared for

Parsons Brinckerhoff

By


R. Bali, B. Lewis[1] & K. Brown[2]

*[1]Lewis Ecological Surveys*
*6 Blue Gum Avenue*
*Wingham NSW 2429*

*[2]Ecopro Pty. Ltd.*
*Lot 35/7 Roseleas Close*
*Cundletown NSW 2430*

# 1.0 INTRODUCTION

Ecosense Consulting Pty Ltd was commissioned by Parsons Brinckerhoff (PB) to undertake a trapping and radio-tracking study on the population of Long-nosed Potoroos (*Potorous tridactylus*) in the Cobaki area. Lewis Ecological Surveys (A2809) was engaged to undertake the fieldwork component of the report and assist in data analysis, while EcoPro Pty Ltd was commissioned to assist in data analysis and undertake the mapping.

The occurrence of a potoroo population near Boyd Street, Tugun, along the proposed route of the Tugun Bypass was confirmed during surveys conducted as part of the Environmental Impact Statement (EIS) and Species Impact Statement (SIS). The presence of potoroos was verified on the basis of a two sightings and one positive hair sample in 2001, but little information was available regarding the status, distribution and habitat use of this population.

Previous route options for the Tugun Bypass were located further to the west and would have resulted in the loss of potoroo habitat and the creation of a north-south barrier to movement. Although the final alignment is located as far as possible to the east within the constraints set by the Tugun landfill, thereby avoiding most potoroo habitat, it was considered necessary to undertake a detailed study of the Cobaki potoroo population as the basis for a management plan.

The aim of this report is to present information that can be used to assess impacts associated with the Tugun Bypass and to develop a plan of management for the Cobaki potoroo population to ensure its long-term survival in the Tugun area.

## 1.1 Cobaki Potoroo Population

A number of flora and fauna surveys have been undertaken in the Cobaki area. These were reviewed by Warren (1994) and Parker (1999) as part of a flora and fauna assessment and SIS for the Cobaki Lakes development. Potoroos were not detected within those areas proposed for residential development.

Potoroos were recorded outside the Cobaki Lakes development area by Warren (1992) during preparation of a Fauna Impact Statement (FIS) for the construction of the Boyd Street extension between Boyd Street and the proposed residential development. Two potoroos were captured in the same trap on consecutive days in the grass tree (*Xanthorrhea fulva*) ecotone north-west of the proposed road (see Figure 1). Apparently both individuals died while in the trap. Although the area near the proposed road was not considered to provide suitable habitat for potoroos, this area had been severely burned in August 1991. Warren (1992) hypothesized that the understorey and hence the potoroo population near the road would recover in 2-3 years.

Mason (1993) undertook a potoroo survey in order to confirm the presence of the population, its structure and distribution. He did not capture any potoroos despite160 trap-nights of effort. Two positive hair samples were recorded in an ecotone between wet heath and heath scrub communities. Mason concluded that, based on potoroo densities that he previously calculated for Tyagarah Nature Reserve located about 45 kms away, the Cobaki population probably consisted of 10-20 individuals. He hypothesized that only 25-50% of the Cobaki area provided suitable potoroo habitat due to recent (1991) fires.

Another potoroo survey was undertaken in 2001 as part of the Tugun Bypass EIS. Hero *et al*. (2001) observed two potoroos near the NSW/Queensland border and recorded one positive hair sample (see Figure 1). Trap effort and potoroo records for these studies are summarised in Table 1.1 below:

Table 1.1: Comparison of survey results for previous potoroo studies at Cobaki.

| Study | Trap Effort | Potoroos Captured | Hair Tube Effort | Hairs Collected |
|---|---|---|---|---|
| Warren (1992) | ? (5 traps) | 2 (both dead*) | NA | NA |
| Mason (1993) | 160 trap-nights | 0 | 1260-1320 tube-nights | 2 |
| Hero *et al*. (2001) | 40 trap-nights | 0 (2 observed) | 760 tube-nights | 1 |

* female found dead on 2/12/92; male found dead 3/12/92

As part of the original EIS investigations for the Tugun Bypass, the more recent potoroo records and surrounding Swamp Mahogany/ Scribbly Gum Forest were mapped as known habitat. Historical records, potential habitat as described by Mason (1993) and additional areas considered possible habitat were mapped as potential habitat (see Figure 1). This entire area measured approximately 150 ha and was subject to an intensive trapping and radio-tracking study by Lewis Ecological Surveys.

### 1.2 Conservation Status

The Long-nosed Potoroo is listed as vulnerable on the *Queensland Nature Conservation Regulation (Wildlife) 1994* and on the NSW *Threatened Species Conservation Act 1995*. It is also listed as Vulnerable on the *Commonwealth Environmental Protection and Biodiversity Conservation Act 1999*. In northern NSW and south-eastern Queensland, this species appears to be very uncommon and is therefore considered to be of high regional significance.

Its distribution is poorly known along the far north coast of New South Wales where Mason (1993) estimated that 150-250 potoroos remain. Known populations are restricted to small isolated remnants from Broken Head to Brunswick and at Cobaki, Tyagarah and Wardell (Mason 1997). Only the Tyagarah population is found in a Nature Reserve; other populations occur on Crown land or on private land.

In Queensland, the Long-nosed Potoroo has apparently declined in range. Little is known about its distribution, especially the northern and western limits of its range. Capararo and Lundie-Jenkins (1998) undertook potoroo surveys at 25 sites in 10 locations in south-eastern Queensland where potoroos had been previously recorded. The authors detected potoroos at four out of 25 sites. The closest one to Tugun was at Green Mountains located about 45 km to the west.

### 1.3 Study Design

The study was designed to obtain ecological data from a potoroo population that was considered to be very small and localized. As the overriding assumption was that potoroos would be difficult or impossible to capture, a contingency plan involving the use of hair tubes was incorporated into the study. Furthermore, a variety of methods were used to attract and/or capture this trap-shy species.

The study design aimed to:

- Systematically trap grid areas radiating outwards from known habitat in three stages;
- Maximise trap and hair tube coverage given logistical and ethical constraints in the study area;
- Capture and attach radio transmitters to as many individuals as possible early in the study by reducing trap spacing in known habitat;
- Collect at least 20-30 location fixes for each radio-tracked individual;
- Maximise the collection of habitat utilisation data through the use of 100 hair tubes distributed widely in potential habitat; and
- Test a variety of bait and trap types.

Although these design principles were generally followed, the study was designed to be flexible and to incorporate changes as new information became available. Variations to the original proposal included:

- The addition of Stages 4-6 to survey habitat not covered by Stages 1-3; and
- The addition of supplementary trapping stages A-J to maximise the capture and recapture of potoroos.

## 2.0 METHODS

This section describes the study area and outlines the trapping and hair tubing surveys and radio-tracking procedures.

### 2.1 Study Area

The study area is located partly in NSW Crown Land managed by the Department of Land and Water Conservation. The area near the bypass is freehold land under the ownership of the Tweed-Byron Local Aboriginal Land Council. A small portion of Crown land in the vicinity of the proposed bypass is still undetermined pending the final alignment. The study area is bounded by Cobaki Broadwater to the south, the NSW/Queensland border to the north and east, cleared Gold Coast Airport lands (GCAL) to the east and south-east and by the approved Cobaki Lakes development to the north and west.

An additional area of GCAL land was also surveyed using cage traps and hair tubes. This area included connecting vegetation from the known potoroo habitat in NSW Crown land southwards to the soil dredge dump site. The Cobaki Broadwater formed the western boundary, while cleared lands defined the eastern limit.

Six broad habitat types covering approximately 150 ha were surveyed, including:

- Dune Woodland/Forest (45.0 ha);
- Heathland (40.7 ha);
- Swamp Forest (39.9 ha);
- Rainforest (13.7 ha);
- Sedgeland (1.1 ha); and
- Disturbed Grassland (5.9 ha).

## 2.2 Field Survey

Cage trapping and hair tube surveys were undertaken between 8 April and 2 June 2003. Radio telemetry was conducted between 18 April and 30 May.

### *2.2.1 Cage Trapping*

Cage trapping was undertaken using five different trap types (e.g. rigid treadle, rigid drop bar, standard collapsible, spring-loaded and double-ended) that are briefly described in Appendix A. Grid trapping was undertaken in six separate stages, each one radiating further south towards the Cobaki Broadwater and east into GCAL controlled lands. Traps were generally arranged in a grid configuration consisting of up to 50 traps set 70-80 m apart, thereby covering an area of approximately 20 ha. The exception to this was the area delineated as known potoroo habitat following surveys by Hero *et al.* (2001). This area was trapped using a spacing of 30-40 m to increase the likelihood of potoroo captures (i.e. Stage 1). Stages 4 and 5 were westward extensions of Stage 3 and targeted suitable habitat not previously covered during Stages 1-3. Stage 6 trapping was undertaken when diggings and suitable habitat types were identified close to GCAL lands. Grid size was considered to be appropriate given the constraints associated with moving through dense vegetation and with animal care and ethics requirements (Licence: AW2001/040) that traps be checked within 2 hours of sunrise. In total, 268 traps were deployed in six stages over five-night trapping periods resulting in a trap effort of 1065 trap-nights (see Figure 2 and Table 2.1).

At the completion of Stages 1-3, some transects comprising mostly 5 traps each were deployed over previously trapped areas. These transect surveys were undertaken to increase the likelihood of recapturing some animals for radio telemetry and to increase survey effort in those areas subject to existing and potential impacts (i.e. adjacent to the existing Cobaki Lakes access track and to the proposed bypass footprint). Traps were deployed at 55 locations over 10 stages resulting in an additional 185 trap-nights (see Figure 3 and Table 2.1). Traps were left operating for 1-5 nights during this phase of the study.

Table 2.1: Cage trap survey effort.

| Stage | Dates | Number of Cages | Distance between traps | Survey Effort |
|---|---|---|---|---|
| 1 | 10 – 16 April 2003 | 50 | 35 | 250 |
| 2 | 15 – 23 April 2003 | 50 | 75 | 250 |
| 3 | 22 – 28 April 2003 | 42, 2 grids of 4 | 75 | 250 |
| 4 | 6 – 11 May 2003 | 10 | 75 | 50 |
| 5 | 11 – 20 May 2003 | 15 | 75 | 75 |
| 6 | 20 – 30 May 2003 | 38 | 75 | 190 |
| | **No. Trap Locations** | **213** | **Stages 1-6 Trap Nights** | **1065** |

| Stage | Dates | Number of Cages | Distance between traps | Survey Effort |
|---|---|---|---|---|
| Supp A | 28 April – 5 May 2003 | 5 | Variable | 25 |
| Supp B | 29 April – 6 May 2003 | 5 | Variable | 25 |
| Supp C | 6 – 11 May 2003 | 5 | Variable | 25 |
| Supp D | 7 – 12 May 2003 | 5 | Variable | 25 |
| Supp E | 12 – 15 May 2003 | 3 | Variable | 9 |
| Supp F | 12 – 19 May 2003 | 5 | Variable | 20 |
| Supp G | 19 – 21 May 2003 | 5 | Variable | 10 |
| Supp H | 20 – 23 May 2003 | 6 | Variable | 12 |
| Supp I | 21 –26 May 2003 | 6 | Variable | 18 |
| Supp J | 28 – 30 May 2003 | 10 | Variable | 16 |
| | **No. Trap Locations** | **55** | **Supplementary Total** | **185** |
| | **Total Locations** | **268** | **Total Trap Nights** | **1250** |

All cage traps were placed in or around dense cover with their wire floors embedded into freshly disturbed soil to provide a natural substrate. It was assumed that this would reduce stress associated with capture and consequently increase trapping success. During Stage 1, traps were baited with the standard bait mix of peanut butter, honey and oats with pistachio essence, mushrooms and diced carrot being added. During all other stages, a variation of the standard bait mix (i.e. more peanut butter) was used as this appeared to be a more successful attractant. Cage traps were baited daily throughout the entire study to increase its effectiveness as an attractant.

### *2.2.2 Handling Captured Potoroos*

All traps were checked and rebaited soon after sunrise in accordance with NSW Agriculture requirements and animals were processed accordingly. The following information was determined for most potoroos captured:

- Sex;
- Age class (adult female >1000 g; adult male >1050 g)
- Breeding status;
- Weight;
- Head length;
- Presence/absence of tail albinism; and
- Cage type and trap number.

Individuals were temporarily marked by clipping a distinctive pattern into their fur; this allowed recaptured potoroos to be identified throughout the study period. Furthermore, the suitability of trapped individuals for radio-tracking was determined (i.e. adult, non-breeding or small pouch young, good health). In cases where females were carrying pouch young, limited data were collected to reduce handling stress to that individual.

### *2.2.3 Hair Tubes*

Hair tube surveys were used to further assess the distribution of potoroo throughout the study area and to provide a contingency plan in case of poor trap success. Prior to the start of cage trapping, a grid comprising 100 hair tubes spaced 50 m apart (i.e. covering approximately 20 ha in Crown land) was used to assess potoroo distribution throughout areas most likely to provide suitable habitat (i.e. those similar to known potoroo habitat). During

Stages 2 and 3, hair tube spacing was increased to 80 m (i.e. covering approximately 52 ha in Crown land). An additional grid consisting of 50 hair tubes spaced 80 m apart was used to assess GCAL land in the southernmost portion of the study area. Hair tubes were baited alternatively with standard bait and a pistachio-scented bait and left out for a period of eight nights (2000 trap-nights) (see Figure 4 and Table 2.2). Baits were considered ineffective in attracting potoroos after this time period. All hair samples were sent to Barbara Triggs (Dead Finish) for analysis.

Table 2.2: Hair tube effort.

| Timing in Relation to Cage Trap Stages | Dates | Number of Hair Tubes | Distance between tubes | Survey Effort |
|---|---|---|---|---|
| Before & During Stage 1 | 8-16 Apr 2003 | 100 | 50 | 800 |
| During Stages 2 & 3 | 17-25 Apr 2003 | 100 | 80 | 800 |
| During Stage 6 | 24 May – 1 Jun 2003 | 50 | 80 | 400 |
| | | **250** | | **2000** |

### *2.2.4 Searches for Diggings*

Searches were undertaken for potoroo diggings during deployment of cage traps and hair tubes. These can be difficult to distinguish from bandicoot diggings. However, bandicoots do not often excavate holes beyond 15 cm in depth while potoroos are capable of digging to depths in excess of 30 cm (B. Lewis, *pers. obs*.). Although both bandicoot and potoroo diggings can be conical in shape, the bottom is likely to be rounded for potoroo and more pointed for bandicoots. The distribution of the potoroo population is based on the distribution of these diggings together with the results of cage trapping and hair tubing.

### *2.2.4 Radio Telemetry*

Transmitters were affixed to 12 potoroos (5 females, 7 males). Eleven (4 females, 7 males) individuals were radio-tracked to determine microhabitat use and to provide some indication of home range size and daily movement patterns. The twelfth individual was not tracked due to transmitter failure (no signal) and we predict the transmitter would have fallen off within two weeks. Transmitters (Titley Electronics, Ballina) were fitted with activity sensors, weighed 7.75 g and had a range of 500 m. The total transmitter package including the attachment device, weighed approximately 12 g or less than 2% of the potoroos' body mass.

Each transmitter was affixed to the base of the potoroo's tail so that the antenna ran along the tail. This area was clipped to remove most hair and the transmitter held in place with a small amount of super glue and elastic leucoplast tape. This method is also used by NPWS for radio-tracking Long-nosed Bandicoots (Rachel Miller NPWS, *pers. comm.*). It was considered appropriate given the short duration of the study and the increased probability that the transmitter would eventually fall off if the potoroo was not recaptured.

Because potoroos were not directly observed during the study, their locations or fixes were determined through close range triangulation. Fixes for each radio transmitter were obtained with a mobile receiver (Regal 2000, Titley Electronics) using a hand-held Yagi antenna from 21 stations or reference points located throughout the study area. Stations were normally positioned 100 m apart and located around the periphery of the subject site. This enabled fixes to be obtained from 3-6 stations in relative close proximity to the subject animal (100-150 m), thus reducing 'locality error'. This normally took 10-15 minutes to complete per animal, depending on the exact distances and topography between stations. A number of features in the environment are likely to have attributed to the locality error including, fragmented landscapes, dense vegetation and/or metal structures. The activity of each potoroo (40 pulses versus 60 pulses) was recorded during each fix. Bearings were initially manually plotted onto graph paper but were subject to a verification process before final plotting (see Section 2.2.6).

Fixes were collected over four time periods defined approximately as follows: dusk (1700-1800 hours); dawn (0500-0700 hours); day (0700-1700); and night (1800-0500). Consecutive locations were separated by more than two hours to minimise temporal autocorrelation (White & Garrot 1990). In general, attempts were made to collect one diurnal fix from a daytime refuge, followed by a number of nocturnal fixes indicating patterns of home range movements and habitat use.

### *2.2.5 Estimating Radio-tracking Error*

There was some location error associated with fixes obtained during radio telemetry. The magnitude of this error varied with transmitter location and equipment used. A number of field tests were undertaken to estimate tracking error both prior to and after the radio telemetry study. Initially, all eight transmitters were placed at three known points and their bearings measured to test the difference between the estimated and actual locations of radio transmitters.

When the study was completed, error associated with the transmitters was again tested. As there were few landmarks within the study area that could be distinguished on a 1:25,000 topographic map, transmitters were placed at 2-6 random locations within an area most likely to have been used (based on cage trap locations) by each radio-collared potoroo during the study. Bearings were then taken only from those stations (normally 4-8 stations) that were used to locate that particular individual during the study. This test was not applied to transmitter frequencies 931 and 901 that were lost or had failed during the study.

The actual locations of the transmitters were determined through use of a Garmin 12-channel Global Positioning System (GPS). It was considered that variability of the error was reduced given that the co-ordinates of both the stations and transmitter locations were recorded no more than 60 minutes apart. Separation error was defined as the difference between the estimated and true location of transmitters at 23 locations and averaged 25.1m (s.d. = 17.9). This was regarded as acceptable to meet the objectives of the study.

### *2.2.6 Movement Sensors*

All transmitters fitted to potoroos had activity pulses to indicate whether the animal was moving or stationary (see Table 2.3). The mortality indicator was activated when the transmitter had not moved for 12 hours.

Table 2.3: Activity recording levels in radio transmitters.

| Pulse Rate | Activity |
|---|---|
| 20 | Low battery |
| 40 | Stationary animal < 12 hrs between movements. |
| 60 | Animal moving |
| 80 | Mortality indicator – transmitter fallen off |

In order to better understand the activity patterns of radio-tracked potoroos, individuals were monitored over seven time periods, defined with respect to the timing of dawn and dusk during each day of the study period (Geoscience Australia 2003): late day, dusk, early night, middle night, pre-dawn, dawn and early day. Each potoroo was detected from a central location (normally the Cobaki Lakes Development Road) that allowed subject animals to be monitored in consecutive order. Activity levels were recorded over five-minute intervals and the proportion of time spent active (i.e. pulse rate of 60) and the number of active periods was recorded. Although most monitoring sessions included five potoroos, the number varied from 1-6. Monitoring periods were usually separated by two hours (minimum one hour) to ensure independence of data sets (White and Garrott 1990). All activity data collected was checked against trapping data to ensure that activity was not recorded for any caged potoroos.

Weather parameters were also recorded during each radio-tracking session to measure their relationship with potoroo activity. These included: maximum and minimum air temperature, rainfall, cloud cover (%), wind speed and lunar phase (in eighths) and are summarised for the study period in Appendix B.

### *2.2.7 Field Survey Limitations*

The survey was designed to maximise the number of potoroos captured and to provide some data about habitat utilization if no individuals were trapped (i.e. hair tubes). Consequently, the various grid sizes and configurations including the use of 10 supplementary transects did not allow systematic sampling of the population, making its size estimation problematic. For ethical reasons, the ultimate number of traps used was limited to the number that could be checked by two field workers moving through dense vegetation.

Weather conditions during part of the survey were not ideal for trapping or radio-tracking. In particular, there were extended rainy periods, notably during 22-27 April, 14-18 May and 26-28 May. Large areas of potential habitat were flooded and therefore inaccessible, in particular Tree Broom Heathland north of the Cobaki Lakes development access track and in the western part of the study area. Drainage lines within Swamp Forest could not be trapped even though these areas were regularly used by potoroos.

Field tests demonstrated that there was a high degree of variability associated with individual transmitters and locations. These may be attributed to the following:

- Fences transecting the study area;
- Close proximity of the Coolangatta Airport and its associated navigational aids;
- Fragmented nature of the site together with the presence of dense heathland vegetation; and
- Noise interference associated with low-flying aircraft and helicopter training area.

However, location data collected during the current study are considered to be adequate for determining habitat use and home range size for the following reasons. Firstly, the majority of the fix locations fall within areas encompassed by the trapping grids. Secondly, the error was likely to be reduced by the use of 21 stations from which data was recorded. Thirdly, the separation error associated with location fixes was calculated to be approximately 25 m which would not be expected to significantly affect the findings of this report.

The Queensland side of the border was not trapped due to licensing issues. However, only 1.8 ha of habitat occurs there and its omission from this study is not likely to significantly affect the outcomes of the study. A general traverse was undertaken in an attempt to identify potoroo diggings and to delineate the north-eastern extent of potoroo habitat.

### 2.3 Data Analysis

Although the present study was designed to address the possibility that few potoroos would be captured, there were sufficient recapture and radio-tracking data to consider the use of simple statistical analysis and home range estimation techniques.

#### *2.3.1 Verification of Radio-tracking Data*

Bearings were systematically verified before being plotted using MAPINFO (Version 5.0). A single location was defined from either the intersection of three or more bearings or the centre of a polygon defined by at least three bearings. If the bearings formed a polygon greater than 0.5 ha, the location point was considered inaccurate and was discarded.

All radio-tracking data sets were verified and plotted and any spurious locations discarded. A total of 296 (83%) fixes collected were used to determine home range size and habitat use. This included 82 (80%) female fixes and 214 (84%) male fixes. In the case of M931, a number of fixes were plotted in Blackbutt Forest. These data points were discarded because this habitat type is not recognised as suitable potoroo habitat and was most likely a function of system error. However, this individual was positively identified during both day and night north-east of the Queensland/NSW border, indicating a preference for both refuge and foraging habitat in Queensland. Therefore any description of home range movements for male M931 would be incomplete without consideration of habitat in Queensland.

*2.3.2 Population Estimate*

Systematic grid trapping undertaken during Stages 2-3 was used to estimate potoroo density over the population's distribution. Data collected during Stage 1 were not suitable for analysis because only one potoroo was captured over a five-day period. As Stage 1 trapping targeted known potoroo habitat and capture success was high during subsequent supplementary surveys, it was assumed that potoroos needed time to habituate to the presence and smell of the traps. Also, trap spacing during Stage 1 was compressed and only covered an area of about 6 ha.

Grids deployed during Stages 2-3 covered an area of approximately 20 ha. However, in order to take account of potoroos with home ranges on the edge of the grid, a boundary strip representing half of the inter-trap distance (i.e. 35 m) was added around the outside of the grid. The boundary strip method is based on the assumption that animals range on average half way to the next trap beyond their peripheral capture sites (Stickel 1954). Together with the boundary strip, the grid effectively sampled approximately 28 ha over a 10-day period.

*2.3.3 Home Range Estimate*

The Minimum Convex Polygon (MCP) was used to provide an index of potoroo home range size and location in the study area. This technique estimates area by connecting the outermost location points in a distribution. It has the disadvantage that each point is given equal value and the resulting area contains large areas that may never be used by an individual (i.e. the home range is overestimated). However, as this method is commonly applied in small mammal studies, it provides a comparative size estimate in this case.

*2.3.4 Data Analysis Limitations*

As much of the trapping was not undertaken systematically, standard mark-recapture models could not be applied. A population estimate range was therefore calculated on the basis of density calculated from two grid trapping stages. This method allowed direct comparison with the closest potoroo population located at Tyagarah.

The MCP was not used to describe home range use for reasons listed in Section 2.3.3. Habitat use was instead described as the number or proportion of captures or radio telemetry fixes recorded within each vegetation type. The distribution of location fixes for each individual was then mapped with respect to vegetation communities. Non-parametric techniques such as the harmonic mean and Fourier transform methods that are not influenced by the underlying distribution of points, are recommended to determine centres of activity.

## 3.0 RESULTS AND DISCUSSION

There were two phases to this investigation. The first was to examine the best means of trapping potoroos given previous unsuccessful attempts (see Sections 3.1 and 3.2). The second was to examine population status and distribution and individual movement patterns for the purposes of impact assessment and mitigation (see Sections 3.3 and 3.4).

## 3.1 Field Survey Results

A number of methods were used in order to maximize the probability of capturing individuals within the Cobaki population. Different bait mixtures and cage trap designs were also trialled.

### *3.1.1 Cage Trap Success*

Systematic trapping undertaken during Stages 1-6 resulted in the capture of 15 potoroos on 20 occasions (1.9% trap success). Supplementary (non-systematic) trapping in some areas increased this figure to 27 individuals from 65 captures (5.2% trap success). Evidence of breeding was recorded in 55% (n=6) of female potoroos captured. The presence of sub-adult animals (15%, n=4) also indicates that there is presently some recruitment into the adult population. Capture locations are shown in Figure 5 and details for all individuals captured is presented in Appendix C.

Trap success showed marked variation throughout the study ranging from no captures in Stage 6 to a trap success of 4.8% in Stage 2 (Table 3.1). Supplementary (non-systematic) trapping often resulted in high trap success (up to 50% trap success) and accounted for 12 new individuals and 45 additional captures.

Table 3.1. Capture summary for systematic (Stages 1-6) and non-systematic (Supplementary A-J) trapping. (M) = male and (F) = female.

| Stages | No. New Individuals | No. Captures | No. Trap-Nights | Trap Success % |
|---|---|---|---|---|
| 1 | 1 (F) | 1 | 250 | 0.4 |
| 2 | 5 (M) 3 (F) | 12* | 250 | 4.8 |
| 3 | 1 (M) 1 (F) | 3 | 250 | 1.2 |
| 4 | 1 (M) | 1 | 50 | 2.0 |
| 5 | 3 (M) | 3 | 75 | 4.0 |
| 6 | 0 | 0 | 190 | 0.0 |
| Supp. A | 2 (F) | 4 | 25 | 16.0 |
| Supp. B | 2 (M) | 4 | 25 | 16.0 |
| Supp. C | 1 (M) 2 (F) | 10 | 25 | 40.0 |
| Supp. D | 0 | 1 | 25 | 4.0 |
| Supp. E | 1 (F) | 3 | 9 | 33.3 |
| Supp. F | 0 | 1 | 20 | 5.0 |
| Supp. G | 1 (M) 1 (F) | 5 | 10 | 50.0 |
| Supp. H | 1 (M) | 6 | 12 | 50.0 |
| Supp. I | 0 | 6 | 18 | 33.3 |
| Supp. J | 1 (M) | 5 | 16 | 6.25 |
| **Total Captures** | **16 (M) 11 (F)** | **65** | **1250** | **5.2%** |

* 1 potoroo recaptured twice, two potoroos recaptured once each

Of the total number of potoroos captured, two were captured six times each, one was captured five times, three were captured four times each, five were captured three times each, five were captured twice each and the remaining 11 individuals were captured only once (see Appendix C). Of the 13 potoroos recaptured, nine (69%) were adult males and one was a sub-adult male.

Five different types of cage traps were deployed to determine if any of these was more successful at trapping potoroos. The trap success for each of these was compared for systematic trapping during Stages 1-6. When adjusted for the total number of trap-nights, it appears that the rigid treadle and the spring-loaded traps were more effective at catching potoroos (see Table 3.2)

Table 3.2: Capture rate for each trap design during systematic sampling.

| Stage Number | Rigid Treadle | Rigid Drop Bar | Spring-loaded | Double-ended | Standard collapsible | Trap-nights |
|---|---|---|---|---|---|---|
| **1** | 10 | 5 | 5 | 10 | 20 | 250 |
| **2** | 10 | 5 | 5 | 10 | 20 | 250 |
| **3** | 10 | 5 | 5 | 10 | 20 | 250 |
| **4** | 10 | 0 | 0 | 0 | 0 | 50 |
| **5** | 10 | 2 | 3 | 0 | 0 | 75 |
| **6** | 10 | 4 | 4 | 0 | 20 | 190 |
| **Total No.** | 60 | 21 | 22 | 30 | 80 | 213 |
| **Trap-nights** | 300 | 105 | 110 | 150 | 400 | 1065 |
| **No. Potoroo Captures** | 9 | 1 | 3 | 3 | 4 | 20 |
| **Trap Success (%)** | 3 | 0.95 | 2.73 | 2 | 1 | 1.9 |

When three trap types with similar closing mechanisms (i.e. rigid treadle, rigid drop bar and standard collapsible) were combined, trap success was 1.7% or close to the overall trap success of 1.9%.

Other non-target species recorded using cage traps included: Northern Brown Bandicoot (29), Black Rat (23), Swamp Rat (17), Long-nosed Bandicoot (15), Cane Toad (6), Bush Rat (3), Echidna (2), Australian Brush Turkey (2), Bar-shouldered Dove (1), Common Brushtail Possum (1) and Grey Shrike Thrush (1).

### *3.1.2 Hair Tube Success*

Results from hair tube surveys are consistent with the cage trapping results (Figure 5). Overall, hair tubes achieved a much lower success rate than cage traps. Only four records (3 definite, 1 probable) of potoroos were obtained from 250 hair tube locations (tube success of 1.65%) and 2000 trap-nights survey effort. Hair tubes covered a larger area than cage traps and were placed at the limits of potential potoroo habitat. Two records each were obtained from standard and pistachio baits.

Other non-target species recorded using hair tubes included: Swamp Wallaby, Bush Rat, House Mouse, Brushtail Possum (*Trichosorus* sp.), Grassland Melomys, Yellow-footed Antechinus and Black Rat.

### *3.1.3 Radio Telemetry*

Supplementary trapping was aimed at maximising the number of potoroos for radio-tracking and at increasing the probability of retrieving transmitters. Seven males and three females were radio-tracked during the study. Most of these were adult males (n=5) and females (n=3) although two were sub-adult males. Two of the females had small and medium pouch young. One non-breeding female potoroo was tracked for three days prior to her transmitter falling off; a transmitter attached to another non-breeding female failed and is likely to have dropped off. Although one adult male was eaten by a Lace Monitor after being tracked for 20 days, the timing of this event is uncertain as the mortality indicator was not activated indicating there was at least some movement during the night.

Location data for the 10 main subject animals was collected over a 43-day period accumulating in 354 location fixes. This includes 315 bearing fixes, 8 transmitter drop locations and 23 cage trap locations. Of these, 296 (83%) locations were accepted as accurate and used in further analysis to determine home range and habitat use. The average number of location points (including captures) for 10 individuals was 35.4 (range=17-54) for raw data and 29.6 for verified data. Transmitters stayed on for an average of 13.5 days although the range was 9-26 days. Some individuals were recaptured and refitted with transmitters to collect further information. For example, Male 950 was radio-tracked for 39 non-consecutive days. Six of the eight transmitters were retrieved at the end of the study. One of these failed while the other was ingested by a Lace Monitor and could not be retrieved by the time the study finished.

### 3.2 Field Survey Discussion

Data was collected both systematically and non-systematically. Generally recapture rates were higher for supplementary surveys. This is to be expected since transects were placed in those areas known to support high densities of potoroos.

Overall trap success was greater than that for previous studies in the Cobaki area (see Table 1.1). However, survey effort was at least eight times that employed by Mason (1993) and 30 times that employed by Hero *et al*. (2001). Compared to other Long-nosed Potoroo studies, trap success was greater than that recorded by Mason (1997) at Tyagarah Nature Reserve (1.3%) but less than that recorded by Bennett (1993) in south-western Victoria (10%). However, the latter population is known to occur at high densities (2.6 potoroos/ha). Furthermore, animals studied in south-western Victoria appear at least 40% smaller then animals captured in this study (Long 2001). Therefore caution should be exercised when comparing population densities and patterns of resource use between potoroos in Victoria and Tasmania to more northerly habitats in NSW and Queensland. Larger animals would most likely occupy habitats at lower densities in order to sustain their use of resources.

Although hair tube effort was considerable, it only yielded three positive hair results. These were located in an area where potoroos had already been recorded through cage trapping. It therefore does not appear to be an accurate means of detecting potoroos at Cobaki where 27 individuals were captured over the survey area. In addition to presence/absence data, cage trapping also provides a more accurate index of potoroo abundance and distribution.

Capararo and Lundie-Jenkins (1998) also evaluated the effectiveness of survey techniques to detect potoroos in south-eastern Queensland. They deployed 5-20 hair tubes at 20-50 m intervals at 25 sites for a total of 3676 hair tube nights. They also recorded digging frequency near hair tubes, undertook spotlighting (11.75 hours) and searched for indirect signs. They recorded only two positive hair records. They detected another two individuals through spotlighting and one by its tracks. They concluded that both hair tubes and spotlighting had a low success rate considering the effort expended. Furthermore, abundant diggings were recorded at four sites where potoroos were not detected by hair tubes or spotlighting.

Results of this study suggest that potoroos can be readily trapped in all cage trap designs provided there is sufficient space for the animal to freely enter the trap. Trap preparation including embedding traps in freshly turned soil, appears to have been an important factor contributing to the success of the present survey. Furthermore, the application of fresh bait on a daily basis throughout the survey period is likely to have resulted in increased capture success. Daily checking of traps is also necessary as often treadle plates had ceased functioning due to soil blocking the treadle mechanism.

This study represents the first time that radio telemetry has been used on the Cobaki population. Despite the location error inherent in the radio telemetry equipment and associated with environmental factors, radio-tracking data were considered to be sufficiently accurate for the purposes of this study. The method used to affix transmitters was considered to be appropriate and humane given the study length and recapture success. However, the technique is not recommended for use during prolonged wet periods where the tape is unable to dry out and may cause chafing of skin at the base of the tail. Several transmitters were removed where this was noted; when these animals were later recaptured, the tail area was healing or recovered in all cases. High recapture success made it possible to retrieve and reattach transmitters on most occasions.

## 3.3 Data Analysis

Field survey results were analysed to determine population distribution and status, home range movement and activity patterns (see Sections 3.3.1 and 3.3.2). Systematic cage trapping was used to determine potoroo distribution, broad habitat utilisation and to derive a population estimate. However, it should be noted that baits may attract individuals from some distance and that distribution data should therefore be interpreted cautiously. Radio-telemetry data were used to describe home range size, microhabitat use, movement patterns and activity (see Sections 3.3.3 and 3.3.4).

### *3.3.1 Population Distribution and Size*

Within the Cobaki area, potoroos were most frequently trapped in Scribbly Gum Mallee Heathland followed by, Tree Broom Heathland, Scribbly Gum/Swamp Mahogany Forest, Black She-oak Heathland, Swamp Mahogany Forest and Scribbly Gum Forest. Our results suggest that potoroos prefer Scribbly Gum Mallee Heathland with an understorey of sedges and grasses such as *Restio* spp., *Lomandra* spp. and *Gahnia* spp., which is found along both sides of the Cobaki Lakes development access track. Areas comprising Swamp Mahogany drainage lines and Tree Broom Heath may only provide movement and refuge habitat. No animals were captured in Swamp Mahogany/ Paperbark Forest, Paperbark Forest or in Forest Red Gum Forest.

However, it should be noted that diggings were observed in the latter two vegetation communities, indicating that potoroos utilise these areas for foraging. Positive hair tube records were recorded from Scribbly Gum Forest and from the edge of Tree Broom Heathland and Scribbly Gum Mallee Heathland.

Both cage trapping and hair tube data indicate that the highest density of potoroos occurs just north and south of the Cobaki Lakes development access track (see Figure 5). In fact, 15 or 55% of all captures were located within an isolated 18-ha patch of habitat located on the northern side of the access track (see Table 3.3):

**Table 3.3:** Capture summary for Long-nosed Potoroos. Numbers in parentheses are breeding females with pouch young.

| Area | Males | Females | Sub-adult | Total |
|---|---|---|---|---|
| North Cobaki Lake Development Access Track | 6 | 7 (4) | 2* | 15 |
| South Cobaki Lake Development Access Track | 7 | 4 (2) | 1 | 12 |
| Total Captures | 13 | 11 (6) | 3 | 27 |

*Sub-adult <1000 g in females and <1050 g in males.

The distribution of the Cobaki potoroo population as determined by cage trapping and frequency of diggings is shown in Figure 6. Overall, this area comprises approximately 112 ha, with 92 ha being contained within the study area. The remaining 20 ha occurs further to the south-west near Cobaki Broadwater. As no potoroos were captured within Swamp Mahogany/ Paperbark Forest, Paperbark Forest or Forest Red Gum Forest, these communities were excluded from density analysis. The corresponding values for potoroo habitat in the Cobaki area and in the study area are 108 ha and 88 ha, respectively.

As 15 potoroos were captured over an area of 28 ha, the overall density was calculated at 0.53 potoroos/ha. If this density estimate is applied over all known habitat (108 ha), then the population size is estimated at approximately 60. However, this assumes that potoroos are distributed evenly over all vegetation communities.

A more realistic scenario supported by the trapping results is that potoroos are found at varying densities related to different vegetation communities. Potoroo density was calculated as the number of individuals captured divided by the area of each community that was trapped. This value was then multiplied by the total amount of that vegetation type in the Cobaki area as shown in Table 3.4 below:

**Table 3.4:** Density estimates in vegetation communities present in potoroo habitat.

| Vegetation Community | Ha in Known Habitat | Potoroo Density | Population Estimate |
|---|---|---|---|
| Scribbly Gum Mallee Heathland | 12.8 | 1.1 | 14.1 |
| Tree Broom Heathland | 15.1 | 0.9 | 13.6 |
| Scribbly Gum/ Swamp | 38.9 | 0.4 | 15.6 |

| Vegetation Community | Ha in Known Habitat | Potoroo Density | Population Estimate |
|---|---|---|---|
| Mahogany Forest | | | |
| Black She-oak Heathland | 7.9 | 0.4 | 3.2 |
| Swamp Mahogany Forest | 12.9 | 0.3 | 3.9 |
| Scribbly Gum Forest | 20.3 | 0.2 | 4.1 |
| TOTAL | 107.9 | | 54.5 |

A conservative population estimate for the Cobaki area is therefore 55-60. However, this would suggest the unlikely scenario that 50% of the population was captured. The true population size is therefore likely to be higher.

### *3.3.2 Broad Habitat Utilisation*

Trapping may not accurately reflect habitat use because baited traps may attract or repel potoroos, intercept individuals moving between habitats and/or confine captured animals for varying lengths of time. Because radio-tracking can be undertaken remotely and is less likely to disturb individuals, it can provide a more fine-grained analysis of habitat use. It allows the researcher to determine refuge sites (daytime fixes), foraging areas (nocturnal fixes) and habitats most likely to be used for movement (dawn and dusk fixes).

Most potoroo fixes (49.4%) were recorded in Scribbly Gum Heathland. This community was most frequently used for diurnal refuge (50% of all day records), nocturnal foraging (48.5% of all night records) and during transitional movements (51.2% of all dawn and dusk records). When all potoroo records were pooled, the next most preferred habitat was Swamp Mahogany/ Scribbly Gum Forest (19.6% of all records) followed by Tree Broom Heath (16.3%), Scribbly Gum Forest (13.5%), Black She-oak Heathland (0.8%) and Paperbark Forest (0.4%).

Males and females showed similar trends with respect to habitat utilisation. However, radio-collared females were recorded predominantly in Tree Broom Heath (37% of all records). They preferred this community for diurnal refuge (43.4% of all daytime records), nocturnal foraging (30% of all night records) and transitional movements (50% of all dawn and dusk records). Females then preferred Scribbly Gum Heathland (31.5%), Scribbly Gum Forest (21.9%) and Swamp Mahogany/Scribbly Gum Forest (9.6%). No females were recorded in Black She-oak Heathland or in Paperbark Forest.

Radio-collared males, on the other hand, were recorded most frequently in Scribbly Gum Mallee Heathland (57% of all records). They preferred this community for diurnal refuge (60.8% of all daytime records), nocturnal foraging (52.2% of all night records) and for transitional movements (64.5% of all dawn and dusk records). Males next prefer Swamp Mahogany/Scribbly Gum Forest for diurnal refuge (19.6%) and nocturnal foraging (27.8%) but were less frequently during dawn and dusk (1.9%). Males were recorded less frequently in Scribbly Gum Forest (9.9%), Tree Broom Heath (7.6%), Black She-oak Heathland (1.2%) and Paperbark Forest (0.6%). However, one male used Paperbark Forest as a refuge site and another was recorded in Tree Broom Heath at both dawn and dusk.

*3.3.3 Home Range Size and Use*

Home range sizes for 10 potoroos (3 females, 7 males) were calculated using the MCP method. Subsequent plotting of this data indicates that potoroos have home ranges with extensive overlap amongst both males and females (Figure 7). Location points for individual radio-tracked potoroos are shown in Appendix D and relevant information is summarised in Table 3.5 below:

**Table 3.5:** Summary of home range data.

| ID | Sex | Age | Dates | Home Range Size | No. Locations ($R^1$, $C^2$) | Average distance/day |
|---|---|---|---|---|---|---|
| 972 | Fpy | A | 22/4 – 6/5, 21/5 | 3.2 ha | 27 (24, 3) | 117 m |
| 852 | F | A | 27/4 – 19/5 | 1.5 ha | 46 (45, 1) | 110 m |
| 931 | Fpy | A | 18-26/4, 7-13/5 | 4.2 ha | 29 (24, 5) | 132 m |
| 931 | M | A | 30/4 – 19/5 | 3.6 ha | 33 (31, 2) | 92 m |
| 990 | M | SA | 21/4 – 12/5, 25/5 | 1.7 ha | 41 (37, 4) | 119 m |
| 990n | M | A | 5-14/5 | 1.7 ha | 17 (14, 3) | 111 m |
| 950 | M | A | 18-27/4, 7-14/5 | 2.2 ha | 30 (26, 4) | 110 m |
| 950n | M | A | 27/4 – 22/5 | 5.1 ha | 54 (50, 4) | 195 m |
| 831 | M | SA | 22/4 – 6/5 | 2.7 ha | 27 (23, 4) | 127 m |
| 790 | M | A | 22/4 – 1/5, 20-30/5 | 2.5 ha | 52 (46, 6) | 164 m |

1 Radio-tracking locations, transmitter drops
2 Captures
Py Pouch young

The average home range size for potoroos at Cobaki is 2.8 ha. The largest home range belonged to a male potoroo M950n (5.1 ha) and the smallest was that of a female F852 (1.5 ha). Female home ranges averaged 3 ha (range = 1.5 – 4.2 ha) and male ranges averaged 2.8 ha (range = 1.7 – 5.1 ha). No differences in home range size were detected between adults and sub-adults.

On average, females moved 120 m between subsequent fixes (range = 110-132 m) whereas males moved an average of 131 m between subsequent fixes (range = 92-195 m). Over a 24-hour period, females moved a minimum of 101 m (F972) and a maximum of 418 m (F931). Males moved a minimum of 45.3 m (M931) and a maximum of 842 m (M950n) over the same period. Potoroos readily crossed narrow tracks (less than 6 m) with a natural substrate but none traversed the 49-m wide Cobaki Lakes development access track even though they are physically capable of crossing this distance. The open nature of the track acts as a behavioural barrier.

At a microhabitat level, potoroos spend the day in shelters called ‘squats’. Squats were examined on four occasions during the study. Transmitters were recovered from two male (M790, M990) and two female (F972, F931) squats. Squats typically occurred in dense stands of vegetation and were found on the edges of Tree Broom Heathland and Scribbly Gum Mallee Heathland. These areas consist of low matted vegetation including grasses, heath, sedges and other dense cover. The squat itself consists of a shallow depression or form in the soil or vegetation connected to well-defined runways and a number of exits/entrances. Some squats appear to be used intensively and had a characteristic potoroo odour associated with them (F931) while others were used less frequently (F972n) or were less well-formed (both male squats).

Taking into account the error inherent in the radio-tracking fixes (i.e. any daytime fixes less than 25 m apart were considered to be the same squat), the estimated number of squats per individual varied from 3 (M831) to 8 (M950n). The number of squats per male varied from 3-8 and the number of squats per female was 5-7.

Microhabitat use varies amongst individual potoroos (see Appendix D). For example, although F931 sheltered predominantly in Tree Broom Heathland, she foraged widely along the Scribbly Gum Mallee Heathland ecotone. On the other hand, F852 was recorded sheltering and foraging in Swamp Mahogany/ Scribbly Gum Forest, Scribbly Gum Forest, Tree Broom Heathland and Scribbly Gum Mallee Heathland. Similarly, M990 confined his activities predominantly to Scribbly Gum Mallee Heathland whereas M950 moved widely and appeared to have at least two centres of activity. One of these was in Scribbly Gum Forest that overlapped almost completely with F852's home range. The other activity node was located in Scribbly Gum Mallee Heathland and overlapped with the home range of another female that was captured on three occasions, all of which occur within the home range defined for M950. The capture of this female on three occasions suggests that it was also resident in that area.

*3.3.4 Activity Patterns*

The activity levels of 11 potoroos were analysed as part of the current study (see Table 3.6):

**Table 3.6:** Sex, age class and number of potoroos used in activity study. Note two female carried young.

| Potoroo | Male | Sub Adult Male | Adult Female |
|---|---|---|---|
| Wt range (g) | 1290-1490 | 890-970 | 1100-1180 |
| Sample Size | 5 | 2 | 4 |
| Average wt (g) | 1391 | 930 | 1146 |

A total of 256 5-minute monitoring periods was collected over a 34-day period, with 248 periods considered suitable for analysis (see Table 3.7). The remaining eight activity periods were removed due to the possibility that the subject animal had been trapped.

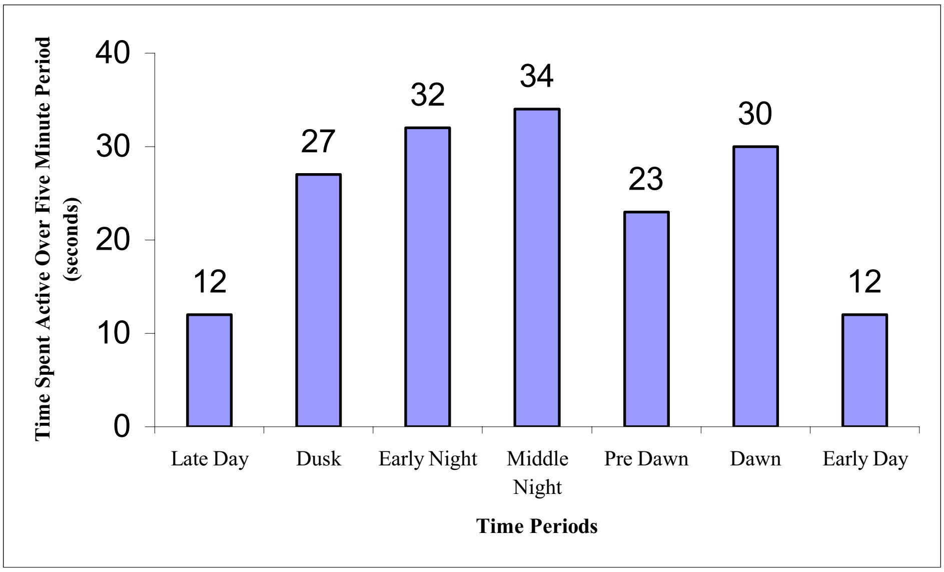
**Table 3.7:** Activity sampling periods and effort.

| Category | Time (24hr) | No 5 min observations |
|---|---|---|
| Late Day | 1200-1645 | 29 |
| Dusk | 1645-1745 | 23 |
| Night Period 1 | 1745-2130 | 53 |
| Night Period 2 | 2130-0130 | 50 |
| Night Period 3 | 0130-0520 | 38 |
| Dawn | 0520-0720 | 26 |
| Early Day | 0720-1200 | 29 |
| | | N=248 |

The results indicate that potoroos were active across all time periods but that activity levels increased at dusk and peaked during the first half of the night

(Figure 8). Activity declined during the pre-dawn period but increased at dawn before a marked decline of the same intensity for both day periods.

**Figure 8:** Activity levels (per 5 min) for Long-nosed Potoroos across seven time periods. All data (male & female) is pooled to increase robustness (n =248).




## 3.4 Data Analysis Discussion

This section discusses the broad utilization of habitat types by the potoroo population at Cobaki and microhabitat usage within individual potoroo home ranges.

### *3.4.1 Population Distribution and Size*

The current survey targeted approximately 150 ha of known and potential potoroo habitat based on previous surveys undertaken by Mason (1993) and Hero *et al*. (2001). It confirmed that most of this area provides potoroo habitat with the exception of GCAL land to the south. The Cobaki potoroo population occurs over approximately 112 ha of habitat, 92 ha of which is contained within the study area. The population utilizes the following vegetation types: Scribbly Gum Mallee Heathland, Tree Broom Heath, Swamp Mahogany/ Scribbly Gum Forest, Black She-oak Heathland, Swamp Mahogany Forest and Scribbly Gum Forest.

Because grid trapping was not undertaken systematically, only capture data collected during Stages 2-3 were used to estimate potoroo density. The Cobaki potoroo population was conservatively estimated to be at least 55-60 potoroos. Using a similar methodology, Mason (1997) estimated that the Tyagarah NR potoroo population located 45 km to the south, was made up of 78-88 individuals based on an overall density of 0.23 potoroos/ha. From his Tyagarah study, Mason (1993) extrapolated that the Cobaki population would comprise 10-20 potoroos assuming that 25-50% of the area (i.e. 200 ha) was unsuitable for potoroos. Mason recognised that much of the habitat in Cobaki lacked suitable understorey habitat due to the fire that swept through the area in 1991 but he predicted that the habitat would re-establish in ‘several years’.

This study indicates that population of potoroos at Cobaki is considerably larger than that predicted by Mason and that the density of potoroos is at least twice that found at Tyagarah NR. Nevertheless, the Cobaki population is still considered to be small and at risk of extinction from stochastic events.

### *3.4.2 Broad Habitat Utilisation*

Potoroos occur in a broad range of habitat types from warm-temperate rainforest through to tussock grass woodland and heathland (Bennett 1993, Long 2001). They are a cover-dependent species requiring habitats that provide a mosaic of dense shrubs and areas of reduced ground cover. Whereas dense cover provides diurnal shelter and protection from predators, more open areas provide foraging resources, in particular hypogeal fungi that grow on the roots of eucalypts and fallen timber. Potoroos are not confined to any particular vegetation community or structure but utilise a range of floristic groups and structures (Bennett 1993).

Habitat utilisation as determined through radio-tracking is consistent with trapping results. When all radio-tracking data are pooled, the three most preferred vegetation types at Cobaki are Scribbly Gum Mallee Heathland, Tree Broom Heathland and Swamp Mahogany/ Scribbly Gum Forest. All of these communities are characterised by at least some areas of dense ground cover and proximate open areas used for foraging (based on observations of diggings). However, males and females differ in their habitat use based on vegetation communities but this could be a function of small sample size in females (n=3). The analysis of radio-tracking data indicates that Scribbly Gum Forest is utilised more often by both sexes than is apparent from trapping results.

Radio-tracked females spent more time resting, foraging and moving in Tree Broom Heathland than in any other vegetation communities. It is uncertain whether this indicates a true preference for community type or if it represents an artefact of small sample size. Tree Broom Heath provides areas of very dense habitat, especially along its edges, and may be preferred by females with young. Males, on the other hand, prefer Swamp Mahogany/ Scribbly Gum Forest second only to Scribbly Gum Mallee Heathland. Results of this study suggest that Tree Broom Heath, Black She-oak Heathland and Paperbark Forest are used infrequently by males.

In Tyagarah NR, Mason (1997) trapped significantly more potoroos in dry and moist shrubland habitats in early to mid-successional stages. Although there are no equivalent community types present at Cobaki, they are similar in both structure and floristics and thus provide a similar mosaic of cover and open areas.

### *3.4.3 Home Range Size and Use*

Average home range size for potoroos at Cobaki is 2.8 ha and is similar for males and females. Potoroo home range size was compared to home range estimates determined for species in a similar weight range (Table 3.8):

**Table 3.8:** A comparison of home range sizes for similar-sized species (reproduced from Scott 1995 with the exception of final two entries).

| Species | Weight Range | Method of Analysis | Average Home Range Size (M, F) | Reference |
|---|---|---|---|---|
| Southern Brown Bandicoot | 400-1500 g | MCP | 5.3 ha, 2.3 ha | Heinsohn (1966) |
| | | HM | 1.8 ha, 1.1 ha | Lobert (1990) |
| | | MCP | 2.3 ha, 1.8 ha | Broughton & Dickman (1991) |
| Northern Brown Bandicoot | 500-3000 g | Modified minimum area | 2.8 ha, 1.9 ha | Gordon (1974) |
| Eastern Barred Bandicoot | 500-1100 g | MCP | 4.0 ha, 1.6 ha | Dufty (1994) |
| | | MCP | 26.3 ha, 3.2 ha | Heinsohn (1966) |
| | | MCP | 12.9 ha, 2.4 ha | Dufty (1991) |
| Long-nosed Bandicoot | 850-1100 | MCP | 3.3 ha, - | Chambers (1991) |
| | | MCP | 4.4 ha, 1.7 ha | Scott (1995) |
| Long-nosed Potoroo | 660-1700 | 95% MCP | 4.0 ha, 2.9 ha | Long (2001) |
| | | MCP | 2.8 ha, 3.0 ha | This study |

We would expect home range sizes to be comparable amongst the species listed as they all require dense ground cover for shelter and refuge and hypogeal fungi as a major food source. The fact that this study is the only one where male home ranges are smaller than female ones may be an artefact of sample size or of the home range estimation technique used. However, it may also be due to the fact that habitat utilized by F931 and F972 was flooded during the study. These individuals may have had to travel further in order to obtain shelter and foraging resources by circumventing the flooded area along the verge of the access track or near the Queensland/NSW border. In fact, the transmitter affixed to female 972 fell off near the access track. The home range for female F582 was not subject to these disturbances and may be more representative of true home range size. Alternatively, home range size may be influenced by habitat isolation and competition between the males. The majority of radio-tracked males (n=5) were found north of the Cobaki Lakes development access track and are therefore virtually isolated from interconnecting habitat areas. It is possible their home ranges are smaller due to increased competition in this area.

There is considerable overlap amongst home ranges of both males and females at Cobaki. The degree of home range exclusivity varies amongst potoroo studies. Long (2001) noted that there was more likely to be overlap between males and females (intersexual) than there was within either sex (intrasexual). She noted male home ranges overlapped the ranges of 1-4 females and that female home ranges were overlapped by those of 2-3 males. Although Bennett (1987) and Kitchener (1973) noted a high degree of overlap both within and between sexes, Heinsohn (1968) found that there was home range exclusivity within males and Seebeck and Rose (1988) and Jarman (1991) noted home range exclusivity within females. Long (2001) hypothesised that this variation may be related to the distribution of important resources in both time and space or to the different methodologies used. The

MCP technique does tend to maximise home range size and therefore overlap by including large areas that may never be used by the individual in question. Analysis of the Cobaki data using other techniques such as the 95% and 50% harmonic mean or kernel methods may reduce the overlap between individuals considerably.

Within the study area, home ranges appeared to be tightly packed and to overlap extensively to the north of the Cobaki Lakes development access track. Fifty-five percent of all potoroos were captured in this area and no potoroos crossed the track during the course of the study, indicating that it constitutes a complete behavioural barrier to potoroos. Consequently, this 18-ha area of high quality habitat, isolated between the access track and the Pacific Beach Estate, may be close to carrying capacity. Furthermore, drainage problems associated with the track have resulted in water ponding on its northern side, thereby regularly inundating potoroo habitat. If inundation persists, the vegetation communities in this area would be expected to favour water-tolerant species, thus permanently replacing potoroo habitat.

To the south of the access track, it is expected that the density of potoroos (outside Scribbly Gum Mallee Woodland) would be lower, resulting in larger home ranges. The largest home range was recorded for M950 just south of the access track.

Microhabitat use within home ranges can only be described using radio telemetry. In particular, daytime fixes representing the locations of potoroo shelters or squats would be impossible to detect using other survey methods due to their cryptic nature. Squats are often located under grass tussocks, in dense grass and shrub thickets or against logs. Long (2001) found that potoroos had up to seven squats and that some of these were used for 2-3 days at a time. She noted a high proportion of male-female interactions in squat locations, providing strong evidence that males monitor the sexual status of females using the same squat. There was a high degree of intersexual overlap in areas containing squats but squats were not shared by females.

At Cobaki, male and female potoroos used from 3-8 squats throughout the study. It may eventually be possible to determine intersexual overlap by overlapping core areas (e.g. 50% harmonic means) amongst individuals of both sexes. Based on existing data, it appears that the home range of M950 overlaps that of F852 almost completely, and that these individuals may have shared the same squat.

*3.4.4 Activity Patterns*

Potoroos are generally considered to be nocturnal. However, Seebeck & Rose (1988) provide evidence to suggest that Long- nosed Potoroos are active in the latter part of the day when lower temperatures prevail or during cloudy conditions. During her study at Ralph Illidge Sanctuary in south-western Victoria, Long (2001) recorded frequent diurnal activity that appeared unrelated to climatic conditions or restricted to particular times of the day.

She suggested that this could have been due to their habituation to people and/or to the exclusion of diurnal predators from the sanctuary.

# 4.0 IMPACT ASSESSMENT

The potential impacts associated with the proposed Tugun Bypass are discussed below in relation to the Cobaki population and the regional distribution of Long-nosed Potoroos. Cumulative impacts associated with adjacent developments, Pacific Beach and Cobaki Lakes (and associated access track), are assessed in Section 4.4.

## 4.1 Habitat Loss

Habitat loss would be associated with construction of the road and associated infrastructure. Approximately 0.7 ha of potoroo habitat would be removed as a result of bypass construction. This comprises 0.2 ha of Scribbly Gum Forest in NSW and 0.5 ha of Swamp Mahogany/ Scribbly Gum Forest in Queensland. Although habitat loss has been minimised as a result of the route refinement process (i.e. by moving the bypass as far as possible to the east), there would still be some removal of edge habitat. The loss of 0.7 ha of potoroo habitat is likely to have a local effect on the potoroo population.

## 4.2 Fragmentation

Habitat fragmentation may isolate remnant vegetation and create barriers to the movement of small and/or sedentary fauna species such the potoroo. The proposed bypass would not result in the fragmentation of existing potoroo habitat. However, the bypass may exacerbate edge effects and disturbance to previously undisturbed (interior) habitat (see Section 4.3).

## 4.3 Edge Effects and Disturbance

The proposed bypass would remove existing edge habitat, creating an ecotone between the road easement and less disturbed (interior) habitat, exposing it to edge effects. Edge effects associated with roads may include alterations to microclimate, hydrology, floristics, the pattern and frequency of fire, invasion by exotic species and/or increases in sedimentation, windthrow, rubbish, water pollution, noise and access to predators. A review of international and Australian literature on edge effects, particularly those associated with roads, found that edge-affected zones extend at least 50 m from the edge, although some effects, such as noise and disturbance, may extend much further (Bali 2000).

The Tugun Bypass is likely to be associated with a range of edge effects, thereby resulting in the degradation of potoroo habitat adjacent to it. However, much of the habitat in this area is already subject to edge effects as a result of past clearing and developments. The erection of fauna-proof fencing along the bypass and the lack of underpasses in this area, will aid in discouraging introduced predators entering potoroo habitat from the east. Fencing would also prevent potoroo road mortality. However, the increased vehicular traffic and human access as a result of the bypass would increase the risk of fire in the area.

The footprint area is already subject to disturbance associated with the operation of Gold Coast Airport and the nearby rubbish tip. However, additional disturbance, in particular due to noise, lighting, movement and vibration, would be associated with both the construction and operation phases of the Tugun Bypass. Disturbance effects would be expected to increase from present levels due to the increasing volumes of traffic travelling along the bypass. This may affect the behaviour and activities of Long-nosed Potoroo in the vicinity of the road. This is of particular concern to the animals north of the Cobaki Lakes development access track that are already surrounded by cleared land and may be unable to tolerate any additional loss of habitat resulting from secondary impacts from the bypass. Disturbance and edge effects associated with the bypass are expected to be of high local significance.

### 4.4 Cumulative Impacts

The impacts associated with the Tugun Bypass cannot be assessed in isolation. A number of other developments including the Pacific Beach development and Cobaki Lakes development (and associated access track), are located directly adjacent to or within (i.e. the access track) potoroo habitat. These developments are described briefly below:

In Queensland, the site for the approved Pacific Beach development has recently been cleared. It is located adjacent to the John Flynn Hospital and Medical Centre. The development would consist mainly of medium density residential development located around the proposed Tugun railway station immediately north of Boyd Street. It would also contain commercial and community services components. No mitigation measures associated with potoroo conservation were proposed as part of this development.

In NSW, Cobaki Lakes is a very large approved development located entirely in NSW adjacent to the Queensland border. The master plan prepared in 1999 proposed a gross developable area of 284.5 ha with 1,162 residential lots, 531 'greenstreet' lots, and 202 duplex lots providing a total of 2,260 units with a capacity to accommodate 14,000 residents. Although the development site has been subject to a number of flora and fauna surveys reviewed by Warren (1994) and Parker (1999), no potoroos have been recorded there and the habitat was not considered to be suitable for them. The area has been previously cleared but there is presently no construction being undertaken on the site.

The Boyd Street extension, providing access through Crown land from Boyd Street to the Cobaki Lakes development, was approved by Tweed Council in 1993. A Fauna Impact Statement undertaken by Warren (1992) recorded two (dead) potoroos from habitat adjacent to the proposed access track. While Warren noted that the habitat directly adjacent to the proposed track was not suitable for potoroos as it had been extensively burnt in August 1991, both he and Mason (1993) predicted that the burnt Crown land would recover in several years. However, it appears that no further surveys were undertaken prior to the road being cleared in 2000.

An Environmental Management Plan (Master Planning Services 1993) and a potoroo management plan (Catling 1993) were prepared as specified in the Conditions of Consent for the road development (Tweed Shire Council 1993). The potoroo management plan identifies a number of amelioration measures aimed at protecting the Long-nosed Potoroo population, namely:

- Vegetation to be re-established of within 2.5 m of the road edge;
- A number of box culverts measuring 2.4 m wide by 1.2 m high to be installed;
- Approximately 1.8 ha of Scribbly Gum Mallee Heathland (*Banksia aemula/ Eucalyptus signata*) to be regenerated in two separate areas.

Conditions of Consent specify that the Management Plan be fully implemented within 12 months of road completion. While the road has been cleared and gravelled to allow access for construction purposes, it is not near completion. The date for completion is not known and may be many years away. The existing road easement measures 49 m in width, 26 m of which is constructed fill. There are currently no potoroo mitigation measures incorporated into the road design and it is having a significant deleterious impact on the potoroo population as discussed further below.

In addition, the EMP specifies a number of siltation and sedimentation controls for the road, including the maintenance of existing drainage patterns. However, significant ponding of water was noted to the north of the track during the current study. It is evident that areas of Tree Broom Heathland are being regularly inundated as a direct result of the track construction impeding drainage. If this drainage problem is not corrected, then the habitat characteristics of the inundated areas will change, with water-tolerant species being favoured at the expense of potoroo habitat.

#### *4.4.1 Habitat Loss*
The Pacific Beach development site has recently been partially cleared, resulting in the removal of 0.8 ha of Swamp Mahogany/ Scribbly Gum Forest habitat from the edge of the known potoroo distribution. Once the Tugun Bypass is constructed, only 1.3 ha of potoroo habitat will remain on the Queensland side of the border.

At least 2.8 ha of potoroo habitat was cleared for the Cobaki Lakes development access track in 2000. Presently, it passes through the middle of two of the vegetation communities most preferred by potoroos at Cobaki, Scribbly Gum Mallee Heathland and Tree Broom Heathland. Most individuals in the present study were captured adjacent to the access track, indicating that this area provides high quality habitat. Fewer potoroos were captured in less suitable habitat types found to the south.

Potoroos require dense cover for movement and shelter and will not utilise areas that have been cleared, burned or heavily grazed (Catling 1993). During this study, no potoroos crossed the Cobaki Lakes development access track as determined through radio-tracking and recapture data, despite at least nine individuals being recorded adjacent to the road.

In isolation, none of these developments appear to have more than a local impact on the potoroo population with respect to habitat loss. Their cumulative effect however, is the loss of at least 4.3 ha of habitat. Mason (1993) cautions that any removal of habitat is likely to have a deleterious effect on the population. The Cobaki Lakes development access track not only removes some of the best habitat available but completely fragments the population. It is therefore considered to have a regional impact on the population (see Section 4.4.2 below).

*4.4.2 Fragmentation*

The Cobaki Lakes development access track presently forms a complete movement barrier to potoroos and, although nine individuals were radio-tracked adjacent to the track, none crossed it during the course of the study. As potoroos regularly travel over 100 m, it is assumed that the 49-m wide access track presents a behavioural barrier (i.e. potoroos will not cross open areas) rather than a physical one. It appears that the access track has effectively divided the potoroo population into two sub-populations. The northern sub-population is isolated within an 18-ha area of suitable habitat, some of which was not accessible to animals during the survey period due to flooding associated with the access track.

The northern sub-population, comprising more than half (55%) of all captured individuals and up to 30% of the estimated population, is at particular risk of extinction from stochastic events such as fire. It is presently isolated by the Cobaki Lakes development access track to the south, the approved Pacific Beach development site to the east, the approved Cobaki Lakes development site to the west and unsuitable habitat to the north. The bypass will act to further isolate this sub-population. This area has already been reduced in size through clearing of the Pacific Beach development and inundation of Tree Broom Heathland north of the access track, but would be subject to further edge and disturbance effects once the residential developments are occupied (see Section 4.4.3 below). In particular, the risk of fire would increase with increased vehicular and human activity. Weed proliferation and predation by domestic pets would also be associated with occupation of future nearby residences.

It is possible that the northern sub-population is nearing or at carrying capacity. The high proportion of captures and the degree of overlap amongst individual home ranges support this theory. On the other hand, potoroos occupying habitat to the south of the access track may occur at lower densities, at least outside Scribbly Gum Mallee Heathland. The conservation status of habitat on both sides of the track is undetermined. Although much of this area has been granted to the Tweed-Byron Local Aboriginal Council, the balance remains Crown land with ownership to be determined once the bypass route has been confirmed.

Mason (1993) recommends that further fragmentation at Cobaki should be avoided to maintain the viability of the potoroo population. Fragmentation caused by the Cobaki Lakes development access road is likely to drive the northern sub-population to extinction if no mitigation measures are implemented and is presently having a regional impact on the population.

*4.4.4 Edge Effects and Disturbance*

The cumulative impacts of the bypass together with approved residential developments is likely to be significant, especially for the northern sub-population of potoroos. This 18-ha remnant habitat would be isolated by two major residential developments and two roads. Edge effects and disturbance associated with increased vehicular and human activity include: predation by domestic pets, weed proliferation, increased risk of arson, altered drainage, road strike, vandalism, increased use of off-road recreational vehicles and noise.

Capararo and Lundie-Jenkins (1998) warn that any alteration to potoroo habitat is likely to have a deleterious effect on potoroo populations. Cumulative impacts related to the Tugun Bypass and other developments in the adjacent area are likely to be regional in scale.

# 5.0 MITIGATION AND COMPENSATION MEASURES

A number of mitigation and compensation measures have been recommended as part of the EIS, SIS and compensatory habitat package for the Tugun Bypass.

## 5.1 Mitigation Measures

Mitigation measures that would benefit the Long-nosed Potoroo include the erection of fauna-exclusion fencing along the proposed bypass to prevent potoroos and other ground-dwelling fauna species from crossing the bypass. Culverts would not be constructed near potoroo habitat in order to discourage dogs and foxes from accessing potoroo habitat from the east.

## 5.2 Compensatory Measures

Compensatory measures are generally considered to apply to residual impacts that cannot be mitigated. Residual impacts associated with the Tugun Bypass include habitat loss and cumulative impacts on the Cobaki potoroo population. The cumulative effects of habitat loss and barrier impacts associated with the bypass and adjacent approved residential developments may result in the extinction of this regionally significant population. A number of compensatory measures for Long-nosed Potoroos have therefore been included as part of an overall compensatory habitat package for the Tugun Bypass (PPK 2001). These are aimed at minimising predation on the population and include:

- Provision of predator control fencing along both sides of Boyd Street extension, if and when it becomes operational;
- Provision of predator control fencing around part of the Cobaki Lakes development area once construction on this stie commences in order to reduce the incidence of cats and dogs from the development preying on native wildlife in adjacent NSW Crown land; and
- Initiation of fox control measures for vacant NSW Crown land adjacent to Cobaki Lakes development.

Foxes, dogs and cats were regularly recorded using the roads, tracks and pastoral boundaries at Cobaki (B. Lewis; S. Phillips *pers. obs.*). Fox dens were located within areas delineated as potoroo habitat. Management of the local potoroo population should involve a well-designed and monitored pest management program involving direct (trapping, shooting) and indirect (baiting) methods. As a Critical Weight Range species (18-5500 g), Long-nosed Potoroos are particularly susceptible to predation by these introduced species.

## 6.0 OTHER MANAGEMENT ISSUES

Other outstanding management issues affecting the viability of the Cobaki potoroo population include fire and grazing.

### 6.1 Fire

The study area does not appear to have been burnt since 1991. However, the future encroachment of residential development and high traffic flow will result in an increased fire risk in the immediate area. A fire management plan should be prepared for the area with careful consideration being given to the habitat requirements of Long-nosed Potoroos. Potoroos are a cover-dependant species preferring habitats in the early to mid-seral stages (i.e. post-fire). They require a mosaic of infrequent patch burning to reduce the risk of predation.

### 6.2 Grazing

Grazing and trampling of shrubs and dense ground cover by cattle reduces habitat suitability for potoroo. Cattle were observed throughout the northern and eastern part of the Cobaki study area. This is largely the result of local vandals cutting fences and allowing stock to entering lands where they cannot be easily mustered.

## 7.0 RECOMMENDATIONS

Although mitigation and compensation measures have been outlined as part of the Tugun Bypass, it is considered that, unless other measures are implemented immediately, the conservation of this regionally significant population cannot be guaranteed and local extinction may occur. These measures are:

1.0 Mitigation measures (even temporary ones) should be constructed to allow potoroos to cross the Cobaki Lakes development access track. These could include the box culverts specified in the Conditions of Consent. However, it should be noted that use of culverts by potoroos is unconfirmed and opinions vary as to whether this species would utilise a 50-m long culvert. While Catling (1993) reported that there were no field trials substantiating use of culverts by potoroos, Warren (1994) claimed that Andrew Murray from the Victorian Department of Conservation and Natural Resources confirmed that potoroos utilise culverts in Victoria. In NSW, there are no confirmed records of potoroos using culverts but there is an unconfirmed record of a Long-nosed Potoroo using a 20-m long 1.2 m by 1.2 m diameter box culvert at Brunswick Heads (Linda Gibson, Australian Museum *pers. comm.*).

2.0 If safe access for potoroos across the Cobaki Lakes development access track cannot be guaranteed, then the track should be rehabilitated and an alternative access track to the development constructed. It is understood that access to the site is also available from Piggabeen Road. It may also be possible to construct an alternative access track between John Flynn Hospital and the Pacific Beach development on Boyd Street along the edge of Paperbark Forest as shown in Figure 9. This option appears to have minimal ecological impacts.

3.0 Mitigation measures should be implemented immediately to re-establish former drainage patterns and prevent inundation on the northern side of the access track. Regular inundation over prolonged periods will result in a further loss of preferred potoroo habitat in this small habitat remnant.

4.0 The future conservation status of lands containing potoroo habitat needs to be determined. Discussions should be held with the Tweed-Byron Local Aboriginal Land Council in order to discover their intentions for the land. Ideally the land should be purchased and managed for potoroo conservation. An acceptable alternative would be for the Tweed-Byron LAC to enter into a Voluntary Conservation Agreement with the NPWS to ensure its future conservation and the appropriate management of potoroos.

5.0 An appropriate monitoring plan should be designed and implemented to ensure the long-term viability of the population. Results of the present study provide suitable baseline data for comparative purposes.

6.0 A Management Plan for the Long-nosed Potoroo population at Cobak should be designed and implemented. It should incorporate an appropriate fire management strategy which takes into account the habitat requirements of the potoroo by prescribing a mosaic of 'patch' burning and the prevention of catastrophic wildfires.

## 8.0 CONCLUSIONS

The current trapping and radio-tracking study targeted approximately 150 ha of known and potential potoroo habitat. It confirmed that most of this area provides potoroo habitat with the exception of GCAL land to the south. The Cobaki potoroo population occurs over approximately 112 ha of habitat, 92 ha of which is contained within the study area. The population utilizes the following vegetation types: Scribbly Gum Mallee Heathland, Tree Broom Heath, Swamp Mahogany/ Scribbly Gum Forest, Black She-oak Heathland, Swamp Mahogany Forest and Scribbly Gum Forest.

The Cobaki potoroo population was conservatively estimated to be at least 55-60 potoroos. Although this is larger than previous estimates of 10-20 individuals, the population is still considered to be small and at risk of extinction from stochastic events. Furthermore, the population is not afforded any protection under the conservation reserve system in the Cobaki-Tugun area. As potoroos are uncommon on the far north coast of NSW and in south-eastern Queensland, the Cobaki population is considered to be of regional significance.

The Cobaki potoroo population is currently under imminent threat of extinction from cumulative effects associated with existing and approved developments, including the proposed Tugun Bypass. It has been fragmented into two sub-populations by the Cobaki Lakes development access track that transects the two vegetation communities most preferred by potoroos. No potoroos were recorded crossing the track throughout the study period. The northern sub-population, comprising more than half (55%) of all captures and up to 30% of the estimated population, is at particular risk of extinction due to stochastic events. It is restricted to an 18-ha habitat remnant that would be completly isolated by proposed road and residential developments. This area has already been reduced in size by clearing for the Pacific Beach Estate and inundation of potoroo habitat

Despite mitigation and compensation measures associated with the Tugun Bypass, the existing Cobaki Lakes development access track is presently exerting a regional impact on the population. Unless measures to mitigate these impacts are implemented urgently, the conservation of this regionally significant population cannot be guaranteed and local extinction may occur. In the short-term, mitigation measures (even temporary ones) should be constructed to allow potoroos to cross the Cobaki Lakes development access track. Alternatively, the track should be revegetated and an alternative access track constructed. In the longer term, appropriate monitoring and management (including fire management) plans should be designed and implemented to ensure the viability of this important population.

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# Appendix A: Cage Trap Specifications

Table A1: Cage trap designs used to undertake potoroo trapping at Cobaki

| Trap Design | No. Used | Trigger Mechanism | Width | Length |
|---|---|---|---|---|
| Collapsible | 20 | Treadle Plate | 30 x 30 | 60 |
| Rigid | 10 | Treadle | 31 x 31 | 58 |
| Double-ended Collapsible | 10 | Treadle Plate | 30 x 30 | 90 |
| Rigid Drop Bar | 5 | Slip Pin | 30 x 30 | 75 |
| Spring-loaded | 5 | Spring Loaded | 30 x 30 | 75 |

# Appendix B: Weather Conditions

**Table B1: Daily meteorological observations during survey period (Geoscience Australia 2003).**

| Date | Maximum Temperature | Minimum Temperature | Relative Humidity | Wind | Relative Humidity | Wind | Rainfall in 24 hours to 9 am | Survey Type |
|---|---|---|---|---|---|---|---|---|
| | °C | °C | % | km/h | % | km/h | mm | |
| 7/04/03 | 24.0 | 17.3 | | SSW 22 | | SW 13 | 1.0 | M |
| 8/04/03 | 25.7 | 15.9 | | S 11 | | WSW 8 | 0.0 | M |
| 9/04/03 | 26.2 | 14.6 | | WSW 4 | | SSW 8 | 0.0 | M |
| 10/04/03 | 25.9 | 16.7 | | S 11 | | SW 9 | 0.0 | M |
| 11/04/03 | 22.6 | 19.2 | | SW 8 | | SSW 11 | 0.8 | M |
| 12/04/03 | 24.1 | 17.7 | | S 9 | | SW 11 | 9.0 | M |
| 13/04/03 | 26.1 | 17.7 | | SW 17 | | SW 9 | 0.0 | M |
| 14/04/03 | 27.1 | 19.1 | | NNW 22 | | NNW 15 | 0.2 | M |
| 15/04/03 | 26.5 | 18.1 | | S 15 | | WSW 5 | 0.0 | M |
| 16/04/03 | 25.6 | 16.3 | | SSW 30 | | S 33 | 0.0 | M |
| 17/04/03 | 22.9 | 16.3 | | SSW 28 | | SSW 24 | 0.2 | M |
| 18/04/03 | 23.9 | 15.9 | | SSW 26 | | SW 9 | 0.0 | M |
| 19/04/03 | 24.6 | 17.1 | | SSW 26 | | SSW 26 | 0.0 | M |
| 20/04/03 | 23.0 | 17.3 | | SW 24 | | SSW 18 | 0.0 | M |
| 21/04/03 | 23.0 | 17.0 | | SSW 22 | | SSW 18 | 1.0 | M |
| 22/04/03 | 24.3 | 17.0 | | SSW 24 | | SW 18 | 0.0 | M |
| 23/04/03 | 22.7 | 16.4 | | SSW 28 | | SSW 21 | 1.0 | M |
| 24/04/03 | 21.6 | 16.7 | | SSW 22 | | SSW 21 | 0.2 | M |
| 25/04/03 | 22.0 | 16.7 | | SSW 21 | | SE 30 | 23.0 | M |
| 26/04/03 | 24.0 | 18.3 | | S 17 | | SE 24 | 38.0 | M |
| 27/04/03 | 23.7 | 19.3 | | SSE 17 | | ENE 24 | 0.2 | M |
| 28/04/03 | 24.3 | 19.2 | | SW 9 | | NE 9 | 85.0 | M |
| 29/04/03 | 25.4 | 18.2 | | S 8 | | S 15 | 0.0 | M |
| 30/04/03 | 25.8 | 16.3 | | SSW 21 | | S 11 | 0.0 | M |
| 1/05/03 | 25.1 | 16.9 | | SW 17 | | SSW 9 | 0.0 | M |
| 2/05/03 | | | | SW 22 | | SSW 15 | 0.0 | M |
| 3/05/03 | 22.8 | | | SSW 17 | | 0 | 0.0 | M |
| 4/05/03 | 22.6 | 13.5 | | SSW 17 | | SSW 31 | 1.6 | M |
| 5/05/03 | 19.7 | 13.4 | | SSW 24 | | SSW 22 | | |
| 6/05/03 | 20.9 | 14.9 | | SSW 15 | | SSW 17 | 6.0 | M |
| 7/0503 | 23.0 | 16.5 | | SSE 26 | | S 15 | 7.6 | M |
| 8/05/03 | 23.8 | 14.4 | | SSW 18 | | SSW 8 | 1.4 | M |
| 9/05/03 | 22.6 | 12.6 | | S 11 | | WSW 11 | 0.2 | M |
| 10/05/03 | 24.1 | 11.6 | | WSW 5 | | SW 2 | 0.0 | M |
| 11/05/03 | 23.9 | 11.0 | | SSW 17 | | SW 13 | 0.0 | M |
| 12/05/03 | 23.5 | 14.4 | | SSW 22 | | SSW 18 | 0.0 | M |
| 13/05/03 | 23.2 | 16.6 | | S 17 | | SSW 13 | 11.6 | M |
| 14/05/03 | 23.0 | 16.3 | | SSW 15 | | SSW 11 | 8.0 | M |
| 15/05/03 | 21.8 | 18.3 | | NE 26 | | SW 21 | 88.0 | M |

| Date | Maximum Temperature | Minimum Temperature | Relative Humidity | Wind | Relative Humidity | Wind | Rainfall in 24 hours to 9 am | Survey Type |
|---|---|---|---|---|---|---|---|---|
| | °C | °C | % | km/h | % | km/h | mm | |
| 16/05/03 | 22.9 | 15.9 | | S 11 | | W 9 | 74.2 | M |
| 17/05/03 | 25.7 | 12.5 | | WNW 11 | | WNW 5 | 0.2 | M |
| 18/05/03 | 27.0 | 10.4 | | N 8 | | WNW 15 | 0.0 | M |
| 19/05/03 | 28.4 | 13.9 | | NNE 11 | | NNW 15 | 0.0 | M |
| 20/05/03 | 27.5 | 19.2 | | NNW 17 | | WNW 8 | 0.0 | M |
| 21/05/03 | 25.3 | 11.6 | | WNW 9 | | SSW 9 | 0.0 | M |
| 22/05/03 | 23.5 | 9.6 | | SSW 2 | | SSW 8 | 0.0 | M |
| 23/05/03 | 21.9 | 10.3 | | SSW 11 | | SSW 8 | 0.0 | M |
| 24/05/03 | 22.0 | 10.6 | | SSE 8 | | SSW 8 | 0.0 | M |
| 25/05/03 | 22.8 | 9.4 | | SSW 13 | | SW 9 | 0.0 | M |
| 26/05/03 | 22.2 | 9.3 | | SW 5 | | SSW 5 | 0.2 | M |
| 27/05/03 | 22.5 | 10.1 | | S 21 | | SSW 17 | 0.0 | M |
| 28/05/03 | 19.3 | 15.4 | | S 21 | | S 17 | 16.8 | M |
| 29/05/03 | 20.5 | 15.5 | | SE 11 | | WSW 11 | 22.2 | M |
| 30/05/03 | 21.1 | 15.1 | | SSW 24 | | SSW 17 | 15.8 | M |
| 31/05/03 | 21.8 | 13.4 | | S 18 | | SSW 9 | 4.2 | M |

Note: M = Mammal Trapping (Elliott Trapping, Cage Trapping, Pitfalls)
A = Amphibians (Pitfalls, Searches)
R = Reptiles (Pitfalls, Searches
B = Birds
H = Hair Tubes
S = Spotlighting
Bats = Anabat and/or Harp Trapping
I = Invertebrate Surveys

# Appendix C: Capture Data

Table C1: Summary of potoroo capture data between 7 April and 2 June 2003.

| ID | Sex | Age | Weight (g) | Pouch Young | # captures |
|---|---|---|---|---|---|
| Unmarked | F | Adult | - | Large | 1 |
| Transmitter 950 | M | Adult | 1435 | NA | 5 |
| Transmitter 931 | F | Adult | 1175 | Small pink | 6 |
| Transmitter 990 | M | Sub-adult | 970 | NA | 4 |
| Transmitter 790 | M | Adult | 1290 | NA | 6 |
| Transmitter 831 | M | Sub-adult | 1025 | NA | 4 |
| Transmitter 901 | F | Sub-adult | 890 | None | 1[1] |
| Transmitter 972 | F | Adult | 1180 | Moderate | 2 |
| Clip right rump large | M | Adult | 1300 | NA | 2 |
| Transmitter 950n | M | Adult | 1490 | NA | 4 |
| Transmitter 852 | F | Adult | 1100 | None | 1[2] |
| Clip between ears | F | Adult | 1320 | Small pink | 3 |
| Transmitter 931 | M | Adult | 1350 | NA | 2 |
| Transmitter 990n | M | Adult | 1390 | NA | 3 |
| Unmarked | F | Adult | - | Large pink | 3 |
| Clip left rump short broad tail | F | Adult | 1680 | Large | 1 |
| Clip mid-back left forequarter | F | Adult | 1200 | None | 3 |
| Clip between ears | M | Sub-adult | 880 | NA | 2 |
| Clip base of tail | M | Adult | 1700 | NA | 1 |
| Clip left flank | M | Adult | 1750 | NA | 1 |
| Clip mid-rump back | M | Adult | 1600 | NA | 1 |
| Clip mid-back | M | Adult | 1700 | NA | 1 |
| Transmitter 972n | F | Adult | 1130 | None | 1[2] |
| Clip above tail | M | Adult | 1650 | NA | 3 |
| Clip right rump | M | Adult | 1130 | NA | 1 |
| Clip mid-back large | F | Adult | 1100 | None | 2 |
| Unmarked | M | Adult | 1440 | NA | 1 |
| **TOTAL** | **27** | | | | **65** |

[1] transmitter failed
[2] transmitter dropped

## Appendix D:  Individual Home Ranges

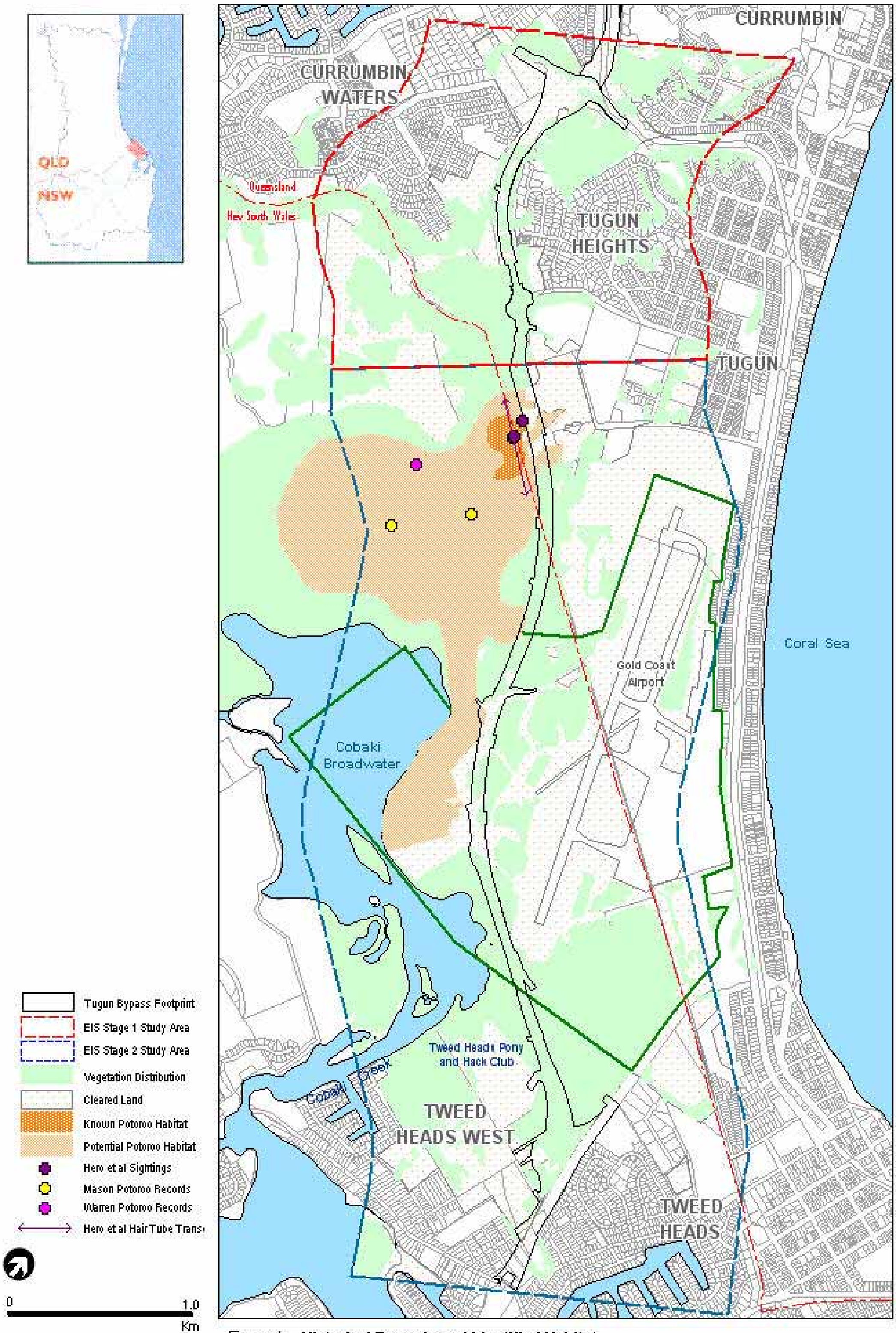


Figure 1 **Historical Records and Identified Habitat**

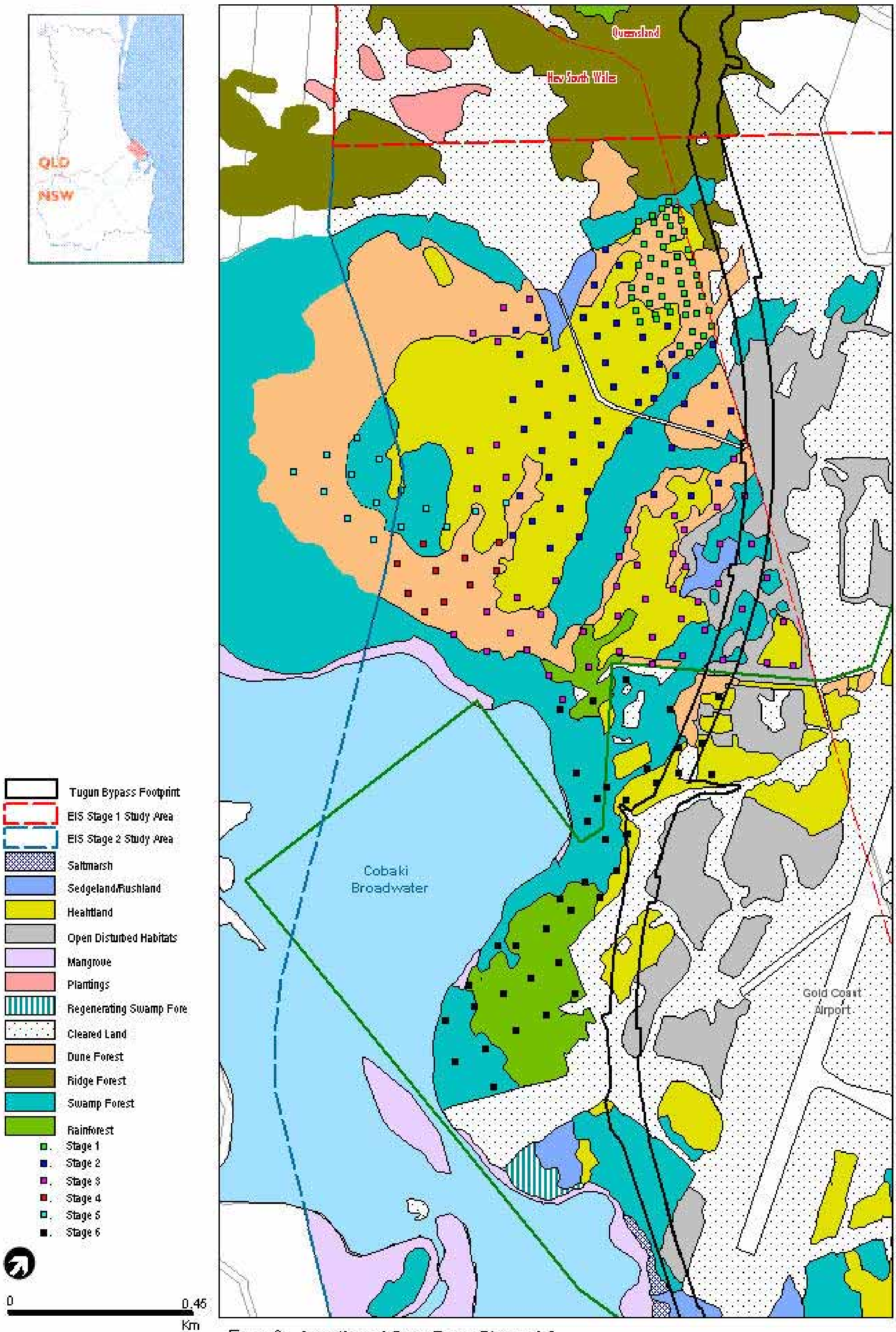


Figure 2 **Location of Cage Traps Stages 1-6**

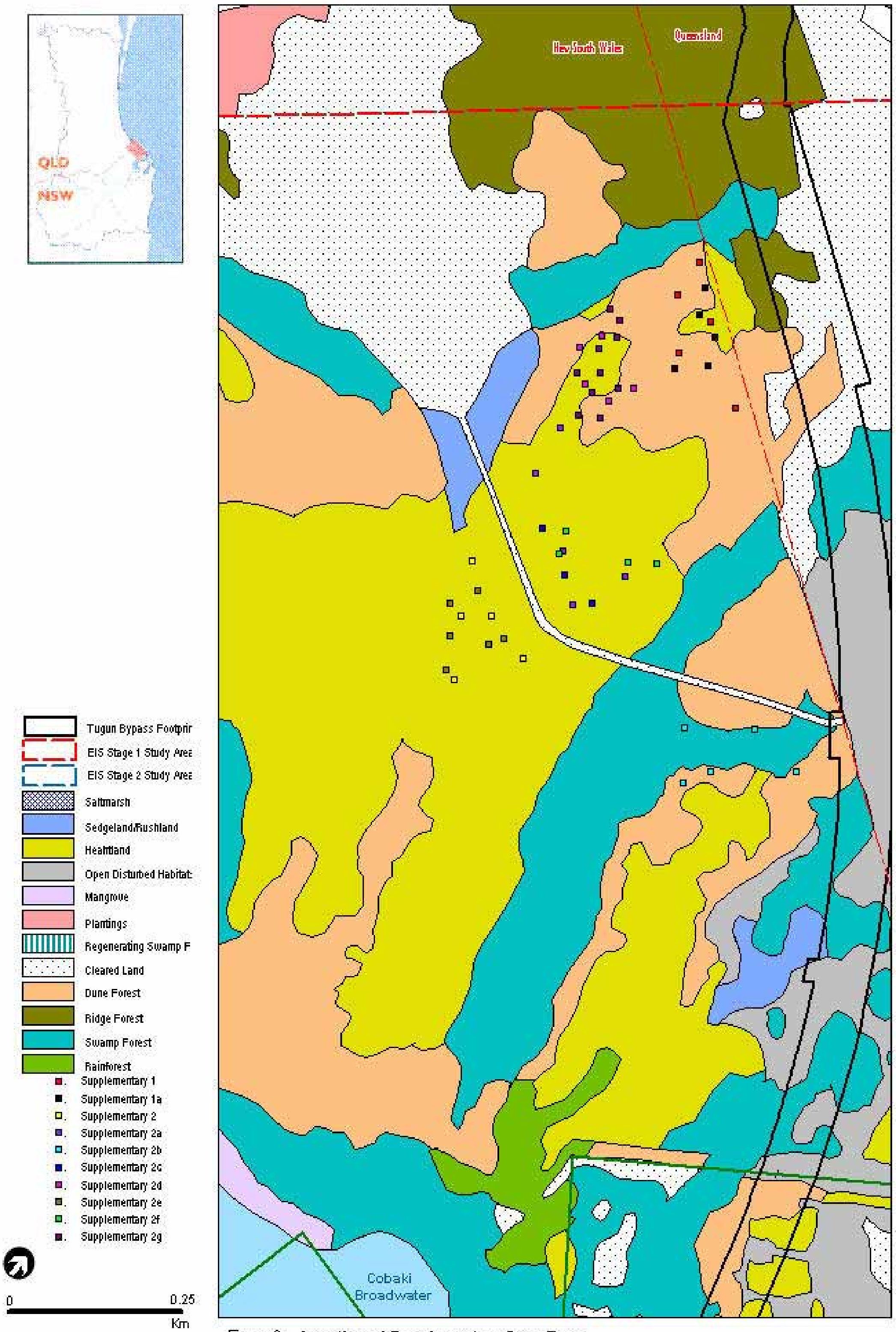


Figure 3 **Location of Supplementary Cage Traps**

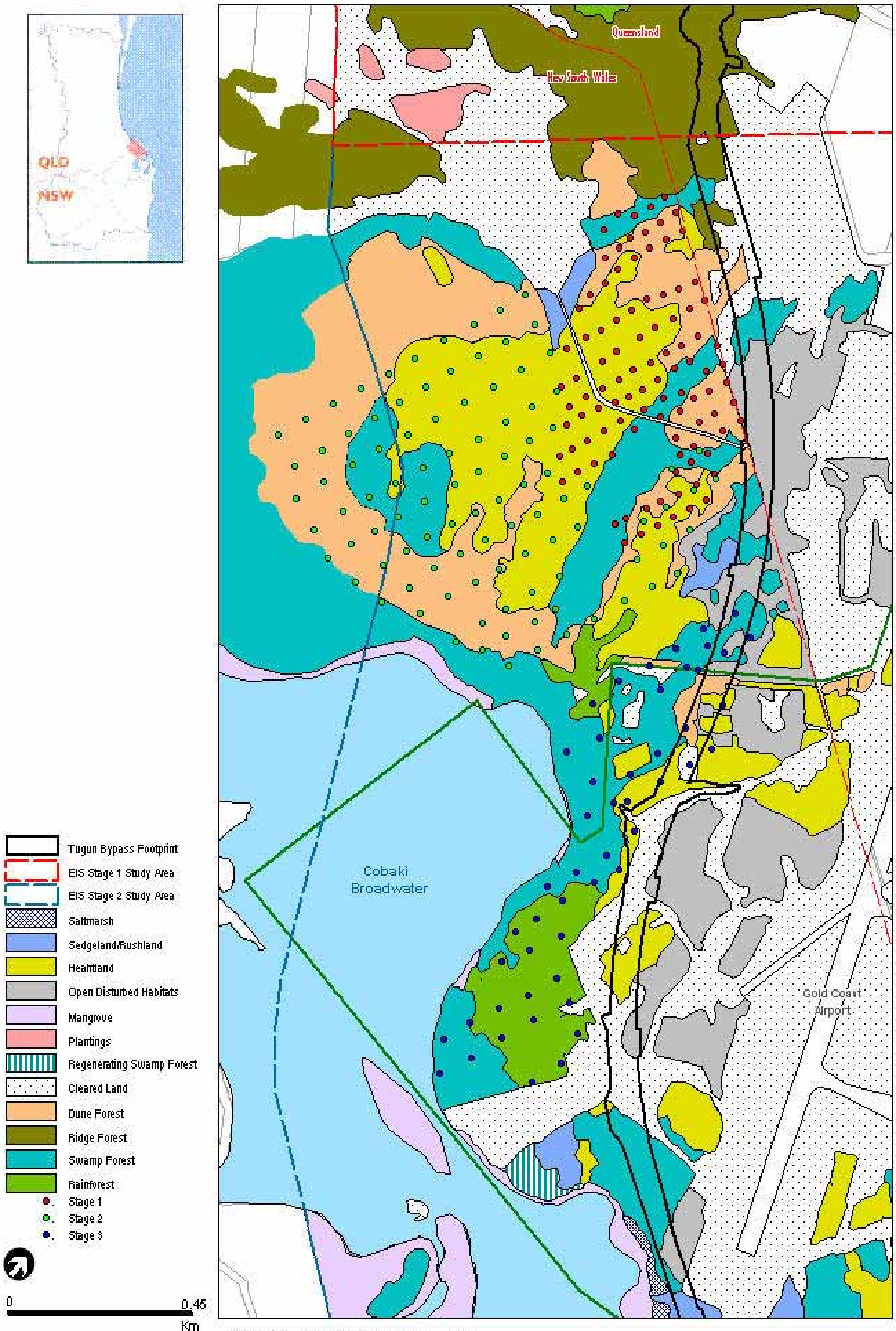


Figure 4 **Location of Hair Tubes**

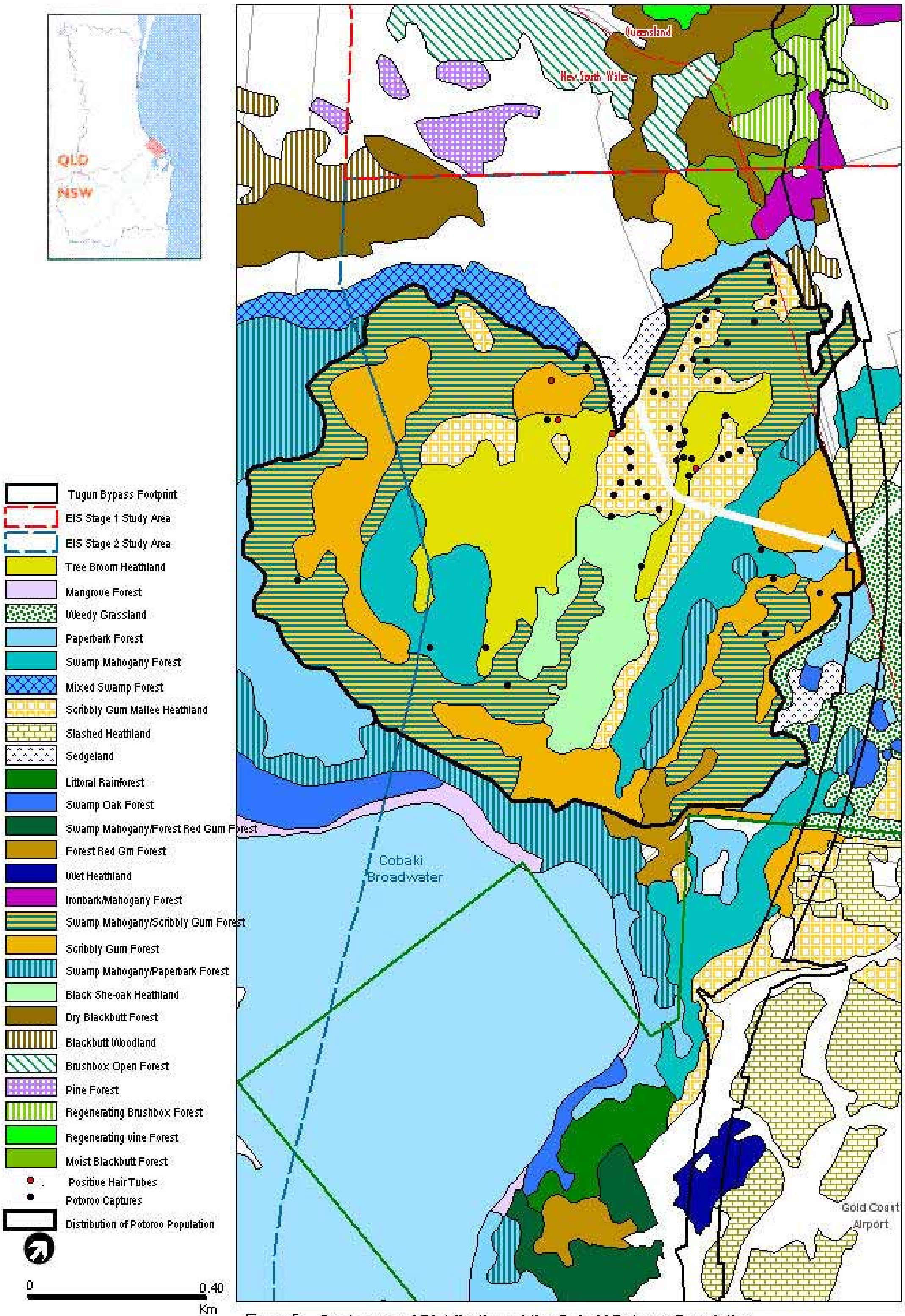


Figure 5 **Captures and Distribution of the Cobaki Potoroo Population**

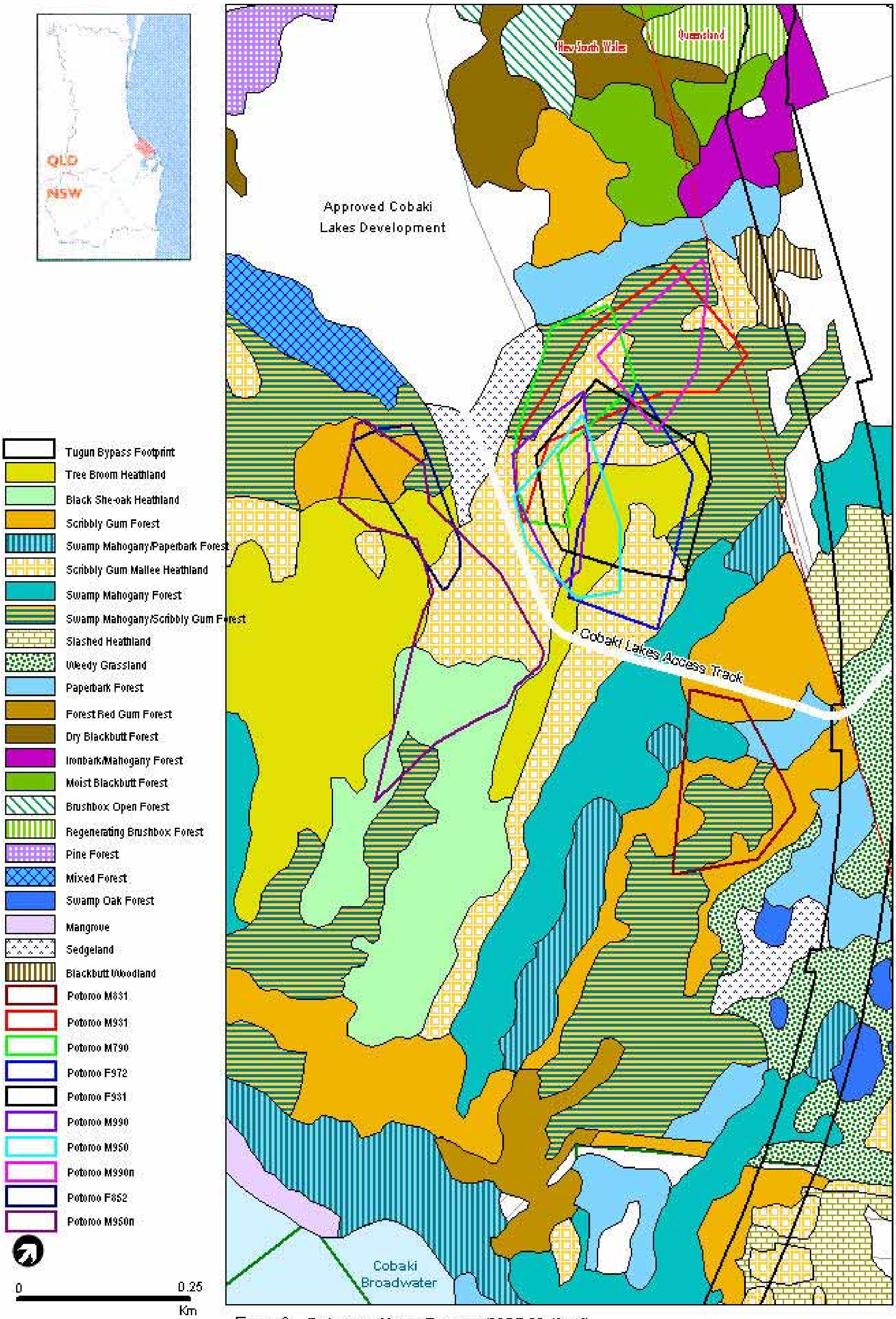

Figure 6 **Potorooo Home Ranges (MCP Method)**

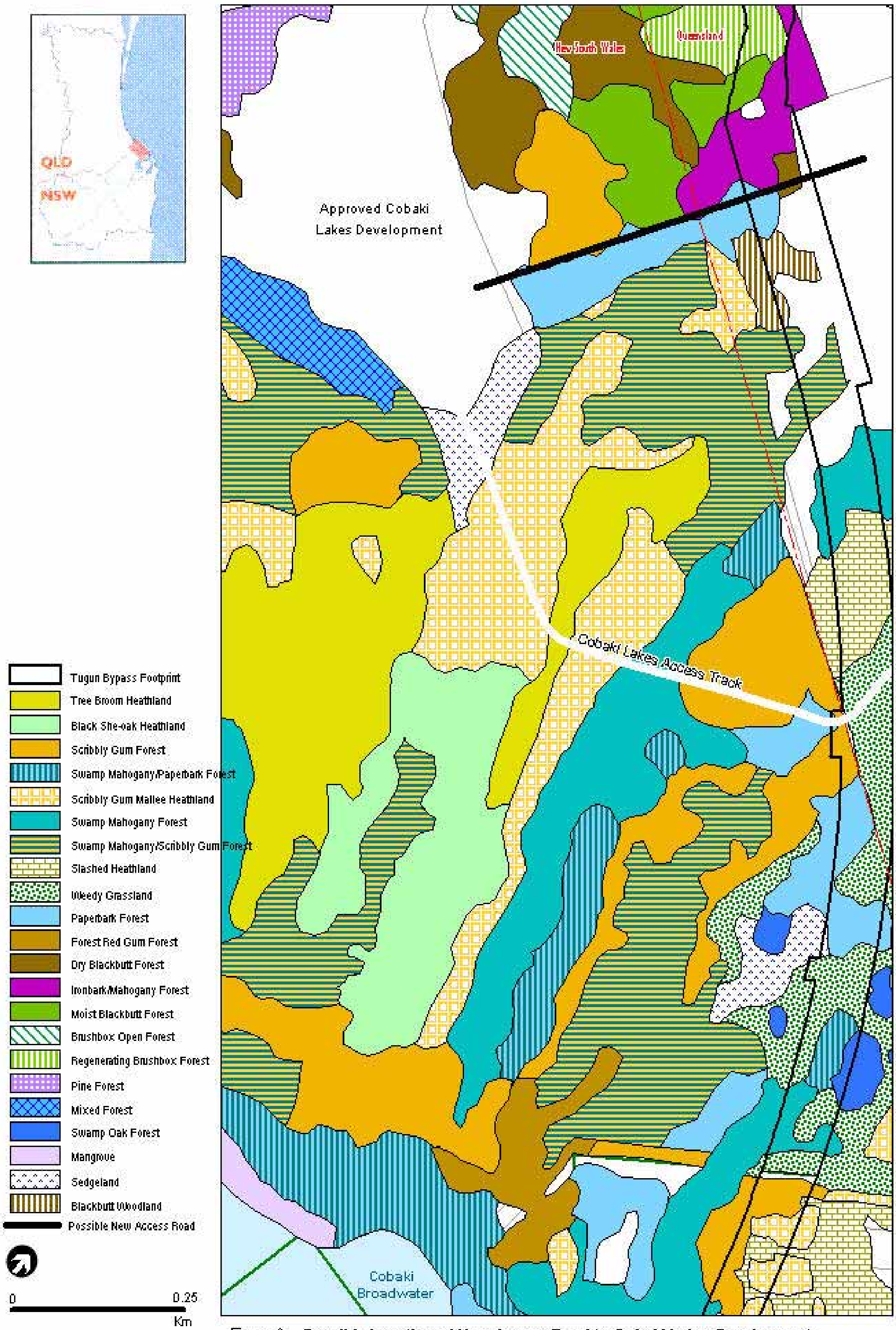


Figure 8 **Possible Location of New Access Road to Cobaki Lakes Development**

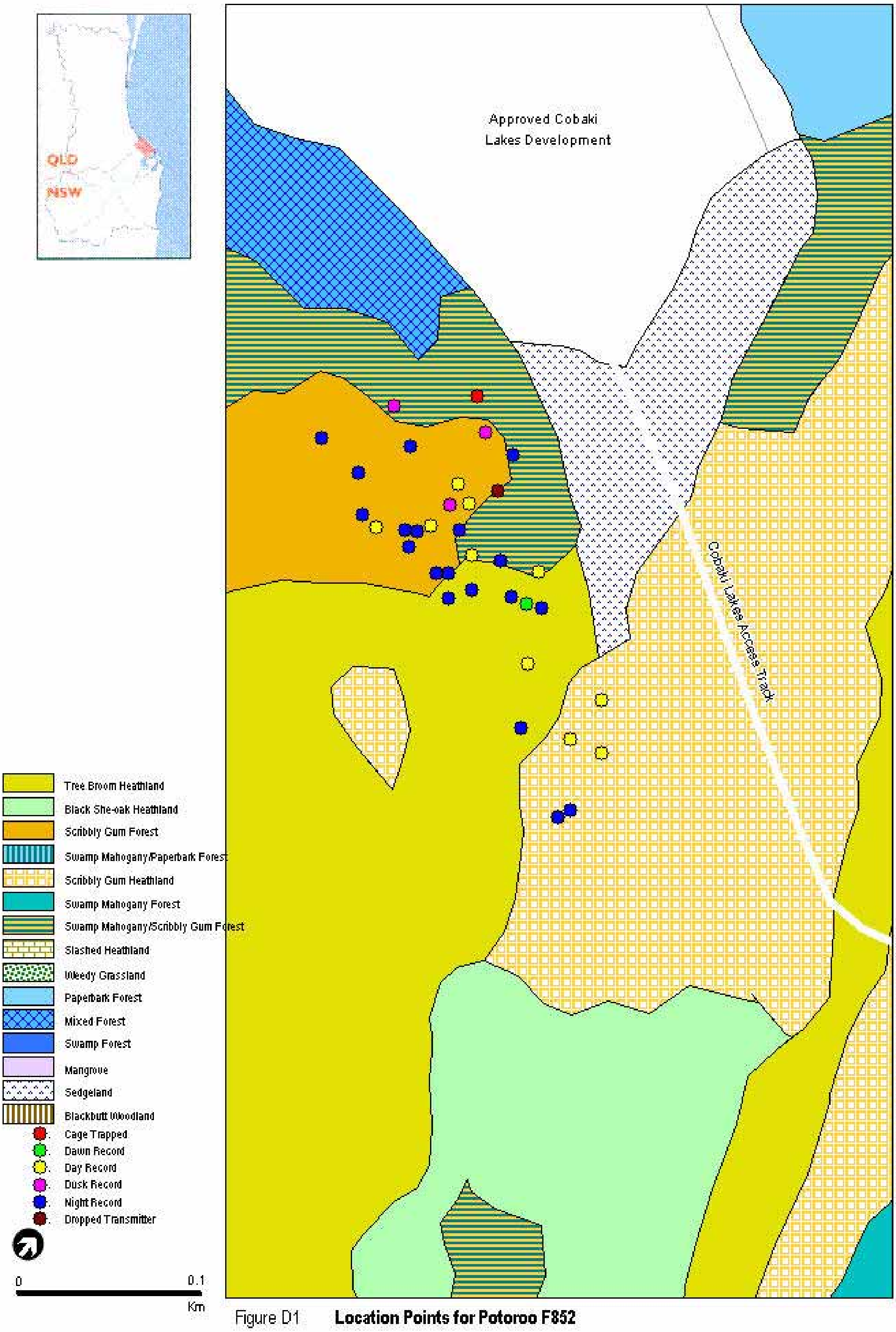


Figure D1 **Location Points for Potoroo F852**

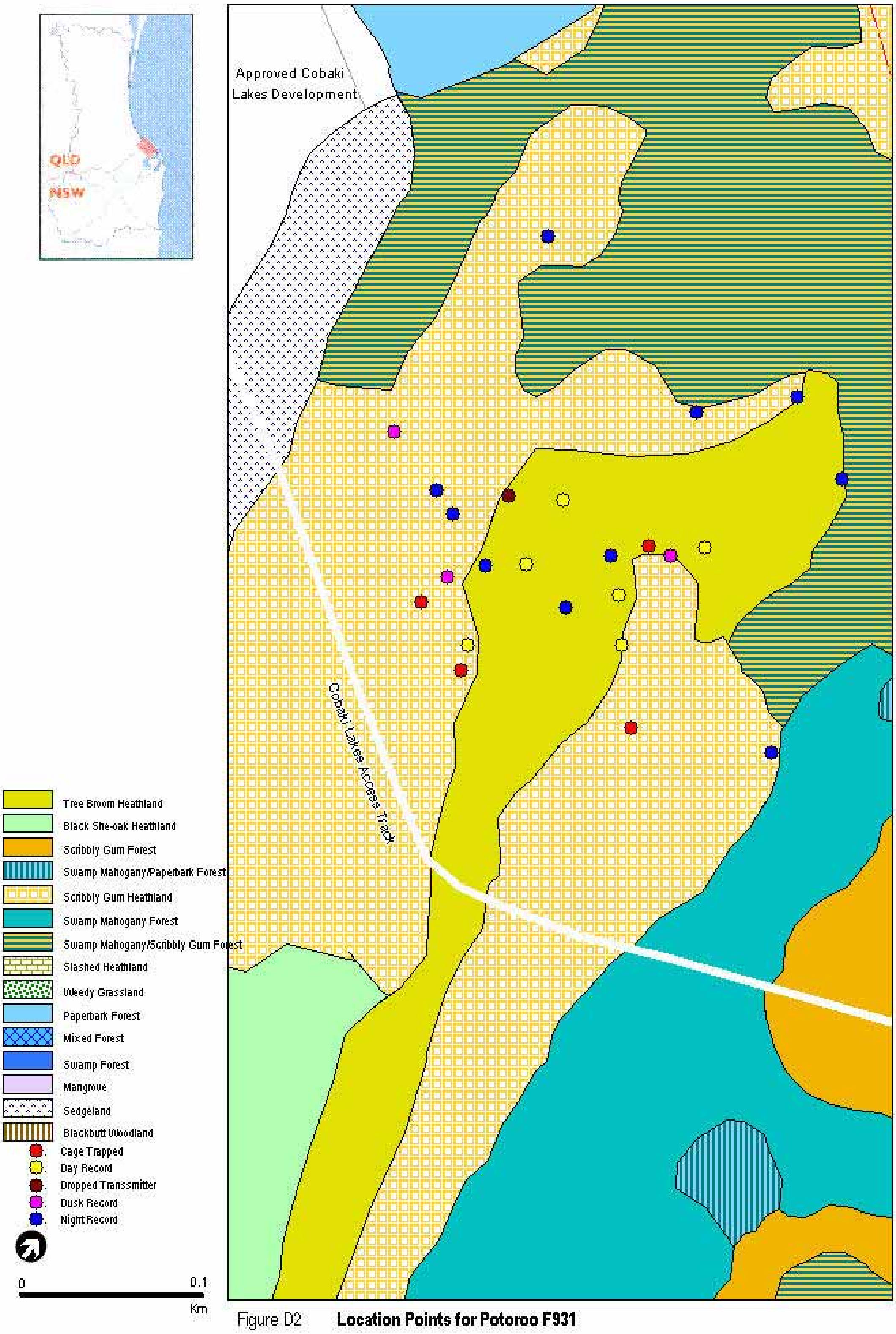


Figure D2 **Location Points for Potoroo F931**

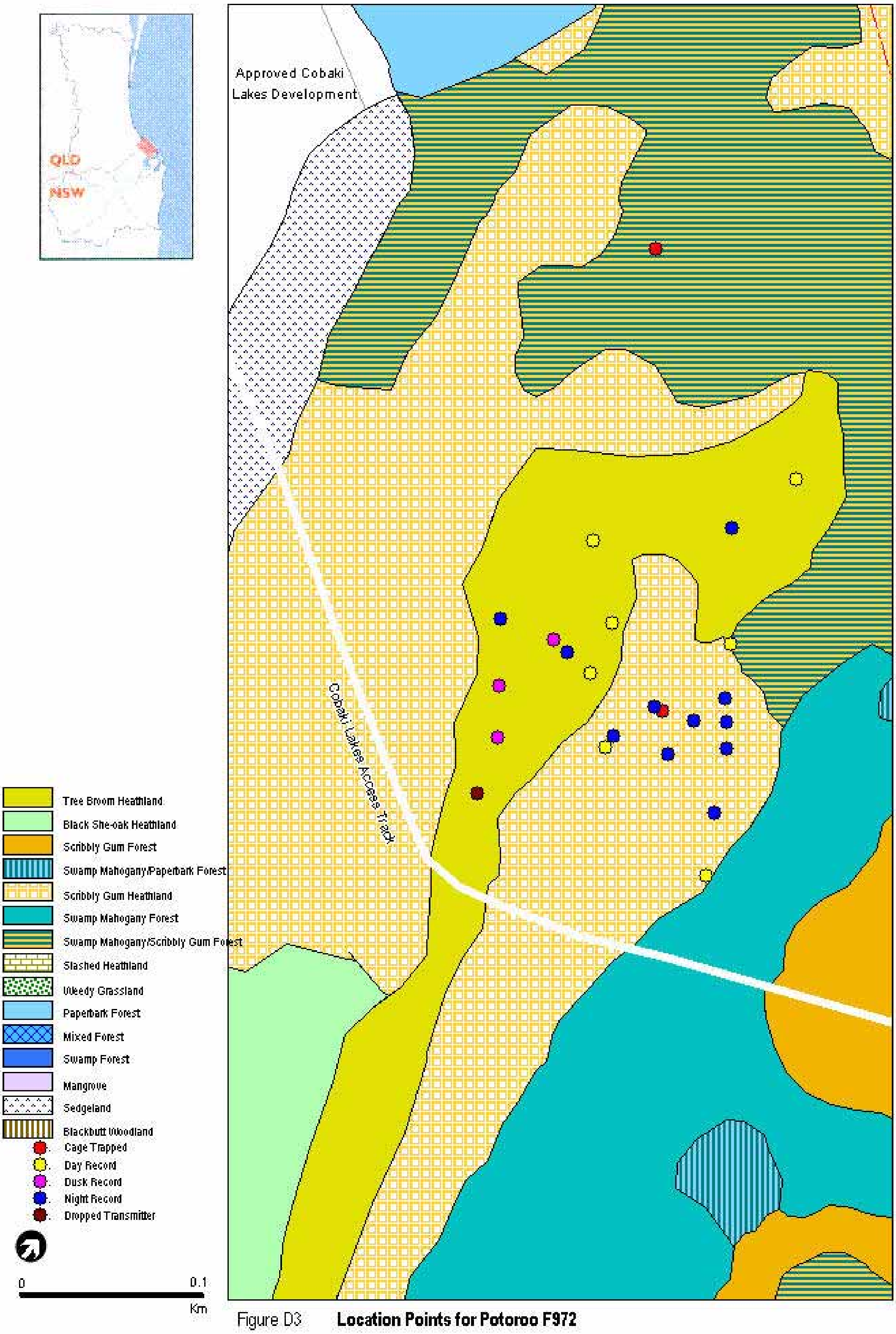


Figure D3 **Location Points for Potoroo F972**

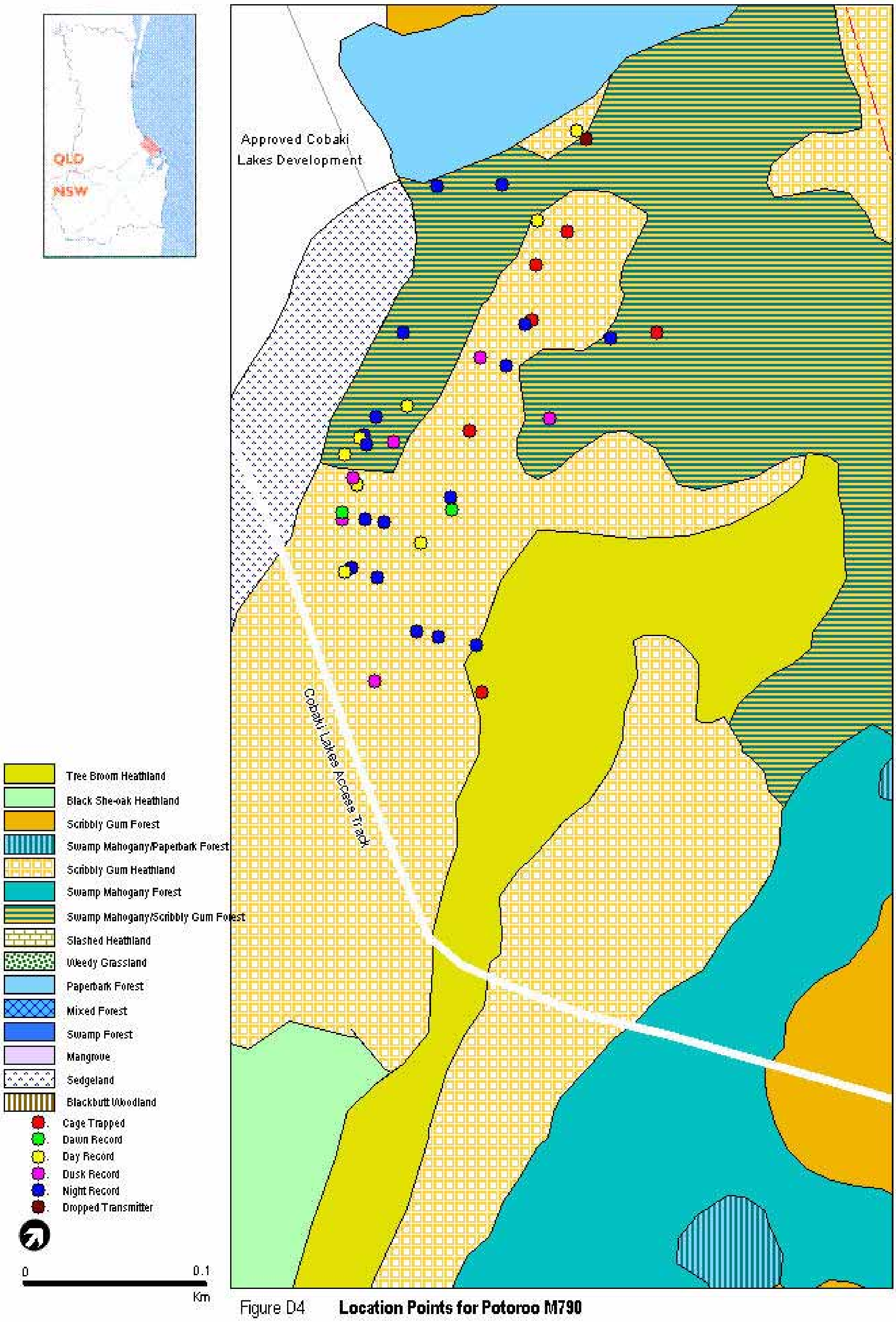


Figure D4 **Location Points for Potoroo M790**

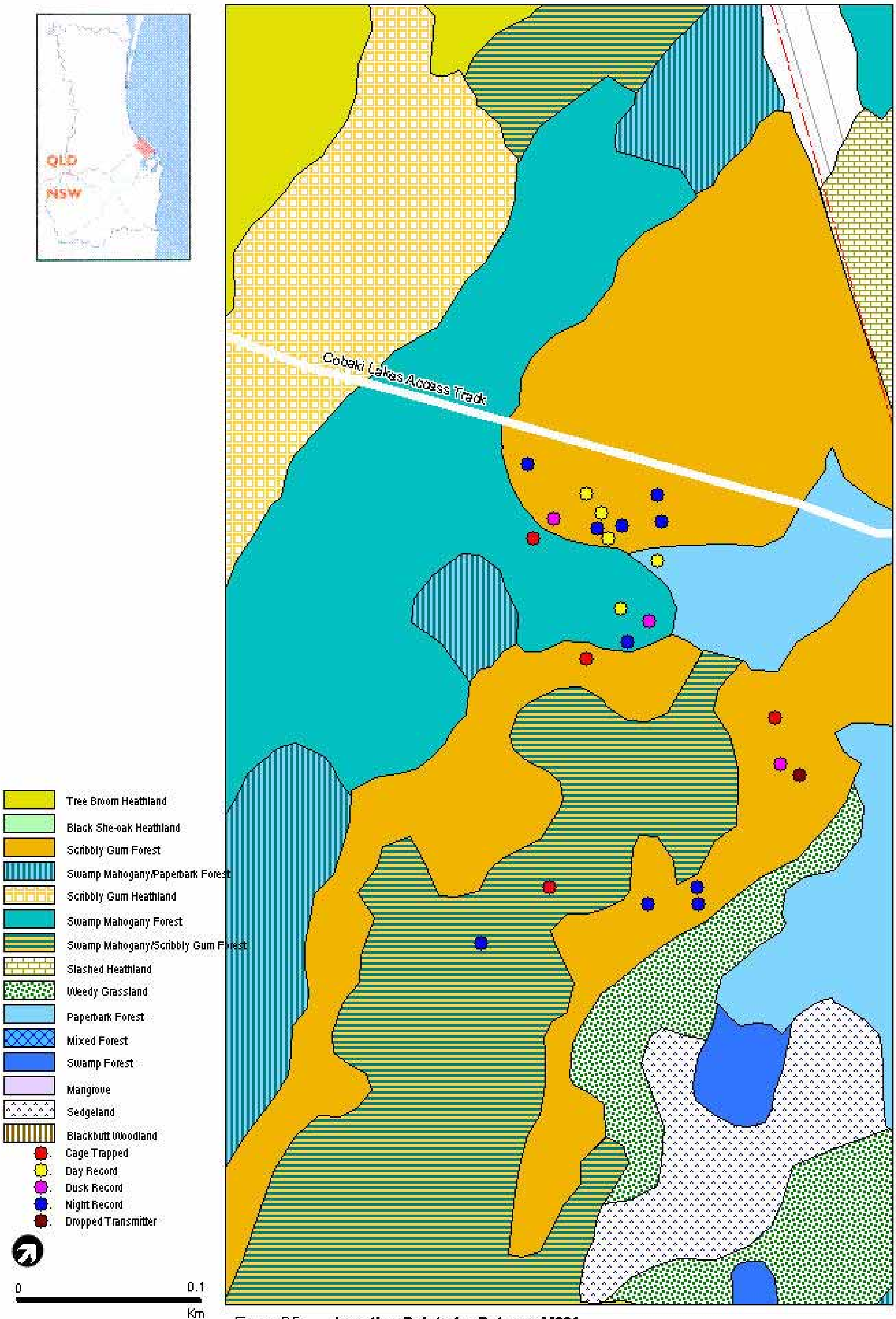


Figure D5 **Location Points for Potoroo M831**

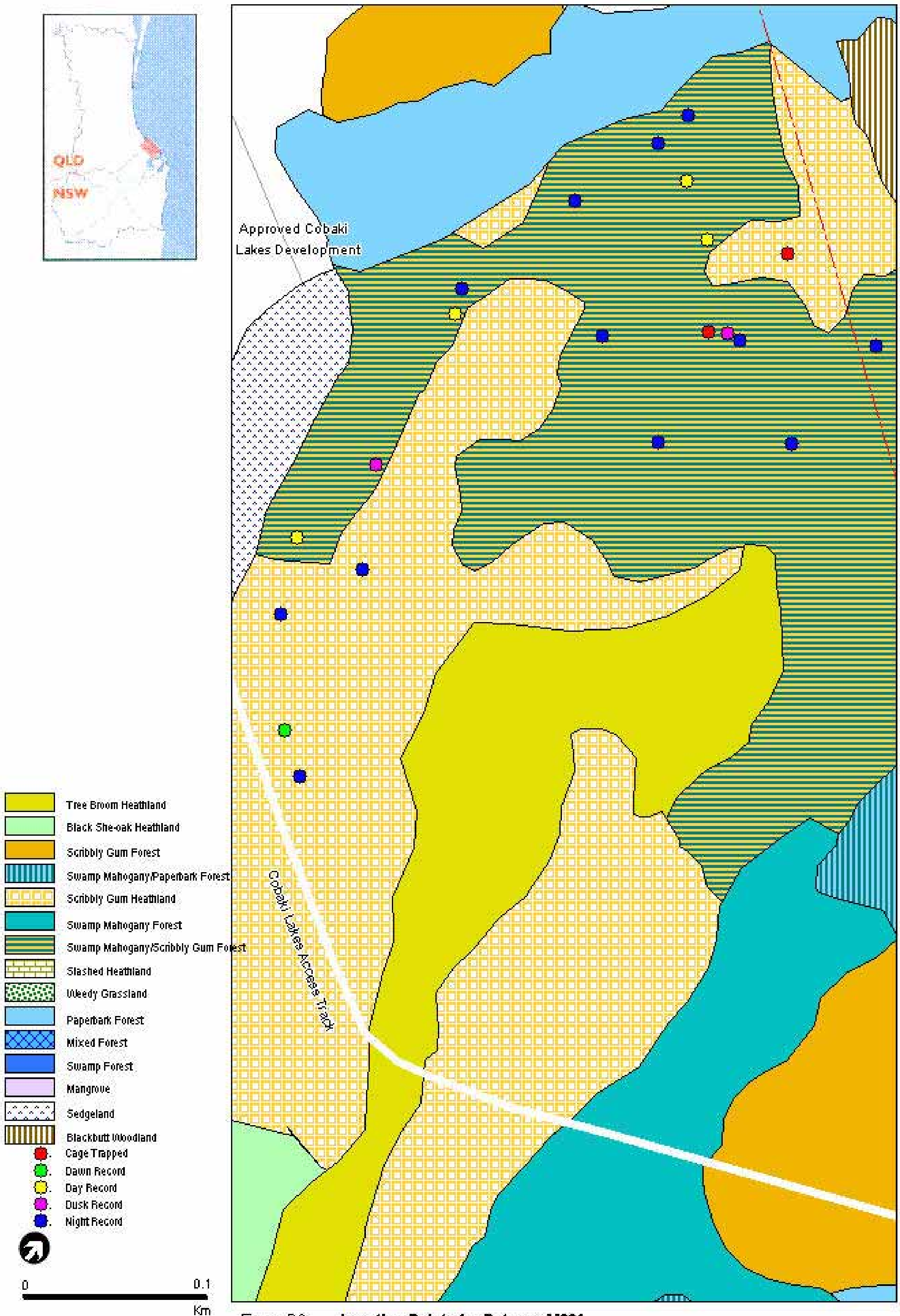


Figure D6 **Location Points for Potoroo M931**

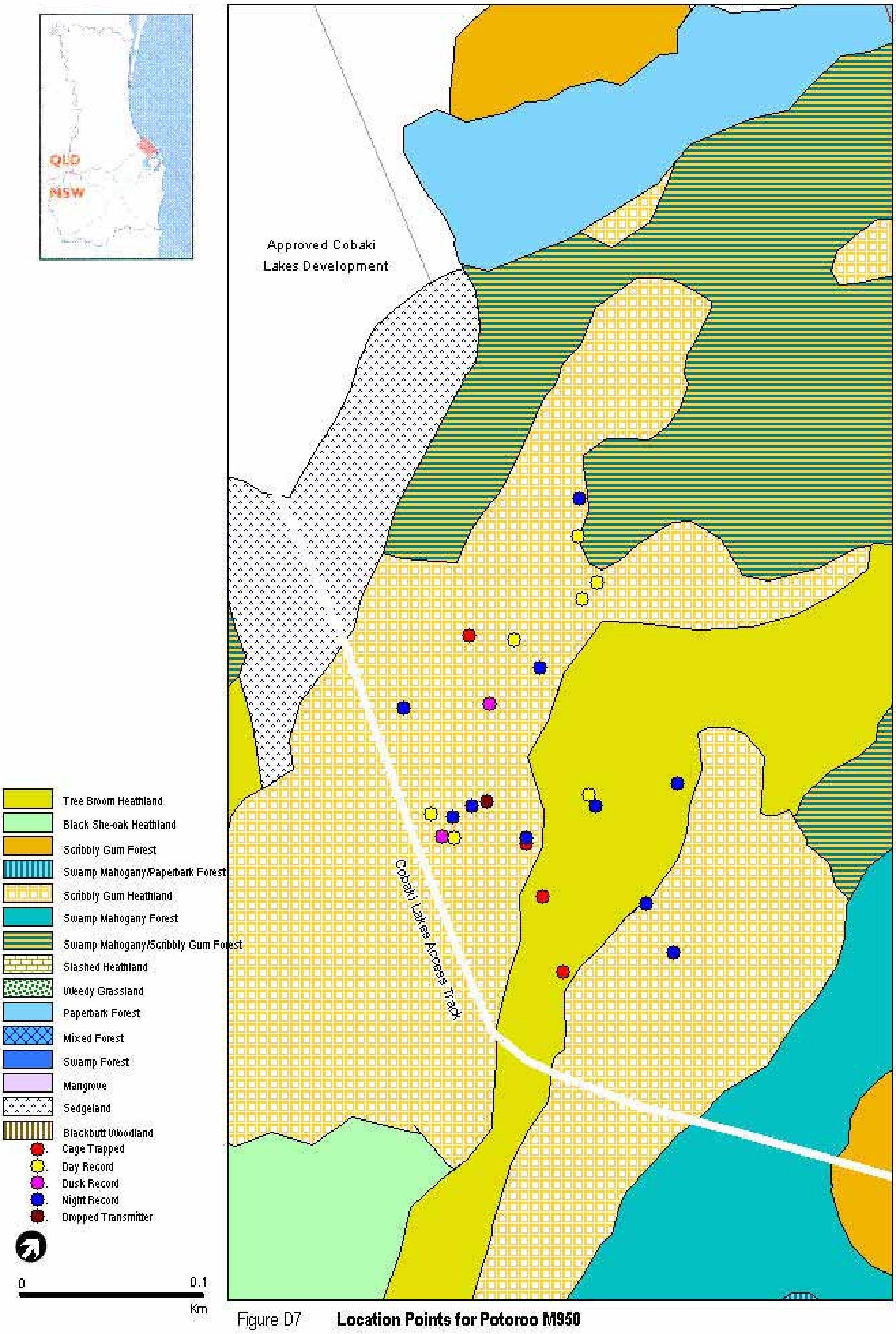


Figure D7 **Location Points for Potoroo M950**

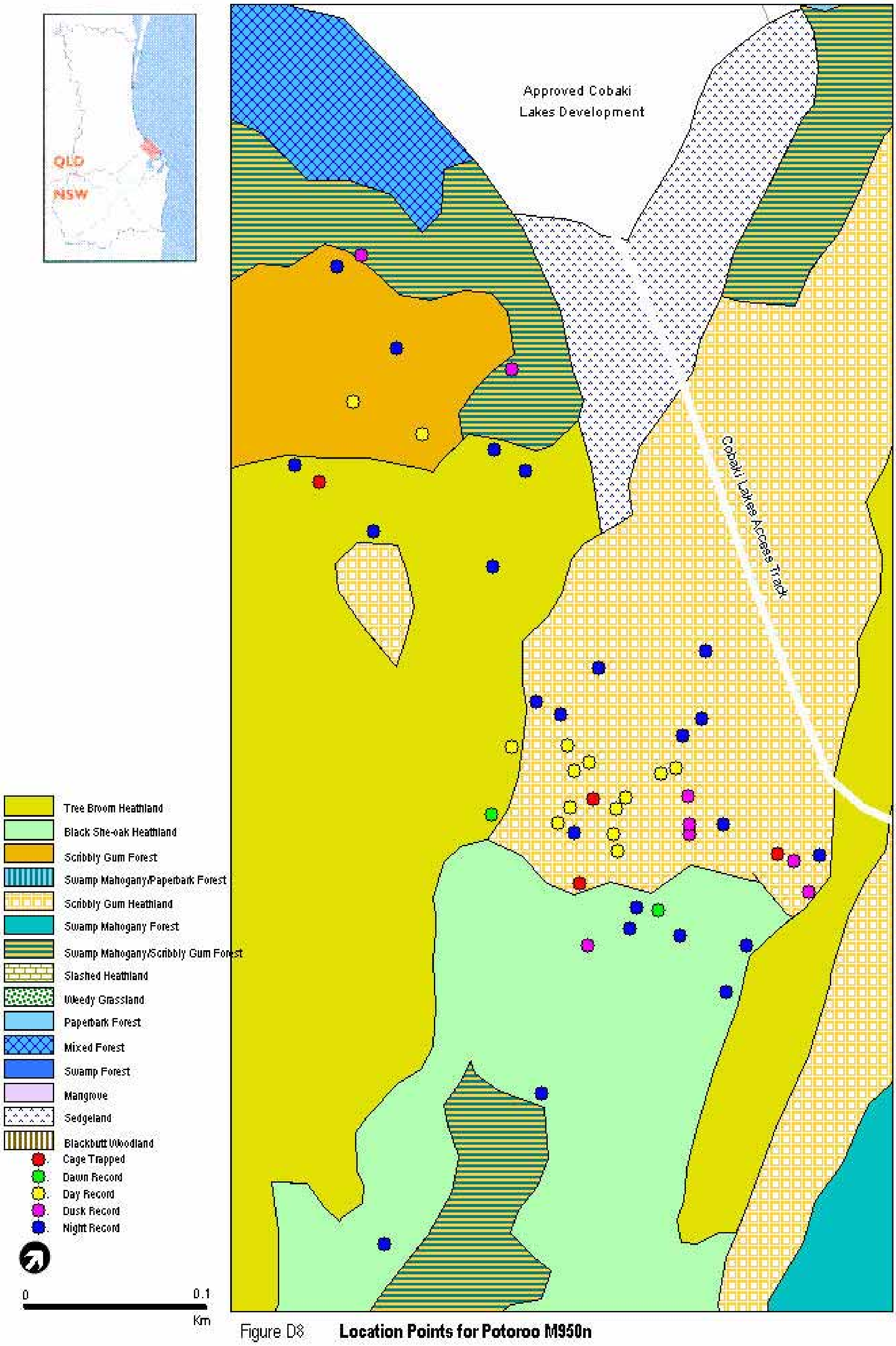


Figure D8 **Location Points for Potoroo M950n**

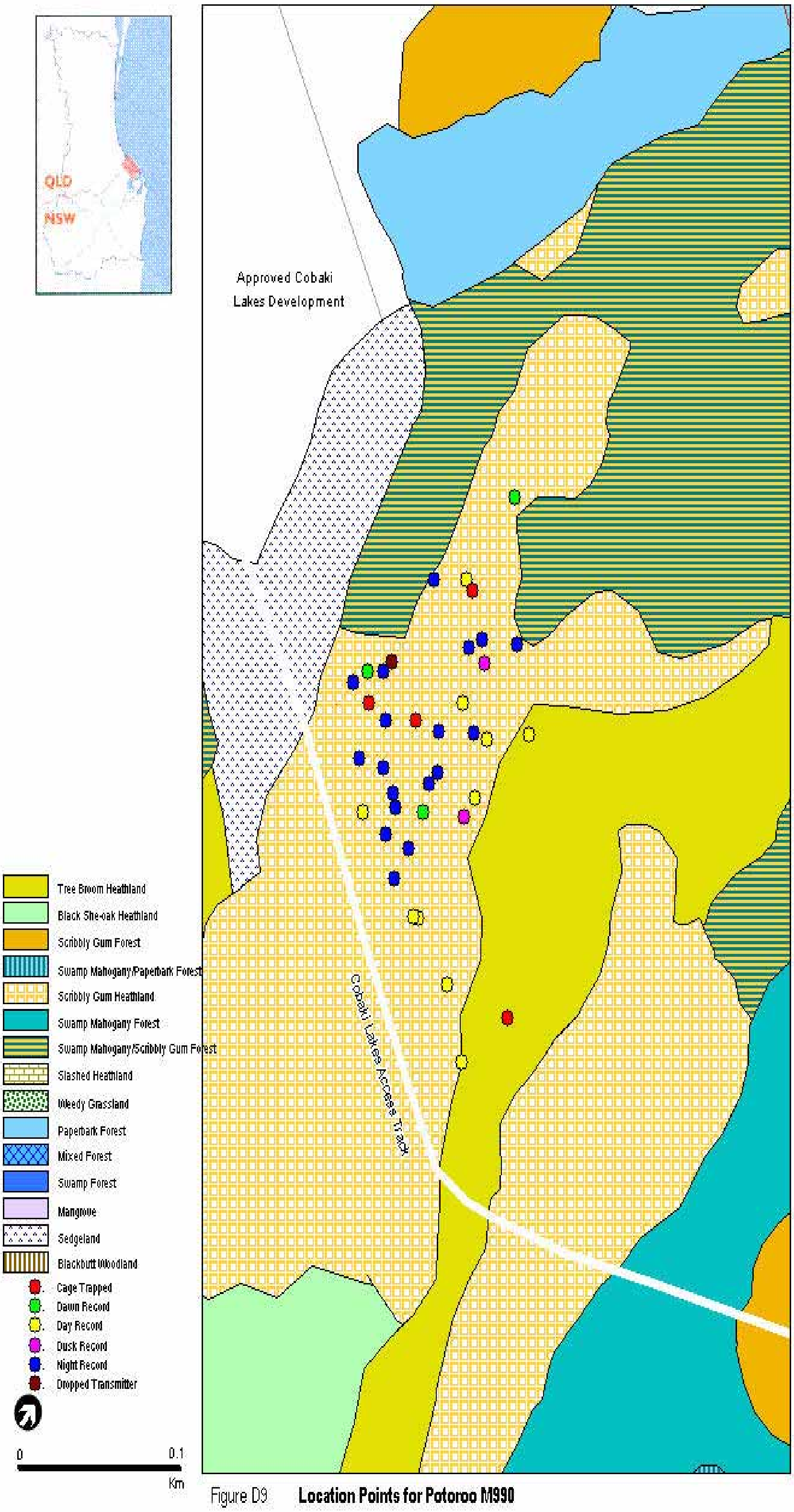


Figure D9 **Location Points for Potoroo M990**

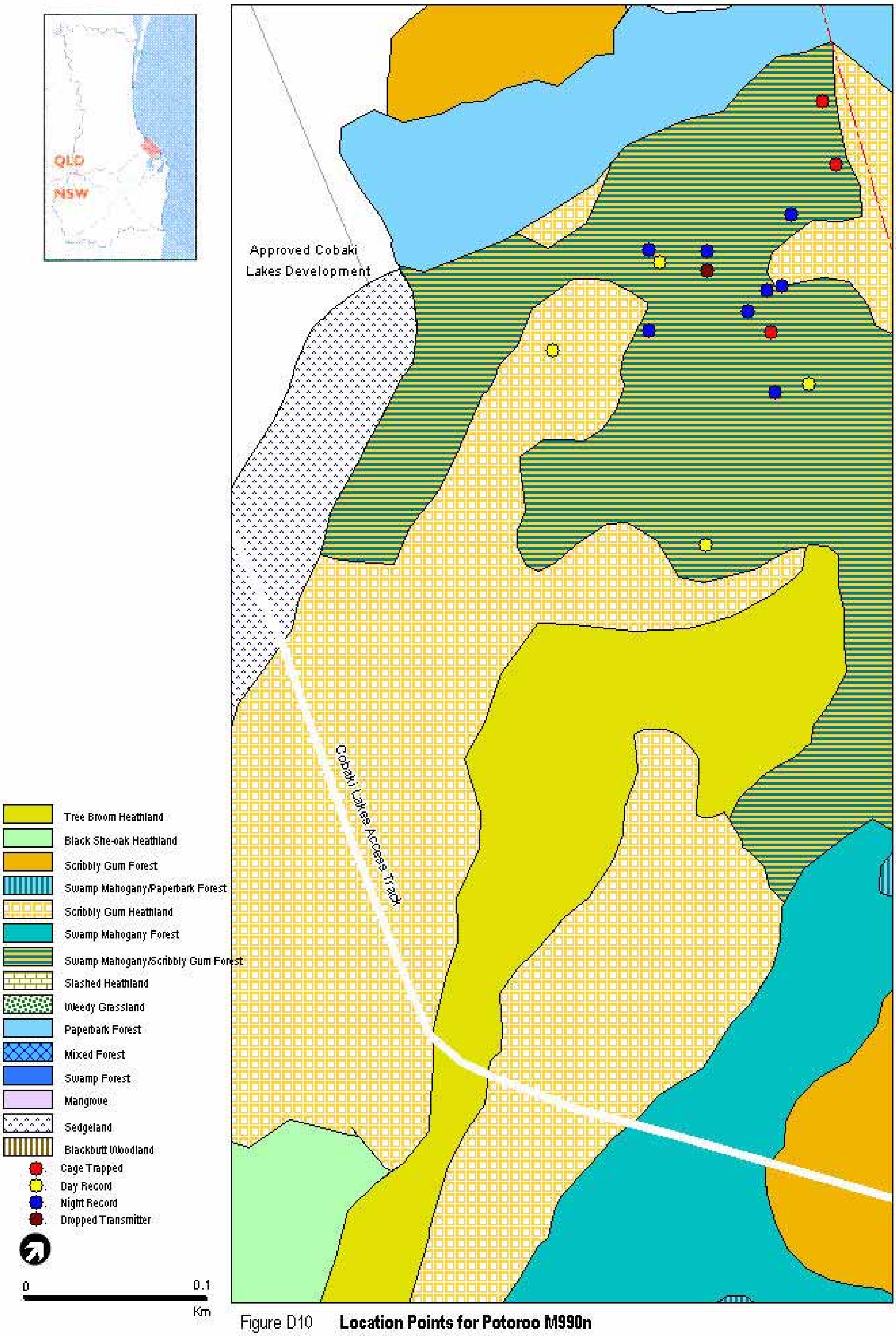


Figure D10 **Location Points for Potoroo M990n**

# Appendix H

*Systematic Surveys for the Coastal Planigale* (Planigale maculate*) on Crown Lands and a Detailed Habitat Appraisal of the Tugun/Cobaki Locality* (Lewis 2004a)

# SYSTEMATIC SURVEYS FOR COASTAL PLANIGALE (*PLANIGALE MACULATA*) ON COBAKI CROWN LANDS AND A DETAILED HABITAT APPRAISAL OF THE TUGUN/COBAKI LOCAILITY

**REPORT PREPARED FOR PARSONS BRINCKERHOFF (PB) BRISBANE**

BY

**LEWIS ECOLOGICAL SURVEYS**

**JULY 2004**

*Lewis Ecological Surveys*
*6 Blue Gum Ave*
*Wingham NSW 2429*
*Mob: 0413 019279*

This ecological report has been prepared for Parsons Brinckerhoff (PB) and their client: Department of Main Roads and Transport in accordance with the specified brief – stage 1 proposal. Stage 2 was abandoned due to poor trap success. This report relies upon data, surveys, measurements and results based on a short-term objective study in response to a brief provided by the client (PB). Although conclusions have been based on the available data at the time, some professional judgement has been applied in reaching the conclusions. Every attempt has been made to ensure the accuracy and objectivity of the reports findings, conclusions and recommendations.

……………………….
Author
Ben Lewis
(B.App.Sc – Hons)

Date: 14 July 2004...

**Relevant Licence:** NPWS - No.S10524;
NSW Agriculture Animal Care and Ethics – No:AW2001/040;

**Report to be cited as**: Lewis, B.D (2004). Systematic surveys for the coastal planigale (*Planigale maculata*) on crown lands and a detailed habitat appraisal of the Tugun/Cobaki locality. Report prepared for Parsons Brinckerhoff (Brisbane) and Department of Main Roads and Transport (Nerang) by Lewis Ecological Surveys.

**Acknowledgements:**

***Field Personnel***: Ben Lewis, D. Rohweder, S. Stennett
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***ECOSURE:*** Phil Sure for discussion of planigale records along sector three of Coolangatta Creek.
***EcoPRO:*** Khaalyd Brown for provision of relevant maps.
***Damien White***: Discussion regarding capture of planigale in the Cobaki-Tugun locality.

**Photography:** Ben Lewis

# TABLE OF CONTENTS

# LIST OF TABLES



# LIST OF FIGURES

# *EXECUTIVE SUMMARY*


Systematic surveys were undertaken for the coastal planigale (*Planigale maculata*) on crown lands west of the existing C4 footprint. Three sites were selected along prominent drainage lines where various forest types converged to form an ecotonal forest with dense ground covers. Each site comprised eight pitfall lines of five pits arranged in a 1 ha grid configuration. Grids were left operating over a consecutive 6-7 night period between 15-24 June 2004 culminating in 845 pit nights. Elliott traps positioned at the end of each pitfall line culminated in 192 trap nights. No planigale were captured during the survey although 16 other vertebrate species were detected including the vulnerable wallum froglet (*Crinia tinnula*). A number of reasons have been proposed for the lack of capture data during the survey, among these are the cool and dry weather conditions, and the competition and predatory interactions with *Antechinus flavipes*. Both explanations have validity within scientific literature on dasyurid fauna.

To compensate for the lack of planigale capture data a detailed habitat assessment was undertaken. The objective of this was to determine the principal habitat components associated with the presence of planigale. Fourteen sites were surveyed in the Tugun/Cobaki locality using previous ecological works to determine the status of planigale at these sites. Various habitat data were collected including landscape attributes, anthropogenic disturbances, hydrological regimes, floristic structure and composition. Detailed quantitative data were obtained from a 50 x 5m transect (250m$^2$) or within the general area (i.e.100m) at each site. Data were then subjected to a range of univariate and multivariate techniques.

Principal components analysis (pca) identified eight habitat components responsible for 91.6% of the variability between sites with planigale and sites without planigale. Ordination of the primary components has identified the sites surveyed during the current assessment lie within known planigale sites and should still be regarded as potential habitat. For this reason sites within Hidden Valley and the rainforest ecotone on GCAL controlled lands also should be regarded as suitable habitat. The results of the current survey have facilitated the creation of a habitat suitability map.

The habitat data suggest planigale inhabit more disturbed sites which are characterised by smaller dbh's consistent with regenerating swamp or riparian forests. All sites are closely associated with ecotone environments, particularly those within or proximate to watercourses. These areas provide sufficient dense covers comprising either grass, ferns, litter and sedges. There also appears to be a preference for sites with ample log debris that has reached a later stage of decay. Sites which are devoid of log debris have dense grass covers which tend to provide a surrogate refuge habitat. Such sites may provide suitable transient habitat capable of facilitating movement between more optimal habitats, a statement substantiated by the low capture rates of planigale over long survey periods (2001-2004).

Among the recommendations is the need for a survey to determine the suitability of the compensatory lands for planigale. At present there is no knowledge to suggest the likelihood if any that planigale occur on these lands. Should re-routing be proposed in the vicinity of the known planigale habitat the alterations should seek to improve on reducing the amount of habitat removal whilst ensuring the estuarine environments are not compromised. Notwithstanding the above recommendations a two stage monitoring program should be instigated to measure the level of impact and mitigative measures proposed.

# 1.0 INTRODUCTION

*Lewis Ecological Surveys* has been engaged by *Parsons Brinckerhoff* (PB) on behalf of the proponent (*Department Main Roads & Transport*) to conduct a specialist target survey for the coastal planigale (*Planigale maculata*). The area subject to the current assessment occurs in the vicinity (<1km) of the proposed footprint for the Tugun Bypass Project. The work is not intended to provide a detailed assessment on the current status of planigale in the Cobaki-Tugun area but rather supplement an existing sweet of comprehensive surveys to facilitate the impact assessment process.

### 1.1 General Ecology

Coastal planigale occur along coastal and sub coastal Queensland from Cape York extending southward along the coastal fringe to near Newcastle (Redhead 1995; NPWS 2000; Menkhorst and Knight 2001). This distribution is broadly delineated by the 1000 mm isohyet (Andrew and Settle 1982). Planigales inhabit a range of vegetation communities including rainforest, eucalypt forest, heathland, marshland, grassland and rocky areas (Menkhorst and Knight 2001). Such areas tend to have similar habitat components which include dense ground covers, a close association with water and areas of ecotonal forest (Denny 1982; NPWS 2000; Menkhorst and Knight 2001). In northern NSW, it has been suggested that their distribution often corresponds with the low lying flat and undulating areas of the coastal plains often near intensively settled areas (Gilmore and Parnaby 1994). Such descriptions are analogous with the results of earlier surveys in the Tugun-Cobaki area (Hero *et al*. 2000; 2001a,b; EcoSure 2003). There is currently little movement data available for planigale although other members of this genus are widely recognised as having a shifting home range in response to local climatic conditions and food resources (Denny 1982; Read 1982; 1988; Miller 1998).

### 1.2 Current Status and Threats

Coastal planigale is currently listed as 'vulnerable' on schedule two of the NSW *Threatened Species Conservation* Act (1995). This elevated conservation ranking has been justified on the basis of '*Population and distribution suspected to be reduced; poor recovery potential; threatening processes moderate; ecological specialist".* Principally, these threats arise from land uses which reduce the extent of understorey vegetation and fallen log cover, particularly those adjoining water (NPWS 1998).

A review of available literature and relevant databases (NPWS Wildlife Atlas) infer coastal planigale are widespread (93 records) in the NSW north coast bio region with their stronghold in the Tweed, Byron Bay, Ballina and Richmond Valley Local Government Areas (NPWS 2004; Table 1). Little data is presently available concerning the range and status of this species in Queensland although target surveys on the Gold Coast suggest this species is rare and seldom caught (D. White pers. comm.).

*Table 1.* Coastal planigale records in NSW. Numbers in parentheses represent proximate number localities. NP = National Park, NR = Nature Reserve.

| Local Government Area | No Records | Location | Source |
|---|---|---|---|
| Tweed Heads | 22 | Border Ranges Area (1), Chinderah (1), Cudgen NR (1), Kingscliff (1), Bogangar (1), Pottsville (5), Kunghur (1), Cobaki (1) | NPWS 2004, B. Lewis unpub. records |
| Byron Bay | 28 | Billinudgel NR, Brunswick Heads, Mullumbimby, Tyagarah NR (8), Suffolk Park (6), Broken Head NR (2), Crown Land Lennox Head (1), North Federal (2) | NPWS 2004, LES *et al* 1999 |
| Ballina | 8 | Newrybar, Lennox Head Crown Land, Lennox Head, Flatrock, Alstonville, Marom Creek, Meerschaum Vale, Tuckean Swamp | NPWS 2004, M. Graham unpub. records. |
| Lismore | 2 | West Alstonville and Goolmangar | NPWS 2004 |
| Richmond Valley | 13 | Evans Head Broadwater NP (5), Bundjalung NP (>4), New Italy (2), Busby's Creek | NPWS 2004; Southern Cross University Surveys 1995-6, B. Lewis unpub records |
| Kyogle | 4 | Urbenville, Bonalbo and Mallanganee | NPWS 2004 |
| Tenterfield | 3 | Woodenbong, Paddy's Flat | NPWS 2004 |
| Maclean | 2 | Yamba-Angourie | NPWS 2004 |
| Pristine Waters | 3 | Grafton, Halfway Creek | NPWS 2004 |
| Hastings | 4 | Lake Innes (2) Bonney Hills (1), North haven (1) | NPWS 2004 |
| Greater Taree | 4 | Lansdowne Purfleet, Hallidays Point | Evans *et al.* 1998; NPWS 2004 |
| **Total** | **93** | | |

### 1.3 Capture Methods

Pit falls represent the only reliable technique to capture planigale throughout their range (e.g. Read 1982; 1988; Milledge 1991; Catling *et al.* 1997; Miller 1998) and locally in the Tugun area (Rohweder and Banks 1996; Hero *et al.* 2000; 2001a.b; ECOSURE 2003; White pers. comm.). The use of drift fences appears to enhance capture rates (Read 1982; Read *et al.* 1988).

### 1.4 Aim of the study

Planigale have been recorded in two areas during previous route surveys (Hero *et al.* 2001b) and more recently during ecological monitoring along Coolangatta Creek (Figure 1; Eco Sure 2003). The distribution of these records and the extent of analogous habitat elsewhere in the Cobaki-Tugun area infer planigale potentially exist at several other locations, an impetus for the current assessment.

The focus of this report is to present the findings of a targeted survey for planigale on crown lands to the west of GCAL and Tugun Landfill. The aims of this study were to: 1) confirm the presence of planigale at other locations in the Tugun/Cobaki area; 2) map their current distribution using records from this survey and other recent assessments; and 3) identify and describe the habitat components between sites with planigale and sites with out planigale to predict other areas of suitable habitat.

### 1.5 Terms of Reference

The following terms of reference are used in this document:
*Subject Site* – area subject to the current field survey
*Study Area* – those lands within 1 km of the proposed C4 footprint
*Tugun Bypass footprint* – Reference to the current C4 option (July 2004).

# 2.0 STUDY AREA

### 2.1 Trapping Area

The area subject to the trapping study incorporated lands to the south and west of the proposed Tugun Bypass footprint (Figure 1). Most of this area is designated Crown Land currently managed by the Department of Lands (DIPNR) with some areas under the ownership of the Tweed-Byron Local Aboriginal Land Council. This area was selected for three reasons. Firstly, it had not been previously subject to intensive pitfall surveys (i.e. Hero *et al.* 2000; 2001b), secondly, the habitat components were superficially analogous to areas where planigale have been recently detected (Hero *et al.* 2000), and thirdly, the area maintains a high degree of ecological integrity due to its unfragmented nature and benign land uses.

Five broad habitat types have been previously identified in the study area (see Bali *et al.* 2003). These include swamp forest, heathland, dune forest and open disturbed areas with some smaller discreet areas of sedgeland/rushland. Earlier ecological investigations (i.e. Bali *et al.* 2003) provide a more comprehensive description of each habitat.

### 2.2 Habitat Study

The area subject to the habitat study incorporated the Tugun Bypass study area in conjuncture with an outlying site at Coombabah Creek (20km to the north). The objective of selecting a large area was to ensure a sufficient number of habitat replicates were obtained from sites previously subject to systematic planigale surveys (see below).

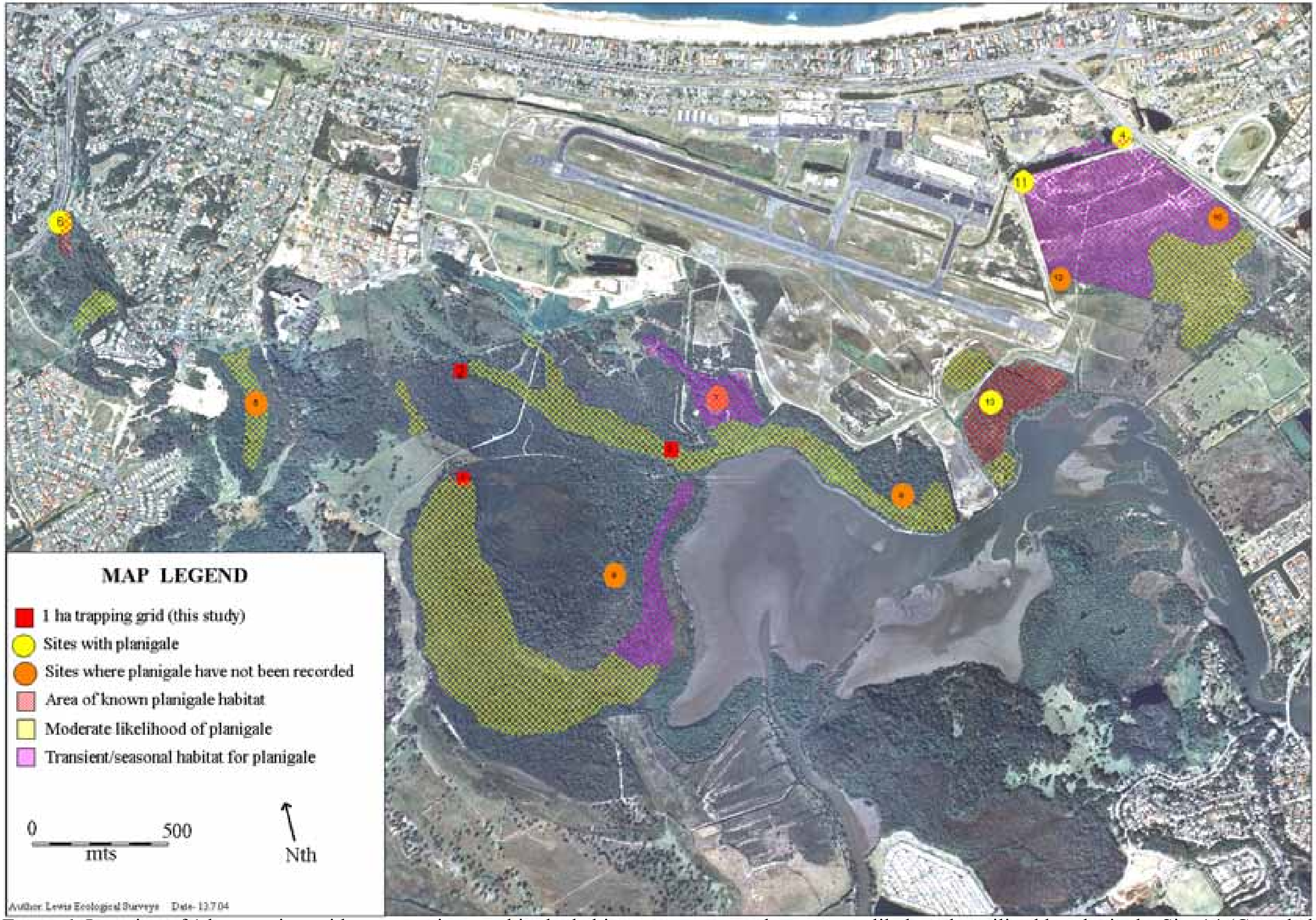



*Figure 1*. Location of 1 ha trapping grids, survey sites used in the habitat assessment and areas most likely to be utilised by planigale. Site 14 (Coombabah creek occur ~20km north Cobaki-Tugun area.

# 3.0 METHODS

### 3.1 Survey Design

Site selection within the designated subject site was based on the following criteria: i) the area (1ha) had sufficient dense ground cover, ii) it was close to surface water and iii) it was not subject to obvious anthropogenic disturbances associated with neighbouring land uses (i.e. Tugun Land Fill and Cobaki Lakes Development Road).

Pit fall trapping was undertaken over a 6-7 night period between 16-24th June 2004. A systematic 1 ha grid design was established at three locations and considered operational only when all pitfall lines were established (Figure 1). Each grid consisted of:

- 40 pits arranged in eight transects (Figure 2);
- each transect comprised five pits (20 litre buckets with 28 cm diameter) interconnected with 30 cm high polythene drift fence; and
- two Elliott traps (Standard Mixture) positioned at the end of each drift fence line to enhance the capture of small fauna which negated capture in the pits.

The objective of this grid method was threefold. It would enable the area to be sampled more intensively than linear methods (e.g. Read *et al.* 1988) thus increasing trap success, and it provided a more robust measure of population size and movement within a given area. Cumulative survey effort was 845 pit nights and 192 Elliott trap nights (Table 2).

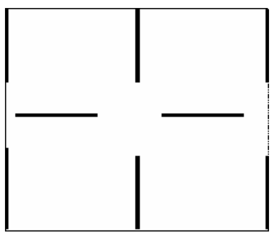


*Figure 2.* Pitfall grid design at each 1 ha plot (40 pits/ha). Dark lines indicate 30 m transects interconnected with 5 pits. Note that two Elliott traps placed at end of each drift fence line.

*Table 2.* Survey effort at each grid site. Ancillary pitfalls were individual transects setup prior to the completion of the grid (i.e. 1 pit night).

| Grid No. | 1 | 2 | 3 | Total |
|---|---|---|---|---|
| Pitfalls | 40 | 40 | 40 | **120** |
| Number Grid Nights | 7 | 7 | 6 | **na** |
| Ancillary Pitfalls (1 night) | 25 | 10 | 10 | **45** |
| Cumulative Pit Nights | 305 | 290 | 250 | **845** |
| No. Elliotts | 16 | 16 | 16 | **48** |
| Elliott Trap Nights | 64 | 64 | 64 | **192** |

### 3.2 Captures

Traps were checked early on each morning of the survey with all fauna identified to species level using standard nomenclature and released at the capture point.

### 3.3 Abiotic Variables

It has been documented that abiotic variables can influence indices of trap response in small dasyurid fauna (Read 1988). To facilitate in our interpretation of trapping data we recorded a series of standard abiotic measurements. Air temperature was measured with a digital thermometer (Radioshack). Rainfall and wind speed data were assessed using a subjective scaling system (0 = >24hrs, 1 = past 24 hrs, 2 = showers, 3 = heavy rain). Cloud cover was measured as a percentage of the sky.

### 3.4 Habitat Assessment

A detailed habitat assessment was undertaken at 14 sites with the objective of describing the principal habitat components associated with planigale. The information collected would then form a foundation for predicting other areas of analogous habitat in the Tugun/Cobaki area. The 14 sites comprised nine sites where planigale had not been detected (absent) and five sites where it had been detected (present), (Table 3). Sites were considered suitable if they had been subject to a pitfall survey for at least 4-5 nights and had incorporated drift fence into their trap design. Independence was assumed if sites where separated by at least 400-500m. This was considered satisfactory given the size and scope of the study.

The decision to use an outlying site (i.e. site B in Rohweder and Banks 1996) located at Coombabah Creek (20km north) was principally based on the lack of replicates for known planigale sites in the Cobaki-Tugun area. This enabled a more robust approach to the habitat assessment by increasing the number of known planigale sites to five.

*Table 3.* Survey sites subject to the habitat survey.

| Site Ref | Reference Study | Planigale Status | State |
|---|---|---|---|
| 1 | This Study | Absent | NSW |
| 2 | This Study | Absent | NSW |
| 3 | This Study | Absent | NSW |
| 4 | EcoSure 2003 | Present | NSW |
| 5 | Hero *et al.* 2001a | Absent | QLD |
| 6 | Hero *et al.* 2001a | Present | QLD |
| 7 | Hero *et al.* 2000 | Absent | NSW |
| 8 | Hero *et al.* 2000 | Absent | NSW |
| 9 | Hero *et al.* 2000 | Absent | NSW |
| 10 | Hero *et al.* 2000 | Absent | NSW |
| 11 | EcoSure 2003 | Present | NSW |
| 12 | BAAM 2004 | Absent | NSW |
| 13 | Hero *et al.* 2000 | Present | NSW |
| 14 | Rohweder and Banks 1996 | Present | QLD |

The detailed habitat assessment measured general landscape, habitat and floristic structure, and levels of disturbance (Table 4). Habitat and floristic data were collected from a 50 x 5m transect (250m$^2$) while general landscape and disturbance levels were assessed in the general vicinity (<100m). Measurements were recorded in categories, absolute values and percentage derivatives. Pictures were taken at each site for reference material should future follow up works be undertaken (*see* Appendix).

### 3.5 Data Analysis

Categorical and some quantitative data are presented as mean values in histograms or descriptive text. Standard errors provide a measure of variability within each of the planigale tenures (present v's absent). Parametric habitat variables were analysed using two approaches. Firstly, a Student's t-test was used examine the influence of univariate data between planigale tenure. The second was a multivariate approach using Principal Components Analysis (PCA). The objective of this method was to summarise the 31 parametric habitat measurements and identify key variables that contribute most to the differences between sites with planigale and sites without planigale (Fowler *et al.* 1998; Zar 1999). Scatter plots has been used to describe the relationships between the principal habitat components. All analysis was performed in SPSS 11.0.

*Table 4.* Habitat attributes measured at each (n=14) site and survey methods used.

| Method | Explanation |
|---|---|
| **Topography** | Classify: crest, upper slope, mid slope, lower slope, gully, flat, watercourse or wetland. |
| **Mean Litter Depth** | Litter and humus profile measured with callipers at five locations (10m intervals) along a 50m transect |
| **Soil Type and Depth** | Clay, loam or sand within defined categories: deep (>50cm), shallow (10-50cm) or skeletal (<10cm) |
| **Dominant Ground Covers** | Subjective percentage scale to describe the cover of tussocks, lichen/moss, herb/grass, sedge/rush, fern and vines within 250m$^2$ plot |
| **Dominant Shrub Growth >2 mts & <2mts** | Percentage scale given the broad vegetation types: rainforest, dry sclerophyll forest, swamp forest, heath and weeds. |
| **Ground cover Assessment** | Measured with foliage projection tubes at 1m intervals along 50m transect. Categories recorded were grass, fern, litter, soil, log, leaf/shrub and sedge/rush. Raw data transformed to derive percentage cover. |
| **Overstorey FPC** | Measured with foliage projection tubes at 1m intervals along 50m transect. Categories included sky, leaf and branch were recorded to derive a relative measure of overstorey cover. |
| **Dominant Florsitics** | |
| **Height** | Estimated in metric system |
| **Mean DBH** | Five stems within each stratum were measured to derive a mean value. |
| **Dominant Species & Crown Composition** | Record dominant species within each stratum and estimate their proportion (%) |
| **Epicormic Growth** | Visual assessment of each stratum to facilitate a fire history assessment. |
| **Senescent** | Percentage of strata with hollow features |
| **Mature** | Percentage of strata estimated to be in a mature growth form. |
| **Regenerating** | Percentage of strata estimated to be in a regenerating form. |
| **Tree Class Assessment** | Measured number of stems in 250m$^2$ plot (50 x 5 m) and assign to one of six categories: <10cm, 11-20cm, 21-40cm, 41-60cm, 61-80cm, >80cm. |
| **Fallen Log Assessment** | Count number of logs (>5cm diameter) within 250m$^2$ plot and record following data: log length, diameter, cause of fall, obvious hollows and fissures, decay stage rated from 1 (recent fall with bark intact) to 5 (excessive decomposition with little structural integrity) |
| **Flooding Frequency** | Subjective scaling system from 1 (seldom) to 3 (regular). Estimated based on previous site experience, anthropogenic disturbances and vegetation type. |
| **Distance to nearest surface water** | Estimated in metres |
| **Nature of water body** | Describe whether it is natural or artificial and its type (i.e. dam, watercourse, wetland) |
| **Water body Attributes** | Classify substrate (gravel, rock, sand, soil, organic), fringing ground vegetation (ferns, grasses, sedges, reeds, mangroves), riparian vegetation (rainforest, swamp forest, heathland, grassland, estuarine complex) and hydrological regime (still, flowing) and turbidity. |
| **Relative Disturbance Assessment** | Subjective scale 0-3 applied to the level of grazing, vehicle trails, defined roads, habitat fragmentation, urbanisation, slashing, weed spraying, weeds, drainage works and sand mining. Cumulative rating given to each site. |
| **Area of similar habitat** | List within one of five categories: <1ha, 1-5ha, 6-20ha, 21-50ha, >50ha) |

# 4.0 RESULTS

### 4.1 Planigale Captures

No planigale were caught during the survey. This may be due to a number of reasons which include:

- Unsuitable habitat;
- The microhabitat was temporarily unsuitable due to dry weather;
- Previously unrecognised predatory and competition related interactions; and the
- Unexpected cool change during the trapping period (Appendix 1).

Further discussion is provided in section five.

### 4.2 Other Fauna

Sixteen species (224 captures) of vertebrate fauna were recorded during the survey (Table 5). This comprised five species of frog, six species of reptile and five ground dwelling mammals. *Crinia tinnula* was the only threatened species (Vulnerable *TSC* Act 1995) recorded, detected at grid one on three occasions. Two introduced species were detected, the house mouse (*Mus musculus*) at grids one and two and the cane toad (*Bufo marinus*) at all grids. Striped marsh frogs (*Limnodynastes peroni*) were the most common species being caught on numerous occasions (17-89) at each grid. The yellow-footed *Antechinus* (*Antechinus flavipes*) was the only dasyurid fauna detected with five individuals caught in elliott traps at grid two.

*Table 5*. Vertebrate fauna recorded at each trap grid.

| Vertebrate Group | G1 | G2 | G3 | Capture Method |
|---|---|---|---|---|
| **Frogs** | | | | |
| *Crinia signifera* | 2 | 14 | 3 | P |
| *Crinia tinnula* | 3 | 0 | 0 | P |
| *Limnodynastes peroni* | 17 | 41 | 89 | P |
| *Lim. terraereginae* | 0 | 0 | 0 | P |
| *Bufo marinus* | 3 | 2 | 3 | P E |
| **Sub Total** | 25 | 57 | 95 | |
| **Reptiles** | | | | |
| *Carlia vivax* | 1 | 1 | 1 | P |
| *Lampropholis delicata* | 0 | 5 | 1 | P |
| *Saiphos equalis* | 3 | 4 | 4 | P |
| *Cacophis krefftii* | 0 | 0 | 1 | P |
| *Dendrelaphis punctulata* | 1 | 0 | 0 | P |
| *Hemiaspis signata* | 0 | 0 | 2 | P |
| **Sub Total** | 5 | 10 | 9 | |
| **Mammals** | | | | |
| *Antechinus flavipes* | 0 | 5 | 0 | E |
| *Melomys bertoni* | 0 | 0 | 1 | P |
| *Mus musculus* | 9 | 1 | 0 | P E |
| *Rattus fuscipes* | 0 | 1 | 3 | P E |
| *Rattus lutreolus* | 0 | 3 | 0 | P E |
| **Sub Total** | 9 | 10 | 4 | |
| **Total Captures** | **39** | **77** | **108** | |
| **Species Diversity** | **8** | **11** | **10** | |

### 4.3 Habitat Assessment

#### *4.3.1 Groundcover Composition*

Ground cover composition showed substantial variation between the planigale tenures (Figure 3). When these data were compared using a student's t-test a significant difference existed only for grass ($t=0.04$, $p<0.05$) although both fern ($t=0.07$) and litter ($t=0.06$) were approaching levels of significance.

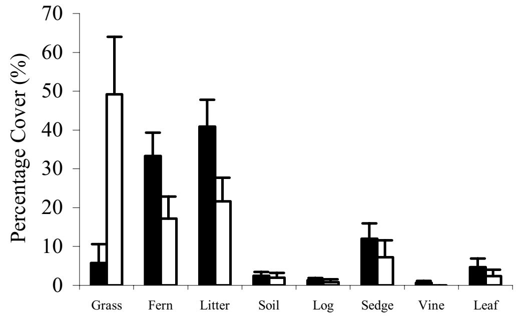



*Figure 3*. Mean (+s.e.) composition of ground stratum at sites with planigale (unshaded bars) and sites without planigale (shaded bars).

#### *4.3.2 Litter and Humus Depth*

Mean litter and humus depth was markedly deeper at sites without planigale but not considered statistically significant ($t=0.12$ & $0.15$ respectively; $p>0.05$; Figure 4). Anecdotal evidence collected at each site suggests fire has been excluded across the study area for at least 5-6 years and cannot explain this variability.

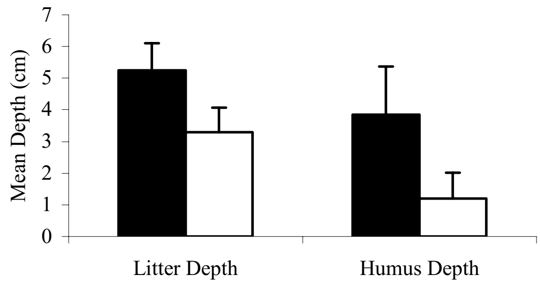



*Figure 4*. Mean (s.e.) litter and humus depth between sites with planigale (unshaded bars) and sites without planigale (shaded bars).

#### *4.3.3 Log Debris*

Log debris was detected at 60% of sites with planigale and at all sites without planigale. Mean number of logs was similar with 6.2 (s.e.=0.7) per 250m$^2$ at sites without planigale and 6.6 (s.e. =3.0) per 250m$^2$ at sites with planigale. The large standard error at known planigale sites is attributed to areas along Coolangatta Creek (i.e. sector 3) which were devoid of logs.

Mean log length was significantly longer at sites without planigale (5.5 v 2.4m; t=0.03, $p<0.05$) with this outcome at least partly attributed to the absence of logs at 40% of planigale sites (sites 4 & 11). Mean log diameter was 17.4 cm (s.e. = 2.86) at sites without planigale and 10.4 cm (s.e. = 4.67) at sites with planigale but not significantly different (t=0.23, $p>0.05$).

Sites with planigale typically had logs in a latter stage of decay (>2 rating; Figure 5). A significant difference exists between the planigale tenures when the early decay stages of one (t=0.01, $p<0.05$) and two (t=0.02, $p<0.05$) were examined but not the remaining stages ($p>0.05$). When decay stages one and two were combined it strengthened the statistical significance (t=0.001, $p<0.01$) of these findings. Combined stages three to five remained at non significant levels (t=0.9, $p>0.05$).

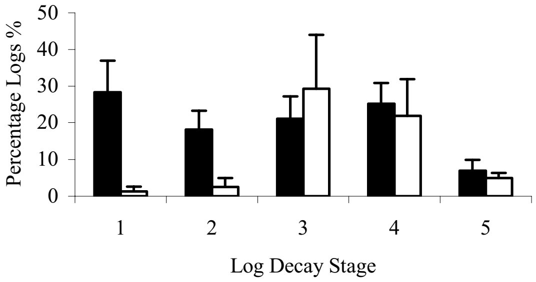



*Figure 5*. Mean percentage (s.e.) of logs recorded at sites with planigale (unshaded bars) and sites without planigale (shaded bars) in various decay stages.

*4.3.4 Floristic Structure*

Mean overstorey FPC was 66% (s.e = 16.0) at sites with planigale and 78% (s.e = 3.3) at sites without planigale but not significantly different (t=0.50, $p>0.05$). The large standard deviation associated with known planigale sites relates to the open nature of site 11 along Coolangatta Creek.

A consistent paradigm was noted in the heights of measured strata (Figure 6). Mean heights for both overstorey, mid storey and understorey were markedly lower at sites with planigale although not statistically significant (t-test, $p>0.05$).

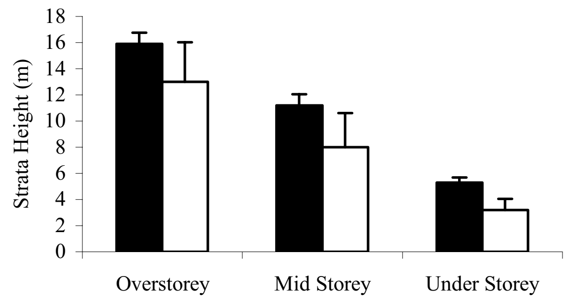



*Figure 6*. Mean (s.e.) stratum heights at sites with planigale (unshaded) and sites without planigale (shaded).

When mean basal area (dbh) of the three strata's were compared between the planigale tenures a significant difference was detected only for the mid stratum (t=0.03, $p<0.05$). Generally, sites with planigale had a consistent lower basal area than sites without planigale suggesting planigale inhabit forests in an early to mid stages of development (Figure 7).

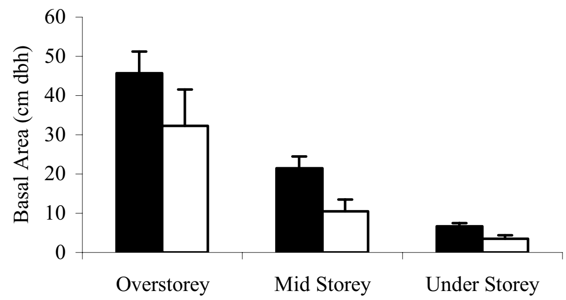



*Figure 7*. Mean (s.e) basal area (dbh – cm) of each stratum at sites with planigale (unshaded) and sites without planigale (shaded).

Sites without planigale typically had higher stem class counts (Figure 8). Despite the marked variation in stem class between planigale tenure there was no statistical significance (Table 6).

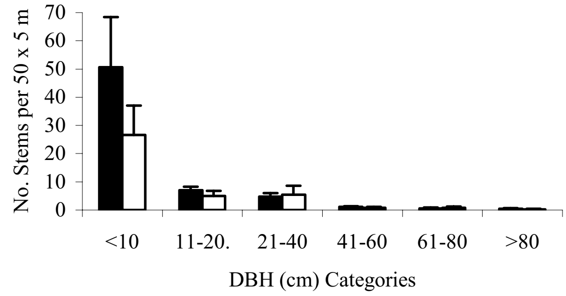



*Figure 8*. Mean (s.e.) number of stems ($250m^2$) at sites with planigale (unshaded) and sites without planigale (shaded).

*Table 6.* Student t-test values ($p<0.05$) between planigale tenures and stem class counts.

| Stem Class (dbh cm) | T value | Significant Value |
|---|---|---|
| <10 | 0.27 | ns |
| 11-20 | 0.38 | ns |
| 21-40 | 0.86 | ns |
| 41-60 | 0.51 | ns |
| 61-80 | 0.68 | ns |
| >80 | 0.45 | ns |

*Table 7.* Student t-test values ($p<0.05$) between planigale tenure and the broad vegetation classification of two shrub classes.

| Shrub Type | Shrubs >2 mts T- value | Shrubs <2 mts – T-value |
|---|---|---|
| Rainforest | 0.47 | 0.22 |
| Dry Sclerophyll Forest | 0.35 | 0.34 |
| Swamp Forest | 0.26 | 0.30 |
| Heathland | 0.09 | 0.06 |
| Weeds | 0.14 | 0.20 |

*4.3.5 Understorey Composition*

Composition of the shrub layers infer sites with planigale are categorised by a higher proportion of swamp forest and weed species in the understorey (Figures 9,10). A considerable proportion of both planigale tenures feature rainforest species. A student t-test did not find any significant difference between planigale tenure and the broad classification of vegetation types for both shrub classes (Table 7).

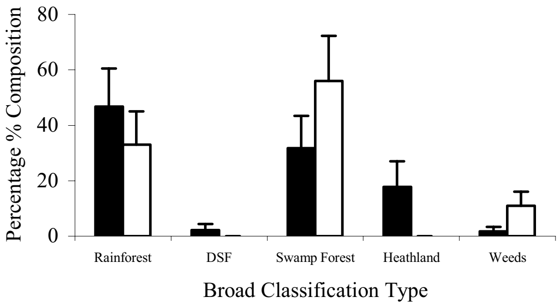



*Figure 9.* Mean (s.e.) composition of tall shrubs (>2 mts) at sites with planigale (shaded bars) and sites without planigale (unshaded bars).

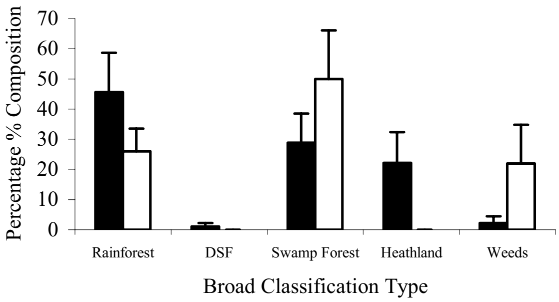



*Figure 10.* Mean (s.e.) composition of shrubs (<2 mts) at sites with planigale (unshaded bars) and sites without planigale (shaded bars).

*4.3.6 Hydrological Features*

All sites with planigale were categorised as being subject to seldom inundation. In contrast, just three of the nine non planigale sites were assigned in this 'seldom inundation' category with the remaining considered more likely to undergo seasonal inundation events.

Mean distance to nearest water was 116m (s.e. = 36.7) for sites without planigale and 45m (s.e. = 10.4) at sites with planigale but not statistically significant ($t=0.13$, $p>0.05$; Figure 11). In most cases, these water bodies were considered permanent on the basis of the dry conditions when the surveys were undertaken. Three of the non planigale sites were adjacent to intertidal areas with no freshwater identified.

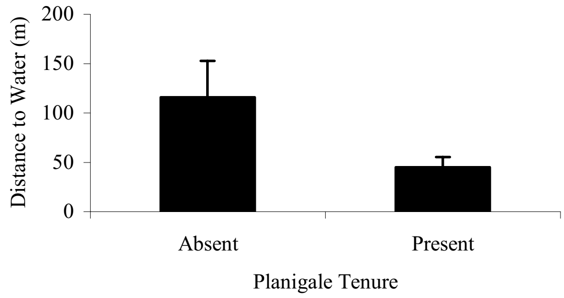



*Figure 11.* Mean (s.e.) distance to water between the two planigale tenures.

*4.3.7 Area of Analogous Habitat*

Sites with planigale typically had 1-5ha of analogous habitat while sites without planigale showed considerable variation (Figure 12).

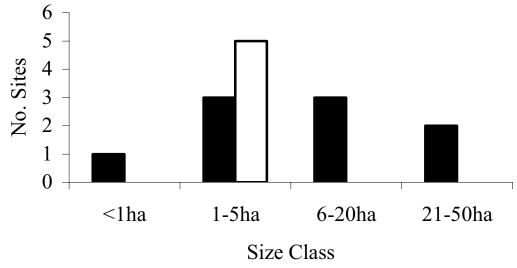



*Figure 12*. Number of sites within each habitat size class at sites with planigale (unshaded bars) and sites without planigale (shaded bars).

*4.3.8 Anthropogenic Habitat Disturbance*

Sites with planigale tend to have significantly higher anthropogenic disturbance levels than sites without planigale ($t=0.03$, $p<0.05$; Figure 13). Most sites with planigale show evidence of anthropogenic disturbance associated with roads, fragmentation, urbanisation, drainage works and historic sand mining. Fire has been generally absent for at least 5-6 years at all sites and scored a zero rating.

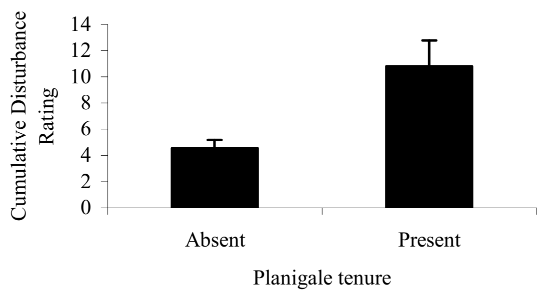



*Figure 13*. Mean (s.e.) cumulative disturbance ratings at sites according to planigale tenure.

*4.3.9 Association with Antechinus flavipes*

A review of trapping data for the Tugun area (n=13 sites) infer yellow-footed *Antechinus* (*Antechinus flavipes*) has not been found in association with planigale. *Antechinus flavipes* has been recorded at four (29%) of the 14 sites with co-existence only recorded at Coombabah Creek (P14 20km north Tugun)[1]. Simply this data could be interpreted as some form of dasyurid competition or inference to different habitat requirements of the two species (i.e. *A. flavipes* requires mature and remnant forests).

**4.4 Multivariate Approach to Habitat Assessment**

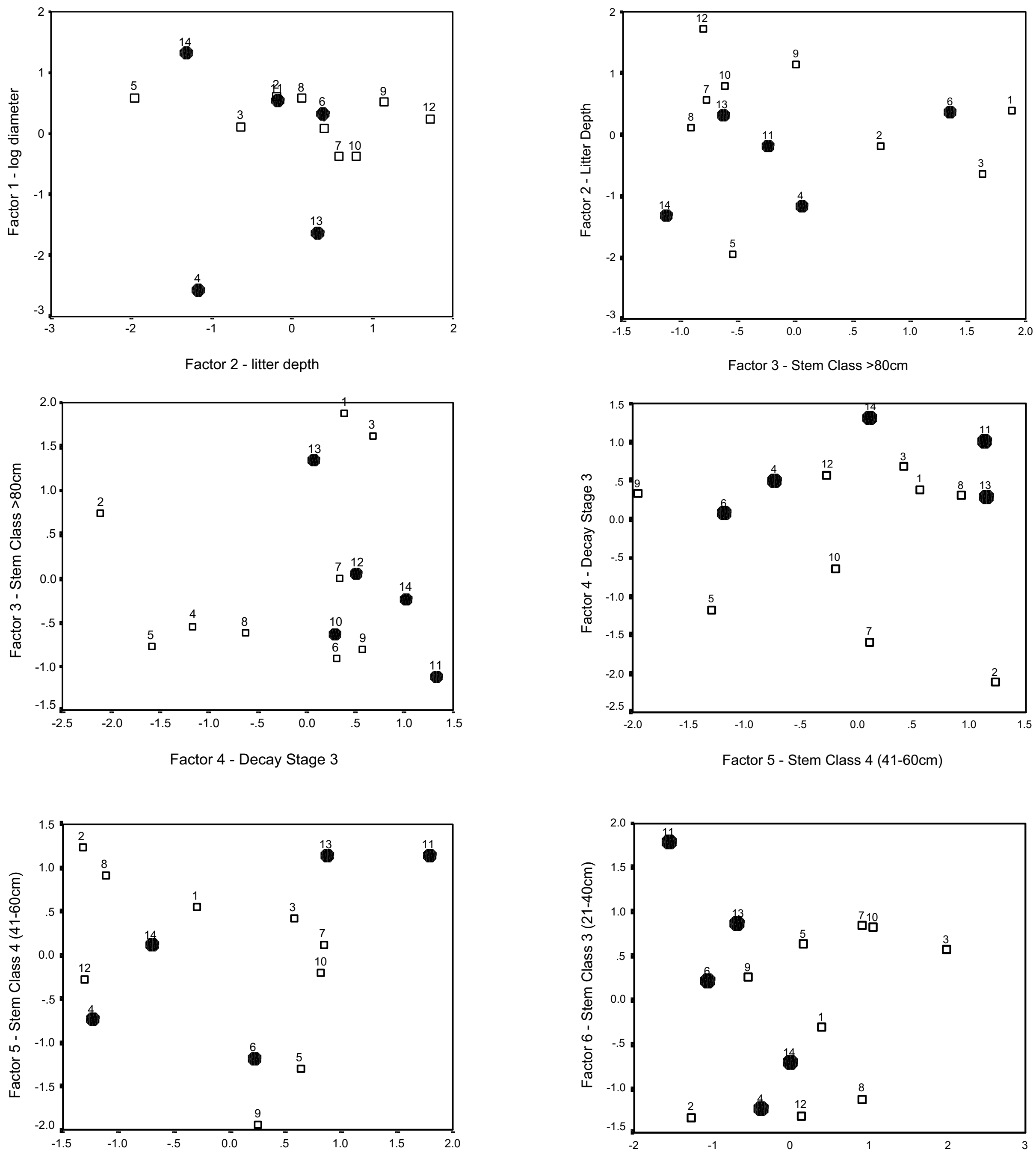
Principal components analysis identified eight habitat variables that accounted for 91.6% of the variability between planigale tenure (Table 8). Generally, these associations were related to the size of fallen logs, their rate of decay, stem size classes and litter depth. Mean log diameter, the number of logs, mid storey dbh and overstorey height contributed most to factor one, whilst litter depth and stem class one (<10cm) contributed most to factor two (Table 8). Stem class six (>80cm dbh), the percentage of logs with visible hollows contributed most to factor three. Logs in the latter stages of decay (stage 3), and the percentage of soil cover contributed most to factor four. The remaining four factors provide progressively less weighting (Table 8).

Ordination of the eight principal factors shows little distinction between the two planigale tenures (Figure 14). Although factor one accounts for 38.6% of the variability between sites with and without planigale sites one, two, three, five and eight remain interspersed within known planigale sites (Figure 14). When factor two is considered in association with factor three (i.e. cumulative 50.8% variability) the ordination shows the same dispersion of these sites (1,2,3,5,8) with known planigale sites (Figure 14). Such displacement of sites along the axes suggests that the habitat attributes are analogous to known planigale locations and could be tentatively regarded as suitable habitat (Figure 14).

[1] Trapping line and pitfall line were ~75m apart.

*Table 8.* Results of Principal Components Analysis conducted on 31 habitat attributes. FPC = foliage projection cover, DBH = Diameter at breast height.

| Habitat Variables | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 | Factor 8 |
|---|---|---|---|---|---|---|---|---|
| Liter Depth | -.177 | .853 | .157 | -.289 | -6.502E | .164 | -.101 | -.108 |
| Grass Cover | -.434 | -.616 | -.416 | .362 | 1.953E-02 | -4.513E | -.314 | -1.515E |
| Fern Cover | .298 | .626 | .158 | .173 | .206 | .320 | .502 | 2.398E-02 |
| Litter Cover | .370 | .256 | .201 | -.753 | .278 | -.212 | -9.866E- | 5.994E-02 |
| Soil Cover | .235 | .123 | 4.025E-02 | .629 | -.148 | -.608 | .304 | -2.462E- |
| Log Cover | .182 | .371 | .736 | .306 | -.304 | -4.391E- | .175 | -1.663E- |
| Sedge Cover | .171 | .453 | .142 | 2.272E-02 | -.660 | .245 | .127 | .250 |
| Overstorey FPC | .735 | .425 | .245 | 3.585E-02 | .289 | .237 | 6.179E-02 | .197 |
| Overstorey Height | .820 | .116 | .185 | -.165 | .200 | .385 | .121 | .135 |
| Overstorey DBH | .746 | .259 | .500 | -7.196E- | .112 | 8.419E-02 | .118 | 8.372E-02 |
| Mid Storey Height | .785 | .163 | .109 | -.190 | .265 | .404 | .157 | 4.209E-02 |
| Mid Storey DBH | .828 | -.143 | -5.974E- | .174 | .184 | 1.004E-03 | .187 | 6.622E-02 |
| Understorey Height | .103 | .112 | .389 | 1.658E-02 | -.337 | 6.565E-02 | -.304 | .537 |
| Understorey DBH | .641 | .350 | 4.657E-02 | -.369 | .444 | .168 | .251 | 1.197E-02 |
| Stem Class 1 (<10cm) | .309 | .822 | .255 | 5.635E-02 | -6.037E- | -7.990E- | -.221 | -7.982E- |
| Stem Class 2 (11-20cm) | .485 | .663 | -4.030E- | 3.461E-02 | .322 | .348 | .169 | -1.408E- |
| Stem Class 3 (21-40cm) | .206 | .222 | .140 | .159 | -.119 | .836 | .144 | -.149 |
| Stem Class 4 (41-60cm) | .236 | .143 | .200 | 2.754E-02 | .865 | 7.107E-02 | .182 | -.169 |
| Stem Class 5 (61-80cm) | .227 | .109 | .758 | .387 | -4.245E- | .399 | -9.544E- | -4.272E- |
| Stem Class 6 (>80cm) | .163 | 2.861E-02 | .924 | -9.816E- | .188 | -.142 | 3.808E-02 | .159 |
| Number of logs | .848 | .156 | .213 | -2.501E- | -.208 | -.125 | .143 | .263 |
| Mean Log Length | .761 | .188 | .147 | -.259 | -.173 | .148 | .416 | -9.089E- |
| Mean Log Diameter | .855 | .264 | .277 | 1.754E-02 | -.145 | 5.652E-02 | 8.415E-02 | -.167 |
| % log hollows | .269 | .204 | .795 | -6.270E- | .120 | .210 | -.116 | -.118 |
| % log fissures | .656 | -.240 | -1.602E- | -5.611E- | 5.629E-02 | -.292 | -.195 | .558 |
| Decay Stage 1 | .202 | .156 | -.287 | -.878 | -.216 | 2.028E-02 | .123 | -6.874E- |
| Decay Stage 2 | .252 | -7.800E- | -6.555E- | -2.999E- | 9.926E-02 | 3.226E-02 | .939 | 5.232E-03 |
| Decay Stage 3 | .513 | .354 | .159 | .653 | 1.805E-03 | .132 | -.110 | 2.453E-02 |
| Decay Stage 4 | .799 | 4.335E-02 | .397 | .141 | -8.561E- | -.249 | -.192 | -4.930E- |
| Decay Stage 5 | .344 | -.225 | -4.491E- | -1.379E- | -.190 | -1.166E- | .245 | .809 |
| Distance to water | .541 | .508 | .130 | .235 | -.237 | -.183 | .149 | .319 |
| **% of total variance** | 38.6 | 12.2 | 11.1 | 8.7 | 7.2 | 5.4 | 4.4 | 4.0 |



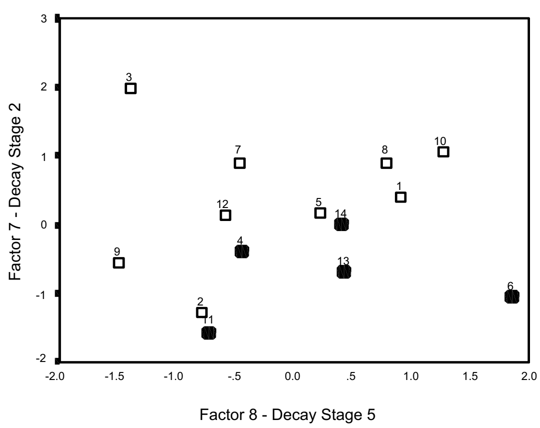




*Figure 14*. Ordination of the principal components analysis (PCA) showing the distribution of sites with planigales (shaded circles) and sites without planigales (unshaded squares) between the eight factors. Sites 1-3 represent the grids surveyed during the current assessment. Site 14 is a reference site from Coombabah Creek.

### 4.5 Habitat Prediction

A habitat suitability map has been prepared using the following resources:

1) results of the pca analysis;
2) the significant statistical relationships of categorical variables;
3) less weighting applied to sites with *A. flavipes*; in conjunction with
4) previous fauna features traverses undertaken by the author in the Cobaki-Tugun area.

Areas of known habitat (red shading) presented in figure one represent what appears to be residual habitat in the study area (Table 9). This is justified by the capture of planigale on more than two separate occasions at each locality (Hero *et al.* 2000, 2001a,b; White pers. comm.). Areas shaded yellow represent habitat with a 'moderate' likelihood of detecting planigale. Although several areas within the yellow shading have been subject to systematic pitfall surveys the habitat attributes at these sites remain suitable (Figure 14). Areas shaded in magenta represent transient habitat which may be used on a seasonal basis or to facilitate movement between more optimal habitats. Although planigale have been detected in some of these areas their intermittent capture rates (i.e. EcoSure 2003) supports the theory of drifting home ranges in planigale species (i.e. Read 1982; 1988; Miller 1998).

*Table 9.* Area of planigale habitat (ha) in the study area

| Tenure | NSW | Queensland | Total |
|---|---|---|---|
| Known | 9.02 | 0.82 | 9.84 |
| Moderate Likelihood | 88.25 | 6.15 | 94.4 |
| Transient-Seasonal | 47.62 | 0 | 47.62 |

# 5.0 DISCUSSION

### 5.1 Lack of Captures

The success of planigale surveys at Tugun has varied substantially since their initial discovery in 2000 (Hero *et al.* 2000). Based on the available trapping data there also appears to be no relationship between the level of survey effort and capture rates (Hero *et al.* 2001b). Even long term studies along Coolangatta Creek have had mixed results with the exclusive capture of two planigale in 2003 during a 2001-2004 study (EcoSure 2003).

Four reasons are proposed for the lack of planigale captures during the current survey. These included:

- The unexpected cool change during the trapping period;
- Temporarily unsuitable habitat due to the dry weather;
- Previously unrecognised predatory and competition related interactions with *A. flavipes*; and
- Unsuitable habitat.

Weather conditions were not ideal during the study with a sudden cool change (i.e. overnight minimum to 3$^{o}$C) reaching the Gold Coast in the early stages of trapping and lasting for most of the survey period[2]. When such conditions arise it is not inconceivable to suggest planigale may have undergone a short period of inactivity (i.e. torpor) a biological trait unique to dasyurid fauna to conserve energy resources (Denny 1982).

It is unquestionable that the extended dry period influenced the results of this study. The study area is currently experiencing a pronounced dry period with ~100mm rainfall between April and June 2004 which is ~300mm below the long term average (BOM 2004). With protracted water and food resources planigale may have moved to others ecotonal areas with more profitable food resources (Denney 1982), a distinct ecological advantage in having no maternal home range (Read 1982; 1988; Miller 1998). Read (1988) demonstrated that rainfall facilitates the capture of small dasyurid species in rangeland and arid zone environments and this may be partly true for the coastal planigale.

It is widely recognised that competition exists among small dasyurid fauna (Fox 1982; Dickman 1986). A review of trapping data in the study area (i.e. Hero et al, 2000, 2001a,b; EcoSure 2003; BAAM 2004; Phil Sure and Damien White pers. comm.) infer co-existence between planigale and *A. flavipes* may not exist. Nonetheless, the reference site (i.e. Coombabah Creek) used in this study has recorded both species in association but this could be the exception rather then the rule given these surveys were undertaken in July during the Antechinus breeding season (i.e. males roaming) and the trap and pitfall lines were some distance apart (~75 m). Similar exclusion has also been noted in the Byron Shire between *Antechinus stuartii* and planigale (Miller 1998). Where records of co-existence occurred closer synthesis of the trapping data also revealed temporal and/or microhabitat exclusion factors (Miller 1998). Given the larger size of *A. flavipes* (~56g) planigale (10-12g) would most likely be viewed as a prey item, particularly when food resources are limited and male *Antechinus* become more aggressive with the onset of breeding (i.e. winter). *Antechinus flavipes* are known to predate on domestic mice (*Mus musculus*) turning them inside out (Troughton 1992; Van Dyck 1995). Such data may infer planigale are unlikely to be caught in areas inhabited by *A. flavipes* and this data

[2] Cool change was not forecast by Bureau of Meteorology. BOM forecast rain on 16 June 2004.

has facilitated the predictive habitat mapping in figure one.

### 5.2 Habitat Appraisal

Although the current study did not locate any new planigale locations synthesis of the habitat data has facilitated a more systematic approach to identifying suitable planigale habitat. Planigale tend to inhabit more disturbed sites which are characterised by smaller dbh's consistent with regenerating swamp or riparian forests. All sites are closely associated with ecotone environments, particularly those within or proximate to watercourses. These areas provide sufficient dense covers comprising either grass, ferns, litter and sedges. There also appears to be a preference for sites with ample log debris that has reached later decay stages. Sites which are devoid of log debris have dense grass covers which tend to provide a surrogate refuge habitat. Such sites may provide suitable transient habitat capable of facilitating movement between more optimal habitats. This is evident by the low capture rates along Coolangatta Creek where two planigale were caught in 2003 during a four year study (EcoSure 2003). These sites should be treated as anomalies in defining habitat requirements although the small sample sizes discriminated against this during the statistical analysis.

The habitat mapping exercise illustrated in figure one has placed considerable emphasis on the results of the multivariate analysis. Central to this approach was to consider factors one and two given they explained over 50% of the variability between the planigale tenures. Ordination of the remaining factors has facilitated in fine tuning the mapping exercise in conjunction with the significant statistical differences in the univariate data and *A. flavipes* records.

# 6.0 RECOMMENDATIONS

The following points have been raised for consideration between Parsons Brinckerhoff and DMRT to enable a more thorough evaluation of their proposal, its impacts and proposed mitigative and ameliorative measures. These include:

- Evaluation of the compensatory habitat for planigale;
- Minimal removal of known habitat; and
- Implement a monitoring program.

Surveys are required to determine the suitability of the compensatory habitat for planigale. At present there is no knowledge to suggest the likelihood if any that planigale occur on these lands. An optimal approach would include a standardised pitfall survey and the collection of habitat data analogous to the current approach. This data could then be subjected to multivariate ordinations to demonstrate its suitability or otherwise.

The current footprint will bisect known planigale habitat on GCAL controlled lands. Although this area has been in receipt of previous route designs to reduce habitat removal any further alterations should seek to improve on this whilst ensuring the estuarine environments are not compromised.

A two stage monitoring program should be instigated. The first stage should seek to undertake a more detailed and systematic survey of the known planigale population adjoining Cobaki Broadwater. The second stage should be a monitoring component designed to measure the level of impact and mitigative measures proposed. The objective of such a program is to ensure we have sufficient baseline data to compare between stages one and two. Currently, there is insufficient data to provide indices of population size, structure and movement in the Cobaki area.

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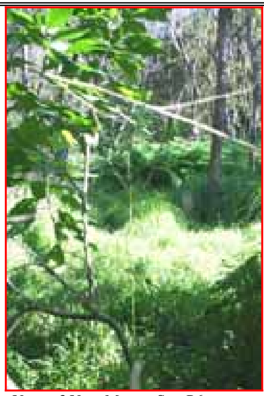
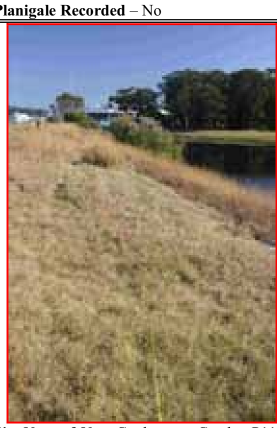
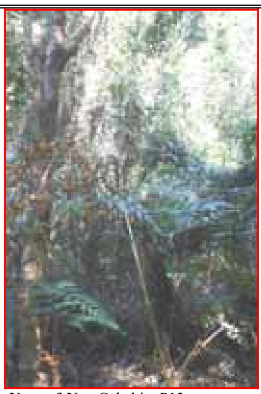
# 8.0 APPENDIX

*Table 10.* Abiotic conditions during the pit fall survey period.

| Date | Maximum Temperature | Minimum Temperature | Rain | Wind | Cloud Cover |
|---|---|---|---|---|---|
| | °C | °C | 0-3 | 0-3 | % |
| 16.6.04 | 21 | 5 | 0 | 0 | 0 |
| 17.6.04 | 20 | 3 | 0 | 0 | 0 |
| 18.6.04 | 22 | 4 | 0 | 0 | 0 |
| 19.6.04 | 21 | 5 | 0 | 1 | 0 |
| 20.6.04 | 21 | 6 | 0 | 1 | 0 |
| 21.6.04 | 22 | 5 | 0 | 1 | 0 |
| 22.6.04 | 21 | 7 | 0 | 1 | 0 |
| 23.6.04 | 22 | 11 | 0 | 1 | 70 |
| 24.6.04 | 22 | 12 | 1 | 1 | 25 |

*Table 11*. Site pictures of the 14 sites used in the habitat study

| | | | |
|---|---|---|---|
| <br>**Site Name &No** – Grid 1 – P1<br>**Location** - Easting: 547874 North: 6884619<br>**Planigale Recorded** – No | <br>**Site Name &No** – Grid 2 – P2<br>**Location** - Easting: 548317 North: 6885001<br>**Historic Record** – No | <br>**Site Name &No** – Grid 3 – P3<br>**Location** - Easting: 548676 North: 6884141<br>**Historic Record** – No | <br>**Site Name &No** – Sector 3 – P4<br>**Location** - East: 550997 North: 6883843<br>**Planigale Recorded** – Yes (2003) |
| <br>**Site Name &No** – Hidden Valley – P5<br>**Location** - Easting: 547595 Northing: 6885588<br>**Planigale Recorded** – No | <br>**Site Name &No** – Murray St – P6<br>**Location** - - Easting: 547479 North: 6886522<br>**Planigale Recorded** – Yes (2000 & 2002) | <br>**Site Name &No** – GCAL – P7<br>**Location** - East: 549026 North: 6884193<br>**Planigale Recorded** – No | <br>**Site Name &No** – GCAL Rainforest - P8<br>**Location** - East: 549269 North: 6883369<br>**Planigale Recorded** – No |
| <br>**Site Name &No** – Cobaki P9<br>**Location** - Easting: 548183 Northing: 6883953<br>**Planigale Recorded** – No | <br>**Site Name &No** – GCAL – P10<br>**Location** - Easting: 551085 North: 6883370<br>**Planigale Recorded** – No | <br>**Site Name &No** – Coolangatta Creek – P11<br>**Location** – East : 550629 North : 6883982<br>**Planigale Recorded** – Yes (2003) | <br>**Site Name &No** – GCAL – P12<br>**Location** - Easting: 550399 North: 6883524<br>**Planigale Recorded** – No |
| <br>**Site Name &No** –Cobaki – P13<br>**Location** - Easting: 549890 Northing: 6883453<br>**Planigale Recorded** – Yes (2000, 2001) | <br>**Site Name &No** – Coombabah Ck – P14<br>**Location** - Easting: 533170 North: 6908983<br>**Planigale Recorded** – Yes (1996) | | |

# Appendix I

*Survey for the Land Snail* Thersites mitchellae*: Proposed Tugun Bypass Route* (Stanisic 2001)

# Survey for the land snail *Thersites mitchellae* in the Proposed Tugun Bypass Route

Final Report

Prepared for:

PPK Environment
& Infrastructure P/L.

18 January 2001

Prepared by:
Dr John Stanisic
Queensland Centre for Biodiversity
Queensland Museum
PO Box 3300
SOUTH BRISBANE QLD 4101

Ph (07) 38407718 Fax (07) 38461226
Email: johns@qm.qld.gov.au

## SURVEY FOR THE LAND SNAIL *THERSITES MITCHELLAE*

PROPOSED TUGUN BYPASS ROUTE

## SCOPE OF THE STUDY

This report details a study involving a survey for the land snail *Thersites mitchellae* (Figure 1) in the proposed Tugun Bypass Route, southeast Queensland for PPK Environment and Infrastructure Pty Ltd. The land snail *Thersites mitchellae* (Cox 1864) is listed under the New South Wales *Threatened Species Conservation Act 1995* as an endangered species. Records held in the Australian Museum, Sydney and Queensland Museum, Brisbane indicate that the species was formerly common in lowland moist forest on the New South Wales north coast from Ballina north to the Tweed River. Much of this habitat has been cleared (Bishop 1978) and there have been comparatively few recordings of the snail over the past 70 years.

A detailed survey of remnant rainforest patches between the Richmond and Tweed Rivers by the author in late 1998 established the presence of this species in several marginal localities within its historical range (Stanisic 1998). Each of these habitats was characterised by subtropical lowland rainforest, usually adjacent to wetlands. An additional survey for the species on Stotts Island (Stanisic 2000) confirmed the preferred habitat of the species as lowland rainforest. The 1998 survey extended the range of the species to just south of Tweed Heads near Banora Point and the proposed bypass route is located within reasonably close proximity to this locality. The present study aimed to establish whether *T. mitchellae* occurred within the proposed bypass route and/or whether suitable habitat for its potential occurrence existed within this area.

Findings from this study would provide important data for the planning of the proposed corridor.

### Key Tasks

- to undertake a targeted scientific survey for *Thersites mitchellae* in the proposed bypass route, in particular those sites where *T. mitchellae* might be expected to occur, and also in adjacent areas of potential *T. mitchellae* habitat;
- to liaise with relevant persons and authorities regarding access to the proposed bypass route. A considerable part of the proposed bypass route is on land under the control of the Coolangatta Airport Ltd (GCAL) and specific arrangements with GCAL representatives were necessary to access to sites along this part of the proposed bypass;
- to identify and assess all potentially favourable habitat for *T. mitchellae* that may exist within the proposed bypass route;
- to determine the extent of the presence and distribution of *Thersites mithellae* within the proposed bypass route and to assess the status and structure of any extant populations;
- to document on 1: 25 000 topographic map and in tabular form, the areas searched and the location(s) (to minimum of 100m accuracy) where *Thersites mitchellae* is found;
- to describe any threats to discovered populations of *Thersites mitchellae* that may be caused by the construction of the proposed bypass road and assess their potential extent and severity.

## LITERATURE SURVEY AND SYSTEMATICS

A detailed account of the systematics, description and distribution of *Thersites mitchellae* is presented in Stanisic (1998). A copy of this report is appended for general information (Appendix I).

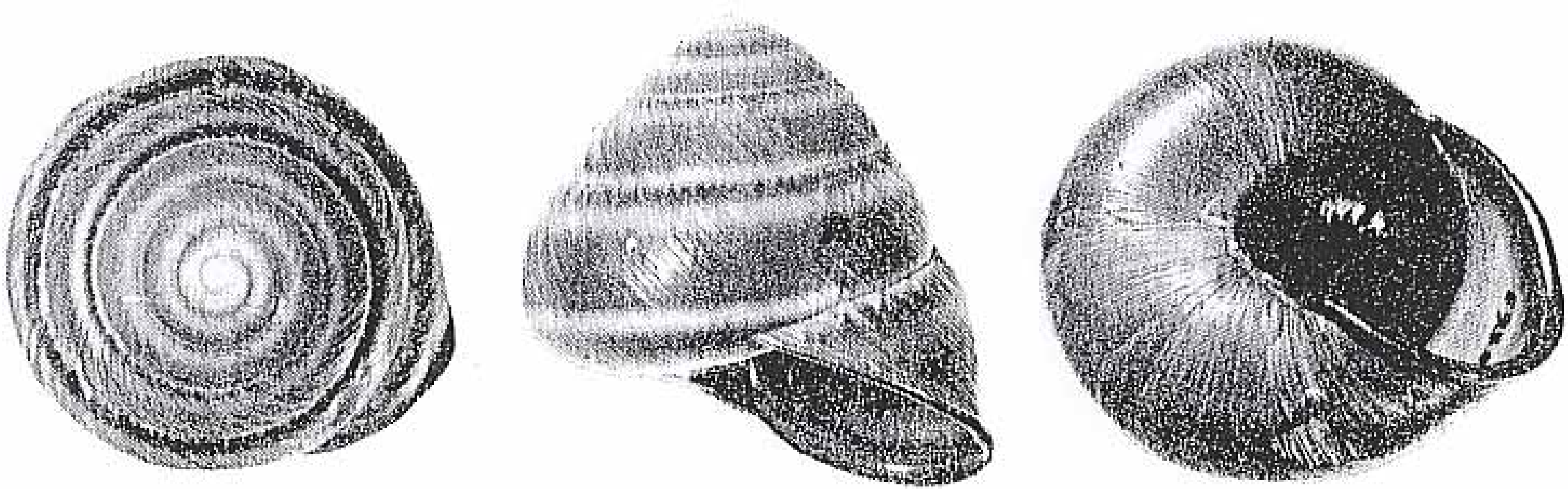


Figure 1. Shell of *Thersites mitchellae* (Cox, 1864). AMSC105563, Broken Head, Byron Bay. Height of shell = 45mm, diameter of shell = 45mm. [From Bishop, 1978].

## FIELD SURVEY

### Description of survey area

The study sites are located along a corridor stretching from the Stewart Road-Gold Coast Highway intersection, south along the western edge of the Coolangatta Airport and then linking with the current Tweed Heads Bypass just north of the Queensland/New South Wales Border. The general area in and surrounding the proposed route is characterised by significant urban development and greatly altered landscapes.

Broad vegetation communities along the proposed bypass route comprise swamp forest (dominated by *Eucalyptus robusta* and/or *Melaleuca quinquenervia*), dry woodland (dominated by *Eucalyptus racemosa* and *Corymbia gummifera*), dry and wet heathland, disturbed sedgeland, mangrove forest and grassland. The first two vegetation communities covered most of the ridges at the northern end of the proposed route while the others predominate in the south particularly in the vicinity of the airport.

These vegetation communities dominate the proposed bypass route but most notably do not include rainforest. However at the northern end of the proposed route there is a gully supporting a tiny patch of rainforest. Here the vegetation changes dramatically from the eucalypt-dominated ridge tops to moist rainforest dominated by the palm *Archontophoenix ramsayi*. Significantly, no *Ficus* spp. were present at this site. This gully rainforest community appears to be a form of notophyll vine forest common in the wetter foothills and uplands of the nearby ranges. Although this forest type contains some species present in the lowland rainforests further to the east e.g. *Archontophoenix* palms the substrate (basalt) is more favourable to species from the subtropical rainforest typical of the ranges to the west.

### Survey methodology and description of sites

The field survey for *Thersites mitchellae* was undertaken on Wednesday 29 November 2000 by Dr John Stanisic. Weather and moisture conditions were strongly conducive to good snail collecting. The day of the survey followed several days of moderate storm rain in the area. Habitat in all the areas searched was relatively moist. *Thersites mitchellae* is an obligate rainforest snail and this habitat was located only in a single gully at the northern end of the proposed route designated as 'Hidden Valley'. This site was sampled intensively while other parts of the route were sampled according to their potential for locating *T. mitchellae*. The location of the Hidden Valley is indicated in Figure 2 and its description is as follows:-

- Hidden Valley, south-west of Stewart Road-Pacific Highway intersection, 28°09.306'S, 153°29.062'E, remnant rainforest adjacent and along creek, 29 November 2000. No *T. mitchellae* found. Other land snails collected comprised *Gyrocochlea eurythma, Sphaerospira fraseri, Strangesta ramsayi* and *Hedleyoconcha delta*.

Access to the Coolangatta Airport was granted by GCAL and a staff member provided a guided tour of the proposed route within the airport precinct. Other portions of the corridor were accessed via easements and unfenced land.

The general observation was that the habitat was for the most part totally unsuited to the requirements of *T. mitchellae*.

Sampling procedure included searching preferred snail microhabitat such as under fallen logs, under rocks and under bark of standing and fallen trees. All land snail species were collected for taxonomic analysis. Visual sighting of dead shell fragments was undertaken in all parts of the proposed bypass route.

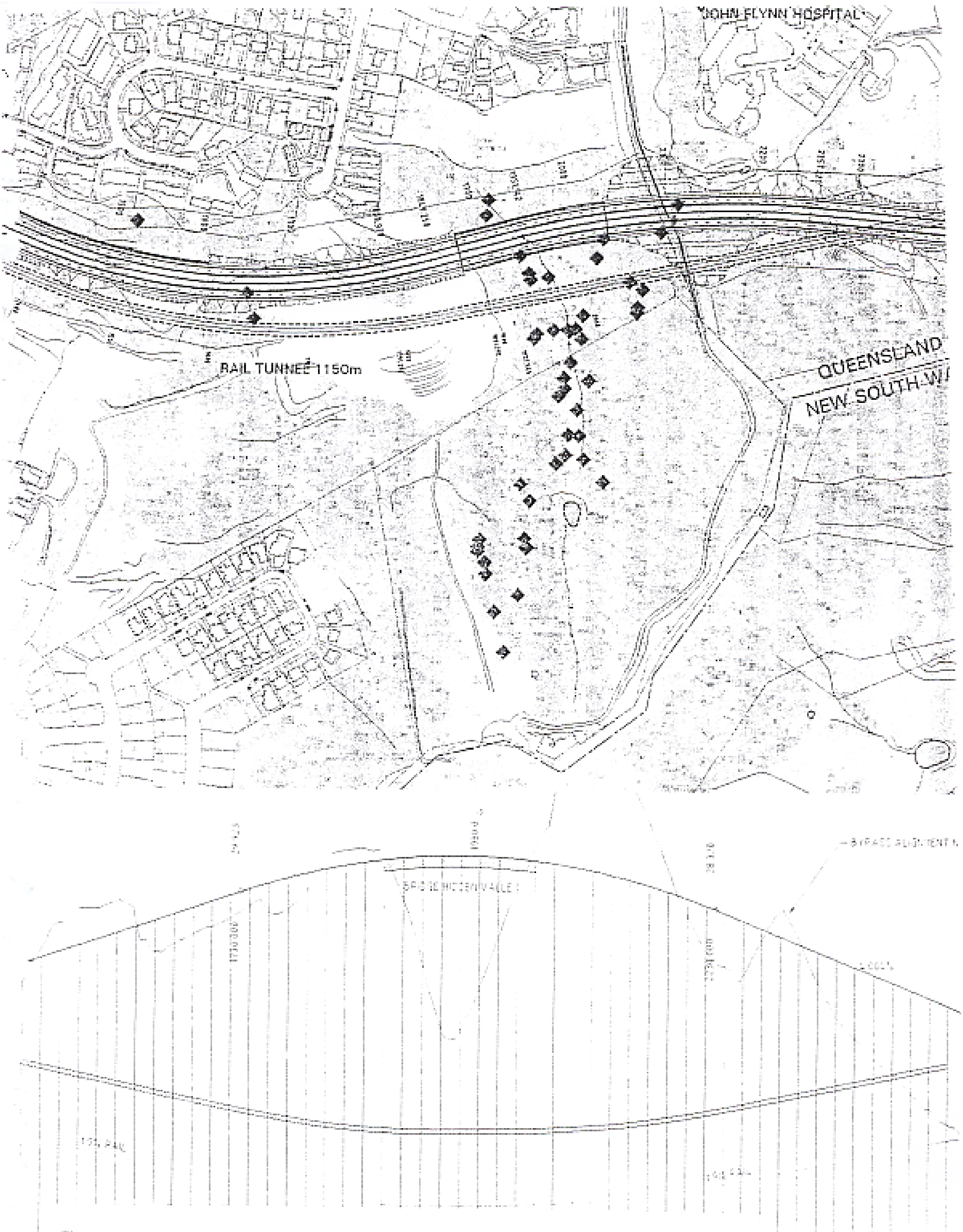



Figure 2. Longitudinal section of Proposed Tugun Bypass Route showing location of 'Hidden Valley' gully containing rainforest.

The part of the study site considered most suitable for *T. mitchellae* was the gully at the northern end of the proposed bypass route and this was searched for -two hours. Other parts of the proposed route were sampled for varying periods during inspection. Total search time over the length of the proposed bypass route was approximately seven hours.

Collecting conditions and time were considered adequate for establishing the presence of the species.

**Queensland Museum database search**

In addition to the field survey a search was made of the Queensland Museum's extensive eastern Australian land snail database records comprising more than 170,000 specimen records. The aim of this search was not primarily to establish the presence of *T. mitchellae* in the area but to gain a profile of the general land snail community liable to be found in there. Local land snail communities in eastern Australia are very specifically structured within general habitat types (Stanisic 1994, 1997) and an analysis of their taxonomic complexity in any area can provide an insight into the likelihood of particular species being present. This technique was previously used for assessing the likely presence of *T. mitchellae* in the Wilsons Creek area, northeastern New South Wales (Stanisic 1999).

## RESULTS

*Thersites mitchellae* was not located along the proposed bypass route. This species is highly selective in its habitat (Stanisic 1998, 1999, 2000) showing preference for lowland subtropical rainforest dominated by a combination of *Archontophoenix, Ficus* and *Erythtrina* spp. This habitat type was also not located along the proposed bypass route.

In general land snail collecting along the proposed route, apart from the 'Hidden Valley' site, was poor. This most likely is a reflection of the altered nature of the general landscape along the proposed route. Even within the patch of gully rainforest land snail diversity was considerably less than would be predicted for this habitat type. Up to 15 species could be expected in an undisturbed rainforest site of similar size and nature; however at this site, only four species were found. In these circumstances an environmentally sensitive species such as *T. mitchellae* might not be expected to be present.

The taxonomic diversity of the other land snails collected during the survey as well as those known from the general area (Queensland Museum database) also strongly indicates that the proposed bypass route is outside the general habitat range preferred by *T. mitchellae.* The other land snail species collected during the survey are common in southeast Queensland and are typical of the rainforests of the foothills and uplands of the Border Ranges. This land snail community is distinct from that inhabiting the lowland subtropical rainforest of the Tweed alluvia.

## STATUS OF *THERSITES MITCHELLAE* IN THE PROPOSED TUGUN BYPASS ROUTE

The inability to locate *Thersites mitchellae* in the proposed bypass route during the survey is in itself not absolute and conclusive evidence of its absence. Land snails are very cryptic in the landscape. They generally occupy a complex and diverse part of the habitat-forest floor/litter zone-which is impossible to search completely. Circumstantial evidence, however, suggests very strongly that its absence from the proposed bypass route is real and not an artefact of collecting.

*T. mitchellae* is very specific in its habitat choice preferring lowland rainforest dominated by palms and figs. Such habitat does not exist along the proposed bypass route or in adjacent areas.

The other snails collected during the survey and those recorded from the area in the Queensland Museum database also provide another level of data suggesting absence. In general most east Australian land snails are geographically (many have very small linear ranges) and often ecosystem (particular combination of vegetation, soil/rock type) restricted. In any ecosystem the land snail community will consist of a particular complement of species (guild profile). Analysis shows that the land snail fauna of the proposed bypass route and environs has a guild profile not typical of that associated with *T. mitchellae*.

According to records in the Queensland Museum, Brisbane and the Australian Museum, Sydney the northeastern New South Wales/southeastern Queensland region has a history of snail collecting dating from the late 1800's. Given the type of species collected since that time (some less than 5mm in shell diameter), the presence of a large species such as *T. mitchellae* would not have gone unnoticed. Combined with the inability to locate even a small fragment of the species during the survey is considered to be strong evidence of its absence from the area.

Given all this evidence it seems reasonable to conclude that the species is not present along the proposed bypass route.

## EXECUTIVE SUMMARY

The significant outcomes of this study were that:

- the field survey, conducted in and adjacent to the proposed bypass route, could not establish the presence of *T. mitchellae* even as broken shell fragments; and
- the field survey could not identify any suitable habitat for *T. mitchellae* along the proposed bypass route.

In addition an analysis of circumstantial evidence such as the taxonomic make-up of the local land snail fauna and historical records from both the Queensland and Australian Museums indicated that *T. mitchellae* is not present along the proposed bypass route.

Hence the proposed road construction is not expected to have an impact on the viability of *T. mitchellae*.

## OTHER CONSIDERATIONS

From a biodiversity conservation perspective, care should be taken during the construction phase to minimise damage to the 'Hidden Valley' gully. This remnant patch of rainforest, albeit small, is significant in the context of the altered nature of much of the surrounding landscape.

## MITIGATING ACTIONS

- road construction activity should if possible, minimise damage to the 'Hidden Valley' rainforest gully at the northern end of the proposed bypass route with particular regard to the plant species.

## LITERATURE CITED

BISHOP, M.J. 1978. A revision of the genus *Thersites* Pfeiffer (Pulmonata: Camaenidae). Journal of the Malacological Society of Australia 4: 9-21.
STANISIC, J. 1994. The distribution and patterns of species diversity of land snails in eastern Australia. Memoirs of the Queensland Museum 36(1): 207-214.
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STANISIC, J. 1998. Survey for the land snail *Thersites mitchellae* in northern New South Wales. Unpublished report for the New South Wales National Parks and Wildlife Service. (Queensland Museum: Brisbane).
STANISIC, J. 1999. Survey for the land snail *Thersites mitchellae* in northern New South Wales. II. Investigation of Wilsons Creek locality. Unpublished report for the New South Wales National Parks and Wildlife Service. (Queensland Museum: Brisbane).

STANISIC, J. 2000. Survey for the land snail *Thersites mitchellae* in northern New South Wales. III. Investigation of Stotts Island locality. Unpublished report for the New South Wales National Parks and Wildlife Service. (Queensland Museum: Brisbane).

## APPENDIX I
Photographs showing habitat quality along Tugun Bypass Road route.

Figure 3. Looking south across 'Hidden Valley' gully; note large scrape in foreground.

Figure 4. Internal view of 'Hidden Valley' gully showing subtropical rainforest.

Figure 5. View looking across bypass corridor just north of Coolangatta Airport and below elevation containing 'Hidden Valley' gully.

Figure 6. View looking along (north-south) bypass corridor route inside perimeter of Coolangatta Airport.

## APPENDIX II

**Copy of initial report on the status of *Thersites mitchellae* in northeastern New South Wales**

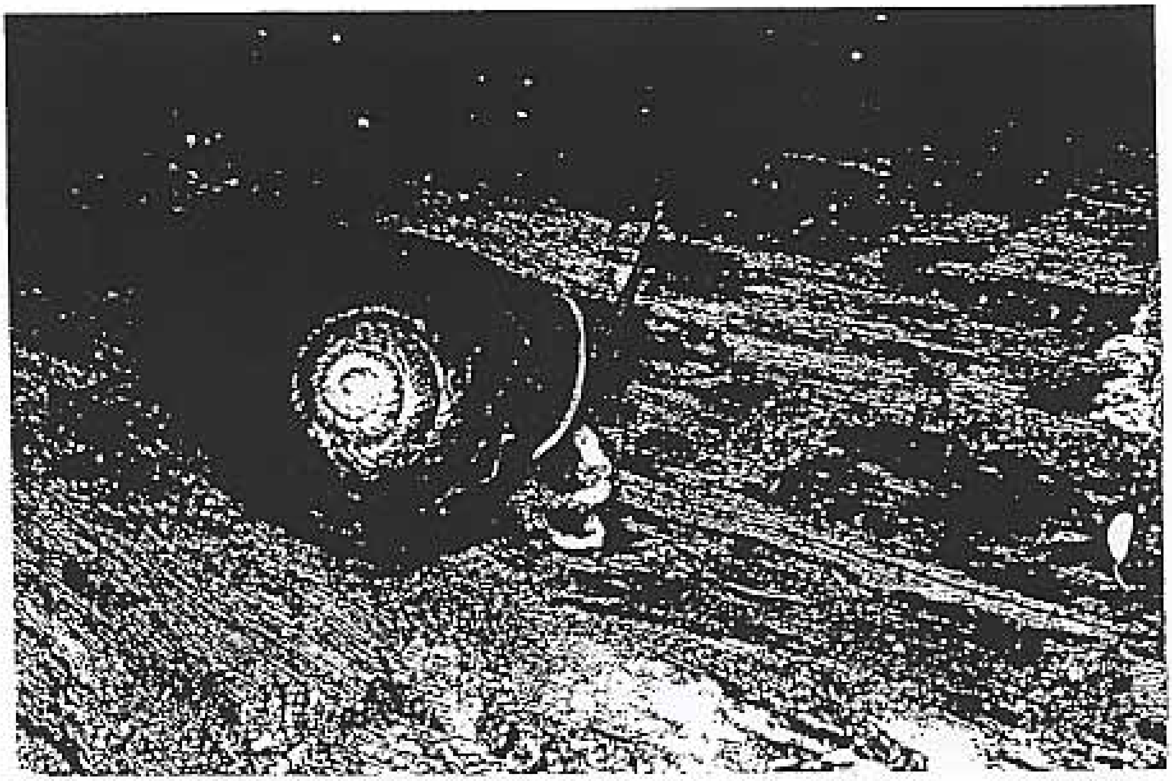
# SURVEY FOR LAND SNAIL *THERSITES MITCHELLAE* IN NORTHERN NEW SOUTH WALES

**Prepared by**

**Dr John Stanisic**
**Senior Curator, Malacology**
**Queensland Museum**

**December 1998**

A CONSULTANCY CONDUCTED FOR
NEW SOUTH WALES NATIONAL PARKS AND WILDLIFE SERVICE



## SURVEY FOR LAND SNAIL *THERSITES MITCHELLAE* IN NORTHERN NEW SOUTH WALES

### SCOPE OF THE STUDY

This report details a study which involved the survey of the land snail *Thersites mitchellae* in northern New South Wales for the New South Wales National Parks and Wildlife Service. The land snail *Thersites mitchellae* (Cox, 1864) is listed under the Threatened Species Conservation Act 1995 as an endangered species. Records held in the Australian Museum, Sydney and Queensland Museum, Brisbane indicate that the species was formerly common in lowland moist forest on the New South Wales north coast from Ballina north to the Tweed River. Much of this habitat has been cleared (Adam, 1987; 1992). and there have been comparatively few recordings of the snail over the past 70 years.

This study aimed to establish the current status of the species through an examination of the historical records held in both the Queensland and Australian Museums, a search of relevant scientific literature and a brief field survey. Information gained on the distribution and habitat requirements of the species would also be used to identify additional potential habitat for *Thersites mitchellae*.

These data will form the basis of a recovery plan for the species.

#### Key Tasks

- to collate relevant literature and museum records on *Thersites mitchellae*;
- to determine the current distribution of *Thersites mitchellae*;
- to provide information on the habitat requirements of *Thersites mitchellae*;
- to identify additional areas of high potential habitat for *Thersites mitchellae*;
- to identify any threats to the extant populations of *Thersites mitchellae*; and
- to determine the conservation status of *Thersites mitchellae*.

### LITERATURE SURVEY AND SYSTEMATICS

**Phylum Mollusca**
**Class Gastropoda**
**Order Eupulmonata**
**Family Camaenidae Pilsbry, 1895**
**Subfamily Camaeninae Pilsbry, 1895**

*Thersites* Pfeiffer, 1855

*Thersites* Pfeiffer, 1855: 141; Pilsbry, 1890: 90; 1895; 127; Zilch, 1960: 616; Bishop, 1978: 10; Smith 1992: 161. - type species: *Helix richmiondiana* Reeve, 1852, by subsequent designation.
*Annakelea* Iredale, 1933:; Iredale, 1937: 37; Iredale, 1942: 38; Burch, 1976: 135. - type species: *Helix richmondiana*, by original designation.

*Thersites mitchellae* (Cox, 1864)
(Figures 1,2)

*Helix mitchellae* Cox, 1864a: 19. Cox, 1864b: 181; Cox, 1868: 65, pl. 9, fig. 9; Pfeiffer, 1868: 279; - type locality: Clarence River, New South Wales. Whereabouts of type unknown.
*Thersites mitchellae* (Cox, 1864a). Bishop, 1978: 12, figs 2, 4c, 8-10; Smith, 1992: 161.
*Hadra (Sphaerospira) mitchellae* (Cox, 1864a). Pilsbry, 1890: 154: pl 47, figs 92, 93.
*Thersites (Sphaerospira) mitchellae* (Cox, 1864a). Pilsbry, 1894: 127, 133, pl. 33, figs 2, 3 & pl. 34, fig. 1.
*Thersites (Thersites) mitchellae* (Cox. 1864). Cox 1909: 50.
*Annakelea mitchellae* (Cox. 1864). Iredale 1933: 43; Iredale, 1942: 38.

*Annakelea peregrans* Iredale, 1937: 37, pl.3, fig.22.; 1942: 39, text fig. 11 - type locality: Bangalow, Byron Bay, New South Wales. Type in Australian Museum, Sydney.

**Etymology.** Named for Mrs James Mitchell (Cox, 1864b).

**Historical Material.** QUEENSLAND MUSEUM: 2 live adults (1 shell only) ,QMMO6898, Stotts I., Tweed R., 13 Jan 1980; 1 adult shell & 6 mainly adult shell fragments, QMMO10526, Stotts I., Tweed R., 28°16'S, 153°30'E, notophyll vine forest/palm swamp, Mar 1981; 1 adult shell & 1 subadult shell, QMMO5786, Tweed R.; 2 adult shells, QMMO5784, Tweed R.; 2 adult shells, QMMO5783, QMMO5787, Richmond R.

AUSTRALIAN MUSEUM (all shells except where noted): 1, AMSC100663, Bangalow, Byron Bay (type of *A. peragrans*); 3, AMSC3392, Richmond R., lower Emigrant Ck, 1896, ex Cox coll.; 3, AMSC105563, SW of Byron Bay, Bangalow, W of Broken Head, at racecourse, S.W. Jackson, 1899; 5, AMSC112232, AMSC112234, Richmond R., Ballina, 1955, ex C.F. McLauchlan coll.; 1, AMSC112233, Richmond R., Ballina, in a deep gully, E.A Lower 1898, ex Cox coll.; 2, AMSC112235, S of Byron Bay, Broken Head, Nicholls Farm, S.W. Jackson, 1904; 3, AMSC112236, S of Byron Bay, Broken Head, scrub, S.W. Jackson, 1920; 1, AMSC112237, Byron Bay, S.W.Jackson, 1914, ex Helms coll.; 18, AMSC112238, AMSC112240, AMSC112242, Byron Bay, E.A.Lower, 1898, ex Cox coll.; 1, AMSC112239, Byron Bay, 1941, ex Iredale coll.; 1, AMSC112241, Byron Bay, S.W.Jackson, 1900; 9, AMSC112243, S of Byron Bay, W of Suffolk Park, foot of Coopers Shoot, scrub, S.W.Jackson, 1899; 1, AMSC112249, Richmond R., lower Emigrant Ck, 1912, ex Cox coll.; 1, AMSC112250, Byron Bay, 3 Mile Scrub (= The Big Scrub, behind Tallow Beach, scrub, 1950; 76, AMSC114513, S of Byron Bay, Broken Head, 1912, ex Cox coll.; 2, AMSC117022, Stotts I. Nature Reserve, Tweed R., 1976; 1, AMSC117044, Stotts I. Nature Reserve, 1977; 2 live adults, AMSC348956, Fultons Farm, Wilsons Ck, via Mullumbimby, W.G. Fulton, 1979; 1, AMSC121725, near (SW of) Mullumbimby, Wilsons R., W.G. Fulton, 1980; 7, AMSC129335, Stotts I. Nature Reserve, Tweed R., notophyll vine forest/palm swamp, 1981; 4, AMSC158030, Stotts I. Nature Reserve, Tweed R., inside dead palm leaf stem in rainforest, 1977; 5, AMSC163390, Stotts I. Nature Reserve, Tweed R., 1990; 1, Byron Bay, Cumbebin Swamp, G. Clancy, 1996.

**Survey Material.** 16 mainly adult shell fragments, QMMO63720, Stotts I., Tweed R., 28°16'S, 153°30'E, notophyll vine forest/palm swamp, on ground, 21 Nov 1998; 1 live juvenile, QMMO63793, Byron Bay, S on road to Broken Head opposite golf club, 28°40'43"S, 153°36'31"E, remnant rainforest strip adjacent to wetland, on ground under palm frond, 7 Nov 1998; 1 adult shell, QMMO63795, Banora Point, S of Tweed Heads, N of Barneys Point bridge, 28°13'10"S, 153°32'57"E, in remnant rainforest strip adjacent to wetland, on ground among palm fronds, 8 Nov 1998; 1 live adult, 1 subadult shell & 1 live juvenile, QMMO63794, 1km N of Lennox Head on road to Broken Head, 28°47'20"S, 153°34'52"E, remnant rainforest strip adjacent to wetland, adult under litter at base of fig tree; live juvenile and subadult shell under bark up in fig tree, 14 Nov 1998

**Description.** Shell large, obtusely trochiform, almost as high as wide size variable, height range approximately 30 - 50mm, width range approximately 35 - 55mm, spire strongly elevated. Whorls approximately 5 - 6 1/2 relatively flattened in profile, regularly coiled; body whorl rounded to distinctly angulate at the periphery, descending rapidly in front, rounded below. Shell sculpture of fine recurved radial lines, microsculpture of fine granules. Umbilicus closed. Base convex, parietal callus dark. Aperture sub-ovate laterally inclined about 45° to shell axis and deflected backward about 45° to shell axis. Lip thickened and reflected with a distinct ridge-like thickening on the columellar margin. Shell colour deep reddish chestnut to black with two prominent yellow bands, one below the suture and one at the periphery; base with yellow circum-umbilical patch; lip brownish purple to chestnut black. Animal black with a lighter thin stripe dorsally midline in the neck region.

Genitalia with relatively long muscular epiphallus, entering penis laterally. Penial retractor muscle inserting about half-way along epiphallus. Penis short, barrel shaped, without sheath, internally with long, tapered, longitudinally sculptured verge.

**Distribution and Habitat.** On the coastal plain between the Richmond and Tweed Rivers, northeastern New South Wales; in lowland subtropical rainforest on basaltic alluvium.

Remarks. The record of *Thersites mitchellae* from the Clarence River (type specimen) must be regarded as questionable since no other records are known south of the Richmond River. Pilsbry (1894) presented details on the radula and anatomy of *T. mitchellae*. Bishop (1978) revised *Thersites* and first noted the lack of recently collected material. The species is comparatively rare with few large lots of material in museum collections. This is remarkable for a large snail that occurs in an area which was subject to relatively extensive collecting in the late 1800's. The exceptions are a lot of 76 specimens from "S of Byron Bay, Broken Head" and another lot of 16 specimens from "Byron Bay". A search of the Broken Head area during the current survey revealed no signs of the species and it is probable that the relevant area has been cleared. It is also possible that this broad locality could have referred to the northeastern edge of the Big Scrub (now only present in tiny patches), south of Mullumbimby. Such a large lot of material, of what appears to be live-taken specimens, might indicate that they were collected during land clearing activity. A lot of recently collected material which includes several; large live adults (AMSC348956) from SW of Mullumbimby suggests that this may well have been the case. This locality warrants further investigation.

## FIELD SURVEY

**Description of survey area.** Maps of the survey area showing study sites are provided in Figures 3-6. The area is located between the Richmond and Tweed Rivers approximately east of 153°25' and contains a number of important regional centres, large tracts of farming land and some relatively undisturbed patches of native vegetation. Most noticeable are a series of wetlands which run in a line from just north of Ballina to south of Tweed Heads. These swamps are dominated by *Melaleuca* sp. and palms. Along the edges of these wetlands where the land is slightly more elevated, there are narrow verges of rainforest dominated by *Archontophoenix* palms, *Ficus* spp and *Erythrina vespertilio*. These are remnants of once more extensive tracts of lowland subtropical rainforest.

Large rainforest stands in the study area are now comparatively rare and are located at the Brunswick Heads Nature Reserve, Broken Head Nature Reserve and on Stotts Island in the Tweed River. A major stand of littoral rainforest is also present near Cape Byron. The other significant vegetation complexes include coastal heath, drier littoral rainforest and eucalypt forest. In spite of this seemingly impressive mosaic of native vegetation, the area has been significantly modified for grazing and agriculture. More recently, housing and road building seem to have taken an additional toll on the natural environment. Lowland subtropical rainforest appears to have been the vegetation community most affected. These rainforests occur on high nutrient basaltic alluvium, usually adjacent to low lying swamps (Floyd, 1987; 1990a,b), and would have been much sought after by farmers. The largest remaining stand of this rainforest type is on Stotts Island. The wetlands, and the narrow verges of lowland subtropical rainforest which now skirt many of these swamps, appear to have survived mainly because the problems associated with developing these low lying areas in the past, were considerable. Modern land developing techniques are able to deal with these problems. Fortunately a number of the wetlands are designated nature reserves.

### Survey Methodology

The steps followed in the preparation of the field survey were as follows:-

- Collation of relevant literature and museum records to establish basic distribution and habitat requirements;
- Identification of all known habitats for *T. mitchellae* based on historical distribution records, with specific emphasis on habitat and microhabitat data;
- Identification of prospective habitats for *T. mitchellae* from a scrutiny of available maps and vegetation data covering the species' suspected range.

Apart from revisiting areas where *T. mitchellae* had been collected since the mid-1970's, collecting sites (Figs 3-6) were chosen on the basis of whether rainforest was present. Individual museum records did not provide a specific indication of the habitat requirements of *Thersites mitchellae*. However, the presence of the species on Stotts Island and the general range of historical localities provided by museum records suggested that rainforest was the prime vegetation community in which the species was liable to occur. A range of closed-forest communities within the survey area were searched in order to more accurately determine the precise habitat limits of the species within rainforest complex. The microhabitat (ie. where if prefers to forage and rest) of *Thersites mitchellae* is unknown though some literature (Cox, 1864a) and museum records suggest that *Thersites mitchellae* lives in the litter zone. The vast majority of past records of the species do not include any microhabitat information. Most rainforest snail species in eastern Australia live in the litter zone of the forest floor, often under rocks, rotting logs and other vegetational debris. Consequently these microhabitats were searched extensively at each of the sites. Some arboreal searching was also undertaken because experience has shown that the juveniles of some of the larger eastern Australian camaenids (which have quite different shell shapes to the adult) live arboreally under the bark of trees.

Land snails leave their shells behind after death and these dead shells will survive chemical and mechanical breakdown for varying periods of time. Hence, the presence or absence of species can also be established from these remains. Dead shells, in particular their condition, are good indicators not only of the presence of live animals even though the latter might be difficult to locate within the time constraints of such a survey. They may also indicate the effects of any ongoing predation by mammals or birds. A portion of leaf litter was also taken from the major sites for sorting by microscope mainly to establish the background community of smaller snails which might be present with *Thersites mitchellae*. Land snail communities (guilds) as well as individual species may be useful indicators of both specific vegetation structure and general environmental condition. These 'background' species might provide some additional information on the breadth of environmental tolerance shown by *Thersites mitchellae*.

Chief emphasis in the sampling program was on selecting a wide selection of sites across the known historical range of the species because one of the main aims of survey was to determine some estimate of the overall field presence of *Thersites mitchellae*. In order to maximise field coverage a search time of an hour was allowed at each site if no *T. mitchellae* was found. Because land snails may be distributed unevenly throughout their range (a factor likely to be exacerbated in an area of high habitat disturbance), reduced single site sampling time is compensated by increasing the number of sites sampled throughout the range of the species. This methodology has been used effectively by the author over 20 years of collecting land snails in eastern Australia. Hence in most sites two person-hours applied. The only exception to this protocol was in sampling the known population on Stotts Island, where 4 x 4 person-hours were allocated. This locality is the best known habitat of *Thersites mitchellae* and the main aim at this site was to try and gain information on the status of the population and the ecology of the species.

## Sampling programme and description of sites

The field survey for *Thersites mitchellae* was undertaken over five days by Dr John Stanisic (Senior Curator, Queensland Museum), Jan Chaseling (Honorary Assistant, Queensland Museum) on 6, 7, 14, 15, 21 November, 1998. On 21 November Darryl Potter (Senior Technician, Queensland Museum) and Maria Bavins (Temporary Technician, Queensland Museum) also assisted. Weather prior to the start of the survey was showery and warm which provided an ideal climate in which to survey land snails. Conditions spanning the 15 days of the collecting period were intermittently showery.

The locations of all sites are indicated in Figures 3-6 and their descriptions (in order of collection) are as follows:-

1. Byron Bay, S on road to Broken Head opposite golf club, outlier of Cumbebin Swamp, 28°40'36"S, 153°36'41"E, remnant rainforest strip adjacent to wetland, 7 Nov 1998. 1 live juvenile of *T. mitchellae* on ground under palm frond. No other snails found (Fig. 7).

2. Byron Bay, SW at Hayters Hill, , 28° 40'17"S, 153°34'48"E, notophyll vine forest remnant on hillside, 7 Nov 1998. No *T. mitchellae* found. Other snails recorded from under logs and litter comprise *Sphaerospira fraseri*, *Echotrida strangeoides*, Helicarionidae sp., *Fastosarion aquila*.

3. Broken Head, W on road in from highway, 28°42'00"S, 153°36'34"E, remnant rainforest patch, 7 Nov 1998. No *T. mitchellae*. No snails recorded

4. Brunswick Heads, N edge of Brunswick Heads Nature Reserve, 28°31'46"S, 153°32'31"E, disturbed rainforest on sand, 7 Nov 1998. No snails found.

5. West side of Tweed River opposite Stotts I, 28°16'08"S, 153°29'20"E, rainforest along river, 8 Nov 1998. No snails found.

6. Tweed Heads, S at Terranora, 28°14'16"S, 153°33'05"E, remnant vine thicket on sand spit, 8 Nov 1998. *Lamellaxis gracilis* in litter.

7. Tweed Heads, S at Terranora, 28°14'08"S, 153°32'30"E, remnant rainforest in gully next to mangroves, 8 Nov 1998. No snails found.

8. Tweed Heads, S at Banora Point N of Barneys Point bridge, 28°13'10"S, 153°32'57"E, in remnant rainforest strip adjacent to wetland, , 8 Nov 1998.1 dead adult shell of *T. mitchellae* on ground among palm fronds. Other snails found include *Nitor pudibunda, Sphaerospira fraseri, Ramogenia challengeri, Strangesta ramsayi* among litter and under rocks (Fig. 8).

9. Ballina, 28°52'11"S,153°35'25"E, rainforest remnant along cliff adjacent to beach, 14 Nov 1998. No *T. mitchellae*. *Sphaerospira fraseri* in litter.

10. Ballina, Ballina east, 28°51'32' S, 153°35'08"E, rainforest reserve adjacent to wetland, 14 Nov 1998. No snails found (Fig. 10).

11. Skennars Head, approx. 0.5 km north, 28°49'20"S, 153°35'58"E, remnant rainforest adjacent to wetland on sand , 14 Nov 1998. No snails found (Fig. 11 shows adjacent habitat)).

12. 1km N of Lennox Head on road to Broken Head, 28°47'20"S, 153°34'52"E, remnant rainforest strip adjacent to wetland, 14 Nov 1998. 1 adult *T. mitchellae* under litter at base of fig tree; 1 live juvenile and 1 subadult shell found under bark up in fig tree. No other snails recorded (Fig.9).

13. Mullumbimby, W at upper Wilson's Creek, 28°33'24"S, 153°24'05"E, notophyll vine forest, 15 Nov 1998. No snails found

14. Broken Head, Broken Head Nature Reserve, behind caravan park, 28°42'21"S, 153°36'45"E, rainforest/palms, 15 Nov 1998. No *T. mitchellae*. Other snails found include *Sphaerospira fraseri, Austrochloritis* sp., Helicarionidae sp.and *Nitor subrugata* under logs and among palm fronds.

15. Byron Bay, Cumbebin Swamp behind services club, 28°39'09"S, 153°36'31"E, rainforest strip on edge of wetland. No snails found.

16. Stotts I., Tweed R., 28°16'S, 153°30'E, notophyll vine forest/palm swamp, 21 Nov 1998. 16 mainly adult shell fragments of T. mitchellae found on ground mainly around Pitta anvils. Other snails found under logs and among palm fronds include *Fastosarion aquila, Ramogenia challengeri, Papuexul bidwilli, Sphaerospira fraseri, Nitor subrugata and Strangesta ramsayi* (Fig. 12).

## RESULTS

*Thersites mitchellae* was located at four of the 16 survey sites (Figs 3-6). Three of these sites are new records for the species. Numbers of specimens located were relatively low and only the Stotts Island locality was indicative of a thriving population. However, the presence of a single specimen of the species was considered sufficient for the purpose of establishing presence. Although relatively few specimens of *T. mitchellae* were collected, the range of the species was extended in the north (Banora Point locality) and reaffirmed to almost its historical southern limit near Ballina (Lennox Head locality). The site opposite the Byron Bay golf club is an outlier of the Cumbebin swamp and confirms the 1996 record of the species from this locality.

The taxonomic diversity of other native land snails which were collected during the survey indicate that some of the habitats within the area still support a robust land snail fauna. However, the overall numbers of species is low in the context of an area which is comparatively rich in species. More than anything this indicates the disturbed nature of the habitat. Significantly, there was no indication of the widespread presence of introduced species in the remnant patches of rainforest vegetation suggesting that they probably still are important refugial areas for native land snails.

### Analysis of the distribution of *Thersites mitchellae*

Comparison of the number of sites from which *Thersites mitchellae* is known with the total number of sites from northeastern New South Wales that are represented in the databases of the Queensland and Australian Museums indicates that the restriction of the species is real and not an artefact of poor collecting. Based on the comparatively few specimens in museum collections this is probably also true in an historical perspective. Museum records show that this region has been subject to relatively intense land snail collecting particularly in the late 1800's. Yet comparatively few lots of material are present in museum collections.

Records from this survey show that the species inhabits only lowland subtropical rainforest in spite of the presence of several types of rainforest in the study area. Staff of the Queensland Museum Malacology Section have collected extensively in the littoral rainforests of the area since 1980 and have failed to find any trace of the species. That it was once common in some areas such as the 'Broken Head scrubs' and yet has not been recently collected in the area strongly suggests subsequent loss of critical habitat has greatly affected its distribution. Much of the lowland rainforest habitat appears to have survived rather fortuitously on the edge of wetlands where the land is relatively more elevated.

*Thersites mitchellae* was not located in the Mullumbimby area where it was collected in 1979 and 1980. However, there is a discrepancy in the data associated with the two lots of specimens from this area. The lot containing live specimens (AMSC348946) states Wilson Creek. The area in the vicinity of Wilsons Creek was searched but no likely habitat or snails were found. However, the lot with dead shells only (AMSC121725) states Wilson River. I strongly suspect that the latter locality which is less elevated country to the south of Mullumbimby may be the correct locality of the material and may yet yield additional specimens. Unfortunately this discrepancy was discovered in the Australian Museum by the author after completion of the field programme and hence the Wilson River locality was not investigated during the current survey.

### Ecology

Little additional information was gained on the ecology of *Thersites mitchellae*. The few live specimens collected suggest that it is a litter species though the juvenile stages may be arboreal. Although the species is associated with low-lying wetlands, it is significant that none were collected among the *Melaleuca* vegetation. These areas are liable to intermittent inundation which would preclude the long-term survival of snails that feed on the forest floor. The species is apparently only exploiting the higher areas where the subtropical rainforest occurs.

## CONSERVATION STATUS OF *THERSITES MITCHELLAE*

*Thersites mitchellae* still survives across its historical range albeit in small pockets. Furthermore, the collection of two live juvenile specimens during the survey indicates that even the smaller populations are breeding. Nevertheless *Thersites mitchellae* should be regarded as a threatened species since most of its preferred habitat has been cleared. The marginalised nature of the remaining habitats indicates that the populations of *Thersites mitchellae* living in them are probably also marginal. The only robust population of the species occurs on Stotts Island. It is impossible to make a numerical estimate of the number of individuals which make up the various populations because of the cryptic behaviour of the species and the complexity of the habitat in which it occurs. However an estimate of the relative sizes of small patches of lowland subtropical rainforest which still remain in and around the various wetland areas might provide a useful index of the possible relative strengths of populations.

The following table summarises the relevant information in regard to the conservation of *Thersites mitchellae*:-

Table 1. Site and population data for *Thersites mitchellae*. (Post 1975 and current survey records only).

| Site | Location | Population status | Habitat type | Habitat status |
|---|---|---|---|---|
| Stotts Island NR | 28°16'S, 153°30'E | good | lowland subtropical rainforest | good |
| Cumbebin Swamp outlier | 28°40'43"S, 153°36'31"E | marginal | lowland subtropical rainforest | marginal |
| 1km N of Lennox Head | 28°47'20"S, 153°34'52"E | marginal | lowland subtropical rainforest | marginal |
| Banora Point | 28°13'10"S, 153°32'57"E | marginal | lowland subtropical rainforest | marginal |
| Wilson's River, SW Mullumbimby | not searched | unknown | unknown | unknown |

## THREATS AND NEED FOR FURTHER STUDIES

The single most significant threat to the continued viability of *Thersites mitchellae* is the loss of critical habitat. This survey shows that lowland subtropical rainforest is the preferred habitat of the species, but that within the range of *T. mitchellae* this habitat remains only as a series of remnant patches. However, even small areas are still supporting the species. Whereas the tenure of the Stotts Island Nature Reserve is reasonably assured, the other habitats are marginal to larger wetland reserves and appear to have no special reservation status.

The results of the current study also indicate that additional sampling within the study area could lead to the discovery of more populations of *T. mitchellae*. In terms of the long-term survival of the species, it is important that additional populations be located and that more information on the ecology and life cycle be obtained. In order to achieve this, mapping of the archipelago of lowland rainforests should be completed and its full extent surveyed for *Thersites mitchellae*.

The fact that *T. mitchellae* is 'hanging on' in very marginal situations attests to the remarkable resilience of invertebrate populations in marginalised habitat. Elsewhere eg. Queensland Brigalow Lands (Stanisic, 1998) land snails have been shown to maintain local presence in spite of extreme environmental disturbance at the regional level. *T. mitchellae* is no exception. However, the value of the small, marginalised patches of surviving lowland rainforest needs to be formally recognised. Their scattered nature would appear to make them vulnerable to incidental disturbance.

## EXECUTIVE SUMMARY

- literature and museum records indicate that *Thersites mitchellae* was once widespread in the coastal plain of northeastern New South Wales between the Richmond and Tweed Rivers;
- results from this survey show that *Thersites mitchellae* is still surviving across the breadth of its historical range albeit in marginalised populations which are breeding;
- *Thersites mitchellae* shows a distinct preference for lowland subtropical rainforest. This habitat type exists fortuitously as narrow remnants surrounding wetlands but more extensively on Stotts Island;
- additional areas of high potential for the occurrence of *Thersites mitchellae* probably exist within its range and these need to be accurately mapped and more extensively surveyed;
- *Thersites mitchellae* should be considered an endangered species since only a single robust population is known from Stotts Island; other populations should be regarded as marginal because of the marginal nature of the habitat;
- the single major threat to the continued survival of *Thersites mitchellae* is destruction of critical habitat.

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## AUSTRALIAN MUSEUM WEB SITE

The Australian Museum has established a web site for the endangered land snails listed under the Threatened Species Conservation Act 1995. The site for *Thersites mitchellae* is located at:

http://www.austmus.gov.au/science/division/invert/mal/endangered/thersites.htm

This site lists basic data on the species as well as photographs and is updated on a regular basis. The details which are currently on the site are located at the back of this report.

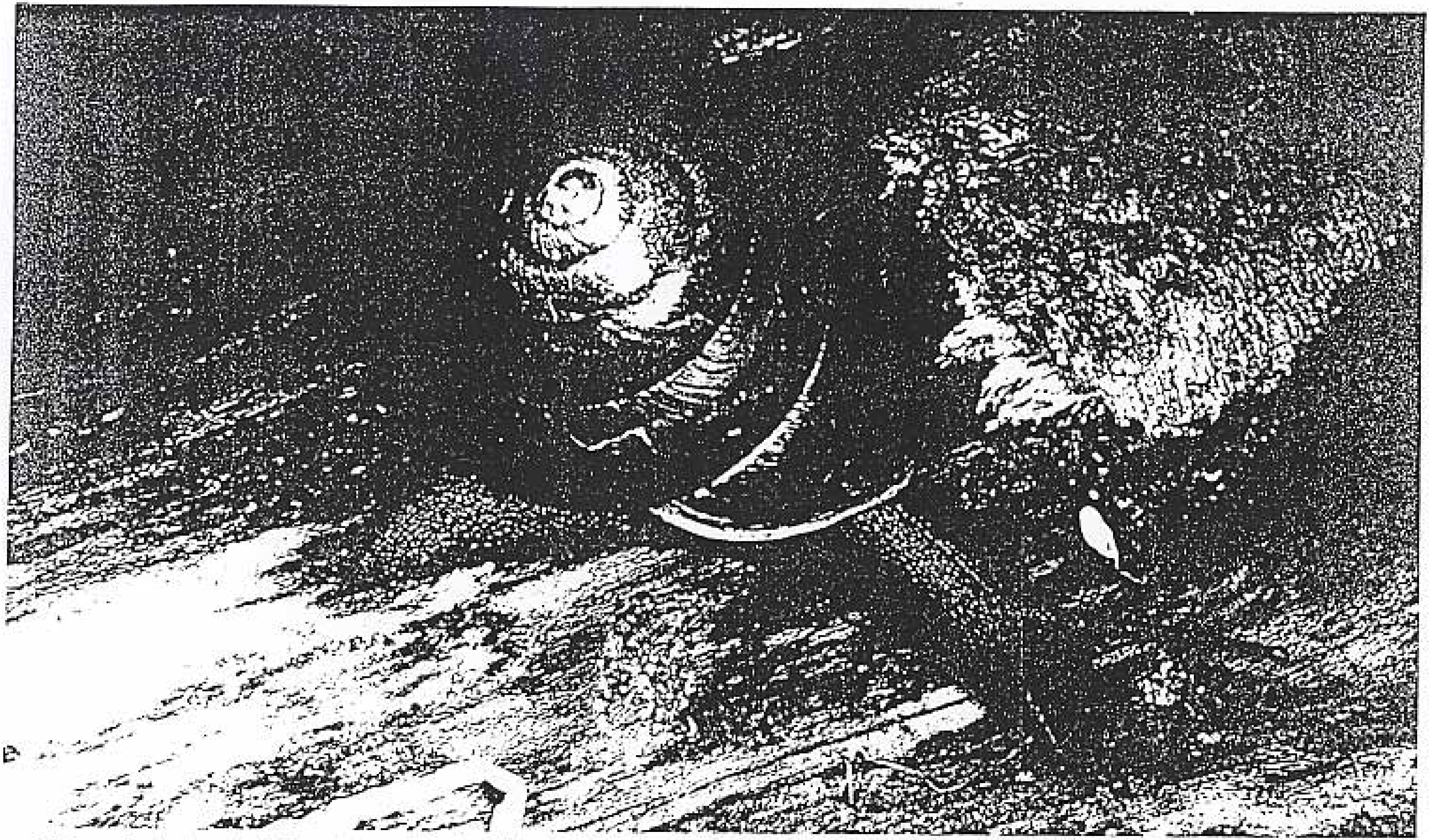

Figure 1. Animal of *Thersites mitchellae* (Cox, 1864). [QMMO63794, 1km N of Lennox Head on road to Broken Head, 28°47'20"S, 153°34'52"E, remnant rainforest strip adjacent to wetland. Collected from under litter at base of fig tree].

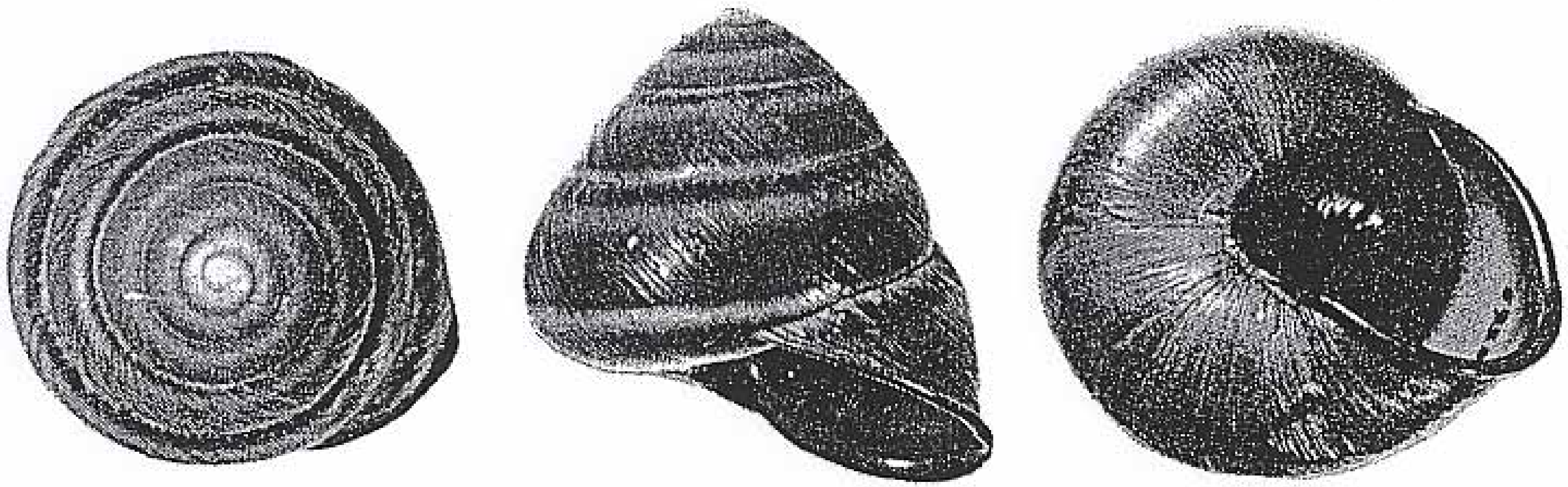

Figure 2. Shell of *Thersites mitchellae* (Cox, 1864). AMSC105563, Broken Head, Byron Bay. Height of shell = 45mm, diameter of shell = 45mm. [From Bishop, 1978].

Figures 3-6. Distribution of collecting sites ( sites 4 & 13 not marked) showing locations of *Thersites mitchellae* populations.
(See next four maps. Scale =1: 25 000)

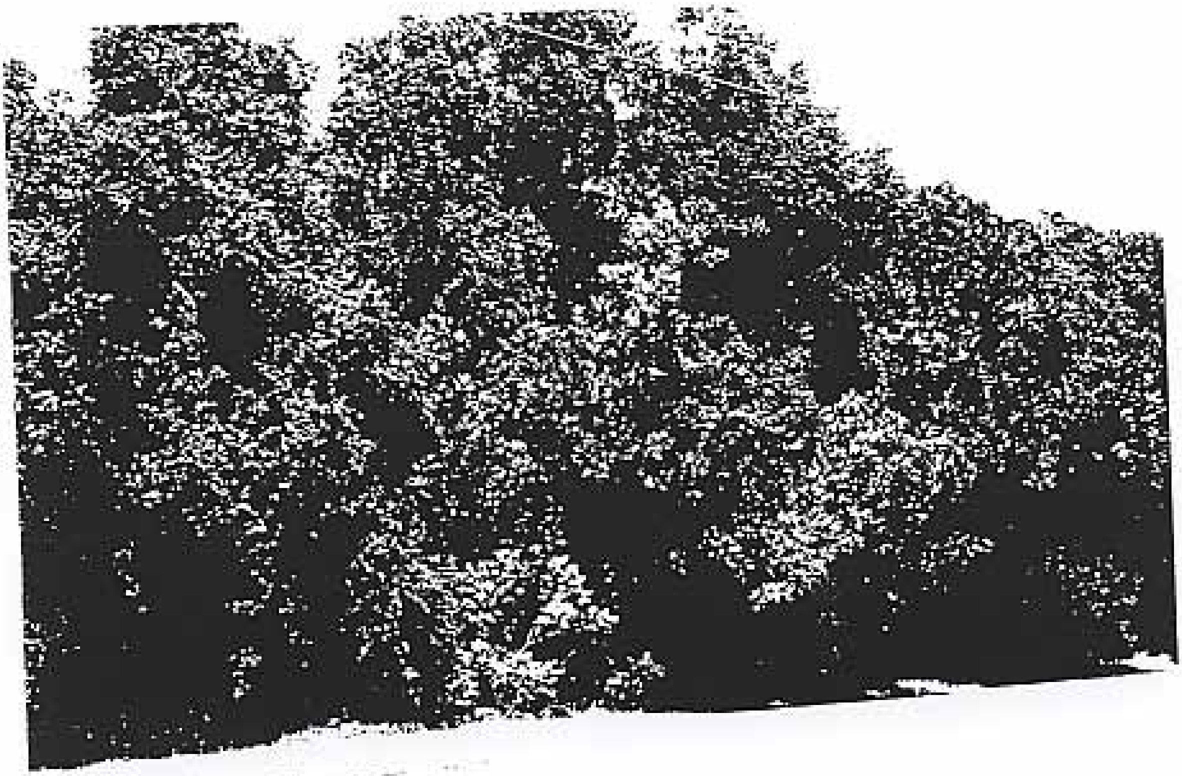

Figure 7. Habitat at Site 1. Byron Bay, S on road to Broken Head opposite golf club, outlier of Cumbebin Swamp, 28°40'36"S, 153°36'41"E, remnant rainforest strip adjacent to wetland.

Figure 8. Habitat at Site 8. Tweed Heads, S at Banora Point NE Barneys Point bridge, 28°13'10"S, 153°32'57"E, remnant rainforest strip adjacent to wetland.

Figure 9. Habitat at Site 12. 1km N of Lennox Head on road to Broken Head, 28°47'20"S, 153°34'52"E, remnant rainforest strip adjacent to wetland.

Figure 10. Habitat at Site 10. Ballina, Ballina east, 28°51'32' S, 153°35'08"E, rainforest reserve adjacent to wetland.

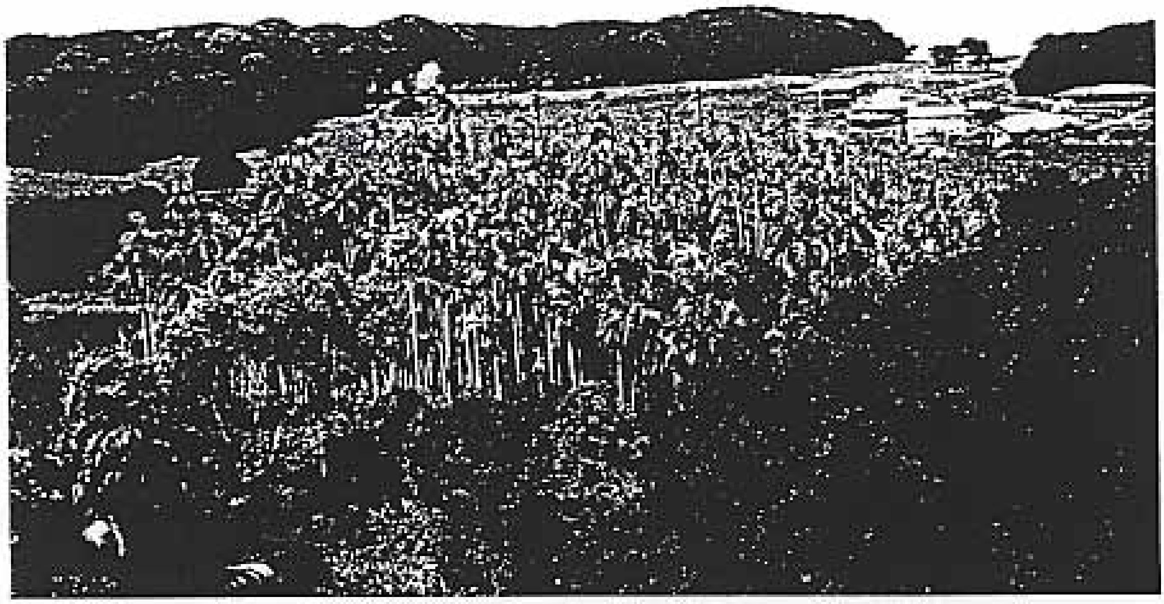

Figure 11. Low-lying wetland west of Skennars Head showing a remnant palm stand. Most of the peripheral rainforest has been cleared for farming.

Figure 12. Habitat at Site 16. Stotts I., Tweed R., 28°16'S, 153°30'E, notophyll vine forest/palm swamp.

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malacology

# *Thersites mitchellae* (Cox, 1864) (Family Camaenidae)


This species used to be common in the coastal areas of northern New South Wales in wet sclerophyll rainforest from the Tweed River south to Ballina, but it is now extremely rare. The lowland rainforest habitat of *Thersites mitchellae* has been drastically reduced and is still being cleared. A snail of this size (45mm diameter) is very vulnerable to predation by birds and introduced mammals such as rats. There are only two sites where this large conspicuous species has been seen in recent years. It is found under loose bark on tree trunks and in palm frond bases.

**Past Distribution:** Common, coastal area of northern New South Wales from the Tweed River south to Ballina. Only two lots (5 specimens) have been collected or seen in the last 70 years (based on Australian Museum, Queensland Museum records)

**Present Distribution:** Remnant, disjunct populations were discovered (four living specimens) on Stotts Island, Tweed River (1977,1981) and Cunbebin Wetland right behind Byron Bay (one freshly dead shell, 1996). No other sightings have been reported.

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Threatened and Endangered Landsnail species
*Meridolum corneovirens* | *Placostylus bivaricosus* | *Thersites mitchellae*
Dr Rudman | Malacology Homepage

TOP | ABOUT THE MUSEUM | WHAT'S NEW | MEMBERSHIP | MAP | HELP | HOME

AUSTRALIAN MUSEUM

***Thersites mitchellae***

Byron Bay, northern New South Wales. (45mm diam) AMC112238.

Photo: Toni Wickey.

**Back**

AUSTRALIAN MUSEUM AM

## ADDENDUM

1. Byron Bay, S on road to Broken Head opposite golf club, outlier of Cumbebin Swamp, small remnant rainforest strip adjacent to wetland. 1 live juvenile of *T. mitchellae* on ground under palm frond. GR: 596 274. **Habitat status**: Good but small in size. **Threats**: Road widening, land development.

2. Byron Bay, SW at Hayters Hill, notophyll vine forest remnant on hillside. **GR**: 567 282. **Habitat status**: Very good but *T. mitchellae* considered unlikely to occur here.

3. Broken Head, W on road in from highway, remnant rainforest patch. **GR**: 597 247. **Habitat status**: Good but small in size; possible *T. mitchellae* locality. **Threat**: Land development.

4. Brunswick Heads, N edge of Brunswick Heads Nature Reserve, disturbed rainforest on sand. **GR**: 599 242. **Habitat status**: Poor but unlikely *T. mitchellae* habitat.

5. West side of Tweed River opposite Stotts I, rainforest along river. **GR**: 483 732. **Habitat status**: Poor and degraded and not considered *T. mitchellae* habitat.

6. Tweed Heads, S at Terranora, remnant vine thicket on sand spit. **GR**: 540 754. **Habitat status**: Poor and considered unlikely *T. mitchellae* habitat.

7. Tweed Heads, S at Terranora, remnant rainforest in gully next to mangroves. **GR**: 532 756. **Habitat status**: Poor and considered unlikely *T. mitchellae* habitat.

8. Tweed Heads, S at Banora Point, N of Barneys Point bridge, in remnant rainforest strip adjacent to wetland, 1 dead adult shell of *T. mitchellae* on ground among palm fronds. **GR**: 538 783. **Habitat status**: Very good. **Threat**: Land development.

9. Ballina, , rainforest remnant along cliff adjacent to beach. **GR**: 575 062. **Habitat status**: Poor and degraded and considered unlikely *T. mitchellae* habitat.

10. Ballina, Ballina east, rainforest reserve adjacent to wetland. **GR**: 572 075. **Habitat status**: Good and considered likely *T. mitchellae* habitat. **Threat**: Fire.

11. Skennars Head, approx. 0.5 km north, remnant rainforest adjacent to wetland on sand. **GR**: 586 115. **Habitat status**: Good and considered possible *T. mitchellae* habitat. **Threat**: land clearing, fire.

12. 1km N of Lennox Head on road to Broken Head, remnant rainforest strip adjacent to wetland. 1 adult *T. mitchellae* under litter at base of fig tree; 1 live juvenile and 1 subadult shell found under bark up in fig tree. **GR**: 568 152. **Habitat status**: Poor and fragmented. **Threats**: Land clearing, fire.

13. Mullumbimby, W at upper Wilson's Creek, notophyll vine forest. **GR**: 392 405. **Habitat status**: Good but considered unlikely *T. mitchellae* habitat.

14. Broken Head, Broken Head Nature Reserve, behind caravan park, rainforest/palms. **GR**: 599 242. **Habitat status**: Good but considered unlikely *T. mitchellae* habitat.

15. Byron Bay, Cumbebin Swamp behind services club, rainforest strip on edge of wetland. **GR** : 596 305. **Habitat status**: Good and known *T. mitchellae* habitat. **Threat**: Land clearing and development.

16. Stotts I., Tweed R., notophyll vine forest/palm swamp. 16 mainly adult shell fragments of *T. mitchellae* found on ground mainly around *Pitta* anvils. **GR**: 490 721. **Habitat status**: Excellent. **Threat**: Fire.

# Appendix J

*Survey for the Giant Dragonflies,* Petalura gigantea *and* Petalura litorea *and the Swordgrass Brown Butterfly,* Tisiphone abeona morrisi (Reeves 2001)

# Survey for the Giant Dragonflies, *Petalura gigantea* and *Petalura litorea* and The Swordgrass Brown Butterfly, *Tisiphone abeona morrisi*

DENISS M. REEVES

30 BRAMSTON TERRACE

HERSTON QLD 4006

# Contents

# SURVEY FOR THE GIANT DRAGONFLIES, *PETALURA GIGANTEA* AND *PETALURA LITOREA* AND THE SWORDGRASS BROWN BUTTERFLY, *TISIPHONE ABEONA MORRISI*.

DENISS M. REEVES

30 BRAMSTON TERRACE

HERSTON QLD 4006

## *1.0 INTRODUCTION*

The aim of this study was to undertake a survey for the giant dragonfly and the swordgrass brown butterfly along the proposed Tugun Bypass. In addition, suitable and potential habitat for these species was assessed along the corridor. This report:

- describes ecological characteristics of these species;
- outlines the methodology used;
- records the locations of individuals and/or habitats observed;
- briefly assesses potential impacts of the proposed bypass; and,
- recommend measures to minimise impacts.

## *2.0 CONSERVATION STATUS*

### 2.1 GIANT DRAGONFLIES

Until recently, the Queensland giant dragonfly was included with the NSW giant dragonfly in a single taxon, *Petalura gigantea.* Theischinger (1999) separated it as a distinct species, *Petalura litorea*. *Petalura gigantea* is considered vulnerable under IUCN (International Union for Conservation of Nature) guidelines (Hawking 1999) and has been designated an endangered species in NSW under the *Threatened Species Conservation Act 1995*. *Petalura litorea*, on the other hand, has no such protection in Queensland or NSW. At the time of writing, no specimens of what Theischinger regards as true *P. gigantea* have been recorded from south-east Queensland; Theischinger (1999) states that *P. gigantea*'s distribution is 'Eastern New South Wales (coastal and montane in some southern areas, possibly only montane in more northern areas) (p. 163). It appears that, due to its recent separation from *P. gigantea*, *P. litorea* is not protected by any conservation or environmental protection legislation. However, it is my opinion that it should be considered vulnerable, having similar habitat requirements to *P. gigantea.*

*Petalura litorea* has been recorded from a number of localities on Fraser, Moreton and North Stradbroke Islands (sand dune islands), from Russell Island in Moreton Bay and from several localities from Byfield near Yeppoon (October1924) to Burleigh Heads (January1933) on the Gold Coast (but see Results section below).

## 2.2 SWORDGRASS BROWN BUTTERFLY

The northern NSW subspecies of the swordgrass brown butterfly (*Tisiphone abeona morrisi*) is not protected by either State or Commonwealth legislation. Waterhouse and Lyell (1914) recorded this subspecies from Southport in south-eastern Queensland and Common and Waterhouse (1981) stated that it had 'formerly occurred...from Southport to Coolangatta...' (p. 369). Braby (2000) states '...it is now locally extinct in south-eastern QLD.' (p. 525). Dr. D. P. Sands (*pers. comm.)*, confirms information previously received, that a colony of *T. a. morrisi* exists in the Jacobs Well area on land under threat of sand mining — its conservation status in Queensland is uncertain at the present time. However, the survival of the swordgrass brown appears to be assured in north-eastern NSW, where Common and Waterhouse (1981) state that 'It is common farther south' (p. 369). Destruction of swordgrass (*Gahnia*) swamps in which the butterfly breeds would pose a threat to its survival.

# *3.0 ECOLOGICAL CHARACTERISTICS*

## 3.1 GIANT DRAGONFLIES

The larvae of *P. gigantea* construct burrows which open above ground in the peaty substrate of their swamp/bog habitat. Tillyard (1911), who excavated burrows in the Blue Mountains, suggested that the larvae 'come up these channels each night, and wander about looking for food' (p. 91). He stated that the burrows had second, underwater, openings and 'channels' through the mud, suggesting that the larvae lay in wait or moved about on the surface, preying on terrestrial arthropods and on aquatic organisms when submerged (pp. 90–91). Larvae of *P. litorea* are thought to have the same habits as *P. gigantea*.

Of the giant dragonfly on North Stradbroke Island, Arthington and Watson (1982) state: 'In common with other petalurids, it breeds in bogs where its larvae dig burrows that extend down to below the water table (Tillyard 1909). Its distribution is therefore patchy, and although it can be very abundant at suitable sites, it may be difficult to detect'. On North Stradbroke Island, adults emerge in summer and are on the wing usually during December and January. I have rarely had more than two or three sightings in a morning's search. Flying slowly at about 1–2 m above the swamp vegetation they will swiftly fly to the shelter of the surrounding trees and shrubs if disturbed. Females are seldom seen, but are sometimes heard when they are ovipositing at the bases of reed clumps. The fluttering of their wings against the vegetation is clearly audible when they are thus occupied. I have not been able to determine whether eggs are inserted into the tissue of the reeds or into clubmoss and/or rotted vegetation on the surface of the substrate. Tillyard (1909) states 'Every female I flushed appeared to be settled on or near the ground at the edge of a mass of decaying vegetable mud. The probability is that the eggs are actually inserted in decaying tissues.' (p.262).

## 3.2 SWORDGRASS BROWN BUTTERFLY.

Of the swordgrass brown, Waterhouse (1928) says 'The eggs are usually laid singly on the very young leaves of the food plant (*Gahnia* spp.) that rise vertically from near the centre of a shoot...' and ' in some cases another egg is laid near the first...usually two eggs are laid with a short interval between, the female then flying away and waiting some considerable time before laying further eggs.' (p. 220). In this way one female may distribute her eggs over a number of plants. New (1991) states 'Larvae hide head-downwards between leaves in the centre of dense *Gahnia* clumps during the day and feed in the early morning, early evening or at night.' and that 'the pupa is suspended head-downwards, and commonly from the pendant outer foliage of the food plant. All early stages are green.' (p. 41). Thus the larvae and pupae are cryptic and difficult to find.

Larvae feed on a number of species of swordgrass, including *Gahnia clarkei* and *G. sieberiana.* A noted Australian lepidopterist, Dr D. P. Sands (*pers. comm.*) states that in Queensland swordgrass brown larvae do not survive on *G. sieberiana* during dry seasons and in periods of dry weather because of the hardness of the leaves under such conditions. *G. sieberiana* is thus a suitable host plant in Queensland only in normal wet seasons and months, when the leaves are softer.

## *4.0 METHODS*

Potential sites were selected from maps of the proposed Tugun Bypass, and at each of the sites visited, evidence of the presence of the giant dragonfly and the swordgrass brown was collected. Field surveys were conducted on 20 December 2000, 4 and 10 January 2001 and 22 February 2001. Searches were made for the following: adults of both taxa; burrows in the substrate; larval exuviae (the dried larval "skins" left clinging to vegetation after the adult dragonfly has emerged); substrate type (ideally, this should be peaty and somewhat moist); and for butterfly larvae of sheltering in clumps of *Gahnia* spp.

The number of hours spent in the field varied from site to site, with less time spent at sites which were unsuitable (for example, permanently dry sites for dragonflies or sites lacking *Gahnia* food plants for butterflies). The time spent looking for signs of the swordgrass brown approximated that spent looking for the giant dragonfly.

When transects were considered necessary, they were followed as far as possible into a site, with a return transect some 3−5 m from the first, repeating this procedure until the area had been thoroughly searched. Detours to left and right of the transect lines were necessary to investigate *Gahnia* clumps or interesting muddy pools. Linear sites did not require transects, for example, the drainage lines on Coolangatta Airport.

Field work was somewhat limited by rough terrain and dense lantana thickets particularly in the part of "Hidden Valley" south-west of the proposed Tugun Bypass. The field work was adequate in that all areas of interest in this survey were investigated.. However, the time of the survey was not satisfactory in regard to the flight season of the swordgrass brown. A further day was spent searching for this species in late February.

## *5.0 RESULTS*

Several areas containing suitable or potential habitat were identified along the proposed bypass. These are recorded on Figures 1-3 and are listed below in order of importance.

### 5.1 SUITABLE HABITAT

A temporarily dry swamp area, approximately 100 m south of the John Flynn Hospital and Medical Centre at Tugun, Queensland is shown at Site 1 (Figure 1).

This site was small and characterised by patches of swamp vegetation including swordgrass (*Gahnia clarkei*), bungwall fern (*Blechnum indicum*) and *Caustis sp. (?recurvata)*, as well as tall grasses and a stand of tall paperbark teatree (*Melaleuca quinquenervia*). Shrubs and small trees divided this habitat into separate "compartments". A surveyor's stake marked the centre of the roadway of the proposed Tugun Bypass, but this was an old marker and the proposed route had been moved approximately 80 m to the east. Three sightings were made of a petalurid dragonfly in this area; it was eventually collected as a voucher specimen, positively identified as *Petalura litorea* . That there were no further sightings after collecting the specimen suggests that the one specimen was observed three times. This is a potential (possibly current) breeding site, particularly in a year of normal rainfall, for both the giant dragonfly and the swordgrass brown.

A further search of this area on 22 February extended to the swamps along the western edge of Boyd Street and revealed much more potential habitat for the giant dragonfly. Numerous small sites, with fringing reeds, ferns and grasses, were found. The subsoil was damp. Although currently the surface is dry, in a normal wet summer these areas would be water-filled pools. The soil became moister towards the Boyd Street swamps until a teatree swamp was reached with many areas of surface water up to approximately 20 cm deep. The substrate was black mud, and the water was flowing almost imperceptibly from pool to pool. Although no giant dragonflies or their exuviae were seen, this an ideal habitat for the giant dragonfly.

*Gahnia clarkei* occurs widely in scattered patches, some quite large, at this site. A colleague, Dr John Moss, an authority on Australian cicadas and butterflies, accompanied me on the 22 February, and recorded the presence of 2nd instar larvae of the swordgrass brown butterfly in this search area. At this stage of development, the larvae are approximately 10 mm long and shelter head down in the centre of the swordgrass clump. They are green and have a bifid (forked) tail end.

An area in NSW bounded by the Tweed Heads Pony and Hack Club, the Tweed Heads Bypass and the Coolangatta Airport boundary, approximately north-west of the proposed Tweed Heads Bypass Interchange is shown at Site 2 Figure 1). A large patch of temporarily dry swamp habitat was found here, containing large paperbark teatrees, many swamp banksia (*Banksia robur*), *Gahnia sieberiana*, *G. clarkei* and coral fern (*Gleichenia* sp.). Of the swamp banksia, Williams (1979) states that it is '...one of the common plants of the "Wallum" heathlands and favours the wet areas of the heath.' (p. 28). This area is a potential habitat for the giant dragonfly and the swordgrass brown butterfly and was searched for approximately 5 hours.

A sandy 4WD track that effectively divided the swamp from drier, sandy, wallum country, ran off at right angles to the Tweed Heads Bypass boundary, crossing a surface-dry drainage line. In wet weather this would run water into the abovementioned swamp. Upstream, two small water holes containing "black" water typical of wallum areas, supported aquatic rushes, one of these being *Lepironia articulata,* which more commonly grows in water up to 2 m or more deep and often reaches approximately 2 m above the water. Beyond these the "creek" was dry. Immediately downstream from the track was an area approximately 4 m wide and 20 m long, with a small, shallow pool at its upper end. Club moss (*Lycopodium* sp.), a blue-flowered *Utricularia (?dichotoma*) and a smaller yellow-flowered species (?*U. exoleta*) grew profusely in what appeared to be dry soil. However, the soil was quite wet beneath the surface. Small shrubs bordered the watercourse and behind them taller shrubs and trees. Many burrows approximately 10–30 mm in diameter were found at this site, at the base of small reed clumps. Freshwater crayfish remains were found on the surface of this area, which, together with the large size of most burrows, suggested that the burrows were those of freshwater crustaceans. One burrow (approximately 10 mm diameter) was occupied by a specimen of the wallum froglet, *Crinia tinnula.* The water table was just beneath the sandy surface and the sub-soil was black and muddy. The smaller burrows extended no more than 100–150 mm below the surface and often two adjacent burrows were joined. No sign was found of the giant dragonfly either in the dry swamp or in the dry watercourse. This is a potential site for the giant dragonfly, but not for the swordgrass brown butterfly.

## 5.2 POTENTIAL SITES

Swamps located approximately south-east of the proposed Boyd Street interchange in NSW are shown at Site 3 (Figure 1). This site was visited over two days for a total of 7 hours.

With large muddy areas and some free water, combined with clumps of swordgrass and other aquatic plants, this swamp/bog habitat comprises possible giant dragonfly habitat. Comparatively shaded in places by paperbark teatree, the lower light intensity may detract from its potential as a suitable giant dragonfly habitat. However it should be ideal for the swordgrass brown butterfly. No giant dragonflies were seen, but a specimen of *Telephlebia (?cyclops*), a crepuscular (that is, flying at dusk) dragonfly was collected in a shady area a little way from the swamp and a female damselfly, *Austroargiolestes icteromelas nigrolabiatus*, was observed flying over a heavily shaded, shallow, muddy pool. Watson *et al.* (1991) state that the former inhabits 'streams, probably along margins' and the latter 'streams and rivers'. The discovery of both these species away from running stream habitats is unusual.

A further search (4.25 hours) was made of this swamp area on February 22 but there were no signs of the giant dragonfly. However, there is profuse growth of swordgrass and a similar muddy substrate to Site 1, with many pools of water. The stream dwelling species noted above were observed again. It is considered to be a potential breeding habitat for both the giant dragonfly and the swordgrass brown butterfly. Dr Moss recorded 2nd instar larvae of the butterfly at this site.

A shallow, boggy soak in a drainage line near the southern end of Runway 32 at the Coolangatta Airport on Commonwealth land is shown as Site 4. Sites on the Coolangatta Airport were searched for approximately 4 hours.

This site supported many blue-flowered Christmas candles (*Burmannia disticha*) as well as many *Utricularia* spp. The banks of the drainage line sloped up to shrubs approximately 3 m in height, providing suitable perching sites for adult giant dragonflies, which often take shelter in such vegetation. This comprises a rather open area, but a possible habitat for the giant dragonfly. Burrows seen in the muddy ground were excavated but all were shallow and empty. Some *Gahnia* was present but the site is not thought to be suitable butterfly habitat.

### 5.3 UNSUITABLE HABITAT

A number of sites encountered were not considered to provide suitable habitat for giant dragonflies.

A pond in the drainage line near Gate 19 on Coolangatta Airport near the Cobaki Broadwater (Site 5, not shown). Plenty of fringing vegetation offered shelter to small species, and water lilies provided oviposition sites for damselflies. Six species of Odonata (dragonflies) were flying over this site.

The drainage line near Runway 35 on Coolangatta Airport (Commonwealth land) was shallow, with muddy substrate and fringing vegetation (Site 6, Figure 3). This site is exposed but there is a small possibility that it provides habitat for giant dragonflies.

An artificial lagoon (a rehabilitated sand-mining site) north of the NSW–Queensland border and west of the Tweed Heads Bypass is shown as Site 7 (Figure 2). This site harboured four common and widespread species of Odonata. Aquatic vegetation was sparse, with some floating, emergent and fringing species present.

A site in the western section of the 'Hidden Valley' area between Stewart Road and Boyd Street and entered via Mirreen Drive is shown as Site 8 (Figure 1). It was visited on 2 different days for 4 hours, but was found to be unlikely to support either the giant dragonfly or the swordgrass brown. However areas further to the south-west may be more suitable.

## *6.0 SUMMARY*

Results of the survey are summarized in Table 1 below:

Table 1: Summary of dragonfly and butterfly records during survey.

| Site Number | Number of Individuals Found | | Suitability of Habitat[1] |
|---|---|---|---|
| Dragonfly | Adult | Larvae | |
| 1 | 1 | 0 | 1 |
| 2 | 0 | 0 | 2 |
| 3 | 0 | 0 | 2 |
| Butterfly | Adult | Larvae | |
| 1 | 0 | 6 | 1 |
| 2 | 0 | 0 | 2 |
| 3 | 0 | 5 | 1 |

[1] 1 = highly suitable; 2 = suitable

The Queensland Giant Dragonfly was recorded from a potential breeding site in Queensland in the Stewart Road to Boyd Street section, south-west of the John Flynn Hospital and Medical Centre. This is possibly the first record of this species from the Gold Coast area for nearly 60 years. A specimen in the Queensland Museum was collected at Burleigh Heads in 1933 (Theischinger 1999) (p. 160) and there is a record of another Burleigh Heads specimen collected in 1942 (NSW National Parks and Wildlife Service 1999, p. 5). No other sightings were made of *P. litorea*. However, potential breeding sites occur in NSW (Site 2), in Queensland (Sites 1 and 3) and in Commonwealth land (Site 4).

There was no indication in January that the swordgrass brown butterfly occurred at any of these sites even when its preferred host plant, *Gahnia clarkei,* was present. The absence of butterfly adults could be explained by its bivoltine (that is, completing 2 generations in one year) nature; in the case of the swordgrass brown according to Braby (2000), a spring generation flying in September and October and a summer-autumn generation in February, March or April (p.525).

A further survey was made in late February in favourable habitats near the Queensland–NSW border, including the swamps to the south-east of Boyd Street and to the south-west of the proposed Tugun Bypass; and at Site 1. Swordgrass brown larvae were found at both sites. Dr D. P. Sands, an expert lepidopterist and most reliable authority confirms the presence of another colony of this presumed extinct species at Jacobs Well, Queensland.

## *7.0 POTENTIAL IMPACTS*

Proposed bypass construction may remove some potential habitat for giant dragonflies south-west of the John Flynn Hospital and Medical Centre. However, suitable habitat extends to the east-south-east and beyond Boyd Street, into NSW. The proposed Tugun Bypass would have a barrier effect, particularly for male giant dragonflies. As individuals usually fly at 1–2 m above ground level, fast-moving traffic, particularly high commercial vehicles would potentially cause mortality of individuals. Without carrying out surveys of a giant dragonfly habitat over a number of flight seasons it is not possible to predict flight patterns. However, when searching for a mate, the male dragonfly would, from observations on North Stradbroke Island, cruise over most, if not all, of the suitable habitat. The swordgrass brown butterfly would possibly face the same danger although I have usually seen them flying only in the vicinity of their food plant with females seeking oviposition sites and males searching for females.

It is understood that:

- water table levels in Hidden Valley and in swamp habitat bordering Boyd Street are unlikely to be affected by the proposal;
- any drainage impacts would be minimized during construction; and,
- sub-surface and surface water flows would be re-established and maintained during operation of the bypass.

Given that any hydrological impacts associated with the proposal would be minimised and that surface and sub-surface water flows should be maintained at existing levels, there are unlikely to be any significant impacts to dragonfly and butterfly habitats.

## 8.0 RECOMMENDATIONS

The following recommendations would act to minimize impacts to the giant dragonfly and swordgrass brown butterfly:

- Direct and indirect impacts to Sites 1, 2 and 3 should be avoided.
- No draining or filling of *Gahnia* or *Melaleuca* swamp habitats should be undertaken;
- Mitigation measures should be applied in particularly steep and sensitive gullies such as that overlooking the John Flynn Hospital and Medical Centre, to minimize any alterations to drainage flows; and,
- Trees and shrubs of varying heights should be planted along the edges of the bypass to provide perching sites for dragonflies.

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DENISS M. REEVES
30 BRAMSTON TERRACE
HERSTON QLD 4006

# Appendix K

Tugun Bypass Proposal – *Aquatic Flora and Fauna* (FRC Environmental 2001)

# Tugun Bypass Proposal

## Aquatic Flora and Fauna

FRC Ref: 00.01.02

## Document Control Summary

FRC Environmental
185 Main Road,
Wellington Point Qld 4160

Telephone: (07) 3207 5135
Fax: (07) 3207 5640

**Project No.:** 00.01.02 / 01.01.01
**Status**: Final Report
**Project Manager**: John Thorogood

**Title**: Tugun Bypass Proposal: Aquatic Flora and Fauna

**Authors:** J. Thorogood, C. Conacher and T. Boggon

**Client**: PPK Environment & Infrastructure Pty Ltd

**Client Contact**: Alan Irving / Allison Rushton / Khaalyd Brown

**Client Reference**: 83M081A-LT010Agr:amk (dated 8th August 2000) and subsequent correspondence.

**Synopsis**: This report contributes to the Tugun Bypass EIS and EMP through the description of estuarine flora and fauna and freshwater fishes and macroinvertebrates in the vicinity of the proposed route; the consideration of potential impacts; and of means to mitigate impacts.

Document Record

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# Tugun Bypass Proposal

## Aquatic Flora and Fauna

*Prepared for:*

**PPK Environment & Infrastructure Pty Ltd**

*Prepared by:*

**FRC Environmental**
185 Main Road
Wellington Point, Qld 4160

Phone: (07) 3207 5135
Fax: (07) 3207 5640

Contact: Dr John Thorogood / Carol Conacher

FRC Ref: 00.01.02 / 01.01.01
Date: April 2001

# Summary


## Introduction

This report has been commissioned by PPK Environment & Infrastructure as a contribution to the development of the Environmental Impact Statement for the proposed Tugun Bypass.

This report considers three principal foci of potential impact: the coastal wetlands fringing Cobaki Creek and adjacent to the airport, the aquatic flora, fauna and fisheries of the Cobaki Creek and Broadwater; and the freshwater fish fauna of drainages and water bodies in the immediate vicinity of the proposed route. These foci are addressed through the description of communities, of environmental values; and the consideration of potential impacts associated with both the construction and use of the proposed bypass.

## Wetland Communities

Estuarine wetlands in the region are mainly associated with the Tweed Estuary which consists of a number of bays, islands and broadwaters including the Cobaki Broadwater. The entire Cobaki Broadwater is fringed by mangroves; saltmarsh communities occur to landward. Seagrass in the Tweed estuary suffered significant declines in the 1960s and 70s, but is currently stable.

The 1999 Route Selection Report identifies a number of wetlands listed under the NSW State Environmental Planning Policy (SEPP) 14, that occur in the vicinity of the proposed development. SEPP Wetland No. 5a fringes the north-eastern shores of Cobaki Creek and lies immediately adjacent to the airport. Development of the preferred option (C4) would encroach (albeit below ground level) upon the defined landward boundary of this wetland by 27m and within approximately 25m of the landward boundary of the estuarine wetland floral community. The floral communities of Wetland 5a, and adjoining wetlands are described; the seagrasses of the Cobaki Broadwater are described. The ecological significance of estuarine wetlands is discussed.

**Water Quality of the Cobaki Broadwater**

Waters of the Cobaki Broadwater are of near oceanic salinity (except during periods of flood), with healthy concentrations of dissolved oxygen and little stratification. Concentrations of ammonia and ortho-phosphorus on occasion exceed ANZECC guidelines.

**Fish and Fisheries of the Cobaki Broadwater**

The Tweed estuary supports important recreational and commercial fisheries, and is recognised as one of the highest producing rivers for both finfish and crustacea within the northern estuaries of NSW. The Cobaki Broadwater is a substantial component of the Tweed system and directly contributes to both the recreational and commercial catch from the Tweed.

Fish species commonly caught by recreational anglers within the Cobaki Broadwater include whiting, flathead, bream, mangrove jack, garfish, trevally, herring and mullet. Bloodworms (for bait), prawns and mud crabs are also taken. The Broadwater, and in particular areas of seagrass, is likely to be an important nursery area for several of these species to be a significant breeding ground for fish. The importance of estuarine habitats for fish and invertebrates is discussed.

**Freshwater Fishes of Habitat that May be Impacted**

Freshwater bodies (streams, channels, pools and a lake) in the vicinity of the airport and the Broadwater support a depauperate community of regionally common native fish species, dominated by the introduced mosquito fish.

**Potential Impacts of the Proposed Development**

The development of the proposed road and rail infrastructure is unlikely to result in the loss of any wetland floral communities or habitat critical to the survival of any species of fresh water or estuarine fish. However, care will need to be taken during the construction phase as the corridor in places encroaches upon the boundary of SEPP 14 wetlands. The NSW Fisheries publication 'Policy and Guidelines for Bridges, Roads, Causeways, Culverts and Similar Structures, 1999', provides broad guidelines for impact mitigation and the proposal's water quality engineers provide a number of site specific recommendations.

The consequence of altered flood levels and durations of inundation are unlikely to have any significance with regard to the regions aquatic ecology.

Where 'best practice' surface water quality management is implemented during both construction and operation, the proposed development would be unlikely to significantly impact upon the water quality of either the Cobaki Broadwater or the freshwater streams and lakes to the west and south of the airport. Within the Broadwater, seagrass meadows are most at risk from any increase in concentrations of suspended solids and to a lesser degree, nutrients. Any increase in suspended solids is likely to affect the seagrasses' ability to photosynthesise, and thus contribute to a reduction in its depth distribution and vigour. The waters of the Broadwater currently carry relatively high concentrations of nutrients: the growth of macrophytes and phytoplankton is probably rarely nutrient-limited.

Where 'current best practice' technologies are employed during development and operation, a high proportion of suspended sediments, adsorbed metals, nutrients and hydrocarbons might be expected to be trapped before they are carried to the Broadwater. All practical measures to minimise the transport of contaminants from the roadway reaching the Broadwater should be implemented. Appropriate site management during construction can avoid the oxidation of potential acid sulfate soils disturbed by surface engineering works. However, oxidation that may result from the lowering of the water table may contribute to the leaching of acidified waters (and mobilised metals) to the Broadwater through the groundwater. If unmanaged, acid-related impacts may be significant, resulting in finfish and shellfish mortalities over a wide area: it is recommended that reliable strategies are developed to ensure acidified waters do not reach the Broadwater or tributary water courses.

The temporary lowering of the groundwater may also impact upon the freshwater wetlands to the west and south-west of the airport, and saltmarsh communities to the south-east, in effect simulating severe drought conditions (where little rainfall is experienced). However, this impact would be transitory, and as the water table rose post-construction, the wetland and its associated fauna could be expected to rapidly recover.

# Contents

# 1 Introduction

## 1.1 Background to this Study

This report was commissioned by PPK Environment & Infrastructure as a contribution to the development of the Environmental Impact Statement for the proposed Tugun Bypass.

This report considers three principal foci of potential impact: the coastal wetlands fringing Cobaki Creek and adjacent to the airport, the aquatic flora, fauna and fisheries of the Cobaki Creek and Broadwater; and the freshwater fish fauna of drainages and water bodies in the immediate vicinity of the proposed route. These foci are addressed through the description of communities, of environmental values and the consideration of potential impacts associated with both the construction and use of the proposed bypass.

## 1.2 Approach and Methodology

This report has been prepared following an extensive review of the literature; reference to historical air photographs; consultation with government agencies community groups, local residents and airport staff, and fishers (refer Table 1); and field surveys. All field surveys were undertaken between September 2000 and January 2001.

Table 1. People and organisations consulted with respect the habitat stability, and the fish and fisheries of the Cobaki Broadwater.

| Name | Business / Organisation/ Department | Phone Number |
|---|---|---|
| Alan Legrnd | Fisheries Officer - NSW Fisheries | 07 5523 1822 |
| Sarah Fairfull | Senior Conservation Manager – NSW Fisheries | 02 6686 2018 |
| Alan McDonald | Tweed Bait Pty Ltd | 07 5524 4466 |
| Adrian Saunders | Anglers Warehouse | 07 5536 3822 |
| Susan Ridings | Tweed River Bait and Tackle | 07 5599 5520 |

| Name | Business / Organisation/ Department | Phone Number |
|---|---|---|
| Betty Beasly | Twin Town Services Fishing Club | 07 5524 7053 |
| Graham Poile | Recreational Fisher – Anglers Warehouse | 07 5536 3822 |
| Kerry Vardy | Recreational Fisher | 0407 630 356 |
| Graham Tully | Commercial Fisher | 02 6674 1285 |
| David Smith | Estuary Delegate for the area: mediator between NSW Fisheries and commercial fishermen | 0418 452 527 |
| Dan Boyd | Airport Foreman, Coolangatta Airport Ltd. | 0407 372 741 |

**Beam Trawl Survey**

Whilst consultation provided a substantive description of the fishes caught by recreational and commercial fishers from the Broadwater, a beam trawl survey was undertaken during the current study (10 and 11 October 2000) to describe the juvenile finfish, crustacea and molluscs associated with the dominant habitats of the Broadwater. Replicate trawls of approximately 150 m were taken at four locations encompassing reaches below the Broadwater, adjacent to the SEPP 14 Wetland 5a, and within the Broadwater proper (Figure 1.). These sites included both bare substrates adjacent to fringing mangroves and substrates supporting dense *Zostera capricorni* (eel grass). The depth of loose fine sediments at the mouth of the Broadwater proper (Figure 1), prevented the successful collection of specimens from this site.


Figure 1. Location of beam trawl sites.

Whilst most fishes captured were familiar to the authors, reference was also made to a number of 'field guides' (Grant 1991; Hutchins and Swainston 1986).

**Survey of Freshwater Fishes**

In response to concerns expressed by NSW Fisheries, surveys were conducted of a number of water bodies on, or in the immediate vicinity of the C4 route. These surveys involved the use of set nets, dip nets and baited traps. Survey sites are shown in Figure 2. The survey of these sites were undertaken over a three day period (locations 1 to 4, 7 and 8 December 2000; 5 and 6, 11 January 2001), with nets and traps being set from early afternoon to approximately 1hr past last light on each day.


Figure 2. Drainage lines and water bodies surveyed (numbered) for freshwater fishes.

Whilst most fishes captured were familiar to the authors, reference was also made to Merrick and Schmida's (1984) 'Australian Freshwater Fishes'.

### 1.3 Survey of Macro-invertebrates

Small, fine mesh (approx. 1mm) baited traps were set in each water body surveyed: these traps have proved highly effective at attracting and trapping yabbies, a variety of prawns and freshwater crabs.

Dip net samples were taken only from the relatively natural stream to the west of the airport and landfill (sites 5 and 6). The dip net used was of triangular shape (approx. 350mm x 350mm x 350mm) and made of 250µm mesh. Within the upstream pool close to the Tugun Landfill, and within reaches of the creek immediately upstream of its crossing of Tandy's Lane, 3, 10m long 'scoops' were taken. Given the narrow width of the stream, these 'scoops' collected fauna associated with the leaf litter of the stream bed (the predominant stream habitat), the vegetation of the banks and also associated with the small snags present: it was not practical to discriminate between these micro-habitats (as it would be in a larger body of water). Each sample collected was returned to the laboratory frozen, and sorted under a low-power dissecting microscope. Invertebrate fauna was identified to Family level using published keys and FRC's reference collection.

### 1.4 Water Quality

Basic water quality parameters (pH, dissolved oxygen (DO), salinity/conductivity, turbidity and temperature) were recorded in January 2001, from each water body surveyed, in order to characterise those water bodies and assist with the interpretation of biological sampling. An Horiba U10 multi-probe water quality analyser was used.

# 2 Wetland Communities

## 2.1 Introduction

Estuarine wetlands are coastal communities that are at least occasionally inundated by saline to brackish waters. They are usually most extensive along sheltered parts of the coast. Estuarine wetlands consist of mangrove, saltmarsh / rush and seagrass communities. All plants growing in these communities are tolerant of, or require, saline soils (AS Murray & Associates 1995).

Estuarine wetlands in the region are mainly associated with the Tweed Estuary which consists of a number of bays, islands and broadwaters including the Cobaki Broadwater. Cobaki and Terranora Broadwaters flow into Terranora Creek, which flows into the Tweed River approximately two kilometres south of the mouth.

Prior to European settlement it is likely that virtually all of the coastal plain of the Tweed Shire was covered with an extensive system of wetlands, however the majority of these wetlands have been cleared and drained, with only a small proportion left undisturbed (Brookehouse 1983). Construction of seaways, training walls and groins, and input of sediment and nutrients from terrestrial sources has also modified habitats in the Tweed Estuary (Kingston and Storey 1998). The conservation status of mangrove and saltmarsh communities within the Tweed Shire is considered to be inadequate (Storey and Kingston, 1998).

## 2.2 Estuarine Wetlands of the Tweed Estuary and Cobaki Broadwater

There are approximately 309ha of mangroves, 44ha of saltmarsh and 3ha of seagrass associated with the Tweed River (West et al 1985; Pressey and Griffith 1987). These floral communities are each protected under Section 7 of the *Fisheries Management Act 1994.*

There are substantial areas of mangroves in the Tweed Estuary, fringing the islands and shore (Storey and Kingston 1998). In the lower Tweed River there are large mangrove stands on the islands in Terranora Inlet and in the Cobaki and Terranora broadwaters. The entire Cobaki Broadwater is fringed by mangroves, with mangroves also densely covering the few islands of the Broadwater that were created with dredge spoil in the late 1900's (Figures 5 and 6).

There are five species of mangroves in the Tweed River: *Avicennia marina* (grey mangrove), *Rhizophora stylosa* (red mangrove), *Aegiceras corniculatum* (river mangrove), *Bruguiera gymnorrhiza* (large leafed orange mangrove) and *Excoecaria agallocha* (blind your eye mangrove), and the mangrove fern *Acrostichum speciosum,* each of these are found around the Cobaki Broadwater. *Rhizophora* and *Bruguiera* in the Tweed River are near their southern limit, with *Rhizophora* extending south to Corindi Creek and *Bruguiera* to the Clarence River (West et al. 1985).

Saltmarsh vegetation includes shrublands, sedge and rush swamps and grasslands (Adam, 1981). Along the Tweed estuary there are three main saltmarsh communities: *Sporobolus virginicus* (saltcouch) / *Sarcocornia quinqueflora* (samphire) / *Suaeda australis* associations; *Juncus kraussii* (sea rush) and *Baumea juncea* (bare twig rush). All three saltmarsh community types are represented within the study area. The salt couch / samphire association is generally at the mangrove or seaward edge of the saltmarsh, it grades into the sea rush community and finally into the twig rush community at the upper extremity of tidal action. Boundaries between associations are often diffuse and do not always follow this sequence (Pressey and Griffith 1987; Murray & Associates 1995).

Seagrasses are flowering plants that grow in the intertidal zone and subtidally. Like all plants, seagrasses require light to photosynthesise. Light reaching seagrass beds can be reduced by adding or resuspending fine sediment in the water column, or indirectly through enhanced nutrient levels which increase phytoplankton density (Shepherd et. al , 1989). In nearby Moreton Bay, mean total Kjeldahl nitrogen levels in the water column below 21µM, chlorophyll-a levels below 1.0 $\mu g\ L^{-1}$ and total mean suspended solids below 10 $mg\ L^{-1}$ are necessary for the survival of *Zostera capricorni,* the dominant species in the Tweed Estuary (Abal and Dennison 1996).

There are two species of seagrass in the Tweed Estuary: *Zostera capricorni* (eel grass) and *Halophila ovalis* (paddle weed) (West et al. 1985; Department of Public Works 1991). *Halophila ovata* may also be present (Department of Public Works 1991). *Zostera capricorni* is the dominant species, and in general *Halophila ovalis* has only been recorded from the more sheltered areas in the lower Tweed Estuary (Department of Public Works, 1991). The area of seagrass in the lower Tweed Estuary is increasing following a significant decrease from the 1930's to 1976 (Department of Public Works 1991).

The Cobaki Broadwater was identified in the Lower Tweed Estuary Management Plan as an area of high scenic and ecological value (Department of Public Works 1991). In 1996 the Tweed Shire Council and the Tweed River Management Plan Advisory Committee prepared a management plan for the Broadwater which had a strong focus on the preservation and enhancement of valuable habitats within the Broadwater, whilst encouraging sensitive and low key levels of recreational activity and environmental education (Tweed Shire Council 1998).

### 2.3 SEPP 14 Wetlands

State Environmental Planning Policy (SEPP) 14 (Coastal Wetlands) was created in 1985 to conserve wetlands in the face of escalating development on the coast, especially the north coast (Environment Protection Authority, 1997). Wetlands listed under SEPP 14 are regarded as being of state significance. Proposals to destroy, damage or modify SEPP 14 wetlands (as delineated on SEPP 14 maps) require consent from the relevant local council and the concurrence of the Director-General of DUAP. SEPP 14 takes precedence over other planning instruments (EPA 1997).

In the Tweed Shire approximately 1, 862ha of land, or 1.4% of land in the Shire protected by SEPP 14, with over 42 SEPP 14 units mapped in the Tweed Estuary (Kingstone and Storey 1998; Department of Urban Affairs and Planning 1986). Most of the SEPP 14 wetlands in the Tweed Estuary are dominated by mangroves and saltmarsh, however some such as SEPP 14 No. 1 to the west of Cobaki Broadwater are dominated by *Melaleuca quinquenervia* (broad leaved paper bark) and others, such as SEPP 14 No. 18c, by sedgelands and rushlands (Ecograph 1999; Department of Urban Affairs and Planning 1986).

The 1999 Route Selection Report (Connell Wagner 1999) identifies a number of wetlands listed under the NSW State Environmental Planning Policy (SEPP) 14, that occur in the vicinity of the proposed development. SEPP Wetland No. 5a fringes the north-eastern shores of Cobaki Creek and lies immediately adjacent to the airport (Figure 3).

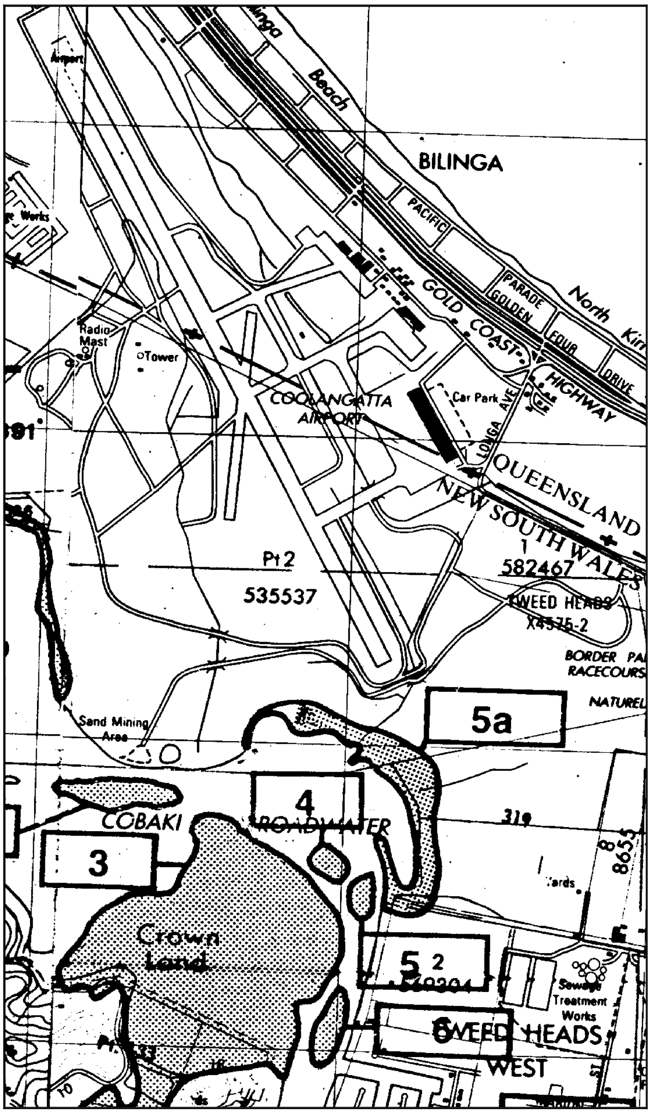


Figure 3 Location of SEPP 14 Wetlands in the vicinity of the Cobaki Broadwater (Supplied by DUAP, April 2001)

Development of the preferred option (C4) would encroach (albeit below ground level) upon the defined landward boundary of this wetland by 27m (DUAP 1986; *pers. comm*. Ms Di Yeates DUAP, 2001) and within approximately 25m of the landward boundary of the estuarine wetland floral community as mapped in our September / October 2000 survey (Figure 4).

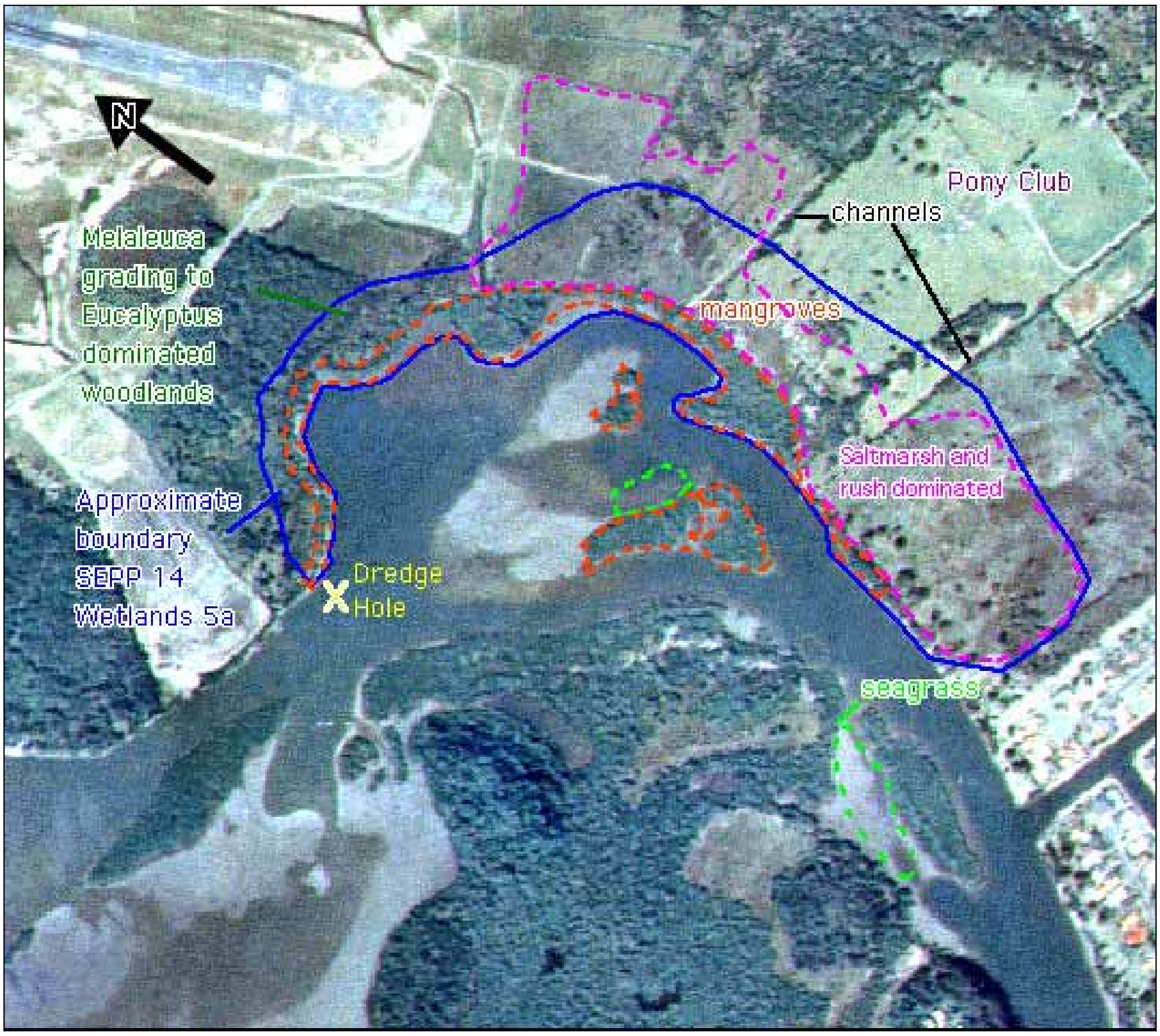


Figure 4. Tugun Bypass study site vegetation communities.

The legislation and regulations relating to SEPP 14 wetlands only apply over NSW land (R. Bali, PPK Environment and Infrastructure, pers. com.): in the vicinity of the Cobaki Broadwater the bypass is proposed to be developed partly within Commonwealth lands.

## 2.4 SEPP Wetland No. 5a and Estuarine Wetlands Close to the Proposed Development

On the eastern side of the Cobaki Broadwater near the Tweed Heads Pony Club there is a 2 to 3ha saltmarsh community (Figure 3) (Department of Public Works, 1991). This saltmarsh community lies entirely within SEPP 14 Wetland 5a. The saltmarsh community is dominated by the salt-tolerant *Sporobolus virginicus* (salt couch) with scattered clumps of *Juncus kraussii* (sea rush) and *Baumea juncea* (bare twig rush) (Figure 5). Other species include *Suaeda australis* (sea blite), *Sarcocornia quinqueflora* (samphire), *Sesuvium portulacastrum* (sea purslane) and *Phragmites australis* (common reed).

Off-road vehicle traffic has degraded the landward edge of this saltmarsh, causing soil compaction and ponding of water. At the landward edge of the saltmarsh, the introduced species *Baccharis halimifolia* (groundsel) forms dense thickets amongst stands of juvenile *Casuarina glauca* (swamp oak). There are also groundsel saplings scattered throughout the saltmarsh.

Two substantial channels constructed prior to 1975, run east-west through the saltmarsh (Figures 4 and 5). The northern channel is bordered by a narrow and discontinuous band of *Avicennia marina* and *Aegiceras corniculatum* saplings. Sparse *Casuarina glauca* and *Hibiscus tileaceus* (cotton tree) also exist along this channel. A series of minor channels have also been constructed to the north of the northern channel to assist in draining the saltmarsh and rushlands. These minor channels are visible in air photos from the late 1980s, and continue to influence the distribution of flora. Construction of the major north-south runway appears to have resulted in the loss of a small area of saltmarsh prior to 1959.

The seaward extent of SEPP 14 Wetland 5a is fringed by mangroves. Each of the species recorded from within this Wetland are also common throughout the region. The seaward edge of the mangrove forests of Cobaki Broadwater (including Wetland 5a) is composed of *Rhizophora* and *Avicennia*, with sparser *Bruguiera*, *Excoecaria*, and *Acrostichium speciosum* to landward. Within the mangrove communities there are shallow tidally inundated pools (Figure 8). *Melaleuca quinquenervia* (swamp paperbark) and *Casuarina glauca* (she oak) dominated communities, often with dense clumps of *Acrostichium*, separate the fringing mangroves from coastal wallum, eucalypt-dominated woodlands and grasslands (Figures 9 and 10). FRC field surveys and recent aerial photographs indicate that these 'terrestrial' floral communities (coastal wallum, eucalypt-dominated woodlands and grasslands) commence well within the landward boundary of Wetland 5a.

Figure 5.

Saltmarsh community to the north of the channel

Figure 6.

Mangrove communities fringing Cobaki Broadwater

Figure 7.

Mangrove communities fringing Cobaki Broadwater

Figure 8.

Tidally inundated pools amongst the mangroves

Figure 9.

Melaleuca forests with dense understory of *Acrostichium*

Figure10.

Eucalypt-dominated woodlands

At its closest point, the infrastructure of Coolangatta Airport (the south-western corner of security fencing enclosing the main runway) is approximately 75m from what appears to be the artificially truncated landward edge of the mangroves fringing the shores of the Broadwater (Figure 4). The designated boundary of Wetland 5a is approximately 20m beyond the airport's perimeter fence, encompassing a large area of grassland and rushes.

Historical aerial photographs indicate there has been a change in the distribution of mangrove communities in the immediate vicinity of the airport since 1959 (Figures 11a, b). In places, siltation has resulted in the seaward expansion of mangroves; whilst agricultural clearing has resulted in the loss of all but the riparian fringe along the northern bank above the Broadwater. For much of the shoreline of the Broadwater, the mangrove fringe is only a few metres wide, however, immediately adjacent to the airport the mangrove community is approximately 50m wide. Immediately adjacent to the end of the runway, a track of approximately 5m wide has been cleared through the mangroves to the waters edge. This clearing appears to be recent (perhaps 18 – 30 months ago) based on the size of seedlings within the clearing. The mangrove communities appear to be healthy, with many mature trees, saplings and seedlings.

Throughout the wetlands adjoining the southern and south-western boundary of the airport (within Wetland 5a), the mangrove community appears to be progressing landward at the expense of melaleuca-dominated communities.

Recently dead (5 – 10 yrs?) mature *Melaleuca* trees are surrounded by mangrove seedlings. There are also abundant *Melaleuca* saplings further landward where the characteristic gnarled roots of the coastal banksia indicate mature banksia once grew. Dredging of the Tweed estuary and of the Broadwater may have resulted in increased tidal amplitude within the Broadwater; or development of the airport may have increased low level runoff to the Broadwater and the extent of freshwater inundation of the supra-littoral zone, with a resulting change in structure of the floral communities. The deposition of flotsam and jetsam clearly indicated that the level of recent tidal inundation exceeds the level of tidal influence on flora. Perhaps maximum tidal inundation occurs coincident with flood conditions that significantly dilute the salinity of the Broadwater (and thus the waters fail to have the characteristic estuarine influence on floral communities). Beyond the region of the southern end of the runway, development appears to have had little direct impact on the fringing mangroves of the Broadwater.

Seagrass distribution in the Cobaki Broadwater is limited to a number of subtidal patches in the entrance (Figure 4), and is composed solely of large (river) morphology *Zostera capricorni*. Historical aerial photography indicates there was a substantial and rapid reduction in the distribution of seagrasses within the Cobaki Broadwater and throughout the rest of the Tweed in the mid 1960s. This loss was most likely the result of a combination of extensive dredging and extensive catchment development (Department of Public Works 1991). The distribution of seagrass in the Cobaki Broadwater has remained relatively constant since the late 1960s, with seagrasses restricted to a few patches in the entrance (Figure 11).

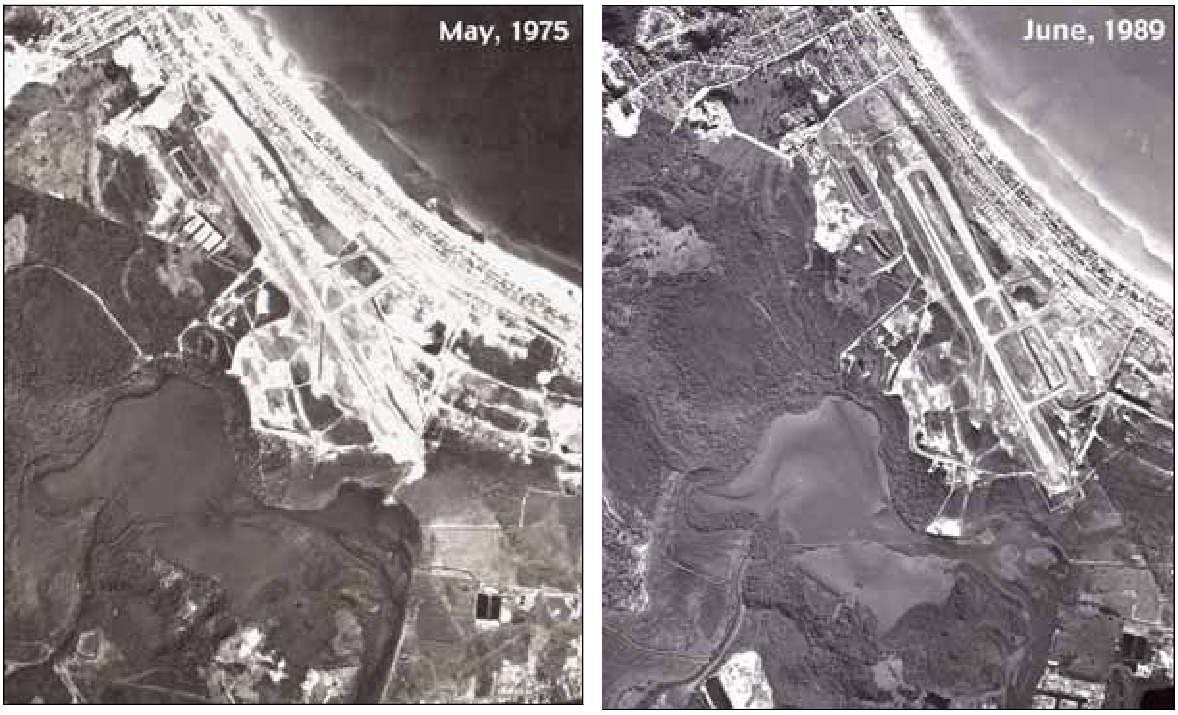


Figure 11. Aerial photography of the Cobaki Broadwater: (a) May 1975; (b) June 1989.

## 2.5 The Ecological Significance of Estuarine Wetlands

The majority of commercially and recreationally important species of fish from eastern Australia depend upon estuarine environments for part or all of their life cycle (Quinn 1992; Pollard 1976). Shallow water and intertidal habitats are amongst the most productive environments for fisheries (Quinn 1992). In addition estuarine wetlands are important habitats and food sources for a variety of terrestrial and avian fauna including conservationally significant species such as the false water rat, migratory species and species listed under International agreements such as JAMBA and CAMBA. Wetland habitats are also important retreats for fauna in adverse conditions such as drought and fire.

### Mangroves

Mangroves are flowering plants that have special adaptations enabling them to live in the intertidal area. They are an important component of the estuarine habitat because they:

- input significant amounts of vegetable matter into the food chain. Leaves, fruits, wood and bark fragments fall either directly into the water or to the ground. As these components decompose, they provide both soluble nutrients and detrital fragments, which are eaten by crustacea such as prawns and crabs and some fish. Bacteria and fungi also feed on the decomposing matter and in turn are eaten by higher order organisms (West, 1985). Mangrove fruit are also eaten by the green turtle (*Chelonia mydas*) an endangered species;
- trap, accumulate and release nutrients (and in some cases pollutants) and particulate matter (silt) from surrounding land, thus acting as a buffer to the direct effects of runoff (West 1985);
- provide a habitat or shelter to a range of fauna and flora (e.g. Morton, et al., 1987). Mangroves provide roost sites for bats, waders and other birds (e.g. Driscoll 1990), and the sediments in which they grow typically support both a high diversity and abundance of fauna. Many species of algae and 'terrestrial' epiphytes are commonly found in association with mangrove communities. The creeks which wind through large mangrove forests are also important as fish habitat; and
- mangroves protect the shoreline from erosion emanating either from the water (waves, boat wash) or the land (runoff) and contribute to the establishment of islands and the extension of shorelines (Blamey 1992).

### Saltmarsh

Saltmarsh plants grow on tidally inundated ground to landward of mangroves. Saltmarsh communities and the role they play in the broad ecology of estuaries are perhaps the least well understood of the intertidal communities, particularly in Australia. However they are thought to have the following important roles:

- stabilisation of bare mud flats. Algae frequently colonise first forming mats over the bare mud. The mucilaginous nature of the algae stabilises the sediment surface, enabling colonisation by other (saltmarsh) plants. Sediment is then trapped by the leaves of these plants, causing a gradual buildup of sediment. The binding of sediment by plant roots also probably confers some resistance to erosion (van Erdt 1985; cited in Adam 1990);
- remineralisation of terrestrial and marine debris: saltmarshes contribute to the nutrient cycling of estuaries, and may buffer the water bodies from excess nutrients from the land (Adam 1990);
- provision of a direct food source for terrestrial, avian and marine fauna; and
- provision of habitat for terrestrial, avian and marine fauna, including migratory species and species protected under international treaties such as JAMBA and CAMBA. The false water-rat (*Xeromys myoides*) is found in areas of saltmarsh dominated by reeds and rushes.

Bird roosting and foraging sites in the Cobaki Broadwater are among the most important sites on the Tweed for both migratory and non-migratory birds, with both a high diversity and abundance of birds using these areas (Department of Public Works 1990). The saltmarsh in SEPP 14 Wetland 5a provides an important roosting habitat for migratory (e.g. eastern curlew, whimbrel, bar-tailed godwit etc.) and non-migratory (e.g. egrets, herons, ibis etc.) shorebirds (Department of Public Works 1990). The roost site adjoining the drain on the east side of the Cobaki Broadwater (Figure 1) is particularly important for the Lesser golden plover (Department of Public Works 1990). The mudflats within the study area are important shorebird and other wader foraging areas (Department of Public Works 1990).

### Seagrass

Seagrasses are protected in Queensland under the *Fisheries Act 1994* and *Regulation 1995* and in NSW under Part 7 of the *Fisheries Management Act 1998*. They are significant primary producers (Hillman et al 1989), and have a critical role in coastal marine ecosystems (Poiner and Roberts 1986; Hyland et al 1989). Seagrasses perform the following functions (from Poiner et al 1992):

- provide shelter and refuge for resident and transient adult and juvenile animals, many of which are of commercial and recreational importance (Howard et al 1989; Hutchings 1982);
- trap, stabilise and hold bottom sediments (Fonseca and Kenworthy 1987);
- slow and retard water movement promoting sedimentation of particulate matter and inhibiting resuspension of organic and inorganic matter (Philips and Menez 1988);
- supply and fix biogenic calcium carbonate (den Hartog 1970);
- produce and trap detritus and secrete dissolved organic matter that tends to internalise nutrient cycles within the system (Moriarty et al 1984);
- provide large amounts of substrate for encrusting animals and plants (Harlin 1975); and
- provide a food source for some species of fish and crustacea (Coles and Lee-Long 1985; Lanyon et al 1989; Staples et al 1985; Young 1978).

Within the Cobaki Broadwater, surveys undertaken as part of this study have shown that areas of seagrass support a far higher diversity and abundance of fishes, than bare substrate.

# 3 Water Quality of the Cobaki Broadwater

Salinities within the Cobaki Broadwater are near oceanic (36 ppt), except during periods of flood. pH and dissolved oxygen are typically within the ANZECC Guidelines (1992, 1999). Throughout the Broadwater there is no stratification in temperature or pH, except within the Cobaki Dredge Hole (Figure 4), where there is slight temperature, salinity and turbidity stratification of the water column. Here, bottom waters were cooler, less saline, lower in dissolved oxygen and more turbid than surface waters (Department of Public Works 1991). This stratification is likely to be intermittent and of short duration, however these conditions are correlated to an impoverished benthic fauna within the dredge hole (Department of Public Works, 1991).

Water quality sampling undertaken by others as a component of the EIA indicate that the waters of the Cobaki Broadwater in the vicinity of the airport are characterised by concentrations of ammonia and ortho-phosphorus exceeding ANZECC guidelines (ANZECC 1992) – though not atypical for similarly impacted estuaries in Queensland and northern NSW.

# 4 Fish and Fisheries of the Cobaki Broadwater

The Tweed estuary supports important recreational and commercial fisheries, and is recognised as one of the highest producing rivers for both finfish and crustacea within the northern estuaries of NSW (McGowan 1989; Pease and Grinberg 1995). The Cobaki Broadwater is a substantial component of the Tweed system and directly contributes to both the recreational and commercial catch from the Tweed (Alan Legrnd; David Smith, pers.comm., 2000). It is considered to provide Class 1 or major fish habitat under NSW Fisheries guidelines (NSW Fisheries 1999).

Fish species commonly caught by recreational anglers (Figure 12) within the Cobaki Broadwater include whiting, flathead, bream, mangrove jack, garfish, trevally, herring and mullet. Bloodworms (for bait), prawns and mud crabs are also taken (Alan Legrnd, Adrian Saunders, Alan McDonald; Graham Poile; Kerry Vardy pers.comm. 2000). The abundance of most species fluctuates seasonally (Graham Tully pers.comm. 2000): whiting and mud crabs are commonly taken in summer whilst mullet and bream are mostly taken in winter (Department of Public Works 1991; Graham Tully pers.comm. 2000).

Figure 12.

Recreational angler on the Cobaki Broadwater

Local recreational and commercial fishers also consider the Cobaki Broadwater to be a significant breeding ground for fish (Susan Ridings; Adrian Saunders; David Smith; Graham Tully pers.comm. 2000), and recognise the important role fringing mangroves and subtidal seagrasses play. A beam trawl survey conducted as a component of this study has confirmed this. Trawls conducted adjacent to the SEPP Wetland 5a, and up and downstream (Figure 4) revealed a diverse finfish, crustacean and molluscan fauna (Appendix A). The majority of fish caught in this survey were juvenile, confirming the significance of the Cobaki Broadwater as a breeding habitat (Appendix B). Whilst catches were indicative of an overall high productivity, catches taken within and in the vicinity of seagrass meadows were very significantly higher in both diversity and abundance (see Appendix B), than those taken over bare substrate (refer Appendix A for details of catch by shot). This survey has also added to the list of species recorded for the region (Table 2).

Recreational fishing using lines and crab traps / dillies is very popular within the Cobaki Broadwater, particularly throughout the summer months. Popular fishing spots include bridges and rocky outcrops, particularly within the reaches between Piggabeen Bridge to West Tweed Heads (Alan McDonald pers. comm. 2000): small boats have easy access, and the waters of the Broadwater are sheltered. Recreational angers are predominantly local to the area, with tourist numbers peaking over the summer months (Susan Riding; Alan McDonald pers. comm. 2000).

There are approximately 30 commercial fishers licensed to fish the Broadwater (and other reaches of the Tweed estuary), targeting a wide range of finfish (including whiting, mullet, flathead, and bream), prawns and mud crabs (Alan Legrnd). Fish are caught by commercial fishers primarily by net (haul and mesh) (David Smith; Alan Legnrd pers.comm. 2000). Fish hauling occurs both up- and downstream of the study area. Crabs are caught commercially using crab pots, whilst prawns are caught by hauling deep holes (Alan Legrnd pers.comm. 2000). Prawn netting occurs primarily around the Tweed Heads Pony Club, surrounding nearby islands and upstream of the study area.

The Cobaki Broadwater is considered important for commercial fishing as are nearby areas such as the Terranora Broadwater and the Tweed River (Alan Legrnd; Graham Poile; Graham Tully; Kerry Vardy pers. comm. 2000). As a part of a large estuary, the Broadwater is fished alternately with other reaches. This is a practice commercial fishers believe contributes to sustainable fishing practice (Graham Tully pers. comm., 2000).

Table 2. Fish species found within the Tweed estuary. Source: Department of Public Works 1991; Gray et al. 1995; NSW Fisheries 1994; this study[∇].

| **Family**<br>*Species* | Common Name |
|---|---|
| **Ambassidae** | |
| *Ambassis jacksoniensis* | Port Jackson glassfish |
| *A. marianus* (Gunther) | yellow perchlet |
| **Belonidae** | |
| *Tylosurus macleayanus* (Ogilby) | stout long-tom |
| **Blenniidae** | |
| *Petroscirtes breviceps*[∇] (Valenciennes 1836) | short headed sabre-tooth blenny |
| *P. lupus* | brown sabretooth blenny |
| **Callionymidae** | |
| *Foetorepus calauropomus* (Richardson 1844) | common stinkfish |
| *Repomucenus calcaratus* | spotted sand dragnet |
| **Carangidae** | |
| *Scomberoides lysan** (Lacepede 1801) | queenfish |
| *Trachurus* spp. | |
| **Clupeidae** | |
| *Herklotsichthys castelnais** | southern herring |
| *Hyperlophus vittatus** (Castelnau 1875) | sandy sprat |
| **Dasyatidae** | |
| *Dasyatis fluviorum* (Ogilby) | brown stingray |
| **Diodontidae** | |
| *Dicotylicthyus punctulatus* (Kaup) | three-bar porcupinefish |
| **Elopidae** | |
| *Megalops cyprinoides* (Broussonet) | oxeye herring |
| **Fistulariidae** | |
| *Fistularia commersonii*[∇] (Ruppell 1838) | smooth flutemouth |
| **Gerreidae** | |
| *Gerres ovatus* (Gunther) | silver biddy |
| *G. subfasciatus** (Cuvier 1830) | common silver belly |

| Family<br>*Species* | Common Name |
|---|---|
| **Girellidae** | |
| *Girella tricuspidata**∇ | luderick |
| **Gobiidae** | |
| *Arenigobius frenatus* | half-bridled goby |
| *Bathygobius krefftii* | frayed-finned goby |
| *Bathygobius sp.* ∇ | goby |
| *Favonigobius exquisites* | exquisite sand goby |
| *F. lateralis* | long-finned goby |
| *Pseudogobius olorum* | blue-spot goby |
| *Redigobius macrostoma* | large-mouth goby |
| **Hemiramphidae** | |
| *Arrhamphus sclerolepis**(Gunther) | snub-nosed garfish |
| *Hemirhamphus australis** (Steindachner) | sea garfish |
| **Lutjanidae** | |
| *Species A.* ∇ | |
| **Microcanthidae** | |
| Monodactylus argenteus (Linnaeus) | butterfish |
| Microcanthus strigatus (Cuvier and Valenciennes) | stripey |
| **Monacanthidae** | |
| Meuschenia trachylepis*∇ (Gunther) | yellow-finned leatherjacket |
| **Mugilidae** | |
| Liza argentea* (Quoy and Gaimard) | tiger mullet |
| L. dussumieri* (Valenciennes) | flat-tailed mullet |
| Mugil cephalus* (*Linnaeus*) | sea mullet |
| M. georgii* (Ogilby) | fantail mullet |
| Myxus elongatus* (Gunther) | sand mullet |
| **Paralichthyidae** | |
| Achlyopa nigra (Macleay) | black sole |
| Pseudorhombus arsius* (Hamilton-Buchanan) | large tooth flounder |
| P. jenynsii (Bleeker) | small tooth flounder |
| **Penaeidae** | |
| Metapenaeus bennettae∇ (Racek 1955) | bay prawn |
| **Platycephalidae** | |
| Platycephalus arenarius* (Ramsay and Ogilby) | flag-tail flathead |

| **Family**<br>*Species* | Common Name |
|---|---|
| P. fuscus* | dusky flathead |
| Papilloculiceps nematophthalmus* (Gunther) | fringe-eyed flathead |
| **Plotosidae** | |
| Plotosus anguillaris (Bloch) | striped catfish |
| **Pomatomidae** | |
| Pomatomus saltatrix*(Linnaeus) | tailor |
| **Scorpaenidae** | |
| *Centropogon australis (*White*)* | fortesque |
| *Centrapogon marmoratus*$^{\nabla}$ (Gunther) | bullrout |
| **Sillaginidae** | |
| *Sillago analis**(Whitley) | golden-line whiting |
| *S. ciliata* (Cuvier)* | sand whiting |
| *S. maculata** (Quoy and Gaimard) | trumpeter whiting |
| **Sparidae** | |
| *Acanthopagrus australis**(Gunther) | bream |
| *Rhabdosargus sarba**$^{\nabla}$ (Forskal) | tarwhine |
| **Syngathidae** | |
| *Urocampus carinirostris*$^{\nabla}$ (Bloch and Schneider) | hairy pipefish |
| **Terapontidae** | |
| *Pelates quadrilineatus*$^{\nabla}$ (Bloch) | trumpter |
| *Pelates sexlineatus** | eastern striped trumpeter |
| **Tetraodontidae** | |
| *Arothon hispidus* (Linnaeus) | stars and stripes toadfish |
| *Tetractenos hamiltoni* (Gray and Richardson) | common toadfish |
| *T. pleurogramma* (Regan) | weeping toadfish |

* indicates species of commercial / recreational importance (Source: Grant 1991; Quinn 1992.; Williams 1997).

Given the varied and seasonally influenced ecology of the species of finfish and crustacea recorded from the region, it is likely that a seasonally-based beam trawl survey would show the Cobaki Broadwater to serve as a nursery ground for many species not recorded in our brief survey.

# 5 Importance of Estuaries for Fish and Invertebrates

The majority of commercially and recreationally important species of fish from eastern Australia depend upon estuarine environments for part or all of their life cycle (Quinn 1992; Pollard 1976; Zeller 1998). Shallow water and intertidal habitats are amongst the most productive environments for fisheries (Quinn 1992). Most species taken from the Cobaki Broadwater and surrounding coastal waters of the Tweed rely upon the habitats available within the estuary (i.e. mangroves and shallow waters) either as juveniles or adults (Figures 13 and 14).

Mangroves are important nursery and feeding grounds for most economically important fish occurring in subtropical Australian estuaries (Morton et al. 1987, 1988; Morton 1990). Seagrasses are also used as nursery habitat by the juveniles of many fish species, several of which are of direct fisheries value.

Figure 13.

Small fish amongst pneumatophores of *Avicennia marina*

Figure 14.

Oysters on prop roots of *Rhizophora stylosa*

# 6 Freshwater Fishes and Macro-Invertebrates

## 6.1 Habitat

Whilst NSW Fisheries had requested only that two water bodies be surveyed, our appraisal of the region indicated that at least four distinct freshwater habitat types were present. These were:

- on the cessation of sand mining in the vicinity of the airport approximately 15 years ago, a small lake was formed as a remnant of the dredge pond (Site 1) (Figure 2). This lake has been colonised by aquatic macrophytes and fringed by riparian vegetation.
- Occasionally flooded *Melaleuca* dominated wetland (Site 2).
- to the immediate west of the southern most portion of the runway an extensive wetland drains surface runoff and on occasion is subject to tidal inundation (Site 3).
- a number of drainage lines which flow across the C4 route to the west of the airport. To the north-west these drainages are undisturbed (i.e. those within the vicinity of Tandy's Lane (Sites 5 and 6)), whilst in the immediate vicinity of the airport (Site 4a/b) they have been channelised and trained.

### Water Quality

Water quality measures were taken for all sites surveyed for fishes in January 2001 (some days after a period of heavy rain). The results are presented in Table 3. Where more than two readings were taken the mean and standard deviation were calculated.

Table 3 Water quality of channels, ponds and pools.

| Site | pH | Conductivity (mS/cm) | Turbidity NTU | Dissolved Oxygen (mg/L) | Temperature °C | Salinity % |
|---|---|---|---|---|---|---|
| 1 | 6.77 | 3.56 | 6 | 5.47 | 29.4 | 0.18 |
| 3 | 5.36 | 0.306 | 11 | 1.80 | 25.9 | 0.01 |
| 4a | 4.9 | 0.86 | 23.0 | 1.94 | 25.15 | 0.04 |
| 4b | 7.30 | 46.3 | 22 | 8.25 | 27.8 | 3.03 |
| 5 | 6.9 | 0.44 | 1.5 | 1.57 | 23.85 | 0.01 |
| 6 | 6.5 | 0.35 | 32.0 | 3.08 | 26.00 | 0.01 |

(Site 4a – approx. 150m upstream from Cobaki Braodwater; Site 4b – approx. 50m from Cobaki Broadwater. Site 2 had no water present)

Both the drain (Site 4b) and the 'natural' creek (below Site 5) are tidally influenced: our observations suggest the penetration of saline waters extends approximately 75m. The waters in these two waterways above this point, and of the other water bodies surveys are essentially 'fresh', being highly influenced by rainfall (Site 4a).

Water temperature appears to be influenced by the shade (or lack of it) provided by riparian vegetation. However, the temperature of waters across the survey fell within a relatively narrow range: 23.8-29.4°C.

pH varied significantly between sites, with Sites 3 and 4 showing the influence of acidic inflow. It is likely that at Site 4 at least, pH has a significant influence on the faunal community (preventing some otherwise suitable species from colonising the stream, and leading to occasional morbidity and mortality in those species living in the stream.

The dissolved oxygen concentration of most water bodies surveyed was very low: critically low in the remnant pools that make up site 3 and in the natural creek to the west (Sites 5 and 6). It is likely that low dissolved oxygen concentrations also significantly influence the finfish and invertebrate fauna of these water bodies.

**Remnant Dredge Pond**

The remnant dredge pond further to the east (Site 1) was largely less than 2m deep and was covered with Cape blue water lily (Figure 15). Mosquito fish, empire gudgeons and striped gudgeons were caught in the lake using nets (dip nets and multi panel set nets of 25, 50 and 75mm mesh) and baited traps (Table 5). It is considered to comprise Class 2 or moderate fish habitat (NSW Fisheries 1999).

Figure 15.

The remnant dredge pond to the south of the existing airport access road.

**Intermittent Pools and Wetlands**

The wetlands adjacent to the western boundary of the southern end of the main runway (Site 3) were all but dry: a small number of shallow, turbid pools remained (Figure 16). Cape blue water lily was found in the ponds, with *Gahnia sieberana* (Sawsedge), *Lepironia articulata*, *Eleocharis* sp., *Restio tetraphyllus* subsp. *meiostachyus* and *Juncus articulatus* (jointed rush) surrounding the ponds. Mosquito fish and small crayfish were abundant in these pools (Table 5). Site 3 provides minimal or Class 3 fish habitat (NSW Fisheries 1999).

Figure 16.

Small, shallow pool within the dried wetland

The Melaleuca 'wetland' site identified by NSW Fisheries to the south-east of the airport was dry (no surface water) (Figure 17). When inundated, it may provide minimal (Class 3) fish habitat (NSW Fisheries 1999).

Figure 17.

*Melaleuca* dominated communities to the south-east of the airport

## Drainage Lines

To the west of the airport, intersecting Tandy's Lane, a small creek meanders through relatively undisturbed bushland (Sites 5 and 6) to Cobaki Broadwater. The creek is fed by flow from both the airport (west of the runway centre-line) and Tugun Landfill. Immediately west of the landfill, a development road has been constructed over / through the creek's upper reaches (a culvert provides continuation of flow). To either side of the development road, wetland vegetation has been cleared and the creek forms shallow silty pools supporting *Typha* (bull rush) ferns and sedges (Site 6). This vegetation community continues downstream for almost 100m, before a distinct channel forms and remnant rainforest vegetation replaces the*Typha*-dominated wetland community. Eucalypts, rather than melaleucas occur across the pools and along the creek, suggesting that the soils retain very little moisture. During October 2000, the creek bed was largely dry between Site 6 and Tandy's Lane (Site 5). Site 5 provides moderate or Class 2 fish habitat (NSW Fisheries 1999).

Downstream of Tandy's Lane, small pools separated by stretches of damp creek bed occurred: there was no flow of water in the creek (Site 5). Long time local resident and Coolangatta Airport Forman, Mr Dan Boyd, has suggested this was the first time in 30 years that this creek had ceased to flow. However in January 2001 the creek was again flowing, albeit at a very low velocity. The deeper pools of the creek rarely exceeded 200mm in depth, and the width of the creek rarely exceeded 1.5m: channels of approx. 100mm depth and 400mm width connect pools. The pools either side of the development road (in the vicinity of Site 6) were effectively stagnant. Weed growth and anecdotal advice indicates that these pools flood rapidly with local rainfall, only to drain over a period of weeks /months. Site 6 provides moderate or Class 2 fish habitat (NSW Fisheries 1999).

Whilst this creek and its upstream wetlands are in a relatively undisturbed state, the lack of permanent flow, low dissolved oxygen concentrations, and the likelihood of runoff associated with either the landfill or airport reaching the creek suggest it is unlikely to support a significant fish fauna. Our survey recorded only mosquito fish (as the numerically dominant species), empire gudgeons and striped gudgeons (Sites 5 and 6) (Table 5).

The creek does however support a diverse, and in the case of several taxa, abundant macro-invertebrate fauna (Table 4). Whilst Chironomid midge larvae are most abundant in the stagnant water of the upstream pool (Site 6), the larval stage of many terrestrial insects, aquatic beetles and bugs, and water snails are most abundant in the shaded, low velocity flow of the creek's mid reaches (Site 5).

The diversity of taxa recorded from Sites 5 and 6 indicate that contaminated runoff (or leachate) from either the landfill or airport is not currently significantly influencing the fauna of the creek.

Table 4 Macro-invertebrates recorded from the natural creek to the west of Tugun Landfill and the airport.

| Family Name | Common Name | Site 5 | Site 6 |
|---|---|---|---|
| **Belostomatidae** | giant water beetles | 0 | 1 |
| **Ceratopogonidae** | biting midges | 0 | 2 |
| **Chironomidae** | midges | 158 | 397 |
| **Coenagrionidae** | terrestrial insect | 15 | 1 |
| **Corduliidae** | dragonfly larvae | 2 | 0 |
| **Corixidae** | water boatmen | 0 | 1 |
| **Dytiscidae** | aquatic beetles | 2 | 0 |
| **Ephemerellidae** | mayfly larvae | 0 | 1 |
| **Helminthidae** | aquatic beetles | 3 | 0 |
| **Helodidae** | aquatic beetles | 12 | 1 |
| **Hydrometridae** | water bugs | 1 | 0 |
| **Hydrophilidae** | water-scavenger beetles | 3 | 1 |
| **Mesoveliidae** | surface dwelling bugs | 15 | 1 |
| **Parastacidae** | *Cherax* sp. yabbies | 4 | 6 |
| **Planorbinae** | water snail | 19 | 0 |
| **Order Ostracoda** | shell shrimps | 0 | 1 |
| **Order Trichoptera** | caddis fly larvae | 1 | 0 |
| **Order Plecoptera** | stone fly larvae | 37 | 0 |

The number of individuals shown is the sum of three replicate 10m ‘scoops’ at each site.

To the east, a larger water course flows from the airport (within the perimeter fence), where it is fed by runoff from the main runway (Figure 18) (Site 4a/b). Also flowing to the Broadwater, this watercourse has been channelised and trained to enhance drainage: it is also tidally influenced for approximately 70m above the Broadwater. Although the watercourse is only likely to flow following local rainfall, the channel carried 20 – 30cm of water, with at least one deeper (1.2m) pool occurring in the freshwater reaches (Figure 19) during the period of survey. The bed of both the channel and pools was characterised by a deep detrital layer. The generally steep banks supported little riparian vegetation (predominantly grasses and woody weeds), however the channel and pools supported both emergent and floating macrophytes. Rushes were the dominant emergents, with Cape blue water lily the dominant floating macrophyte. Whilst no fish were captured by the multi-panel set net (25 and 50mm mesh), dip netting captured mosquito fish and baited traps captured both empire gudgeons and striped gudgeons (Table 5). Whilst mosquito fish were clearly numerically dominant, all three species were abundant within the drain. Sites 4a and 4b provide moderate or Class 2 fish habitat (NSW Fisheries 1999).

Figure 18.

Channelised drain where it leaves the runway precinct

Figure 19.

A deeper pool with set gill net

Locals advise that each water body is also likely to support eels (*Anguila* sp.).

Table 5. Species - habitat associations and relative abundance within the vicinity of the proposed Tugun Bypass.

| **Family** Species | Common Name | Decommissi-oned dredge pond (Site 1) | Remnant pool of natural wetland (Site 3) | Channelised watercourse (Site 4a/b) | Natuarl watercourse (Sites 5 & 6) |
|---|---|---|---|---|---|
| **Eleotridae** | | | | | |
| *Hypseleotris compressa* | empire gudgeon (Lake 1978) | xx | | xx | xx |
| *Gobiomorphus australis* | striped gudgeons (Krefft 1864) | xx | | xx | xx |
| **Poeciciidae** | | | | | |
| *Gambusia affinis* | mosquito fish (Baird and Girard 1853) | xx | xxx | xx | xxx |
| **Crustacea** | | | | | |
| *Cherax* sp. | yabbie | | xx | | x |

x – present  xx – common  xxx - abundant

## 6.2 Species Descriptions

Striped gudgeons (*Gobiomorphus australis)* live in coastal drainages from Maryborough, southern Queensland through to Wilson's Promontory, eastern Victoria. They inhabit a variety of conditions ranging from clear, fast-flowing streams to muddy waterholes, however they are more common in muddy waterholes and slow-flowing creeks (McDowall 1996). Juveniles are common within estuaries, and it is thought that the young are carried downstream and later migrate back upstream. Their diet consists of insects, crustaceans, and mosquito fish and other small fishes (Allen 1989).

The empire gudgeon (*Hypseleotris compressa)* is common within coastal drainage systems around the northern two-thirds of Australia. It is most common in flowing streams, normally in the lower reaches of coastal rivers and streams, where it is often associated with aquatic vegetation or found among branches of submerged trees. Juveniles are often found in swiftly flowing water or brackish estuaries. Empire gudgeon feed on micro-crustaceans, mosquito larvae and algae (Allen 1989).

The introduced mosquito fish, *Gambusia affinis* is common throughout much of Australia, and has become so abundant in some areas that it is considered a pest, competing with native fishes for vital food and space resources (Allen 1989). Mosquito fish are most abundant in warm and gently flowing or still waters, mostly around the margins and along the edges of aquatic vegetation. They are tolerant of a wide range of salinity and temperature conditions, feeding on a wide variety of fauna including, terrestrial insects, ants, flies and aquatic bugs and beetles (McDowall 1996).

### 6.3 Oxleyan Pigmy Perch

Our survey did not record the Oxleyan pigmy perch (*Nanoperca oxleyana*), a species often found in water bodies associated with coastal wallum vegetation. The Oxleyan pigmy perch is listed as 'endangered' on the Australian Society for Fish Biology's Conservation Status of Australian Fishes 1999 listing, and under the NSW *Fisheries Management Act 1994*.

Whilst this species is known to occur within the coastal lowlands of northern NSW and southern Queensland in both enclosed waters and streams, often in association with dense emergent vegetation, it is unlikely to occur in the water bodies adjacent to the airport. Although this species has a wide tolerance to pH (4.2 – 6.5), water clarity and instream structure (Thompson et al 2000), it is unlikely to be tolerant of the contaminants that may be associated with runoff from the landfill and airport. Each water body surveyed was very small and essentially isolated. Further, the small shrimps often abundant in coastal drainages, and that make up a significant proportion of the Oxleyan pigmy perch's diet (Arthington and Marshall 1993; Arthington 1996) were notably absent from all three habitats surveyed. Finally, those species noted to co-occur with the Oxleyan pigmy perch, the honey blue-eye (*Pseudomugil mellis*) and the ornate sunfish (*Rhadinocentrus ornatus*) were not found in this survey. On balance it is considered unlikely that the Oxleyan pigmy perch occurs at the sites identified by NSW Fisheries, or in the general vicinity of the airport. However, an eight-part test has been prepared for this species (see Appendix D).

# 7 Potential Impacts of the Proposed Development

## 7.1 Scope of Potential Impacts

The proposed development of the Tugun Bypass road and rail corridors will not directly impact on wetlands fringing the Cobaki Broadwater, on the aquatic flora and fauna of the Broadwater itself, or upon the freshwater fish fauna of the water bodies in the vicinity of the airport.

However, the construction and operation of the bypass may impact on wetland and aquatic floral and faunal communities adjacent to and 'downstream' of the bypass. The range of potential impacts is discussed in the NSW Fisheries publication 'Policy and Guidelines for Bridges, Roads, Causeways, Culverts and Similar Structures, 1999' (NSW Fisheries, 1999). Those considered relevant to the proposed development are discussed below.

**Degradation of Water Quality**

The Cobaki Broadwater will continue to receive most of the runoff from the proposed C4 (Option D) route in the vicinity of the Coolangatta airport. Surface waters west of the airport drain to the Broadwater through a number of waterways (see Figure 2) which would be traversed by the proposed route.

The construction phase of the proposed development may impact on these receiving waters through contamination of surface waters by uncontrolled erosion (of the construction footprint, stockpiles and adjoining lands) and sedimentation, spills of fuel or chemicals, the release of nutrients, and possibly acid sulfate soil leachate (PPK 2001; WBM 2001a).

Any lowering of the groundwater (see below) may allow the oxidation of potential acid sulfate soils. Once groundwater returns to pre-construction levels, acids may be generated and low-pH water may be carried to the Broadwater. Low pH waters may mobilise toxic metals from the soil.

The operational phase would have the potential to impact receiving waters through road runoff containing heavy metals and hydrocarbon residues, and possibly spills of fuel or chemicals (WBM, 2000).

**Lowering of the Groundwater**

Groundwater flows west of the airport also flow to the Broadwater. Construction of the proposed tunnel may require (or result in) draw-down of the groundwater table (WBM, 2000). Lowering of the groundwater table in this area, or contamination of the groundwater may impact on both adjacent wetlands and the receiving waters.

Acidification of the groundwater may pose a particularly significant risk. Lowering of the groundwater for periods exceeding a few weeks is also likely to detrimentally impact saltmarsh and rush communities.

**Alteration of Surface Water Flows**

With the development of the tunnel, the overflow channel of Coolangatta Creek into the Broadwater may require partial realignment. Roadway levels may also require the re-routing of drains draining the western portion of the airport (WBM, 2001). Given these drains are currently degraded and heavily modified, any rerouting required would not be seen as a significant impact.

## 7.2 Ecological Impacts of Degraded Water Quality

The introduction of contaminants to the Cobaki Broadwater has the potential to significantly impact upon the regions fish and fisheries, both directly and through detrimental effects of aquatic flora and invertebrate communities. Similarly, the introduction of contaminants to adjacent freshwater streams and wetlands has the potential to significantly impact upon the aquatic floral and faunal communities of those waterbodies.

**Elevated Turbidity and Sediment Deposition**

Reduced light penetration as a result of turbidity may adversely affect submerged aquatic macrophytes, and may alter temperature throughout the water column (Department of Natural Resources 1998). Light availability, or specifically the duration of light intensity exceeding the photosynthetic light saturation point, controls the depth distribution of benthic macrophtyes (eg. Abal and Dennison 1996; Dennison 1987; McComb 1986a; cited in Lavery and McComb 1991). That is, if light levels decrease, the distribution of aquatic macrophytes may also decrease. In nearby Moreton Bay mean annual total suspended solids below 10mgL are necessary for the survival of *Zostera capricorni* the dominant seagrass in the Tweed Estuary. The decline in fish community diversity and the abundance of some species within the region's estuaries has been attributed to the loss of aquatic macrophytes (Quinn 1992; McKay and Johnson, 1990).

The effects of sediment deposition over floral communities are highly variable. The likelihood of smothering is closely related to the characteristics of the sediment. Coarse sediments settle from the water column quickly and are unlikely to move away from the site of introduction, whereas finer sediments are more easily suspended, remain suspended longer, may be carried further before settling, and are consequently more likely to smother benthic flora.

Approximately 80% of freshwater fish species lay eggs on the substrate of water courses. The deposition of fine sediments, and the subsequent decrease in stream bed roughness may also lead to a decline in the diversity of both invertebrate and fish communities (e.g. Amesbury 1981). Sedimentation can smother eggs. The distribution of soft sediment benthic fauna is mainly correlated with sediment type and stability and floral cover (Poiner 1980). Changes to sediment characteristics may affect the community composition of benthic fauna, and increased turbidity will adversely affect filter-feeding fauna. Smothering of benthic invertebrates may also impact animals higher in the food chain (Department of Public Works 1992; Ferguson 1991) However, increased turbidity may also be attractive to a range of fishes, and in particular juveniles, as it protects them from predators (Blaber and Blaber 1980).

**Petroleum Hydrocarbons**

Hydrocarbons may be introduced to adjacent waterways through gross spillage, or the transport of residues by surface runoff.

Different organisms and different life-stages of particular organisms react to petroleum hydrocarbon pollution in different ways. The damage to marine biota by petroleum hydrocarbons is determined more by the degree of persistence of the oil than its absolute toxicity when fresh (van Gelder-Ottway 1976).

Both petroleum and petroleum by-products are harmful to mangroves (Odum and Johaness 1975). In *Avicennia marina* oils can cause mechanical damage by blocking the pores in the pneumatophores and may also modify respiration, photosynthesis and translocation (Mackey and Smail, 1995).

Concentrations of dissolved oil fractions below 0.01 ppm have not been shown to have adverse effects on any marine organism either in the short or long term, at any stage of development or at a cellular or sub-cellular level. Between 0.01ppm and 0.1ppm some adult animals show sub-lethal behaviour and physiological disturbance, while developmental stages may show retarded growth or increased abnormalities. In general, developmental stages are far more susceptible than are adults, frequently by one or two orders of magnitude (Brown 1985). Changes in behaviour in response to sub-lethal doses of pollutant may have far reaching ecological effects (Dicks 1976).

Chronic hydrocarbon pollution can result from the cummulative effects of small, yet frequent spills. Such a pattern of spillage may be commonly associated with road runoff. The chronic presence of hydrocarbons, even at low concentrations has the potential to cause locally significant impacts. Low levels of petroleum hydrocarbons in the aquatic environment are adsorbed onto, or incorporated into, the sediments, where they may persist for years (Pelletier et al 1991; Voudrias and Smith 1986). A large number of small-scale oil spills may lead to a significant increase in hydrocarbons over time, in effect resulting in a 'permanent' impact. Mangrove sediments in particular may serve as long-term reservoirs for chronic contamination holding hydrocarbons for periods in excess of 5 years (Burns et al. 1994). Clearly, in determining the potential for chronic contamination at a particular site, characteristics of flushing and sediment stability need to be considered.

Whilst acute (or at least a 'one off") contamination may result in severe ecological consequences, recovery is in most cases inevitable. In contrast, chronic contamination can result in the 'permanent' (or at least for the duration of contamination) morbidity or localised extinction of flora and fauna. Floral communities and sessile faunal communities (such as the many groups of invertebrates that develop attached to the substrate) are clearly most at risk from chronic hydrocarbon pollution. As these communities often form a critical component of 'habitat' (providing structural complexity, shelter and often food), a 'permanent' impact to these communities may have a consequentially widespread impact on the mobile components of the original faunal community including the fishes and crustacea.

**Nutrient Enrichment**

Nutrients released from disturbed sediments or road fill, may alter the community composition of floral communities. High levels of phosphorous and nitrogen can result in algal blooms that may contribute to fish kills through the depletion of oxygen from the water.

Phytoplankton communities respond quickly to changes in nutrient concentrations, particularly in tropical areas where light and temperature are usually not limiting. Increases in nutrient concentrations can lead to rapid increases in the abundance of some species, resulting in algal blooms. The species diversity in these blooms is usually low, with diatoms, blue-green algae, or green algae dominating. Phytoplankton blooms can lead to a number of problems including:

- a change in trophic structure, for example from a diatom-zooplankton-fish food chain to a system characterised by a major 'microbial loop' (Verity 1988);

- the amount of oxygen in the water can be lowered due to the rapid growth and decomposition of the phytoplankton, this can cause the death of fish and other animals (May 1981);
- release of toxic chemicals by some species; and
- shading of submerged aquatic vegetation, which are dependent upon light.

Macroalgae absorb nutrients directly from the water column, and are thus also able to rapidly utilise nutrients when they are present at increased concentration (Weeler and Weidner 1983; Zimmerman and Kremer 1986).

In shallow estuaries experiencing nutrient enrichment, communities dominated by drift algae such as *Cladophora* and *Gracilaria* can physically smother other benthos (Costa, 1988 (cited in Maier and Pregnall 1990). Elevation of nutrients in the water column may also result in enhancement of epiphyte growth (Eminson and Phillips, 1978 (cited in Neckles et al. 1993); Orth et al 1984; Twilley et al. 1985) and phytoplankton abundance (Dennison et al. 1993). Increases in drift algae and phytoplankton abundance increase water turbidity, thus lowering the amount of light available for photosynthesis by benthic flora.

**Heavy Metals**

A variety of heavy metals are commonly present within the soil. Physical disturbance of the soil and acidification of ground or surface waters can result in highly increased mobilisation and hence availability of these metals to both flora and fauna. Metals can also be deposited on roadways from car brake pads etc., and can be carried to adjacent waterways by surface runoff.

Metals occur naturally in the aquatic environment and many, such as copper, cobalt, iron, manganese, nickel, selenium, vanadium and zinc are essential for the survival of aquatic organisms. However if the assimilative capacity of the system is overloaded, either by an excess of an essential metal or by unusually high levels of the rarer, non-essential metals (e.g. silver, cadmium, mercury and lead) there may be deleterious effects (Langston 1988).

The absorption of heavy metals from solution occurs in plants and animals by passive diffusion across gradients created by adsorption at the surface, and by binding by constituents of the surface cells, body fluids, etc. An alternative pathway for animals is when metals are adsorbed onto or are present in food, and by the collection of particulate or colloidal metal by food gathering mechanism, such as the bivalve gill.

There is considerable variation in the extent to which plants and animals can regulate the concentration of metals in their body: plants and bivalve molluscs are poor regulators of heavy metals; crustacea and fish are generally able to regulate essential metals such as zinc, copper and iron (Clark 1992).

Metal concentrations in organisms are usually a function of environmental concentrations and bio-accumulation; however there are a variety of factors which can modify bio-availability and metal toxicity, all of which act synergistically. In general, metals are more toxic at high temperatures and low salinities. Redox potential also affect toxicity, with higher metal concentrations in anoxic conditions. The availability of metals may also increase with low pH (eg under acid sulfate conditions). In addition there are synergistic/antagonistic interactions between the metals themselves; for example the antagonistic effect of selenium on mercury accumulation is often seen as fulfilling a detoxifying role, whereas in algal cells competition from copper may result in deficiencies of essential manganese (Langston 1988).

The effect of chronic heavy metal pollution is still largely unresolved, and effects depend on the interrelationships of many physical and chemical factors. Threshold concentrations of toxicants to ensure the protection of aquatic ecosystems have been developed by the Australian and New Zealand Environment and Conservation Council. An extract of these threshold values is presented in Table 6.

Table 6. ANZECC guidelines for the protection of the aquatic environment (freshwater): metal contamination of water (ANZECC, 1992).

| | Metal concentration (total) µg/L | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Criteria | Al | As | Cd | Cr | Cu | Hg | Ni | Se | Pb | Zn |
| ANZECC,1992 | <100 | 50 | 0.2 - 2.0 | 10 | 2.0 - 5.0 | 0.1 | 15 - 150 | 5.0 | 1.0 - 5.0 | 5.0 - 50.0 |

Some effects of metals on growth, morphology, reproduction and development are listed in Table 7.

Table 7. Sublethal effects of metals on aquatic biota (from Langston 1988)

| | Metal concentration µg/L | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | Ag | As | Cd | Cr | Cu | Hg | Ni | Pb | Zn | Response |
| Phytoplankton | | | 1.0 | | 0.3 | 1.0 | | | | Reduced 14C fixation |
| Phytoplankton | | 5 | 112 | | 6.4 | <6.0 | 60 | 20 | 20 | Reduced growth |
| Macroalgae | | | | | 10 | 0.5 | | | 100 | Reduced growth |
| Macroalgae | | 60 | | | | | | | | Inhibits reproduction |
| Hydroids | | | 195 | | 14.3 | 1.6 | | | 740 | Reduced growth |
| Hydroids | | 300 | 100 | | 10 | 3 | | 300 | | Altered morphology |
| Hydroids | | | | | 0.05 | 0.01 | | | 500 | Inhibits reproduction |
| Polychaetes | | | 560 | 50 | 100 | 50 | 200 | 500 | | Inhibits reproduction |
| Molluscs | | | 10 | | 3 | 0.3 | >200 | >200 | 10 | Reduced shell growth |
| Molluscs | 32 | | | | 16 | 12 | 1200 | | | Reduced growth |
| Molluscs | 14 | 326 | 611 | 4469 | 5 | 6 | 349 | 476 | 199 | 50% abnormal larvae |
| Molluscs | 9.5 | | | | 50 | | | | 200 | Inhibits reproduction |
| Crustaceans | | | 5.5 | | 6.4 | | | | | Inhibits reproduction |
| Echinoderms | | 1500 | 600 | 1000 | 10 | 10 | 600 | 1000 | 30 | Inhibits reproduction |
| Fish | | | 5 | | 10 | | | | | Reduced growth |
| Fish | | 32 | 0.5 | | 0.8 | 0.1 | | 1.2 | 5.3 | Vertebral deformities |
| Fish | | | | | 0.025 | | | | | Inhibits reproduction |

In general, larval and juvenile life-stages are more sensitive to metal toxicity than adults. Animals that burrow in sediment are more directly exposed to contaminants dissolved in interstitial water, and have greater direct contact with contaminated particles than do tube-building or epibenthic species. Animals that ingest sediment particles, such as some species of annelid worms may be more directly exposed to sediment-associated contaminants than species that filter overlaying water for suspended particulate food (Lamberson et al. 1992).

The toxicity of contaminated sediments may be modified by abiotic factors. Chemical factors that may influence the toxicity of a sediment-associated metal or trace element include sorbtion to particulate or dissolved organic matter, the physical chemical form of the compound (including its ionic state), the presence of other ions (e.g. salinity, hardness), interstitial redox potential, and concentrations of limiting compounds (e.g. dissolved oxygen, ammonia, hydrogen sulfide). Interactions between these factors and between geochemical and physical variables (particularly temperature and disturbance) may further modify sediment toxicity (Burgess and Scott 1992; Lamberson et al. 1992). Contaminant bio-availability is typically reduced in organically enriched sediments.

The bio-availability of metals in sediment can be affected by the binding of metal ions to sediment constituents. Interstitial water concentration, rather than total bulk concentration is therefore likely to determine the actual toxicity of contaminated sediments. Metal ions that are bound to sediment constituents may be unavailable to sediment-dwelling (benthic) organisms (Lamberson, et al., 1992). Metals also bind, and thus become less bioavailable, more readily to finer particles in sediment (silts and clays) than to coarser particles (sands and gravels).

**The Effects of Acidified Waters on Aquatic Flora and Fauna**

Short term effects of acid water may include: fish kills; fish disease; mass mortalities of benthic invertebrates (including crustacea, molluscs and worms) and microscopic organisms; and increased light penetration due to water clarity (Sammut et al. 1993; 1996; Wendelaar-Bonga and Dederen 1986). Short-term acidification has the potential to alter the natural community structure for many years. Long term effects may include the alteration (loss) of habitat; reduced spawning success due to stress; reduced food resources; dominance of acid-tolerant plankton species; increased predation; changes in food chain and web; damaged and undeveloped eggs; reduced recruitment; increased availability of toxic elements, and; reduced availability of nutrients. Low pH alone has a deleterious effect on biota, but it is the indirect effects including lowering of dissolved oxygen concentrations (e.g. (Razzell 1990) and the biotoxification of elements that are most crucial.

### 7.3 Ecological Impacts of Lowered Groundwater

Any lowering of the groundwater is likely to influence the freshwater wetlands that lie between the airport and Cobaki Broadwater (refer Figure 4). Whilst lowering of the water table for a period of a few weeks / months may simply reduce vigour; chronic lowering of the water table may change the species composition of these communities, replacing the present species with species less tolerant of / dependant upon high groundwater levels and periods of inundation. Saltmarsh flora may also be similarly impacted; mangroves are likely to be less sensitive.

Loss of all surface water from the wetland communities, as may occur during dry weather and a lowered water table, is likely to result in the loss of all fishes and crustaceans from the wetland. Recolonisation is likely to be rapid following the reflooding of the wetlands.

### 7.4 Summary of Potential Impacts and Opportunities for Mitigation

The development of the proposed road and rail infrastructure is unlikely to result in the loss of any wetland floral communities or habitat critical to the survival of any species of fresh water or estuarine fish. However, care will need to be taken during the construction phase as the corridor in places comes to within a few meters of the boundary of SEPP 14 wetlands. The NSW Fisheries publication 'Policy and Guidelines for Bridges, Roads, Causeways, Culverts and Similar

Structures, 1999' (NSW Fisheries 1999), provides broad guidelines for impact mitigation and WBM (2001a; 2001b) provide a number of site specific recommendations which are endorsed.

The consequence of altered flood levels and durations of inundation (WBM 2001b) are unlikely to have any significance with regard to the regions aquatic ecology.

Where 'best practice' surface water quality management is implemented during both construction and operation, the development is unlikely to significantly impact upon the water quality of either the Cobaki Broadwater or the freshwater streams and lakes to the west and south of the airport. Within the Broadwater, seagrass meadows are most at risk from any increase in concentrations of suspended solids and to a lesser degree, nutrients. Any increase in suspended solids is likely to effect the seagrasses' ability to photosynthesise, and thus contribute to a reduction in its depth distribution and vigour. The waters of the Broadwater currently carry relatively high concentrations of nutrients: the growth of macrophytes and phytoplankton is probably rarely nutrient-limited.

Realignment of drainage canals will obviously result in the loss of small areas of wetland flora and aquatic habitat, however these losses are considered to be ecologically insignificant (in the context of the Cobaki Broadwater), and can effectively be mitigated through compensatory habitat development.

Where 'current best practice' technologies are employed (as recommended by WBM (2001a)) during development and operation, a high proportion of suspended sediments, adsorbed metals, nutrients and hydrocarbons may be expected to be trapped before they are carried to the Broadwater. All practical measures to minimise the transport of contaminants from the roadway reaching the Broadwater should be implemented. Appropriate site management during construction can avoid the oxidation of potential acid sulfate soils disturbed by surface engineering works. However, oxidation that may result from the lowering of the water table may contribute to the leaching of acidified waters (and mobilised metals) to the Broadwater through the groundwater. PPK Environment & Infrastructure have prepared an 'acid sulfate soils assessment' (Technical Paper Number 5) that through various levels of response, will seek to mitigate the effects of any acidification before it impacts upon adjoining waters and floral and faunal communities.

The temporary lowering of the groundwater may also impact upon the freshwater wetlands to the west and south-west of the airport, and saltmarsh communities to the south-east, in effect simulating severe drought conditions (where little rainfall is experienced). However, this impact would be transitory, and as the water table rose post-construction, the wetland and its associated fauna could be expected to rapidly recover from dormant plants and the importation of propagules by natural processes from adjoining communities WBM's (WBM 2000a; 2001b) recommendations for site management during construction and operation are endorsed.

**Recommendations for Environmental Management**

The following guidelines are recommended in order to minimise impacts on aquatic flora or fauna.

- Construction activities should avoid the loss or disturbance of estuarine or freshwater wetland vegetation. Within NSW, mangroves and saltmarsh communities are protected under Section 7 of the *Fisheries Management Act 1994*. Only *Avicennia marina* and *Aegiceras corniculatum* may be trimmed (under permit); and no marine vegetation may be removed from SEPP 14 wetlands. Where practical, 'no go' buffer zones (widths to 100m would be appropriate) should be declared during development activities to emphasise the requirement for conservation management and minimise the risk of accidental disturbance. Consideration should also be given to mitigating any net loss of sedge and saltmarsh / melaleuca habitat (to the south of the airport) through the development of compensatory habitat.

- Where existing drainage channels are to be realigned, measures should be taken to ensure the water quality of adjoining sections is not affected. This may require measures to prevent elevated turbidities, reduced pH and reduced dissolved oxygen concentrations. Consideration should also be given to mitigating any net loss of habitat through the development of compensatory habitat.

- Construction activities in the vicinity of waterways should be scheduled to avoid periods of high rainfall. Impacts on aquatic flora and fauna would be lessened if works are undertaken during periods of low run-off.

- Sediments, particularly fine sediments, should be prevented from being transported from the construction corridor to any water body. The minimisation of sediment disturbance, and erosion, and the use of sediment control ponds are likely to be a key elements in achieving this.

- All practical measures to minimise the transport of contaminants (including hydrocarbons, heavy metals and nutrients) from the corridor reaching any water body should be implemented, both during development and operation of the corridor. ANZECC guidelines (ANZECC 1992) should be used as a guide to determining acceptable concentrations. Spill management plans should be developed prior to development. Run-off from roadways (including bridges) should be treated before release to natural waterways.

- Impacts to groundwater level should be minimised both in terms of areal extent (in the vicinity of wetland floral communities) and duration. Where it may influence wetland flora, the duration of lowering should minimised; and importantly, should be returned to pre-development levels upon completion. Where the groundwater is to be lowered for periods exceeding 1 month, the surface should be rewatered at intervals that prevent observable morbidity and mortality (professional monitoring of the flora is recommended).

- Acidified waters should be prevented from entering any water body or wetland. Where acidified waters accidentally enter a water body, remedial action should be taken to prevent the receiving waters from falling more than 2 pH units below ambient.

- Any alteration of watercourses or floodways should give consideration to the potential impacts on 'downstream' flora and fauna. The deliberate or inadvertent construction of barriers to fish (or stream) movement should be avoided. All waterways should be spanned by appropriately designed crossings that retain as much as practically possible of the natural features of the waterway (topography and flow).

- An environmental monitoring program should be developed that addresses:

  - both water quality within the waterways that may be impacted (natural and trained waterways, wetlands and pools adjacent to the corridor, and the Cobaki Broadwater), and within the development corridor;

  - the health of wetland communities that may be impacted by altered groundwater levels; and potentially

  - the flora and fauna of the waterways adjacent to the corridor.

  Detailed monitoring programs should be developed once development plans are finalised, however the following guidelines are offered:

  pH, DO, turbidity, salinity, nitrogen and phosphorous, and temperature should be measured weekly during development, and then monthly during the first year of operation. Monitoring of aquatic flora and fauna may also be prudent to provide a further means of detecting impacts: plants and animals often serve as better indicators of water quality than a water quality monitoring program based on 'snap shots', as the plants and animals effectively integrate the influences of fluctuating water quality over time. Should monitoring indicate that contaminants may be being exported from the corridor, or should water quality values recorded from the adjacent waterways show significant change indicative of an impact related to the proposed development, remedial measures are likely to be required.

  Saltmarsh, sedge and mangrove communities should be monitored over the period of groundwater draw down and for a period of some years following restoration of groundwater levels. Monitoring should involve an impact /

control style experimental design and be sufficiently sensitive so as to detect the onset of any hydrology-related stress.

To support the effective monitoring of aquatic flora and fauna it would be appropriate to expand the data set presented in this report to provide a robust 'baseline' against which receiving water quality, and floral and faunal monitoring results could be compared. Seasonal (quarterly) baseline surveys are recommended to develop this baseline.

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## Appendix A Field Survey Methodology

### Beam Trawl Survey

A beam trawl survey was undertaken to describe the juvenile finfish, crustacea and molluscs that are associated with the habitats of the Cobaki Broadwater. Beam trawls were made at four sites encompassing reaches below the Broadwater, adjacent to the SEPP 14 Wetland 5a, and within the Broadwater proper. Refer to Figure 1 for the location of beam trawl sites. Three replicates were taken from sites one and two, and two from sites three and four. Sites two and three were characterised by bare substrate whilst site one was a combination of bare substrate and patches of *Zostera capricorni*. Site four was dominated by *Zostera capricorni*.

Samples were collected using a 2mm mesh, metre wide beam trawl. Each trawl was undertaken over a 150m transect at an approximate speed of 2 knots. Samples were sorted and identified in the laboratory.

### Freshwater Fishes

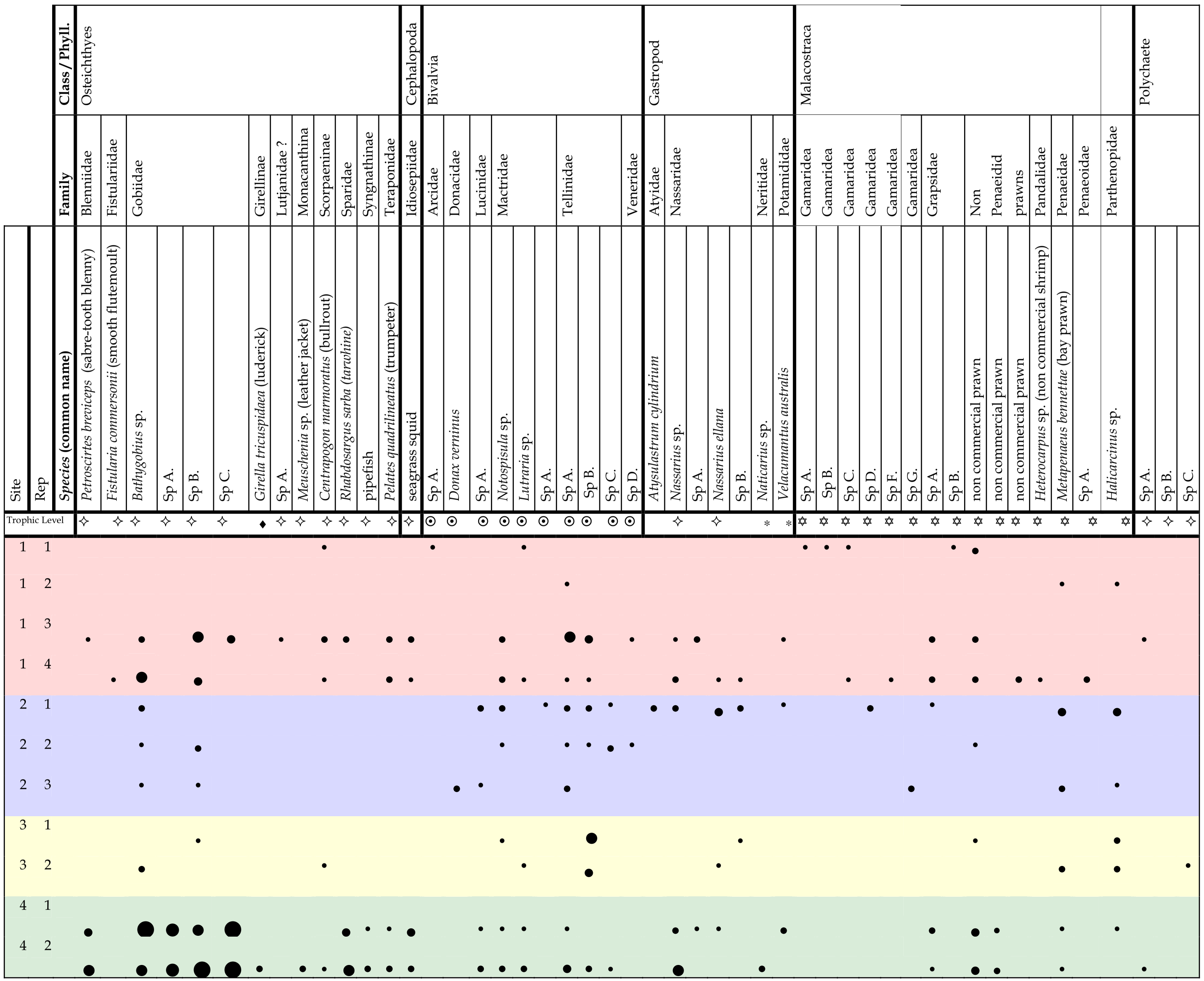
In response to concerns expressed by NSW Fisheries, surveys were conducted of a number of water bodies on, or in the immediate vicinity of the C4 route. These surveys involved the use of set nets, dip nets and baited traps.

A gill net (45m long with a mesh size of 25mm, 50mm and 75mm) was deployed mid afternoon across the waterbody at site 1. Four baited traps (1mm mesh) were set and dip netting was undertaken around the waters edge. The gill net and baited traps were checked four hours after being deployed (an hour after dusk).

The drainage line of site three was essentially dry, and sampling was limited to a single remaining water hole of approximately 2m in diameter and less than 200mm deep. Three baited traps (1mm mesh) were deployed within this waterbody in mid-afternoon and collected shortly after dusk. Dip netting was conducted around the margins.

Panels of 25mm and 50mm mesh gill net were set at location four, extending diagonaly across the approximately 3m wide channel. Four baited traps (1mm mesh) were also set and dip netting was undertaken around the vegetated margins. The gill net and baited traps were deployed mid afternoon and collected shortly after dusk.

# Appendix B Estuarine Fish and Invertebrates Recorded within the Cobaki Broadwater via Beam Trawl




Beam trawl: 1.0 x 0.5m; 2mm mesh

Species Abundance

| Dot Size | No Individuals |
|---|---|
| • | 1 |
| • | 2 - 5 |
| • | 6 - 15 |
| ● | 16 - 50 |
| ● | 51 - 100 |
| ● | < 100 |

Trophic Level
- ⊙ Filter feeders
- ✧ Carnivores / scavengers
- ♦ Herbivores
- ✡ Detritivores
- ⁎ Micro algal grazer

## Appendix C Size Range of Fish Species Recorded within the Cobaki Broadwater.

| Species | Common Name | Size Range (mm) | |
|---|---|---|---|
| **Blenniidae** | | | |
| *Petroscirtes breviceps* | short headed sabre-tooth bleny | 28 - 57 | |
| **Gobiidae** | | | |
| Sp A. | | 15 - 25 | |
| Sp B. | | 11 - 26 | juvenile |
| Sp C. | | 11 - 31 | juvenile |
| *Bathygobius* sp. | | 16 - 30 | |
| **Girellinae** | | | |
| *Girella tricuspidaea* | Luderick | 15 - 17 | juvenile |
| **Lutjanidae** | | | |
| Sp A. | | 15 | juvenile |
| **Monacanthinae** | | | |
| *Meuschenia* sp. | leatherjacket | 20 - 25 | juvenile |
| **Scorpaeninae** | | | |
| *Centrapogon marmoratus* | Bullrout | 10 - 19 | juvenile |
| **Sparidae** | | | |
| *Rhabdosargus sarba* | (tarwhine) | 10 - 17 | juvenile |
| **Syngathida** | | | |
| Sp A. | | 40 - 60 | |
| **Teraponidae** | | | |
| *Pelates quadrilineatus* | Trumpeter | 13 - 20 | juvenile |
| **Pandalidae** | Shrimp | < 15 | |
| **Penaeidae** | | | |
| *Metapenaeus bennattae* | bay prawn | < 20 | |

## Appendix D The Eight Part Test – Oxleyan Pigmy Perch

Whilst the occurrence of the Oxleyan pigmy perch is considered unlikely in the vicinity of the airport, the potential impacts of the proposed development are discussed below in the context of the 'eight part test'.

(a) *In the case of threatened species, is the life cycle of the species likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction?*

No. Should the Oxleyan pigmy perch occur in any of the water bodies that lie between the airport and the Broadwater, the proposed development would not influence either flow or water quality, nor would it result in the loss of habitat.

(b) *In the case of an endangered population, is the life cycle of the species that constitutes the endangered population likely to be disrupted such that the viability of the population is likely to be significantly compromised?*

No.

(c) *In relation to the regional distribution of the habitat of a threatened species, population or ecological community, is a significant area of known habitat to be modified or removed?*

No. The Oxleyan pigmy perch has not been recorded from the study area. Further habitat within the study area is considered 'marginal' for this species. In northern NSW populations have been recorded from Coroki on the Richmond River and Lake Hiawatha near Wooli.

(d) *Is an area of known habitat likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, populations or ecological community?*

No.

(e) *Will critical habitat be affected?*

No.

(f) *Are threatened species, populations or ecological communities or their habitats, adequately represented in conservation reserves (or other similar protected areas) in the region?*

Consideration is currently being given to the declaration of habitat reserves for this species within the region (south-east Queensland and northern NSW) by the respective state government agencies responsible for fisheries management.

(g) *Is the action proposed of a class of action that is recognised as a threatening process?*

Development of major transport infrastructure has the potential to sigificantly impact upon both habitat and species.

(h) *Are any threatened species or ecological communities at the limit of their known distribution?*

No. The distribution of the Oxleyan pigmy perch extends from the Tin Can Bay (Queensland) region in the north to the Richmond River in the south.

# Appendix L

List of flora species recorded from the study area during the field surveys

## Appendix L: List of flora species recorded from the study area during the field surveys

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| **CONIFEROPSIDA** | | | | | |
| ARAUCARIACEAE | | | | | |
| *Araucaria cunninghamii* | Hoop Pine | ✓ | | | MO |
| | | | | | |
| **GYMNOSPERMS** | | | | | |
| PINACEAE | | | | | |
| *Pinus elliottii* * | Slash Pine | ✓ | ✓ | | AB, MO |
| | | | | | |
| **LYCOPSIDA** | | | | | |
| SELAGINELLACEAE | | | | | |
| *Selaginella uliginosa* | Moss | ✓ | ✓ | | MO |
| | | | | | |
| **FILICOPSIDA** | | | | | |
| ADIANTACEAE | | | | | |
| *Adiantum aethiopicum* | Maidenhair Fern | ✓ | | | MO |
| *Adiantum hispidulum* | Rough Maidenhair Fern | ✓ | | | MO |
| ASPLENIACEAE | | | | | |
| *Asplenium australasicum* | Bird's-nest Fern | ✓ | ✓ | | AB, MO |
| BLECHNACEAE | | | | | |
| *Blechnum cartilagineum* | Gristle Fern | ✓ | | | AB, MO |
| *Blechnum indicum* | Bungwal Fern | ✓ | ✓ | | AB, MO |
| *Blechnum wattsii* | Hard Water Fern | | ✓ | | AB |
| *Doodia aspera* | Prickly Rasp Fern | ✓ | | | AB, MO |
| *Doodia media* | Common Rasp Fern | ✓ | | | MO |
| CYANTHEACEAE | | | | | |
| *Cyathea cooperi* | Straw Tree Fern | ✓ | ✓ | | AB, MO |
| *Cyathea leichhardtiana* | Prickly Tree Fern | ✓ | | | MO |
| DAVALLIACEAE | | | | | |
| *Nephrolepis cordifolia* * | Fishbone Fern | ✓ | ✓ | | AB, MO |
| DENNSTAEDTIACEAE | | | | | |
| *Histiopteris incisa* | Bat's Wing Fern | ✓ | ✓ | | AB, MO |
| *Hypolepis muelleri* | Harsh Ground Fern | ✓ | ✓ | | AB, MO |
| *Hypolepis rugosula* | Ruddy Ground Fern | ✓ | ✓ | | MO |
| *Pteridium esculentum* | Bracken Fern | ✓ | ✓ | | AB, MO |
| DICKSONIACEAE | | | | | |
| *Calochlaena dubia* | Common Ground Fern | ✓ | ✓ | | AB, MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| DRYOPTERIDACEAE | | | | | |
| *Lastreopsis marginans* | Glossy Shield Fern | ✓ | | | MO |
| GLEICHENIACEAE | | | | | |
| *Gleichenia dicarpa* | Alpine Coral Fern | ✓ | ✓ | | AB, MO |
| *Sticherus flabellatus* | Shiny Fan Fern | ✓ | | | MO |
| LINDSAEACEAE | | | | | |
| *Lindsaea linearis* | Screw Fern | ✓ | ✓ | | MO |
| OSMUNDACEAE | | | | | |
| *Todea barbera* | King Fern | | ✓ | | AB |
| POLYPODIACEAE | | | | | |
| *Platycerium bifurcatum* | Elkhorn | ✓ | | | MO |
| *Platycerium superbum* | Staghorn | ✓ | | | MO |
| *Pyrrosia rupestris* | Rock Felt Fern | ✓ | | | MO |
| PSILOTACEAE | | | | | |
| *Psilotum nudum* | Skeleton Fork-Fern | ✓ | | | MO |
| PTERIDACEAE | | | | | |
| *Acrostichum speciosum* | Mangrove Fern | | ✓ | | FRC |
| SCHIZAEACEAE | | | | | |
| *Lygodium microphyllum* | Climbing Maidenhair | ✓ | ✓ | | AB, MO |
| *Lygodium scandens* | Climbing Fern | | ✓ | | AB |
| THELYPTERIDACEAE | | | | | |
| *Christella dentata* | Binung | ✓ | ✓ | | MO |
| *Cyclosorus interruptus* | | ✓ | ✓ | | AB, MO |
| **DICOTYLEDONS** | | | | | |
| ACANTHACEAE | | | | | |
| *Pseuderanthemum variabile* | Pastel Flower | ✓ | ✓ | | AB, MO |
| AIZOACEAE | | | | | |
| *Tetragonia tetragonoides* | New Zealand Spinach | | ✓ | | AB |
| ANACARDIACEAE | | | | | |
| *Euroschinus falcata* | Ribbonwood | | ✓ | | AB |
| *Mangifera indica* * | | ✓ | | | MO |
| *Schinus terebinthifolia* * | Broad-leaved Pepper Tree | ✓ | ✓ | | AB, MO |
| APIACEAE | | | | | |
| *Apium prostratum?* | Sea Celery | | ✓ | | AB |
| *Ciclospermum leptophyllum* * | | ✓ | ✓ | | MO |
| *Centella asiatica* | Pennywort | ✓ | ✓ | | AB, MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Hydrocotyle acutiloba* | | | ✓ | | MO |
| *Platysace ericoides* | Heath Platysace | ✓ | ✓ | | AB, MO |
| Trachymene procumbens | | | ✓ | | AB |
| APOCYNACEAE | | | | | |
| *Gomphocarpus fruticosus* * | Balloon Plant | | ✓ | | AB |
| *Melodinus australis* | Rubber Vine | ✓ | | | MO |
| *Nerium oleander* * | Oleander | | ✓ | | AB |
| *Parsonsia straminea* | Twining Silkpod | ✓ | ✓ | | MO |
| *Tabernaemontana pandacaqui* | | ✓ | | | MO |
| ARALIACEAE | | | | | |
| *Asterotricha longifolia* (Tweed Heads Form) | Star hair Plant | | ✓ | RS | AB |
| *Schefflera actinophylla* * | Umbrella Tree | ✓ | ✓ | | AB, MO |
| ASCLEPIADACEAE | | | | | |
| *Asclepias curassavica* * | | ✓ | ✓ | | AB, MO |
| *Cynanchum carnosum* | | | ✓ | | AB |
| *Gomphocarpus physocarpus* * | | ✓ | ✓ | | MO |
| *Marsdenia rostrata* | Milk Vine | | ✓ | | AB |
| ASTERACEAE | | | | | |
| *Ageratina adenophora* * | Crofton Weed | ✓ | ✓ | | AB, MO |
| *Ageratina riparia* * | | ✓ | ✓ | | MO |
| *Ageratum houstonianum* * | Blue Billy Goat Weed | ✓ | ✓ | | AB, MO |
| *Ambrosia artemisiifolia* * | | ✓ | ✓ | | MO |
| *Aster subulatus* * | | ✓ | ✓ | | MO |
| *Baccharis halimifolia* * | Groundsel Bush | ✓ | ✓ | | AB, MO |
| *Bidens pilosa* * | Cobblers Peg | ✓ | ✓ | | MO |
| *Chrysanthemoides monilifera* * | Bitou Bush | ✓ | ✓ | | AB, MO |
| *Conyza bonariensis* * | Fleabane | ✓ | ✓ | | AB, MO |
| *Conyza canadensis* * | | ✓ | ✓ | | MO |
| *Conyza parva* * | | | ✓ | | AB |
| *Conyza sumatrensis* * | | ✓ | ✓ | | MO |
| *Crassocephalum crepidioides* * | | ✓ | ✓ | | MO |
| *Eclipta prostrata* * | | ✓ | ✓ | | MO |
| *Emilia sonchifolia* * | | ✓ | ✓ | | MO |
| *Enydra fluctuans* | | | ✓ | | AB |
| *Epaltes australis* | | ✓ | ✓ | | MO |
| *Epaltes cunninghamii* | | | ✓ | | AB |
| *Erechtites valerianifolia* * | | ✓ | ✓ | | MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Euchiton americanum* * | | | ✓ | | AB |
| *Hypochaeris radicata* * | Bear's Ear | ✓ | ✓ | | AB, MO |
| *Ozothamnus diosmifolius* | | ✓ | | | MO |
| *Pseudognaphalium luteoalbum* | | ✓ | ✓ | | MO |
| *Senecio madagascariensis* * | Fireweed | ✓ | ✓ | | AB, MO |
| *Sonchus asper* * | | ✓ | ✓ | | MO |
| *Sonchus oleraceus* * | | ✓ | ✓ | | MO |
| *Taraxacum officinale* * | | ✓ | ✓ | | MO |
| *Wedelia trilobata* * | Wedelia | ✓ | | | MO |
| AVICENNIACEAE | | | | | |
| *Avicennia marina* | Grey Mangrove | | ✓ | | AB, MO |
| BAUERACEAE | | | | | |
| *Bauera capitata* | Bauera | ✓ | ✓ | | MO |
| *Bauera rubioides* | River Rose | ✓ | ✓ | | AB, MO |
| BIGNONIACEAE | | | | | |
| *Pandorea jasminoides* | Bower Vine | | ✓ | | AB |
| *Pandorea pandorana* | Wonga Wonga Vine | ✓ | | | MO |
| BRASSICACEAE | | | | | |
| *Capsella bursapastoris* * | | ✓ | ✓ | | MO |
| *Coronopus didymus* * | | ✓ | ✓ | | MO |
| CAESALPINACEAE | | | | | |
| *Caesalpinia subtropica* | Corky Prickle Vine | ✓ | ✓ | | AB, MO |
| *Senna coluteoides* * | Winter Senna | | ✓ | | AB |
| *Senna pendula* * | | ✓ | ✓ | | MO |
| CAMPANULACEAE | | | | | |
| *Wahlenbergia gracilis* | Blue Bell | ✓ | ✓ | | MO |
| CAPPARACEAE | | | | | |
| *Capparis arborea* | Native Pomegranate | ✓ | | | MO |
| CARYOPHYLLACEAE | | | | | |
| *Drymaria cordata* | | | ✓ | | MO |
| CASUARINACEAE | | | | | |
| *Allocasuarina littoralis* | Black She-Oak | ✓ | ✓ | | AB, MO |
| *Allocasuarina torulosa* | Forest She-Oak | ✓ | | | AB, MO |
| *Casuarina glauca* | Swamp She-Oak | ✓ | ✓ | | AB, MO |
| CELASTRACEAE | | | | | |
| *Denhamia celastroides* | Denhamia | ✓ | ✓ | | AB, MO |
| *Hedraianthera porphyropetala* | | ✓ | | | MO |
| *Hippocratea barbata* | | ✓ | | | MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| CHENOPODIACEAE | | | | | |
| *Einadia hastata* | | | ✓ | | AB |
| *Sarcocornia quinqueflora* | | | ✓ | | AB |
| *Suaeda arbusculoides* | | | ✓ | | AB |
| CLUSIACEAE | | | | | |
| *Hypericum gramineum* | | ✓ | ✓ | | MO |
| CONVOLVULACEAE | | | | | |
| *Ipomea cairica* * | Fine-leaf Morning Glory | ✓ | ✓ | | AB, MO |
| CUNONIACEAE | | | | | |
| *Geissois benthamii* | Red Carabeen | ✓ | | | MO |
| DILLENIACEAE | | | | | |
| *Hibbertia linearis* | Narrow Leaf Hibbertia | ✓ | ✓ | | MO |
| *Hibbertia riparia* | | | ✓ | | AB |
| *Hibbertia salicifolia* | | ✓ | ✓ | | MO |
| *Hibbertia scandens* | Twining Guinea Flower | ✓ | ✓ | | AB, MO |
| *Hibbertia stricta* | | ✓ | ✓ | | MO |
| DROSERACEAE | | | | | |
| *Drosera burmanni* | | ✓ | ✓ | | MO |
| *Drosera peltata* | Pale Sundew | ✓ | ✓ | | MO |
| *Drosera pygmaea* | Small Sundew | ✓ | ✓ | | MO |
| *Drosera spatulata* | Red Sundew | ✓ | ✓ | | MO |
| ELAEOCARPACEAE | | | | | |
| *Elaeocarpus grandis* | Blue Quandong | | ✓ | | AB |
| *Elaeocarpus obovatus* | Grey Carabeen | ✓ | ✓ | | MO |
| *Elaeocarpus reticulatus* | Blueberry Ash | ✓ | ✓ | | AB, MO |
| *Sloanea woollsii* | Yellow Carabeen | ✓ | | | MO |
| EPACRIDACEAE | | | | | |
| *Acrotriche aggregata* | Red Cluster Heath | ✓ | ✓ | | MO |
| *Brachyloma daphnoides* | Daphne Heath | ✓ | ✓ | | MO |
| *Epacris microphylla* | Coral Heath | ✓ | ✓ | | MO |
| *Epacris obtusifolia* | Blunt Leaf Heath | ✓ | ✓ | | MO |
| *Epacris pulchella* | Pink Coral Heath | ✓ | ✓ | | AB, MO |
| *Leucopogon ericoides* | Pink Beard Heath | | ✓ | | AB |
| *Leucopogon lanceolatus var. gracilis* | Beard Heath | ✓ | ✓ | | AB, MO |
| *Leucopogon leptospermoides* | Tea tree Beard Heath | ✓ | ✓ | | AB, MO |
| *Leucopogon margarodes* | Pearl Beard Heath | ✓ | ✓ | | AB, MO |
| *Leucopogon pedicellatus* | | ✓ | ✓ | | MO |
| *Leucopogon pimeleoides* | | ✓ | ✓ | | MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Leucopogon virgatus* | Common Beard Heath | ✓ | ✓ | | MO |
| *Lissanthe sp. A* | | | ✓ | | AB |
| *Monotoca elliptica* | Tree Broom Heath | | ✓ | | AB |
| *Monotoca scoparia* | Prickly Broom Heath | | ✓ | | AB |
| *Monotoca sp.* | | ✓ | ✓ | | MO |
| *Sprengelia sprengelioides* | White Swamp Heath | ✓ | ✓ | | MO |
| *Styphelia viridis* | | ✓ | ✓ | | MO |
| ESCALLONIACEAE | | | | | |
| *Quintinia verdonii* | Grey Possumwood | ✓ | | | MO |
| EUPHOMATIACEAE | | | | | |
| *Euphomatia laurina* | Bolwarra | | ✓ | | AB |
| EUPHORBIACEAE | | | | | |
| *Breynia oblongifolia* | Drawfs Apples | ✓ | ✓ | | MO |
| *Chamaesyce drummondii* | | ✓ | ✓ | | AB, MO |
| *Cleistanthus cunninghamii* | Omega | ✓ | | | MO |
| *Croton verreauxii* | Green Native Cascarilla | ✓ | | | MO |
| *Excoecaria agallocha* | Milky Mangrove | | ✓ | | AB, FRC |
| *Glochidion ferdinandi* | Cheese Tree | ✓ | ✓ | | AB, MO |
| *Glochidion sumatranum* | Umbrella Cheese Tree | ✓ | ✓ | | AB, MO |
| *Macaranga tanarius* | Macaranga | ✓ | ✓ | | AB, MO |
| *Mallotus discolor* | White Kamala | ✓ | | | MO |
| *Mallotus philippensis* | Red Kamala | ✓ | ✓ | | AB, MO |
| *Omalanthus nutans* | | ✓ | ✓ | | MO |
| *Omalanthus populifolius* | Bleeding Heart | | ✓ | | AB |
| *Phyllanthus virgatus* | | | ✓ | | AB |
| *Pseudanthus orientalis* | Sand Hill Pseudanthus | ✓ | ✓ | | AB, MO |
| *Ricinocarpos pinifolius* | Wedding Bush | ✓ | ✓ | | AB, MO |
| FABACEAE | | | | | |
| *Aotus ericoides* | Common Aotus | ✓ | ✓ | | MO |
| *Aotus lanigera* | | ✓ | ✓ | | AB, MO |
| *Austrosteenisia blackii* | | ✓ | | | MO |
| *Bossiaea heterophylla* | Variable Bossiaea | ✓ | ✓ | | AB, MO |
| *Callerya megasperma* | | ✓ | | | MO |
| *Chorizema parviflora* | | | ✓ | | AB |
| *Crotalaria lanceolata* * | | ✓ | ✓ | | MO |
| *Davesia arborea* | Tree Bitter Pea | ✓ | | | AB, MO |
| *Desmodium intortum* * | | ✓ | ✓ | | MO |
| *Desmodium rhytidophyllum* | Rusty Desmodium | ✓ | | | AB |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Desmodium tortuosum* * | | ✓ | ✓ | | MO |
| *Dillwynia floribunda* | Flowery Parrot Pea | ✓ | ✓ | | MO |
| *Dillwynia retorta* | Twisted Parrot Pea | ✓ | ✓ | | AB, MO |
| *Erythrina sykesii* * | | ✓ | | | MO |
| *Eutaxia microphylla* | | | ✓ | | MO |
| *Glycine clandestina* | Twining Glycine | ✓ | ✓ | | AB |
| *Gompholobium pinnatum* | Pinnate Wedge Pea | | ✓ | | AB |
| *Gompholobium virgatum* | Leafy Wedge Pea | ✓ | ✓ | | AB, MO |
| *Hovea acutifolia* | Hovea | ✓ | | | AB, MO |
| *Hovea lanceolata* | Lance Leaf Hovea | ✓ | ✓ | | MO |
| *Indigofera hirsuta* | | ✓ | | | MO |
| *Jacksonia scoparia* | Dogwood | ✓ | | | AB |
| *Jacksonia stackhousii* | | ✓ | ✓ | | MO |
| *Kennedia rubicunda* | Dusky Coral Pea | ✓ | ✓ | | AB, MO |
| *Lotononis bainesii* * | | ✓ | ✓ | | AB, MO |
| *Macroptilium atropurpureum* * | Siratro | ✓ | ✓ | | AB, MO |
| *Macroptilium lathyroides* * | | ✓ | ✓ | | AB, MO |
| *Mirbelia rubiifolia* | Heath Land Mirbelia | ✓ | ✓ | | MO |
| *Mucuna gigantea* | Candelabra Vine | | ✓ | RS | AB |
| *Oxylobium robustum* | Golden Shaggy Pea | ✓ | ✓ | | AB, MO |
| *Phyllota phylicoides* | Phyllota | ✓ | ✓ | | MO |
| *Pultenaea paleacea* | Chaffy Pea-Bush | ✓ | ✓ | | MO |
| *Pultenaea retusa* | | ✓ | ✓ | | AB |
| *Stylosanthes scabra* * | | ✓ | | | MO |
| *Swainsonia galegifolia* | | ✓ | | | AB |
| *Trifolium repens* * | | ✓ | ✓ | | MO |
| GOODENIACEAE | | | | | |
| *Goodenia bellidifolia* | Rocket Goodenia | ✓ | ✓ | | MO |
| *Goodenia paniculata* | Branched Goodenia | | ✓ | | AB |
| *Goodenia rotundifolia* | | ✓ | ✓ | | AB, MO |
| *Goodenia stelligera* | Spike Goodenia | ✓ | ✓ | | MO |
| *Velleia paradoxa* | | | ✓ | | AB |
| *Velleia spathulata* | | ✓ | ✓ | | MO |
| HALORAGACEAE | | | | | |
| *Gonocarpus chinensis* | | ✓ | ✓ | | MO |
| *Gonocarpus micranthus* | | ✓ | ✓ | | AB, MO |
| LAURACEAE | | | | | |
| *Beilschmiedia elliptica* | Grey Walnut | ✓ | | | MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Beilschmiedia obtusifolia* | Blush Walnut | ✓ | | | MO |
| *Cassytha glabella* | | ✓ | ✓ | | MO |
| *Cassytha pubescens* | Devils Twine | ✓ | ✓ | | MO |
| *Cinnamomum camphora* * | Camphor Laurel | ✓ | ✓ | | MO |
| *Cinnamomum virens* | Native Camphor Laurel | ✓ | | | MO |
| ***Cryptocarya foetida*** | **Stinking Cryptocarya** | ✓ | ✓ | TSC (V) NCR (V) EPBC (V) ROTAP | MO |
| *Cryptocarya laevigata* | Glossy Laurel | ✓ | | | MO |
| *Cryptocarya obovata* | Pepperberry Tree | ✓ | | | MO |
| *Cryptocarya triplinervis* | Three-veined Cryptocarya | ✓ | | | MO |
| ***Endiandra globosa*** | **Black Walnut** | ✓ | | NCR (R) ROTAP | MO |
| ***Endiandra muelleri subsp. bracteata*** | | ✓ | | TSC (E) | MO |
| *Endiandra muelleri subsp. muelleri* | | ✓ | | | MO |
| *Endiandra pubens* | Hairy Walnut | ✓ | | | MO |
| *Endiandra sieberi* | Hard Corkwood | ✓ | ✓ | | AB, MO |
| *Litsea australis* | Brown Bolly Gum | | ✓ | | AB |
| *Litsea reticulata* | Bolly Gum | ✓ | | | MO |
| *Neolitsea dealbata* | White Bolly Gum | ✓ | | | MO |
| LENTIBULARIACEAE | | | | | |
| *Utricularia lateriflora* | | ✓ | ✓ | | MO |
| *Utricularia sp.* | | ✓ | ✓ | | MO |
| LOBELIACEAE | | | | | |
| *Lobelia alata* | Swamp Lobelia | ✓ | ✓ | | AB, MO |
| *Lobelia gracilis* | Trailing Lobelia | ✓ | ✓ | | MO |
| *Lobelia purpurascens* | | ✓ | ✓ | | MO |
| LOGANIACEAE | | | | | |
| *Mitrasacme paludosa* | Swamp Mite-Wort | ✓ | ✓ | | MO |
| *Mitrasacme polymorpha* | Bishop's Mitre | | ✓ | | AB |
| LORANTHACEAE | | | | | |
| *Muellerina celastroides* | Coast Mistletoe | | ✓ | | AB |
| LYTHRACEAE | | | | | |
| *Cuphea carthagenesis* * | | | ✓ | | AB |
| MALVACEAE | | | | | |
| *Hibiscus diversifolius* | | | ✓ | | MO |
| *Hibiscus splendens* | Pink Hibiscus | ✓ | | | MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Hibiscus tiliaceus* | Cottonwood Hibiscus | | ✓ | | AB |
| *Rhaphiolepis indica* * | | ✓ | | | MO |
| *Sida cordifolia* * | | ✓ | ✓ | | MO |
| *Sida rhombifolia* * | Paddy's Lucerne | ✓ | ✓ | | AB, MO |
| *Urena lobata* * | | | ✓ | | MO |
| MELASTOMATACEAE | | | | | |
| *Melastoma affine* | Native Lasiandra | ✓ | ✓ | | AB, MO |
| MELIACEAE | | | | | |
| *Dysoxylum mollissimum* | | ✓ | | | MO |
| *Synoum glandulosum* | | ✓ | | | MO |
| MENISPERMACEAE | | | | | |
| *Austrostephania aculeata* | | ✓ | | | MO |
| *Stephania japonica* | Snake Vine | ✓ | ✓ | | AB, MO |
| MENYANTHACEAE | | | | | |
| *Villarsia exaltata* | Yellow Marsh Flower | ✓ | ✓ | | MO |
| MIMOSACEAE | | | | | |
| *Acacia aulacocarpa* | Scrub Ironbark Wattle | ✓ | ✓ | | AB, MO |
| *Acacia aulacocarpa var. aulacocarpa* | | | ✓ | | MO |
| ***Acacia baueri subsp. baueri*** | **Little Wattle** | | ✓ | NCR (V) | MO |
| *Acacia concurrens* | | ✓ | ✓ | | AB, MO |
| *Acacia falcata* | Sickle Wattle | ✓ | ✓ | | MO |
| *Acacia fimbriata* | Fringed Wattle | ✓ | ✓ | | MO |
| *Acacia longissima* | Narrow-leaved Wattle | ✓ | | | AB, MO |
| *Acacia melanoxylon* | Sally Wattle | ✓ | ✓ | | AB, MO |
| *Acacia obtusifolia* | Blunt-leaved Wattle | | ✓ | RS | AB, MO |
| *Acacia penninervis* | Hickory Wattle | ✓ | ✓ | | MO |
| *Acacia sophorae* | Coast Wattle | ✓ | ✓ | | AB, MO |
| *Acacia suaveolens* | Sweet Wattle | ✓ | ✓ | | MO |
| *Acacia ulicifolia* | Prickly Mosses | ✓ | ✓ | | AB, MO |
| *Archidendron grandiflorum* | Lace Flower Tree | ✓ | | | AB, MO |
| ***Archidendron hendersonii*** | **White Lace Flower** | | ✓ | TSC (V) | AB |
| ***Archidendron muellerianum*** | **Veiny Lace Flower** | ✓ | | NCR (R) ROTAP | MO |
| MONIMIACEAE | | | | | |
| *Wilkiea austroqueenslandica* | Smooth Wilkiea | ✓ | | | MO |
| *Wilkiea huegeliana* | Veiny Wilkiea | ✓ | | | MO |
| MORACEAE | | | | | |
| *Ficus coronata* | Creek Sandpaper Fig | ✓ | ✓ | | AB, MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Ficus fraseri* | Sandpaper Fig | ✓ | | | MO |
| *Ficus macrophylla* | Moreton Bay Fig | ✓ | ✓ | | AB, MO |
| *Ficus obliqua* | Small-leaved Fig | ✓ | ✓ | | AB, MO |
| *Maclura cochinchinensis* | Orange Thorn | ✓ | ✓ | | AB, MO |
| *Morus alba* * | Mulberry | | ✓ | | AB |
| *Streblus brunonianus* | Whalebone Tree | ✓ | | | MO |
| *Trophis scandens* | | ✓ | | | MO |
| MYOPORACEAE | | | | | |
| *Myoporum boninense* subsp. *australe* | Mangrove Boobialla | | ✓ | | AB |
| MYRSINACEAE | | | | | |
| *Aegiceras corniculatum* | River Mangrove | | ✓ | | AB, MO |
| *Ardisia crispa* * | | ✓ | | | MO |
| *Embelia australiana* | | ✓ | | | MO |
| *Rapanea variabilis* | | ✓ | ✓ | | MO |
| MYNSW Roads and Traffic AuthorityCEAE | | | | | |
| *Acmena smithii* | Lilly Pilly | | ✓ | | |
| *Archirhodomyrtus beckleri* | | ✓ | | | MO |
| *Austromyrtus acmenoides* | Scrub Ironwood | ✓ | | | MO |
| *Austromyrtus bidwillii* | Python Tree | ✓ | | | MO |
| *Austromyrtus dulcis* | Midgenberry | ✓ | ✓ | | AB, MO |
| *Austromyrtus sp.* (Brookfield) | | ✓ | | | MO |
| *Babingtonia virgata* | | ✓ | ✓ | | MO |
| *Baeckea diosmifolia* | Drosma Myrtle Heath | ✓ | ✓ | | MO |
| *Baeckea sp* | | | ✓ | | MO |
| *Baeckea stenophylla* | Weeping Baekea | ✓ | ✓ | | AB, MO |
| *CalIistemon pachyphylIus* | Heath Bottlebrush | ✓ | ✓ | | AB, MO |
| *Calistemon salignus* | Willow Leaf Bottle Brush | ✓ | ✓ | | AB, MO |
| *Calytrix tetragona* | Fringe Myrtle | ✓ | ✓ | | MO |
| *Corymbia gummifera* | Red Bloodwood | ✓ | ✓ | | AB, MO |
| *Corymbia intermedia* | Pink Bloodwood | ✓ | | | AB |
| *Corymbia torelliana* * | Cadaghi | ✓ | ✓ | | AB, MO |
| *Corymbia varigata* | Spotted Gum | ✓ | | | AB |
| *Decaspermum humile* | | ✓ | | | MO |
| *Eucalyptus carnea* | Broad-leaved White Mahogany | ✓ | | | AB |
| *Eucalyptus grandis* | Flooded Gum | ✓ | | | MO |
| *Eucalyptus microcorys* | Tallowwood | ✓ | | | MO |
| *Eucalyptus pilularis* | Blackbutt | ✓ | | | AB, MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Eucalyptus propinqua* | Small-fruited Grey Gum | ✓ | | | AB, MO |
| *Eucalyptus racemosa* | Scribbly Gum | ✓ | ✓ | | AB, MO |
| *Eucalyptus resinifera* | Red Mahogany | | ✓ | | AB |
| *Eucalyptus robusta* | Swamp Mahogany | ✓ | ✓ | | AB, MO |
| *Eucalyptus siderophloia* | Broad-leaved ironbark | ✓ | | | AB, MO |
| *Eucalyptus tereticornis* | Forest Red Gum | | ✓ | | AB |
| *Homoranthus virgatus* | | ✓ | ✓ | | MO |
| *Leptospermum juniperinum* | Prickly Tea-Tree | ✓ | ✓ | | AB, MO |
| *Leptospermum laevigatum* | Coastal Tea-Tree | ✓ | ✓ | | MO |
| *Leptospermum liversidgei* | Lemon-scented Tea-Tree | ✓ | ✓ | | AB, MO |
| *Leptospermum polygalifolium ssp. polygalif.* | Common Tea-Tree | | ✓ | | AB |
| *Leptospermum semibaccatum* | Soft-fruited Tea-Tree | ✓ | ✓ | | AB, MO |
| *Leptospermum trinervium* | Shaggy Tea-Tree | ✓ | ✓ | | AB, MO |
| *Leptospermum whitei* | Tea-Tree | ✓ | ✓ | | AB, MO |
| *Lophostemon confertus* | Brushbox | ✓ | ✓ | | AB, MO |
| *Lophostemon suaveolens* | Swamp Brushbox | ✓ | ✓ | | AB, MO |
| *Melaleuca linariifolia* | Snow-in-Summer | ✓ | ✓ | | MO |
| *Melaleuca nodosa* | Ball Honey Myrtle | ✓ | ✓ | | MO |
| *Melaleuca quinquenervia* | Broad-leaved paperbark | ✓ | ✓ | | AB, MO |
| *Melaleuca thymifolia* | Thyme Honey Myrtle | ✓ | ✓ | | AB, MO |
| *Ochrosperma citriodora* | Lemon-scented Baekea | | ✓ | RS | AB |
| *Ochrosperma diosmifolius* | | | ✓ | | AB |
| *Ochrosperma lineare* | Sand Baekea | ✓ | ✓ | | AB, MO |
| *Pilidiostigma glabrum* | | ✓ | | | MO |
| ***Rhodamnia maideniana*** | **Smooth Scrub Turpentine** | ✓ | | NCR (R)<br>ROTAP | MO |
| *Rhodamnia rubescens* | Scrub Turpentine | ✓ | | | MO |
| *Syzygium corynanthum* | Sour Cherry | ✓ | | | MO |
| *Syzygium luehmannii* | Small-leaved Water Gum | ✓ | | | MO |
| ***Syzygium moorei*** | **Durobby** | ✓ | | TSC (V)<br>NCR (V)<br>ROTAP<br>EPBC (V) | MO |
| *Syzygium oleosum* | Blue Lilly Pilly | ✓ | ✓ | | AB, MO |
| *Syzygium uniflorum* * | | ✓ | ✓ | | MO |
| NYPHAEACEAE | | | | | |
| *Nymphaea caerulea* * | | | ✓ | | MO |
| *Nymphaea capensis* * | Cape Water Lily | ✓ | | | MO |
| OCHNACEAE | | | | | |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Ochna serrulata* * | Ochra | ✓ | ✓ | | AB, MO |
| OLEACEAE | | | | | |
| *Notelaea longifolia* | Mock Olive | ✓ | ✓ | | AB, MO |
| ONAGRACEAE | | | | | |
| *Oenothera indecora* * | | | ✓ | | AB |
| OXALIDACEAE | | | | | |
| *Oxalis debilis* | | ✓ | | | MO |
| PASSIFLORACEAE | | | | | |
| *Passiflora edulis* * | Common Passionflower | ✓ | ✓ | | AB, MO |
| *Passiflora suberosa* * | Corky Passionflower | ✓ | ✓ | | AB, MO |
| *Passiflora subpeltata* * | | ✓ | ✓ | | MO |
| PHYTOLACCACEAE | | | | | |
| *Phytolacca octandra* * | | | ✓ | | MO |
| PITTOSPORACEAE | | | | | |
| *Pittosporum undulatum* | | ✓ | | | MO |
| PLANTAGINACEAE | | | | | |
| *Plantago lanceolata* * | | ✓ | ✓ | | MO |
| POLYGALACEAE | | | | | |
| *Comesperma defoliatum* | Leafless Comesperma | ✓ | ✓ | | AB, MO |
| *Comesperma ericinum* | Match Sticks | | ✓ | RS | MO |
| *Comesperma volubile* | Love Creeper | | ✓ | | AB, MO |
| *Persicaria lapathifolia* * | | ✓ | ✓ | | MO |
| *Persicaria strigosa* * | | ✓ | ✓ | | AB, MO |
| *Rumex crispus* * | Common Dock | ✓ | ✓ | | AB, MO |
| PRIMULACEAE | | | | | |
| *Anagallis arvensis* * | | ✓ | ✓ | | MO |
| PROTEACEAE | | | | | |
| *Banksia aemula* | Wallum Banksia | ✓ | ✓ | | AB, MO |
| *Banksia integrifolia* | Coast Banksia | ✓ | ✓ | | AB, MO |
| *Banksia oblongifolia* | Swamp Banksia | ✓ | ✓ | | AB, MO |
| *Banksia robur* | large Leaf Banksia | ✓ | ✓ | | AB, MO |
| *Conospermum taxifolium* | Cone Seeds | ✓ | ✓ | | AB, MO |
| ***Grevillea hilliana*** | **White Silky Oak** | ✓ | | **TSC (E)** | **MO** |
| *Grevillea robusta* | Silky Oak | ✓ | | | MO |
| *Helicia glabriflora* | Smooth Helicia | ✓ | | | MO |
| ***Macadamia tetraphylla*** | **Rough-leaved Queensland Nut** | ✓ | | TSC (V)<br>NCR (V)<br>EPBC (V)<br>ROTAP | MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Persoonia adenantha* | | ✓ | ✓ | | MO |
| *Persoonia linearis* | Narrowleaf Geebung | ✓ | | | AB |
| *Persoonia stradbrokensis* | Geebung | ✓ | ✓ | | AB, MO |
| *Persoonia virgata* | Geebung | ✓ | ✓ | | AB, MO |
| *Stenocarpus sinuatus* | | ✓ | | | MO |
| *Strangea linearis* | | | ✓ | RS | AB, MO |
| RANUNCULACEAE | | | | | |
| *Ranunculus innudatus* | | | ✓ | | AB |
| RHAMNACEAE | | | | | |
| *Alphitonia excelsa* | | ✓ | ✓ | | MO |
| RHIZOPHORACEAE | | | | | |
| *Bruguiera gymnorrhiza* | Large Leafed Orange Mangrove | | ✓ | | FRC |
| *Rhizophora stylosa* | Red Mangrove | | ✓ | | FRC |
| ROSACEAE | | | | | |
| *Rubus ellipticus* * | Yellow Himalyan Raspberry | ✓ | | | MO |
| *Rubus hillii* | Wild Raspberry | | ✓ | | AB |
| *Rubus moluccanus* * | | ✓ | ✓ | | MO |
| *Rubus parvifolius* | Native Bramble | ✓ | | | MO |
| *Rubus rosifolius* | Native Raspberry | | ✓ | | AB |
| RUBIACEAE | | | | | |
| *Durringtonia paludosa* | | | ✓ | | AB |
| *Morinda jasminoides* | Morinda | ✓ | ✓ | | AB, MO |
| *Pomax umbellata* | Pomax | ✓ | ✓ | | AB, MO |
| *Psychotria loniceroides* | Hairy Psychotria | ✓ | | | AB |
| *Richardia brasiliensis* * | | ✓ | ✓ | | MO |
| RUTACEAE | | | | | |
| *Acronychia imperforata* | Coastal Aspen | | ✓ | | AB |
| *Acronychia pubescens* | | ✓ | | | MO |
| *Boronia falcifolia* | Sickle Boronia | ✓ | ✓ | | AB, MO |
| *Boronia rosmarinifolia* | | ✓ | ✓ | | AB, MO |
| *Citrus limon* * | | ✓ | | | MO |
| *Flindersia australis* | Ausralian Teak, Crows Ash | ✓ | | | MO |
| *Flindersia schottiana* | | ✓ | | | MO |
| *Melicope elleryana* | Pink Euodia | ✓ | ✓ | | AB, MO |
| *Phebalium squamulosum* | Scaly Phebalium | | ✓ | | MO |
| *Phebalium squameum* | Satinwood | | ✓ | | AB |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Sarcomelicope simplicifolia* | | ✓ | | | MO |
| *Zieria laevigata* | Coastal Zieria | | ✓ | | AB |
| *Zieria laxiflora* | | ✓ | ✓ | | MO |
| *Zieria smithii* | Stunkwood | ✓ | ✓ | | AB, MO |
| SANTALACEAE | | | | | |
| *Leptomeria drupacea* | Native Currant | ✓ | ✓ | | AB, MO |
| SAPINDACEAE | | | | | |
| *Arytera distylis* | | ✓ | | | MO |
| *Arytera divaricata* | | ✓ | | | MO |
| *Cupaniopsis anacardioides* | Tuckeroo | ✓ | ✓ | | AB, MO |
| ***Cupaniopsis newmanii*** | **Long-leaved Tuckeroo** | ✓ | | NCR (R)<br>ROTAP | MO |
| *Diploglottis australis* | Native Tamarind | ✓ | | | MO |
| *Dodonaea triquetra* | Hop Bush | ✓ | ✓ | | AB, MO |
| *Elattostachys nervosa* | Green Tamarind | ✓ | | | MO |
| *Guioa semiglauca* | Guioa | ✓ | ✓ | | AB, MO |
| *Jagera pseudorhus* | Foambark Tree | ✓ | ✓ | | AB, MO |
| ***Lepiderema pulchella*** | **Fine-leaved Tuckeroo** | ✓ | | TSC (V)<br>NCR (R)<br>ROTAP | MO |
| *Mischocarpus pyriformis* | Yellow Pear-Fruit | ✓ | | | MO |
| *Planchonella chartacea* | Thin-leaved Coondoo | | ✓ | | AB |
| *Pouteria australis* | | ✓ | | | MO |
| *Pouteria chartacea* | | ✓ | | | MO |
| *Sarcopteryx stipata* | Steelwood | ✓ | | | MO |
| SCROPHULARIACEAE | | | | | |
| *Bacopa monnieri* | | | ✓ | | AB |
| SOLANACEAE | | | | | |
| *Duboisia myoporoides* | Soft Corkwood | | ✓ | | AB |
| *Solanum americanum* * | | ✓ | ✓ | | MO |
| *Solanum callium* | Brush Nightshade | ✓ | | | MO |
| *Solanum capsicoides* * | Devil's Apple | | ✓ | | AB |
| *Solanum densevestitum* | Furry Nightshade | ✓ | ✓ | | MO |
| *Solanum mauritianum* * | Tobacco Bush | ✓ | ✓ | | AB, MO |
| STACKHOUSIACEAE | | | | | |
| *Stackhousia nuda* | | | ✓ | | AB |
| *Stackhousia viminea* | Swamp Stackhousia | ✓ | ✓ | | MO |
| STERCULIACEAE | | | | | |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Argyrodendron trifoliolatum* | White Booyong | ✓ | | | MO |
| *Brachychiton acerifolius* | Flame Tree | ✓ | | | MO |
| *Commersonia bartramia* | Brush Kurrajong | ✓ | ✓ | | AB, MO |
| *Sterculia quadrifida* | Red-Fruited Kurrajong | ✓ | | | MO |
| STYLIDIACEAE | | | | | |
| *Stylidium graminifolium* | Trigger Plant | ✓ | ✓ | | MO |
| *Stylidium ornatum* | | ✓ | ✓ | | MO |
| SYMPLOCACEAE | | | | | |
| *Symplocos stawellii* | White hazelwood | | ✓ | | AB |
| *Symplocos thwaitesii* | Buff hazelwood | ✓ | ✓ | | MO |
| THYMELAEACEAE | | | | | |
| *Pimelea linifolia* | | ✓ | ✓ | | AB, MO |
| TILIACEAE | | | | | |
| *Triumfetta rhomboidea* * | Chinese Burr | | ✓ | RS | AB, MO |
| ULMACEAE | | | | | |
| *Aphananthe philippinensis* | | ✓ | | | MO |
| *Celtis sinensis* * | | ✓ | ✓ | | MO |
| *Trema aspera* | Poison Peach | | ✓ | | AB |
| VERBENACEAE | | | | | |
| *Clerodendrum floribundum* | Smooth Clerodendrum | ✓ | | | MO |
| *Lantana camara* * | Lantana | ✓ | ✓ | | MO |
| *Verbena bonariensis* * | Verbena | ✓ | ✓ | | MO |
| VITACEAE | | | | | |
| *Cayratia clematidea* | | ✓ | | | MO |
| *Cissus antarctica* | Simple Leaved Water Vine | ✓ | | | MO |
| *Cissus hypoglauca* | Fine-leaved Water Vine | ✓ | ✓ | | AB, MO |
| *Cissus opaca* | | ✓ | ✓ | | AB, MO |
| **MONOCOTYLEDONS** | | | | | |
| AMARYILLIDACEAE | | | | | |
| *Crinum pedunculatum* | Swamp Lily | | ✓ | | AB |
| ANTHERICACEAE | | | | | |
| *Arthropodium milleflorum* | | ✓ | ✓ | | MO |
| *Caesia parviflora* | | ✓ | ✓ | | MO |
| *Laxmannia gracilis* | Wire Lily | ✓ | ✓ | | AB, MO |
| *Sowerbaea juncea* | | ✓ | ✓ | | MO |
| ARACEAE | | | | | |
| *Alocasia brisbanensis* | | ✓ | | | MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Gymnostachys anceps* | Native Flax | ✓ | | | AB, MO |
| *Pothos longipes* | | ✓ | | | MO |
| ARECACEAE | | | | | |
| *Archontophoenix cunninghamiana* | Bangalow Palm | ✓ | ✓ | | AB, MO |
| *Calamus muelleri* | | ✓ | | | MO |
| *Syagrus romanzoffianum* * | | ✓ | | | MO |
| ASPARAGACEAE | | | | | |
| *Asparagus africanus* * | | ✓ | | | MO |
| *Protoasparagus aethiopicus* | Sprengeri Fern | | ✓ | | AB |
| ASTELIACEAE | | | | | |
| *Cordyline congesta* | Coast Palm Lily | ✓ | ✓ | RS ROTAP | AB, MO |
| *Cordyline rubra* | Red-fruited Palm Lily | ✓ | | | MO |
| *Cordyline stricta* | Narrow-leaved Palm Lily | ✓ | | | MO |
| BLANDFORDIACEAE | | | | | |
| **Blandfordia grandiflora** | **Christmas Bells** | | ✓ | NCR (R) | MO |
| BURMANNIACEAE | | | | | |
| *Burmannia disticha* | Native Stattrus | | ✓ | | AB, MO |
| COMMELINACEAE | | | | | |
| *Commelina cyanea* | Wandering Dew | | ✓ | | AB |
| *Commelina diffusa* | | ✓ | ✓ | | MO |
| *Pollia crispata* | | ✓ | | | MO |
| CYPERACEAE | | | | | |
| *Abildgardia ovata* | | | ✓ | | AB |
| *Baumea articulata* | Bamboo Reed | ✓ | ✓ | | AB, MO |
| *Baumea juncea* | Bare Twig Rush | | ✓ | | AB, MO |
| *Baumea muelleri* | | ✓ | ✓ | | MO |
| *Baumea rubiginosa* | | ✓ | ✓ | | AB, MO |
| *Baumea teretifolia* | Slender Twigrush | ✓ | ✓ | | MO |
| *Carex appressa* | Tall Sedge | ✓ | ✓ | | AB, MO |
| *Carex hubbardii* | | ✓ | | | MO |
| *Caustis recurvata* | Grand Fathers Whiskers | ✓ | ✓ | | AB, MO |
| *Chorizandra cymbaria* | | | ✓ | | AB |
| *Chorizandra sphaerocephala* | | ✓ | ✓ | | MO |
| *Cladium procerum* | Tall Cladium | ✓ | ✓ | | MO |
| *Cyperus difformis* | Rice Weed | ✓ | ✓ | | MO |
| *Cyperus eragrostis* * | | | ✓ | | AB |
| *Cyperus gracilis* | | ✓ | | | MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Cyperus haspan* | | ✓ | ✓ | | MO |
| *Cyperus haspan subsp. juncoides* | | | ✓ | | AB |
| *Cyperus lucidus* | | | ✓ | | AB |
| *Cyperus polystachyos* | Bunchy Sedge | ✓ | ✓ | | AB, MO |
| *Cyperus sesquiflorus* * | Mullimbimby Couch | ✓ | ✓ | | MO |
| *Cyperus sphaeroideus* | | | ✓ | | AB |
| *Cyperus stradbrokensis* | | | ✓ | | AB |
| *Eleocharis equisetina* | Sag Spikerush | ✓ | ✓ | | MO |
| *Fimbristylis cinnamometrum* | | | ✓ | | AB |
| *Fimbristylis dichotoma* | Common Fringe Rush | | ✓ | | AB |
| *Fimbristylis ferruginea* | Sedge | | ✓ | | AB |
| *Fimbristylis nutans* | | | ✓ | | AB |
| *Fimbristylis pauciflora* | | ✓ | ✓ | | MO |
| *Fimbristylis polytrichoides* | | ✓ | ✓ | | MO |
| *Fuirena ciliaris* | | ✓ | ✓ | | MO |
| *Gahnia aspera* | Red-fruit Sawsedge | ✓ | | | AB, MO |
| *Gahnia clarkei* | Coastal Sawsedge | ✓ | ✓ | | AB, MO |
| *Gahnia sieberiana* | Saw Sedge | ✓ | ✓ | | AB, MO |
| *Lepidosperma laterale* | Broad Sword Sedge | ✓ | | | MO |
| *Lepironia articulata* | | ✓ | ✓ | | MO |
| *Rhynchospora corymbosa* | | | ✓ | | AB |
| *Schoenoplectus mucronatus* | | ✓ | | | MO |
| *Schoenus apogon* | Fluke Bogrush | ✓ | ✓ | | MO |
| *Schoenus brevifolius* | Small Bogrush | ✓ | ✓ | | MO |
| *Schoenus ericetorum* | Bogrush | ✓ | ✓ | | AB, MO |
| *Schoenus melanostachys* | Rifle Grass | ✓ | ✓ | | MO |
| *Schoenus pachylepis* | | ✓ | ✓ | | MO |
| DIOSCORACEAE | | | | | |
| *Dioscorea transversa* | Native Yam | ✓ | ✓ | | AB, MO |
| ERIOCAULACEAE | | | | | |
| *Eriocaulon scariosum* | Common Pipewort | | ✓ | | AB, MO |
| FLAGGELLARIACEAE | | | | | |
| *Flagellaria indica* | Whip Vine | ✓ | ✓ | | AB, MO |
| GEITONOPLESIACEAE | | | | | |
| *Geitonoplesium cymosum* | Scrambling Lily | ✓ | ✓ | | AB, MO |
| HAEMODORACEAE | | | | | |
| *Haemodorum austroqueenslandicum* | | ✓ | ✓ | | MO |
| IRIDACEAE | | | | | |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Patersonia fragilis* | Little Purple Flag | ✓ | ✓ | | AB, MO |
| *Patersonia sericea* | | ✓ | ✓ | | AB, MO |
| JUNCACEAE | | | | | |
| *Juncus continuus* | | ✓ | ✓ | | MO |
| *Juncus kraussii* | Sea Rush | ✓ | ✓ | | AB, MO |
| *Juncus prismatocarpus* | | ✓ | ✓ | | MO |
| *Juncus usitatus* | Common Rush | ✓ | ✓ | | AB, MO |
| JUNCAGINACEAE | | | | | |
| *Triglochin striatum* | Streaked Arrowgrass | ✓ | ✓ | | AB, MO |
| LOMANDRACEAE | | | | | |
| *Lomandra elongata* | | ✓ | ✓ | | MO |
| *Lomandra laxa* | | ✓ | | | MO |
| *Lomandra longifolia* | Spiny Mat Rush | ✓ | ✓ | | AB, MO |
| LUZURIAGACEAE | | | | | |
| *Eustrephus latifolius* | Wombat Berry | ✓ | ✓ | | AB, MO |
| LYCOPODIACEAE | | | | | |
| *Lycopodiella cernua* | | ✓ | ✓ | | MO |
| ORCHIDACEAE | | | | | |
| *Caladenia carnea* | | ✓ | ✓ | | MO |
| *Calanthe triplicata* | Christmas Orchid | | ✓ | | AB |
| *Erythrorchis cassythoides* | | ✓ | | | MO |
| ***Geodorum densiflorum*** | | | ✓ | TSC (E) | AB |
| *Microtis unifolia* | | ✓ | ✓ | | MO |
| ***Phaius australis*** | **Swamp Orchid** | | ✓ | TSC (E)<br>NCR (E)<br>EPBC (E)<br>ROTAP | MO |
| *Spiranthes sinensis* | Ladies Tresses | ✓ | ✓ | | MO |
| *Thelymitra pauciflora* | | ✓ | ✓ | | MO |
| PHILYDRACEAE | | | | | |
| *Philydrum lanuginosum* | Frogsmouth | ✓ | ✓ | | AB, MO |
| PHORMIACEAE | | | | | |
| *Dianella brevipedunculata* | | | ✓ | | MO |
| *Dianella caerulea* | Rough Flax Lily | ✓ | ✓ | | AB, MO |
| *Stypandra glauca* | Nodding Blue Lily | ✓ | ✓ | | MO |
| POACEAE | | | | | |
| *Andropogon virginicus* * | Whisky Grass | ✓ | ✓ | | MO |
| *Aristida queenslandica* | | ✓ | ✓ | | AB, MO |
| *Aristida ramosa* | | ✓ | | | AB |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Axonopus compressus* * | Carpet Grass | ✓ | ✓ | | AB, MO |
| *Brachiaria mutica* * | | ✓ | ✓ | | MO |
| *Bromus catharticus* * | | ✓ | ✓ | | MO |
| *Cenchrus echinatus* * | | ✓ | ✓ | | MO |
| *Cenchrus pennisetiformis* * | A Buffel Grass | | ✓ | | AB |
| *Cymbopogon refractus* | Barb-wire Grass | ✓ | | | AB, MO |
| *Cynodon dactylon* * | Common Couch Grass | ✓ | ✓ | | AB, MO |
| *Diplachne uninervia* * | | | ✓ | | AB |
| *Echinochloa telmatophila* | Swamp Barnyard Grass | | ✓ | | AB |
| *Eleusine indica* * | | ✓ | | | MO |
| *Entolasia stricta* | Entolasia | ✓ | ✓ | | AB, MO |
| *Eragrostis cilianensis* * | | ✓ | ✓ | | MO |
| *Eragrostis elongata* | Clustered Love Grass | ✓ | ✓ | | MO |
| *Eragrostis sororia* | Love Grass | | ✓ | | AB |
| *Eragrostis spartinoides* | | ✓ | ✓ | | MO |
| *Eragrostis tenuifolia* * | | ✓ | ✓ | | MO |
| *Eriachne glabrata* | | ✓ | ✓ | | MO |
| *Hyparrhenia rufa* * | | ✓ | ✓ | | MO |
| *Imperata cylindrica* | Blady Grass | ✓ | ✓ | | AB, MO |
| *Isachne globosa* | | | ✓ | | AB |
| *Ischaemum australe* | | ✓ | ✓ | | AB, MO |
| *Ischaemum fragile* | | ✓ | ✓ | | MO |
| *Isolepis inundatus* | | | ✓ | | AB |
| *Leersia hexandra* | Swamp Rice Grass | ✓ | ✓ | | AB, MO |
| *Melinis minutiflora* * | Malassus Grass | ✓ | ✓ | | AB, MO |
| *Melinis repens* * | | ✓ | ✓ | | MO |
| *Microlaena stipoides* | | | ✓ | | AB |
| *Oplismenus aemulus* | | ✓ | | | MO |
| *Ottochloa gracillima* | | ✓ | ✓ | | AB, MO |
| *Panicum effusum* | Hairy Panic | ✓ | | | MO |
| *Panicum maximum* * | | ✓ | ✓ | | MO |
| *Panicum simile* | | | ✓ | | AB |
| *Paspalidium distans* | | ✓ | ✓ | | MO |
| *Paspalidium sp* | | | ✓ | | MO |
| *Paspalum conjugatum* * | | | ✓ | | AB |
| *Paspalum dilatatum* * | Paspalum | ✓ | ✓ | | AB, MO |
| *Paspalum scrobiculatum* | | ✓ | ✓ | | MO |
| *Paspalum urvillei* * | Vasey Grass | ✓ | ✓ | | AB, MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Pennisetum atropurpureum* * | | ✓ | | | MO |
| *Pennisetum clandestinum* * | | ✓ | | | MO |
| *Phragmites australis* | | ✓ | ✓ | | MO |
| *Phragmites communis* | Common Reed | | ✓ | | AB |
| *Sacciolepis indica* | Indian Cup Grass | ✓ | ✓ | | AB, MO |
| *Setaria sphacelata* * | South African Pigeon Grass | ✓ | ✓ | | AB, MO |
| *Sporobolus virginicus* | Saltwater Couch | | ✓ | | AB |
| *Themeda australis* | Kangaroo Grass | ✓ | ✓ | | AB |
| *Themeda triandra* | | ✓ | ✓ | | MO |
| PONTEDERIACEAE | | | | | |
| *Eichhornia crassipes* * | Water Hyacinth | | ✓ | | AB |
| RESTIONACEAE | | | | | |
| *Baloskion complanatus* | | | ✓ | | MO |
| *Baloskion pallens* | | ✓ | ✓ | | MO |
| *Baloskion tenuiculmis* | Dwarf Restio | ✓ | ✓ | | AB, MO |
| *Baloskion tetraphyllus* | Feather Plant | ✓ | ✓ | | AB, MO |
| *Empodisma minus* | Spreading Rope Rush | ✓ | ✓ | | AB, MO |
| *Hypolaena fastigiata* | | ✓ | ✓ | | MO |
| *Leptocarpus tenax* | | ✓ | ✓ | | MO |
| *Lepyrodia interrupta* | | ✓ | ✓ | | AB, MO |
| SMILACACEAE | | | | | |
| *Ripogonum album* | | ✓ | | | MO |
| *Ripogonum elseyanum* | Hairy Supplejack | | ✓ | | AB |
| *Smilax australis* | Prickly Supplejack | ✓ | ✓ | | AB, MO |
| *Smilax glyciphylla* | Native Sarsparilla | ✓ | ✓ | | AB, MO |
| TYPHACEAE | | | | | |
| *Typha domingensis* | | ✓ | ✓ | | MO |
| *Typha orientialis* | Bullrush | | ✓ | | AB |
| UVALARIACEAE | | | | | |
| *Tripladenia cunninghamii* | Tripladenia | | ✓ | | AB |
| XANTHORRHOEACEAE | | | | | |
| *Xanthorrhoea fulva* | | ✓ | ✓ | | AB, MO |
| *Xanthorrhoea johnsonii* | | | ✓ | | AB |
| *Xanthorrhoea latifolia* | Grass Tree | | ✓ | | AB |
| XYRIDACEAE | | | | | |
| *Xyris complanata* | | ✓ | ✓ | | MO |
| *Xyris juncea* | | ✓ | ✓ | | MO |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status | Recorded By |
|---|---|---|---|---|---|
| *Xyris operculata* | Xyris | | ✓ | | AB |
| ZINGIBERACEAE | | | | | |
| *Alpinia caerulea* | Native Ginger | ✓ | | | AB, MO |

Notes:

EPBC = Commonwealth *Environment Protection and Biodiversity Conservation Act 1999;*
TSC = NSW *Threatened Species Conservation Act 1995;*
NCR = Queensland Nature Conservation (Wildlife) Regulation 1994;
ROTAP = Rare or Threatened Australian Plants (Briggs and Leigh 1996);
E = Endangered;
V = Vulnerable;
R = Rare;
RS = Regionally Significant;
* = introduced species;
AB = Andrew Benwell;
MO = Mike Olsen;
FRC = FRC Environmental;
Bold = Legislatively Significant Species.

# Appendix M

List of fauna species recorded from the study area during the field surveys

## Appendix M: List of fauna species recorded from the study area during the field surveys

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status |
|---|---|---|---|---|
| **AQUATIC FAUNA:** | | | | |
| *Petroscirtes breviceps* | Short-headed Sabre-tooth Blenny | | ✓ | |
| *Fistularia commersonii* | Smooth Flutmouth | | ✓ | |
| *Girella tricuspidata* | Luderick | | ✓ | |
| *Bathygobius sp.* | Goby | | ✓ | |
| *Meuschenia trachylepis* | Yellow-finned leatherjacket | | ✓ | |
| *Rhabdosargus sarba* | Tarwhine | | ✓ | |
| *Urocampus carinirostris* | Hairy Pipefish | | ✓ | |
| *Pelates quadrilineatus* | Trumpter | | ✓ | |
| *Gobiomorphys australis* | Striped Gudgeon | | ✓ | |
| *Hypseliotris compressa* | Empire Gudgeon | | ✓ | |
| *Centrapogon marmoratus* | Bullrout | | ✓ | |
| *Gambusia affinis** | Mosquito Fish | | ✓ | |
| *Cherax sp.* | Yabbie | | ✓ | |
| *Metapenaeus bennettae* | Bay Prawn | | ✓ | |
| **INVERTEBRATES:** | | | | |
| *Petalura litorea* | Queensland Giant Dragonfly | ✓ | | RS |
| *Telephlebia ?cyclops* | A Crespuscular Dragonfly | | | |
| *Austroargiolestes icteromelas nigrolabiatus* | Damsefly | | | |
| *Tisiphone abeona morrisi* | Swordgrass Brown Butterfly | | ✓ | RS |
| *Gyrocochlea eurythma* | Land Snail | | | |
| *Sphaerospira fraseri* | Land Snail | | | |
| *Strangesta ramsayi* | Land Snail | | | |
| *Hedleyoconcha delta* | Land Snail | | | |
| **TERRESTRIAL VERTEBRATE FAUNA:** | | | | |
| **Frogs:** | | | | |
| *Bufo marinus** | Cane Toad | ✓ | ✓ | |
| *Crinia parinsignifera* | Plains Froglet | ✓ | ✓ | |
| *Crinia signifera* | Common Eastern Froglet | ✓ | ✓ | |
| ***Crinia tinnula*** | **Wallum Froglet** | ✓ | ✓ | TSC (V) NCR (V) |
| *Limnodynastes ornates* | Ornate Burrowing Frog | | ✓ | |
| *Limnodynastes peronii* | Striped Marsh Frog | ✓ | ✓ | |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status |
|---|---|---|---|---|
| *Limnodynastes terraereginae* | Northern Banjo Frog | ✓ | ✓ | |
| *Litoria caerulea* | Green Tree Frog | ✓ | ✓ | |
| *Litoria dentata* | Bleating Tree Frog | | ✓ | |
| *Litoria fallax* | Eastern Dwarf Tree Frog | ✓ | ✓ | |
| *Litoria gracilenta* | Dainty Green Tree Frog | ✓ | ✓ | |
| *Litoria nasuta* | Rocket Frog | ✓ | ✓ | |
| ***Litoria olongburensis*** | **Wallum Sedge Frog** | | ✓ | TSC (V)<br>NCR (V)<br>EPBC (V) |
| *Litoria peronii* | Peron's Tree Frog | ✓ | ✓ | |
| *Litoria rubella* | Desert Tree Frog | | ✓ | |
| *Litoria tyleri* | Tyler's Tree Frog | ✓ | ✓ | |
| *Pseudophyrne raveni* | | ✓ | | |
| **Reptiles:** | | | | |
| *Carlia vivax* | | | ✓ | |
| *Cacophis krefftii* | Dwarf Crowned Snake | | ✓ | |
| *Cryptoblepharus virgatus* | Wall Lizard | | ✓ | |
| *Ctenotus arcanus* | | | ✓ | |
| *Ctenotus robustus* | Striped Skink | | ✓ | |
| *Demansia psammophis* | Yellow-faced Whip Snake | | ✓ | |
| *Dendrelaphis punctulata* | Green Tree Snake | ✓ | ✓ | |
| *Eulamprus murrayi* | Blue-speckled Forest-skink | ✓ | | |
| *Hemiaspis signata* | Black-bellied Swamp Snake | ✓ | | |
| *Hemisphaeriodon gerrardii* | Pink Tongue Skink | ✓ | | |
| *Lampropholis delicata* | Grass Skink | ✓ | ✓ | |
| *Physignathus lesuerii* | Eastern Water Dragon | | ✓ | |
| *Pogona barbata* | Bearded Dragon | ✓ | ✓ | |
| *Pygopus lepidopodus* | Common Scaly-foot | | ✓ | |
| *Rhinoplocephalus nigrescens* | Eastern Small-eyed Snake | ✓ | ✓ | |
| *Saiphos equalis* | Three-toed Skink | ✓ | ✓ | |
| *Saproscincus challengeri* | Gully Skink | ✓ | | |
| *Tiliqua scincoides* | Eastern Blue-tongued Lizard | ✓ | | |
| *Tropidechis carinatus* | Rough-scaled snake | | ✓ | |
| *Varanus varius* | Lace Monitor | | ✓ | |
| **Mammals:** | | | | |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status |
|---|---|---|---|---|
| *Antechinus flavipes* | Yellow-footed Antechinus | ✓ | ✓ | |
| *Chalinolobus morio* | | | ✓ | |
| *Felis catus** | Feral Cat | | ✓ | |
| *Hydromys chrysogaster* | Water Rat | | ✓ | |
| *Isoodon macrourus* | Northern Brown Bandicoot | ✓ | ✓ | |
| *Lepus capensis** | Cape hare | ✓ | ✓ | |
| *Melomys burtoni* | Grassland Melomys | ✓ | ✓ | RS |
| ***Miniopteris australis*** | **Little Bent-wing Bat** | ✓ | ✓ | TSC (V) |
| *Mus domesticus** | House Mouse | ✓ | ✓ | |
| ***Myotus adversus*** | **Large-footed Myotis** | | ✓ | TSC (V) |
| ***Nyctophilus bifax*** | **Eastern Long-eared Bat** | | ✓ | TSC (V) |
| *Nyctophilus gouldii* | Gould's Wattled Bat | | ✓ | |
| *Oryctolagus cuniculus** | Rabbit | | ✓ | |
| *Perameles nasuta* | Long-nosed Bandicoot | | ✓ | |
| *Petaurus breviceps* | Sugar Glider | ✓ | | |
| ***Petaurus norfolcensis*** | **Squirrel Glider** | | ✓ | TSC (V) |
| ***Planigale maculata*** | **Common Planigale** | ✓ | ✓ | TSC (V) |
| ***Potorous tridactylus*** | **Long-nosed Potoroo** | | ✓ | TSC (V)<br>NCR (V)<br>EPBC (V) |
| ***Pteropus alecto*** | **Black Flying-fox** | | ✓ | TSC (V) |
| ***Pteropus poliocephalus*** | **Grey-headed Flying-fox** | ✓ | ✓ | TSC (V)<br>EPBC (V) |
| *Ratttus lutreolus* | Swamp Rat | ✓ | ✓ | |
| *Rattus fuscipes* | Bush Rat | ✓ | ✓ | |
| *Rattus rattus** | Black Rat | ✓ | ✓ | |
| *Scotorepens orion* | Eastern Broad-nosed Bat | | ✓ | |
| ***Syconycteris australis*** | **Common Blossom Bat** | | ✓ | TSC (V) |
| *Tachyglossus aculeatus* | | | ✓ | |
| *Trichosurus caninus* | Mountain Brush-tailed Possum | ✓ | ✓ | |
| *Trichosurus vulpecula* | Common Brushtail Possum | | ✓ | |
| *Vespedalus pumilus* | | | ✓ | |
| *Wallabia bicolor* | Swamp Wallaby | ✓ | ✓ | |
| * | Dog/Fox | ✓ | ✓ | |
| **Birds:** | | | | |
| *Acanthiza nana* | Yellow Thornbill | | ✓ | |
| *Acanthiza pusila* | Brown Thornbill | ✓ | ✓ | |
| *Acanthorhynchus tenuirostris* | Eastern Spinebill | ✓ | ✓ | |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status |
|---|---|---|---|---|
| *Accipiter fasciatus* | Brown Goshawk | ✓ | ✓ | |
| *Acridotheres tristis** | Common Myna | ✓ | | |
| *Acrocephalus stentoreus* | Clamorous Reed-Warbler | ✓ | ✓ | |
| *Actitus hypoleucos* | Common Sandpiper | | ✓ | C, J |
| *Aegotheles cristatus* | Australian Owlet Nightjar | | ✓ | |
| *Alcedo azurea* | Azure Kingfisher | | ✓ | |
| *Alectura lathami* | Australian Brush Turkey | ✓ | ✓ | |
| *Alisterus scapularis* | Australian King Parrot | ✓ | | |
| ***Amaurornis olivaceus*** | **Bush-Hen** | ✓ | ✓ | TSC (V) |
| *Anas castanea* | Chestnut Teal | ✓ | | |
| *Anas gracilis* | Grey Teal | | ✓ | |
| *Anas superciliosa* | Pacific Black Duck | ✓ | ✓ | |
| *Anhinger melanogaster* | Darter | | ✓ | |
| *Anthochaera chrysoptera* | Little Wattlebird | ✓ | ✓ | |
| *Anthus novaeseelandiae* | Richard's Pipit | ✓ | ✓ | |
| *Apus pacificus* | Fork-tailed Swift | ✓ | | C, J |
| *Ardea alba* | Great Egret | | ✓ | C, J |
| *Ardea ibis* | Cattle Egret | ✓ | ✓ | C, J |
| *Artamus leucorynchus* | White-breasted Woodswallow | ✓ | ✓ | |
| *Aviceda subcristata* | Pacific Baza | ✓ | | CS |
| *Butorides striatus* | Striated Heron | | ✓ | |
| *Cacatua galerita* | Sulphur Crested Cockatoo | ✓ | ✓ | |
| *Cacatua roseicapilla* | Galah | ✓ | ✓ | |
| *Cacatua tenuirostris* | Long Billed Corella | ✓ | | |
| *Cacomantis flabelliformis* | Fan-tailed Cuckoo | ✓ | ✓ | |
| *Cacomantis variolosus* | Brush Cuckoo | ✓ | ✓ | |
| *Calyptorhynchus funereus* | Yellow-tailed Black Cockatoo | ✓ | | |
| ***Calyptorhynchus lathami*** | **Glossy Black Cockatoo** | | ✓ | TSC (V)<br>NCR (V) |
| *Centropus phasianinus* | Pheasant Coucal | ✓ | ✓ | |
| *Chalcophaps indica* | Emerald Dove | ✓ | ✓ | |
| *Chenonetta jubata* | Australian Wood Duck | ✓ | ✓ | |
| *Chrysococcyx basalis* | Horsfield's Bronze Cuckoo | ✓ | | |
| *Chrysococcyx lucidus* | Shinning Bronze Cuckoo | ✓ | ✓ | |
| *Chrysococcyx minutillus* | Little Bronze Cuckoo | ✓ | ✓ | CS |
| *Colluricincla harmonica* | Grey Shrike Thrush | ✓ | ✓ | |
| *Colluricincla megarhyncha* | Little Shrike Thrush | ✓ | ✓ | CS |
| *Columba leucomela* | White-Headed Pigeon | ✓ | ✓ | |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status |
|---|---|---|---|---|
| *Columba livia* | Feral Pigeon | | ✓ | |
| *Coracina novaehollandiae* | Black-Faced Cuckoo Shrike | ✓ | ✓ | |
| *Coracina tenuirostris* | Cicadabird | ✓ | ✓ | |
| *Cormobates leucophaeus* | White-Throated Treecreeper | | ✓ | |
| *Corvus orru* | Torresian Crow | ✓ | ✓ | |
| *Coturnix chinensis* | King Quail | | ✓ | |
| *Coturnix pectoralis* | Stubble Quail | | ✓ | |
| *Coturnix ypsilophora* | Brown Quail | ✓ | ✓ | |
| *Cracticus nigrogularis* | Pied Butcherbird | ✓ | ✓ | |
| *Cracticus torquatus* | Grey Butcherbird | ✓ | ✓ | |
| *Cristicola exilis* | Golden-headed Cisticola | ✓ | ✓ | |
| *Cuculus pallidus* | Pallid Cuckoo | | ✓ | |
| *Dacelo novaeguineae* | Laughing Kookaburra | ✓ | ✓ | |
| *Daphoenositta chrysoptera* | Varied Sitella | | ✓ | |
| *Dendrocygna arcuata* | Wandering Whistling Duck | ✓ | ✓ | CS |
| *Dicaeum hirundinaceum* | Misletoebird | ✓ | ✓ | |
| *Dicrurus bracteatus* | Spangled Drongo | ✓ | ✓ | |
| *Egretta gazetta* | Little Egret | | ✓ | |
| *Egretta novaehollandiae* | White-faced Heron | ✓ | ✓ | |
| *Elanus axillaris* | Black-shouldered Kite | ✓ | ✓ | |
| *Elseyornis melanops* | Black-fronted Dotterel | ✓ | ✓ | |
| *Entomyzon cyanotis* | Blue-faced Honeyeater | ✓ | ✓ | |
| *Eopsaltria australis* | Eastern Yellow Robin | ✓ | ✓ | |
| *Eudynamys scolopacea* | Common Koel | ✓ | ✓ | |
| *Eurostopodus mystacalis* | White-throated Nightjar | | ✓ | |
| *Eurystomus orientalis* | Dollarbird | ✓ | ✓ | |
| *Falco longipennis* | Australian Hobby | | ✓ | |
| *Falco peregrinus* | Peregrine Falcon | ✓ | ✓ | CS |
| *Fulica atra* | Eurasian Coot | | ✓ | |
| *Galliago hardwickii* | Latham's Snipe | | ✓ | C, J |
| *Gallinula tenebrosa* | Dusky Moorhen | ✓ | ✓ | |
| *Gallirallus philippensis* | Buff-banded Rail | ✓ | ✓ | |
| *Geopelia humeralis* | Bar Shouldered Dove | ✓ | ✓ | |
| *Geopelia striata* | Peaceful Dove | ✓ | ✓ | |
| *Gerygone levigaster* | Mangrove Gerygone | | ✓ | CS |
| *Gerygone mouki* | Brown Gerygone | ✓ | ✓ | |
| *Gerygone olivacea* | White-throated Gerygone | ✓ | ✓ | |
| *Glossopsitta pusilla* | Little Lorikeet | | ✓ | |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status |
|---|---|---|---|---|
| *Grallina cyanoleuca* | Magpie Lark | ✓ | ✓ | |
| ***Grus rubicunda*** | **Brolga** | | ✓ | TSC (V) |
| *Gymnorhina tibicen* | Australian Magpie | ✓ | ✓ | |
| *Haliaeetus leucogaster* | White-bellied Sea Eagle | ✓ | ✓ | C |
| *Haliaster indus* | Brahminy Kite | ✓ | ✓ | CS |
| *Haliaster sphenurus* | Whistling Kite | ✓ | ✓ | |
| *Heteroscelis brevipes* | Grey-tailed Tattler | | ✓ | C, J |
| *Himantopus himantopus* | Black-winged Stilt | | ✓ | |
| *Hirundapus caudacutus* | White-Throated Needletail | ✓ | ✓ | C, J |
| *Hirundo ariel* | Fairy Martin | ✓ | ✓ | |
| *Hirundo neoxena* | Welcome Swallow | | ✓ | |
| *Hirundo nigicans* | Tree Martin | | ✓ | |
| ***Ixobrychus flavicollis*** | **Black Bittern** | | ✓ | TSC (V) |
| *Lalage leucomela* | Varied Triller | ✓ | ✓ | |
| *Larus novaehollandiae* | Silver Gull | | ✓ | |
| *Lichenostomus chrysops* | Yellow-faced Honeyeater | | ✓ | |
| ***Lichenostomus fasciogularis*** | **Mangrove Honeyeater** | | ✓ | TSC (V) |
| *Lichmera indistincta* | Brown Honeyeater | ✓ | ✓ | |
| *Limosa lapponica* | Bar-tailed Godwit | | ✓ | C, J |
| *Lonchura castaneothorax* | Chestnut-breasted Mannikin | ✓ | ✓ | |
| *Lopholaimus antarcticus* | Topknot Pigeon | | ✓ | |
| *Macropygia aboinensis* | Brown Cuckoo-Dove | ✓ | ✓ | |
| *Malurus cyaneus* | Superb Fairy Wren | ✓ | ✓ | |
| *Malurus lamberti* | Varigated Fairy Wren | ✓ | ✓ | |
| *Malurus melanocephalus* | Red-backed Fairy Wren | ✓ | ✓ | |
| *Manorina melanocephala* | Noisy Miner | ✓ | ✓ | |
| *Megalurus gramineus* | Little Grassbird | | ✓ | |
| *Megalurus timoriensis* | Tawny Grassbird | ✓ | ✓ | |
| *Meliphaga lewinii* | Lewins Honeyeater | ✓ | ✓ | |
| *Melithicptus albogularis* | White-throated Honeyeater | ✓ | | |
| *Melithreptus lunatus* | White-naped Honeyeater | ✓ | ✓ | |
| *Merops ornatus* | Rainbow Bee-eater | ✓ | ✓ | C, J |
| ***Monarcha leucotis*** | **White-eared Monarch** | ✓ | | TSC (V) |
| *Monarcha melanopsis* | Black-faced Monarch | ✓ | ✓ | |
| *Monarcha trivirgatus* | Spectacled Monarch | ✓ | ✓ | |
| *Myiagra inquieta* | Restless Flycatcher | | ✓ | |
| *Myiagra rubecula* | Leaden Flycatcher | ✓ | ✓ | |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status |
|---|---|---|---|---|
| *Myzomela obscura* | Dusky Honeyeater** | | ✓ | CS |
| *Myzomela sanguinolenta* | Scarlet Honeyeater | ✓ | ✓ | |
| *Neochima temporalis* | Red-browed Finch | ✓ | ✓ | |
| *Ninox novaeseelandiae* | Southern Boobook | | ✓ | |
| ***Numenius madagascariensis*** | **Eastern Curlew** | | ✓ | NCR (R), C, J |
| *Numenius phaeopus* | Whimbrel | | ✓ | C, J |
| *Nycticorax caledonicus* | Nankeen Night Heron | | ✓ | |
| *Ocyphaps lophotes* | Crested Pigeon | ✓ | ✓ | |
| *Oriolus sagittatus* | Olive Backed Oriole | ✓ | ✓ | |
| *Pachycephala pectoralis* | Golden Whistler | ✓ | ✓ | |
| *Pachycephala rufiventris* | Rufous Whistler | ✓ | ✓ | |
| ***Pandion haliaetus*** | **Osprey** | | ✓ | TSC (V) |
| *Pardalotus punctatus* | Spotted Pardalote | ✓ | ✓ | |
| *Pardalotus striatus* | Striated Pardalote | ✓ | ✓ | |
| *Passer domesticus** | House Sparrow | ✓ | ✓ | |
| *Pelecanus conspicillatus* | Australian Pelican | | ✓ | |
| *Petroica rosea* | Rose Robin | | ✓ | |
| *Phalacrocorax carbo* | Great Cormorant | | ✓ | |
| *Phalacrocorax melanoleucos* | Little Pied Cormorant | ✓ | ✓ | |
| *Phalacrocorax sulcirostris* | Little Black Cormorant | ✓ | ✓ | |
| *Phalacrocorax varius* | Pied Cormorant | | ✓ | |
| *Philemon citreogularis* | Little Friarbird | | ✓ | |
| *Philemon corniculatus* | Noisy Friarbird | ✓ | ✓ | |
| *Philidonyris nigra* | White-cheeked Honeyeater | ✓ | ✓ | |
| *Pitta versicolor* | Noisy Pitta | | ✓ | |
| *Platalea regia* | Royal Spoonbill | ✓ | ✓ | |
| *Platycerus adscitus* | Pale-headed Rosella | ✓ | ✓ | |
| *Platycerus eximius* | Eastern Rosella | ✓ | | |
| *Plectorhyncha lanceolata* | Striped Honeyeater | ✓ | ✓ | |
| *Pluvialis fulva* | Pacific Golden Plover | | ✓ | C, J |
| *Podargus strigoides* | Tawny Frogmouth | ✓ | ✓ | |
| *Porphyrio porphyrio* | Purple Swamphen | ✓ | ✓ | |
| *Porzana tubuensis* | Spotless Crake | | ✓ | |
| *Psophodes olivaceus* | Eastern Whipbird | ✓ | ✓ | |
| ***Ptilinopus magnificus*** | **Wompoo Fruit-Dove** | ✓ | | TSC (V) |
| ***Ptilinopus regina*** | **Rose-crowned Fruit Dove** | ✓ | ✓ | TSC (V) |
| ***Ptilinopus superbus*** | **Superb Fruit Dove** | ✓ | ✓ | TSC (V) |

| Scientific Name | Common Name | Stage 1 | Stage 2 | Status |
|---|---|---|---|---|
| *Ptilonorhynchus violaceus* | Satin Bowerbird | ✓ | ✓ | |
| ***Rallus pectoralis*** | **Lewins Rail** | ✓ | ✓ | NCR (R) |
| *Rhipidura leucophrys* | Willie Wagtail | ✓ | ✓ | |
| *Rhipidura fuliginosa* | Grey Fantail | ✓ | ✓ | |
| *Rhipidura rufifrons* | Rufous Fantail | | ✓ | |
| *Scythrops novaehollandiae* | Channel Billed Cuckoo | ✓ | ✓ | |
| *Sericornis frontalis* | White-browed Scrubwren | ✓ | ✓ | |
| *Sericornis magnirostris* | Large-billed Scrubwren | ✓ | ✓ | |
| *Sphecotheres viridis* | Figbird | ✓ | ✓ | |
| *Sterna bergii* | Crested Tern | | ✓ | J |
| *Strepera grucelena* | Pied Currawong | ✓ | ✓ | |
| *Streptopelia chinensis** | Spotted Turtle Dove | ✓ | ✓ | |
| *Sturnus vulgaris** | Common Starling | ✓ | ✓ | |
| *Tachybaptus novaehollandiae* | Australian Grebe | ✓ | ✓ | |
| *Taeniopygia bichenovii* | Double-Barred Finch | ✓ | ✓ | |
| *Threskiornis molucca* | Australian White Ibis | ✓ | ✓ | |
| ***Todiramphus chloris*** | **Collared Kingfisher** | | ✓ | TSC (V) |
| *Todiramphus macleayi* | Forest Kingfisher | ✓ | ✓ | CS |
| *Todiramphus sanctus* | Sacred Kingfisher | ✓ | ✓ | |
| *Trichoglossus chlorolepidotus* | Scaly-breasted Lorikeet | ✓ | ✓ | |
| *Trichoglossus haematodus* | Rainbow Lorikeet | ✓ | ✓ | |
| *Tringa nebularia* | Common Greenshank | | ✓ | C, J |
| *Tyto alba* | Barn Owl | ✓ | | |
| ***Tyto capensis*** | **Eastern Grass Owl** | | ✓ | TSC (V) |
| ***Tyto novaehollandiae*** | **Masked Owl** | | ✓ | TSC (V) |
| *Vanellus miles* | Masked Lapwing | ✓ | ✓ | |
| *Zosterops lateralis* | Silvereye | ✓ | ✓ | |

Notes:
EPBC = Commonwealth *Environment Protection and Biodiversity Conservation Act 1999;*
TSC = NSW *Threatened Species Conservation Act 1995;*
NCR = Queensland Nature Conservation (Wildlife) Regulation 1994;
V = Vulnerable;
R = Rare;
C = CAMBA;
J = JAMBA;
CS = Conservation Significant;
RS = Regionally Significant;
* = Introduced species;
** = Recorded by Steve Phillips;
Bold = Legislatively Significant Species (excluding JAMBA/CAMBA species).

# Appendix N

Vegetation conservation significance in the Tweed Shire

## Appendix N: Vegetation conservation significance in the Tweed Shire

### Regionally Significant Natural Areas – Type 1

Regional Vegetation Type Not Conserved > 2 hectares; or
Vegetation Type – Lowland Rainforest on Floodplain
Regional Vegetation Type Not Conserved within remnants > 5 hectares; or
Regional Vegetation Type Inadequately Conserved > 10 hectares; or
Estuarine Communities; or
Riparian Communities >2 hectares; or
Endangered species present
NOT Major Vegetation Community – Highly Modified/Disturbed

### Regionally Significant Natural Areas – Type 2

Remnant size extensive (> 500 hectares); or
Dunal/High Biodiversity/Wetland Systems associated with remnants >50 hectares or
NOT Major Vegetation Community – Highly Modified/Disturbed

### Core Ecological Areas and Corridors – Type 1

Regional Vegetation Type Inadequately Conserved 2 to10 hectares; or
Regional Vegetation Type Not Conserved < 2 hectares; or
Koala habitat Status – Primary < 2 hectares; or
Riparian Communities < 2 hectares; or
Remnant Diversity High
Vulnerable/Rare species present
NOT in any category above
NOT Major Vegetation Community – Highly Modified/Disturbed

### Core Ecological Areas and Corridors – Type 2

Remnant size large (25 to 500 hectares); or
Connectivity well connected
Dunal/High Biodiversity/Wetland systems 5 to 10 hectares or
NOT in any category above
NOT Major Vegetation Community – Highly Modified/Disturbed

### Other Significant Remnants

Remnant size Moderate (5 to 25 hectares); or
Regional Vegetation Status Inadequately Conserved <2 hectares; or
Dunal/High Biodiversity/ Wetland systems <5 hectares; or
Remnant Diversity Moderate or
Connectivity at least Partially Connected or
Major Vegetation Community – Highly Modified/Disturbed within Riparian areas or

Vegetation Types – Early Regrowth Rainforest, Acacia/Other Sclerophyll Regrowth Open Forest to Woodland, Post-mining Regeneration >5 hectares

NOT in and category above

NOT Vegetation Types – Camphor Dominated Closed to Open Forest, Native Plantation, Urban Bushland

# Appendix O

Threatened flora and fauna species that may occur along the proposed Tugun Bypass alignment

## Appendix O: Threatened flora and fauna species that may occur along the proposed Tugun Bypass alignment

### Table O1: Threatened Plant Species That May Occur Along the Proposed Alignment

| Common Name | Scientific Name | Conservation Status |
|---|---|---|
| Mountain Wattle | *Acacia orites* | NCR (R), ROTAP |
| | *Acomis acoma* | NCR (R), ROTAP |
| Byron Bay Acronychia | *Acronychia baeuerlenii* | NCR (R), ROTAP |
| Scented Acronychia | *Acronychia littoralis* | TSC (E), NCR (E), ROTAP, EPBC (E) |
| Rusty Plum | *Amorphospermum whitei* | TSC (V), NCR (V), ROTAP |
| Veiny Lace Flower | *Archidendron muellerianum* | NCR (R), ROTAP |
| | *Ardisia bakeri* | NCR (R), ROTAP |
| Silver Leaf | *Argophyllum nullumense* | NCR (R), ROTAP |
| Pink Cherry | *Austrobuxus swainii* | NCR (R), ROTAP |
| | *Austromyrtus fragrantissima* | TSC (E), NCR (E), ROTAP, EPBC (E) |
| Three-leaved Bosistoa | *Bosistoa transversa* | TSC (V), EPBC (V) |
| | *Callerya australis* | NCR (R) |
| | *Cassia brewsteri var marksiana* | NCR (R), ROTAP, TSC (E) |
| | *Corokia whiteana* | TSC (V), ROTAP, EPBC (V) |
| Davidson's Plum | *Davidsonia jerseyana* | TSC (E), ROTAP, EPBC (E) |
| Smooth Davidson's Plum | *Davidsonia johnsonii* | TSC (E), ROTAP, NCR (E), EPBC (E) |
| Gympie Stinger | *Dendrocnide moroides* | TSC (E) |
| Red-fruited Ebony | *Diospyros mabacea* | TSC (E), ROTAP, EPBC (E) |
| Small-leaved Tamarind | *Diploglottis campbellii* | TSC (E), NCR (E), ROTAP, EPBC (E) |
| Giant Rasp Fern | *Doodia maxima* | ROTAP |
| | *Drynaria rigidula* | TSC (E) |
| Hairy Quandong | *Elaeocarpus williamsianus* | TSC (E), ROTAP, EPBC (E) |
| Square-stemmed Spike Rush | *Eleocharis tetraquetra* | TSC (E) |
| | *Endiandra floydii* | TSC (E), NCR (E), ROTAP, EPBC (E) |
| Black Walnut | *Endiandra globosa* | NCR (R), ROTAP |
| Rusty Rose Walnut | *Endiandra hayesii* | TSC (V), NCR (V), ROTAP, EPBC (V) |
| Ball Nut | *Floydia praealtra* | TSC (V), NCR (V), ROTAP, EPBC (V) |
| Southern Fontainea | *Fontainea australis* | TSC (V), NCR (V), ROTAP, EPBC (V) |
| | *Helmholtzia glaberrima* | NCR (R), ROTAP |
| Red Boppel Nut | *Hicksbeachia pinnatifolia* | TSC (V), NCR (V), ROTAP, EPBC (V) |
| | *Isoglossa eranthemoides* | TSC (E), ROTAP, EPBC (E) |
| Southern Ochrosia | *Ochrosia moorei* | TSC (E), NCR (E), ROTAP, EPBC (E) |
| | *Olearia heterocarpa* | NCR (R), ROTAP |
| Onion Cedar | *Owenia cepiodora* | TSC (V), NCR (V), ROTAP, EPBC (V) |

| **Common Name** | **Scientific Name** | **Conservation Status** |
|---|---|---|
| | *Ozothamnus vagans* | NCR (V), ROTAP, EPBC (V) |
| | *Quassia sp. A* | ROTAP |
| Spiny Gardenia | *Randia moorei* | TSC (E), NCR (E), ROTAP, EPBC (E) |
| | *Rulingia salviifolia* | NCR (R), ROTAP |
| | *Senna acclinis* | TSC (E), ROTAP, NCR (R) |
| Brush Sophora | *Sophora fraseri* | NCR (V), ROTAP, EPBC (V), TSC (V) |
| Small-leaved Hazelwood | *Symplocos baeuerlenii* | TSC (V), NCR (V), ROTAP, EPBC (V) |
| Red Lilly Pilly | *Syzygium hodgkinsoniae* | TSC (V), NCR (V), ROTAP, EPBC (V) |
| Arrow-head Vine | *Tinospora tinosporoides* | TSC (V), NCR (V), ROTAP, EPBC (V) |
| | *Trichosanthes subvelutina* | ROTAP |
| | *Xylosma terrae-reginae* | TSC (E), ROTAP |

Notes:
EPBC = Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*;
TSC = NSW *Threatened Species Conservation Act 1995*;
NCR = Queensland Nature Conservation (Wildlife) Regulation 1994;
ROTAP = Rare or Threatened Australian Plant (Briggs and Leigh 1996);
E = Endangered;
V = Vulnerable;
R = Rare.

## Table O2: Threatened Fauna Species That May Occur Along the Proposed Alignment

| Common Name | Scientific Name | Conservation Status |
|---|---|---|
| **Mammals** | | |
| Koala | *Phascolarctos cinereus* | TSC (V), NCR(C) |
| Yellow-bellied Sheathtail Bat | *Saccolaimus flaviventris* | TSC (V) |
| **Amphibians** | | |
| Freycinet's Frog | *Litoria freycineti* | NCR (V) |
| **Birds** | | |
| Barred Cuckoo-Shrike | *Coracina lineata* | TSC (V) |
| Black-tailed Godwit | *Limosa limosa* | TSC (V), J/C |
| Great Knot | *Calidris tenuirostris* | TSC (V), J/C |
| Grey Goshawk | *Accipeter novaehollandiae* | NCR (R) |
| Lesser Sand Plover | *Charadrius mongolus* | TSC (V), J/C |
| Marbled Frogmouth | *Podargus ocellatus* | TSC (V), NCR (V) |
| Pied Oystercatcher | *Haematopus longirostris* | TSC (V) |
| Square-tailed Kite | *Lophoictinia isura* | TSC (V), NCR (R) |
| Terek Sandpiper | *Xenus cinereus* | TSC (V), J/C |
| **Reptiles** | | |
| White-crowned Snake | *Cacophis harriettae* | TSC (V) |

Notes: EPBC = Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*;
TSC = NSW *Threatened Species Conservation Act 1995;*
NCR = Queensland Nature Conservation (Wildlife) Regulation 1994;
V = Vulnerable;
R = Rare;
J/C = JAMBA/CAMBA.

# Appendix P

Compensatory habitat policies and report