The Bellinger Emydura
Ecology, Population Status and Management

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THE BELLINGER EMYDURA
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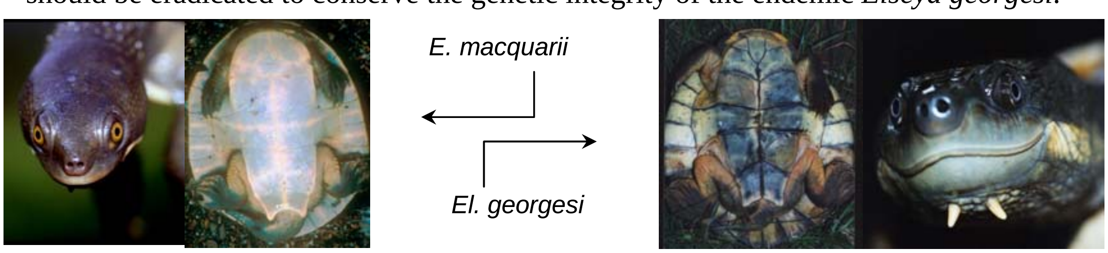
EXECUTIVE SUMMARY

1. 76 Bellinger River *Emydura* and 360 *Elseya* georgesi were captured over a 3-week survey in March 2007.
2. Despite the capture of relatively large numbers of *Emydura macquarii*, compared to previous surveys, densities are less than 10 per hectare and habitat preferences are highly specific. Less than 100 individuals have ever been captured.
3. Molecular and morphological analyses indicates that *Emydura macquarii* that the Bellinger River *Emydura* population is not particularly distinctive, certainly not a distinct biological species. Indeed, evidence to hand suggests that it is not native to the river. More extensive sampling of adjacent drainages is required to definitively determine if it is introduced or naturally occurring in the Bellinger drainage.
4. Although well established as a flagship "species" upon which a range of conservation initiatives hang, it is difficult to justify the conservation status currently accorded this form. *Elseya georgesi* in the Bellinger is of much greater concern. The priority for conservation of the Bellinger *Emydura* should be downgraded, equivalent only to that of populations of any widespread species that are at low density in sub-optimal habitat or at the edges of their ranges.
5. This presents a particular problem for management. We recommend that the emphasis on the Bellinger *Emydura* be broadened to encompass also the endemic *Elseya georgesi*. This shift in focus should be easy to achieve without putting at risk valuable community support for fox control and restoration of riparian vegetation. Subsequently, the emphasis can be further shifted to the local endemic *Elseya georgesi*, should this be required as more definitive information comes to hand.
6. *Elseya georgesi* should be considered a vulnerable species because of its limited distribution and specific habitat requirements.
7. Changes in water quality and habitat will greatly affect both species because the habitat preferences relate to water quality (aquatic vegetation) and physical attributes of waterholes (substrate) of both species.
8. Morphological intermediates suggest that *Emydura macquarii* and *Elseya georgesi* are hybridizing. Further work is proposed using nuclear gene markers to confirm these suspected instances of hybridization and introgression and to address the issue of whether the Bellinger population of *Emydura* should be conserved or whether it should be eradicated to conserve the genetic integrity of the endemic *Elseya georgesi*.



Elseya georgesi have dark colouration along the edge of the shields of the plastron and distinct barbels on the lower jaw. *Emydura macquarii* also lack the head shield of *El. georgesi*.

INTRODUCTION

The *Emydura macquarii* complex has a widespread distribution throughout central and eastern Australia (Cann 1998) and is extremely common in most catchments that they inhabit. In the Murray River, the species occurs at biomasses that are amongst the highest recorded in the world (Spencer 2001). In contrast, The Bellinger River *Emydura* is possibly one of the rarest turtles in Australia (Cann 1998). The number of animals within the population is unknown but is thought to be small and appears restricted to two sites along a single stretch of the Bellinger River, upstream of Thora (Cann 1993, Spencer and Thompson 2000). Nest predation rates by foxes are high and dead adult turtles have been found on the banks of the River in these areas (Blamires et al.2005). Given its restricted range and the evidence of threats, it is likely to become endangered unless the factors threatening its survival cease to operate (NSW Scientific Committee 1997). The Bellinger *Emydura* is currently listed as a vulnerable species on Schedule 2 of the Threatened Species Conservation Act 1995 (TSC Act) and also as a vulnerable species in the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

The three major threats to the Bellinger River *Emydura* have been identified as predation of nests by foxes (*Vulpes vulpes*), inter-specific competition and hybridisation with the endemic Bellinger River *Elseya* and introduction of captive or pet *Emydura macquarii*, sourced from elsewhere, into the Bellinger River population (Spencer and Thompson 2000). The aim of this study was to assess the status of the Bellinger *Emydura* by determining the distribution of individuals and populations in the Bellinger River catchment. In contrast to previous surveys, this was a large-scale survey that employed a range of techniques, personnel and resources to maximize the potential to capture the Bellinger River *Emydura.* In assessing the status of the Bellinger River *Emydura*, we also assessed crucial population parameters, including densities, age and size structure, and the habitat preferences of both species of freshwater turtle that inhabit the catchment. *Elseya georgesi* is only endemic to the Bellinger River and although it has been regularly captured in previous surveys, very little is known about habitat preferences and population dynamics.

METHODS

Site selection

The survey took place from 1/04/07-17/04/07 throughout the Bellinger River catchment. Turtles were collected from ~31 km stretch of the Bellinger River (Fig. 1). The area was partitioned into three sections (Thora upstream, Thora downstream and Kalang) and a total of 26 waterholes (23 Bellinger River + 3 Kalang River) were sampled throughout the catchment. Sites were chosen by exploring the river on the ground, examining topographic maps, and by liaison with local landholders and other river-using locals. Most waterholes were known to locals as “swimming holes”. As much effort was made to sample waterholes on the whole river within potential turtle distribution, however logistical constraints meant that some more isolated parts of the river (upstream of Winch Flat) were not sampled.

Sampling

Turtles were captured by hand while snorkelling, in traps by dip netting off a small boat from 01/04/07-17/04/07. Straight-line carapace length and width, and straight-line plastron length and width were measured on all turtles captured using callipers. Weight was measured to the nearest 0.1 kg (turtles >300 g) or 0.01 kg (turtles <300 g) using an electronic and/or spring balance. Males were identified as having an elongated precloacal length relative to their body length. The minimum size of visually identifiable males (118 mm carapace length) was used as the upper size limit for all juveniles. All turtles were released after marking and measuring. Turtles with discernable growth annuli in the plastral scutes (Sexton 1959) had their annuli counted. Turtles were marked by drilling a small hole in the marginal scutes. Holes were usually placed close to the centre of the scute to prevent chipping of the edge of the scute, yet not to close to the flesh of the turtle. Digital photographs were taken of each turtle above the carapace, the top of the head, side of the head, and the plastron. The presence or absence of a nuchal scute was recorded. For each *Emydura* captured, growth rings on the marginal scutes were counted so estimates could be made of the turtle's age.

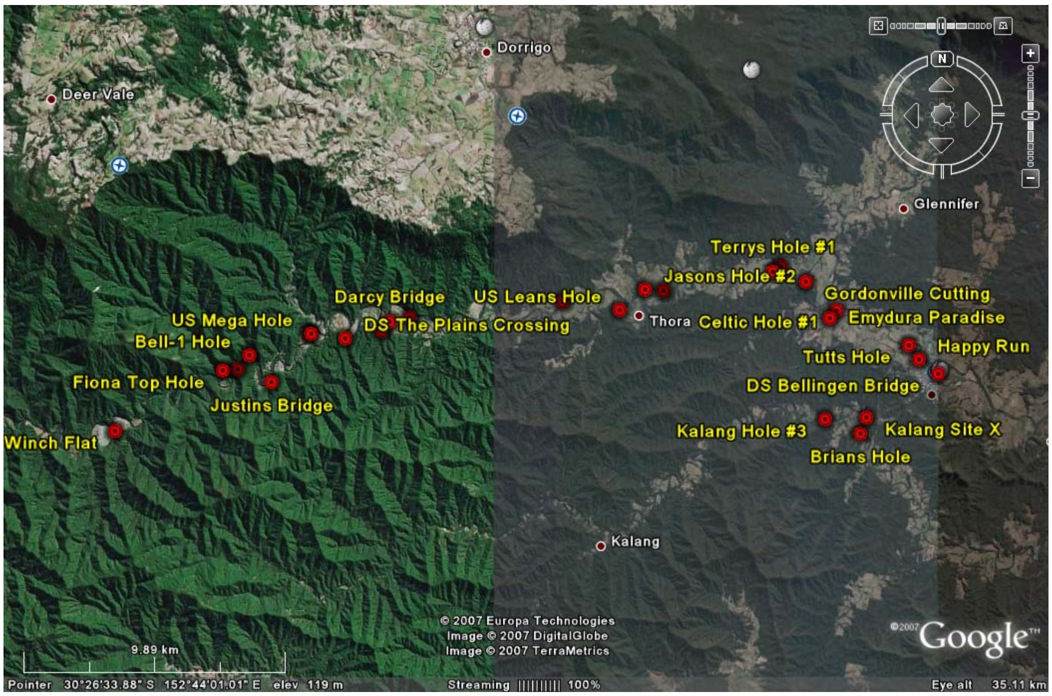


Fig. 1. Localities of waterholes surveyed during the study. Turtles were distributed from Bellingen Bridge to Winch Flat.

Snorkelling

Sites were snorkelled by 1-7 persons for a varied amount of time. The time spent snorkelling depended on condition and the number of snorkellers. In clearer, upstream sections of river, we were able to capture the majority of turtles in a waterhole, however in other sections of the River, snorkelling was stopped after 2 hours, or when no new turtles were caught. Snorkellers either swam along the surface or dived when searching for turtles. Extra time was spent around logs and submerged snags, because turtle were harder to detect in these places. Snorkelling was used throughout the Bellingen River, but was less commonly employed downstream and in the Kalang because of poor visibility.

On Boat at Night

Turtles were captured using long-handled dip-nets off a small boat at night. To locate turtles, portable spotlights were used. This method was restricted to deeper waterholes around

Bellingen, where the water was deep enough to operate a small flat-bottomed boat, and where poorer visibility and long waterholes excluded snorkelling.

Trapping

Cathedral traps were used to capture turtles. The upper parts of the traps were tied to overhanging trees for support and traps were placed next to bank in the vicinity of good microhabitat (eg logs, overhanging banks, aquatic vegetation). Traps were baited with sardines, with part of the bait held loosely in nylon mesh bags and available for the turtles to eat, and part of the bait held in perforated cans. Traps were checked at intervals of 4-10 hours. Traps were re-baited after approximately 24 hours. Traps were left in place for 24-48 hours at each location.

Analyses

Size Distribution

Size-distribution curves were generated for adult males and females of each species, using straight plastron length as the standard measure, to enable direct comparison with other species (Spencer 2001). Size distributions were tested for normality using a Kolmogorov–Smirnov test.

To assign age to size classes in *El. georgesi*, the relationship between size and age was estimated by fitting plastron lengths to a von Bertalanffy growth equation (parameters were developed by Blamires et al 2005). Growth curves have not been developed for the Bellinger River *Emydura*, however we compared size distributions of each sex with *El. georgesi* and applied similar growth equations to estimate age. These estimates were checked with data from growth annuli that were collected from each individual.

Population Density

Length and mean width of each waterhole were estimated and water surface area was calculated from these measurements. Mean Number Alive (MNA) of *Elseya georgesi* and *Emydura macquarii* were calculated from populations that were sampled on multiple occasions. Only populations where at least 1/3 of turtles during the last sampling session were recaptures were included for density estimates. Densities were estimated by dividing MNA by the water surface area of each waterhole.

Habitat Preferences

A range of physically and biologically relevant habitat variables were collected at sites both with and without turtles to determine habitat preferences of both species (Table 1). Distance variables were determined using a tape measure or google earth for longer measurements. Percentage estimates of variables were determined by a single observer (MW) to the nearest 10% immediately after comprehensively snorkelling/boating a site. Non-metric multi-dimensional scaling (nMDS) was used to compare habitat variables between waterholes both with and without turtles. Differences in habitat preferences between waterholes were determined using analysis of similarities (ANOSIM), a multivariate non-parametric analogue of ANOVA (Clarke and Green, 1988) and SIMPER (calculates the average Bray-Curtis dissimilarity between all pairs of inter-group samples) was used to identify discriminating features between species. Data were square root transformed and standardised prior to analyses (Legendre and Legendre, 1998).

Table 1. Habitat variables recorded at 33 waterholes to assess habitat preferences of both species of turtle

Variable
Subregion (Thora upstream/downstream/Kalang)
Waterhole Length (m)
Mean Waterhole Width (m)
Maximum Depth (m)
Mean Waterhole depth (m)
Water Clarity (5 categories)
Percentage of Waterhole Substrate with Sand(%)
Percentage of Waterhole Substrate with Bedrock (%)
Percentage of Waterhole Substrate with Gravel (%)
Percentage of Waterhole Substrate with Rocks (%)
Water Vegetation Cover (Vallisneria) (%)
Water Vegetation Cover (*Hydrilla*) (%)
Water Vegetation Cover (Other) (%)
Filamentous Algae (present/absent)
Riparian Vegetation Score
Percentage of Waterhole with Overhanging Trees (%)
Potential Nesting Substrate (Sand) (present/absent)
Potential Nesting Substrate (grass/soil) (present/absent)
Morning Sun (present/absent)
Distance to Nearest bridge (m)
Basking Habitat Score (6 categories)
Number of *Elseya*
Number of *Emydura*

RESULTS

Distribution and Density

A total of 360 *El. georgesi* and 76 *E. macquarii* were captured during the survey. Capture technique significantly influenced the proportion of species captured, with *El.* geogesi more likely to be captured by hand while snorkelling than in traps or by dip net from a boat (Table-2. χ^2= 135 p<0.001 d.f=2). Capture technique did not influence which sex was more likely to be captured in both species.

Table 2. Number of each species captured by different capture techniques.

	Diving	Boat	Trap
Elseya georgesi	348	12	0
Emydura macquarii	39	26	11

Both species were captured throughout the River. No turtles were caught within the tidal zone of the river and only one turtle was captured downstream of the Bellingen Bridge. The upstream limit for both species in this survey was Winch Flat waterhole (Fig. 1), and this waterhole may represent the upstream distribution of the both species because few distinct waterholes occur further upstream.

Densities of turtles varied considerably throughout the River. *El. georgesi* occurs in high densities in the upper reaches of the River and although more *E. macquarii* were captured downstream (Table 3), densities were similar to upstream populations (Fig. 2).

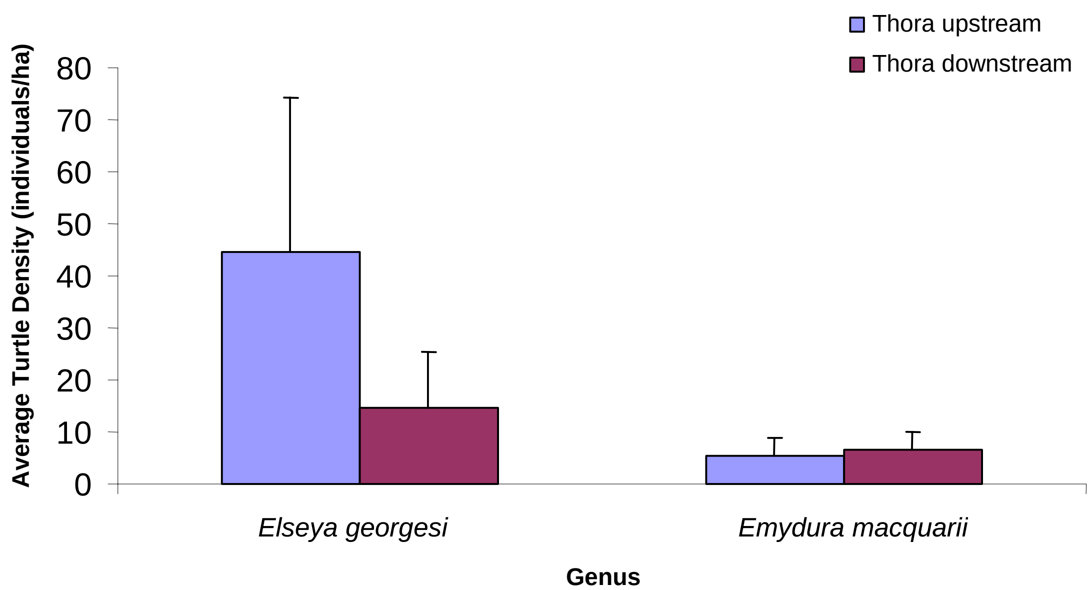


Fig. 2. Turtle densities in the upper and lower regions of the Bellinger River

Size and Age Distribution

The majority of female *E. macquarii* and *El. georgesi* had plastron lengths between 150mm and 180mm. Although the distributions of both species are negatively skewed, 50% of individuals have plastron lengths smaller than the 150mm size class (Fig. 3). Consequently, over 30% of turtles in the River are 15 years or younger (Figs. 5, 6). The size distribution of male *E. macquarii* and *El. georgesi* were significantly different with male *E. macquarii* growing to larger sizes (Fig. 4).

A large proportion of *E. macquarii* were 6-10 years of age both up- and down-stream of Thora and almost 25% of the upstream population of *E. macquarii* were in the 5 year old category. There was no difference in the age distributions of *El. georgesi* between up- and down-stream populations (Fig. 5). The age structure of male *E. macquarii* was unable to be evaluated because the size structure was significantly different to that of *El. georgesi*, hence growth curve parameters developed for *El. georgesi* could not be applied to *E. macquarii*.

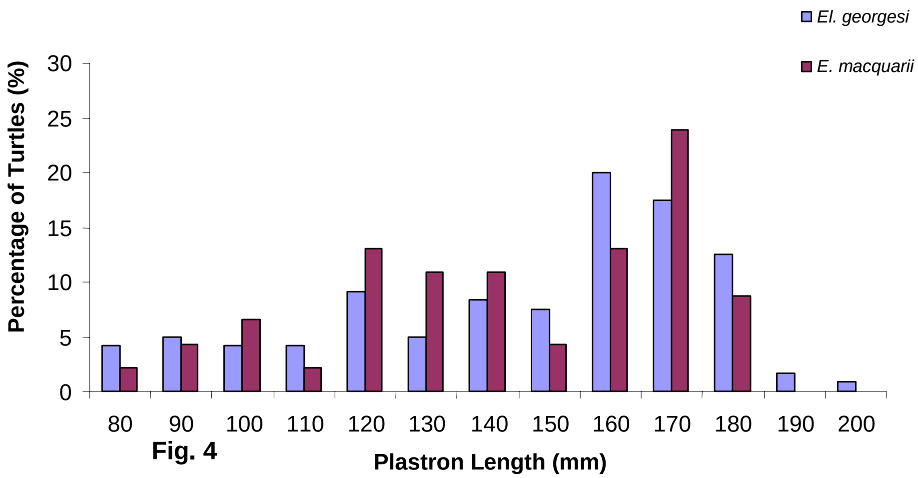


Fig. 3. Size structure of female and juvenile *Elseya georgesi* and *Emydura macquarii*.

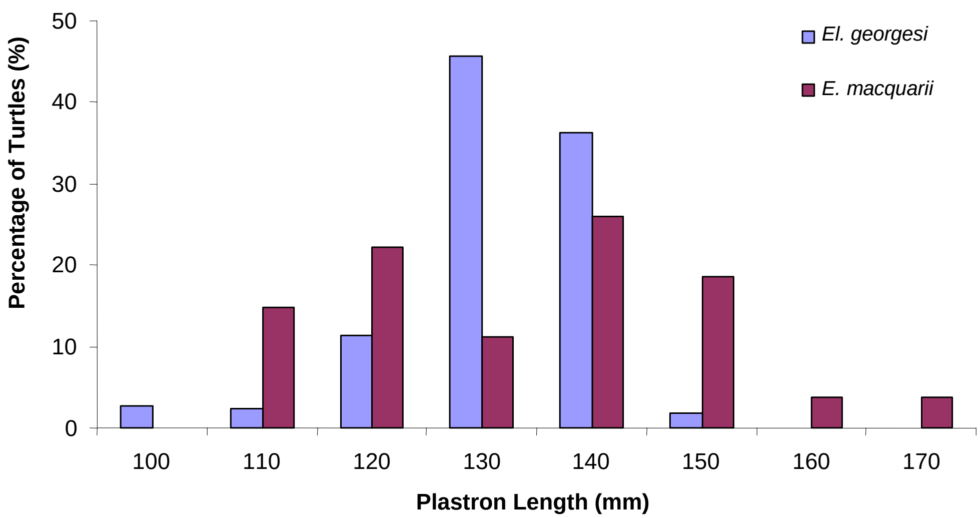


Fig. 4. Size structure of male *Elseya georgesi* and *Emydura macquarii*.

Table 3. The number captured, average plastron length (PL±S.D) and average age of both species in different regions of the catchment

Species	Sex	Location	No	PL (mm)	St. Dev. (mm)	Age(years)
Elseya georgesi	F	Thora downstream	65	151.1	21.4	19.0
		Thora upstream	40	151.8	17.6	17.2
		Kalang	0	0	0	0
		Catchment	**105**	**151.3**	20.1	**18.4**
	M	Thora downstream	140	126.2	9.9	21.1
		Thora upstream	96	127.1	6.3	20.6
		Kalang	0	0	0	0
		Catchment	**236**	**126.6**	8.7	**20.9**
	J	Thora downstream	12	90.5	12.5	5.2
		Thora upstream	7	85.0	10.3	4.8
		Kalang	0	0	0	0
		Catchment	**19**	**88.6**	11.8	**5.1**
Emydura macquarii	F	Thora downstream	28	149.5	23.2	19.1
		Thora upstream	5	139.2	20.0	12.6
		Kalang	5	141.7	21.4	12.8
		Catchment	**38**	**147.1**	22.4	**17.0**
	M	Thora downstream	14	133.0	17.1	?
		Thora upstream	9	133.1	10.9	?
		Kalang	4	107.2	6.0	?
		Catchment	**27**	**129.2**	16.5	**?**
	J	Thora downstream	4	98.0	12.4	5.9
		Thora upstream	3	80.8	50.1	5.1
		Kalang	1	91.1	0.0	5.2
		Catchment	**8**	**90.7**	29.3	**5.5**

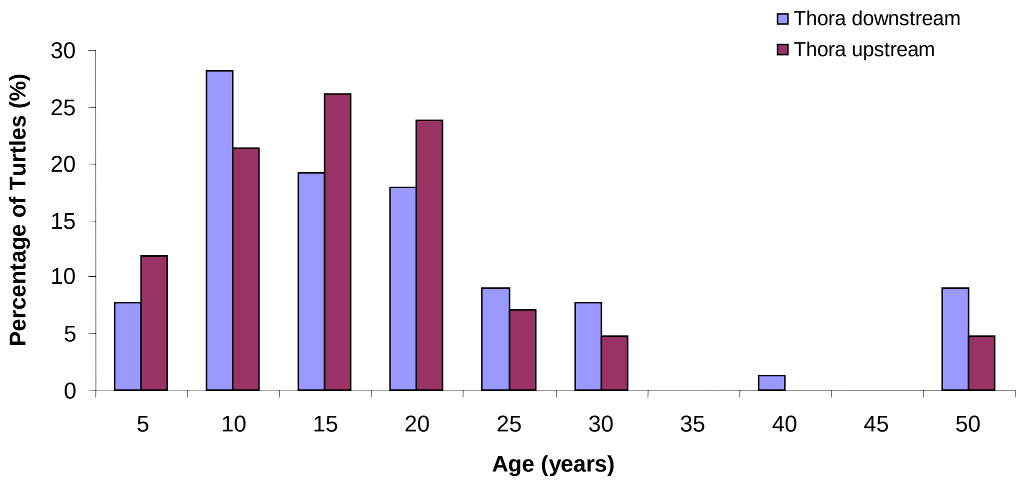


Fig. 5. Age structure of female *Elseya georgesi* in the Bellinger River.

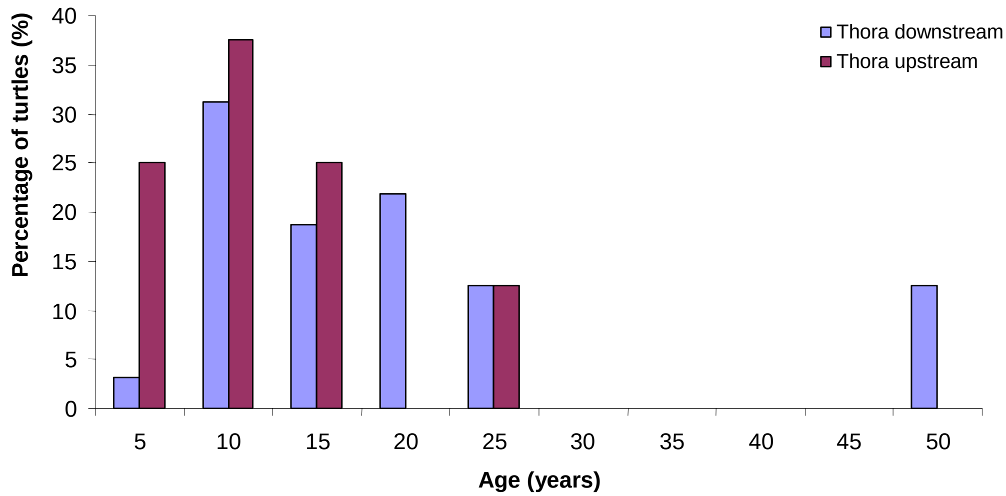


Fig. 6. Age structure of female *Emydura macquarii* in the Bellinger River.

Habitat Preferences

Observations

Habitat preferences appeared to depend on species and time of day. *Elseya georgesi* was usually captured in deep water (>3m) on rocky substrate. *Elseya georgesi* generally remain motionless before capture (50% of time) or attempt to flee (50% of time). They were often found partly buried in sand, silt or leaves and they are usually found in the deepest part of the waterhole. *Elseya georgesi* was rarely captured using a dip-net from the boat at night; however, those captured were in deeper parts of waterholes than *E. macquarii*.

Emydura macquarii were usually found in shallower water (<3m), in any substrate including patches of vegetation. *Emydura macquarii* was generally captured while attempting to flee and they were often captured near submerged snags. *Emydura macquarii* were often observed feeding near the bank or under overhanging ridges of river banks. At night, *E. macquarii* were readily captured near banks with aquatic vegetation or snags. These areas were often very shallow water (<1.5m). *Emydura macquarii* were also regularly captured in patches of *Hydrilla* (*Hydrilla verticillata*).

Quantitative Analyses

There was a significant difference between habitats with and without *Emydura macquarii* (R= 0.18 p=0.04- Fig. 7). *Emydura macquarii* were more likely to be found in long waterholes with a rocky substrate (Table 4). The waterhole will have a reasonable amount of *Hydrilla* and will also have a high density of *El. georgesi* (Table 4). *Emydura macquarii* occurred less commonly in waterholes far from bridges with a sandy substrate.

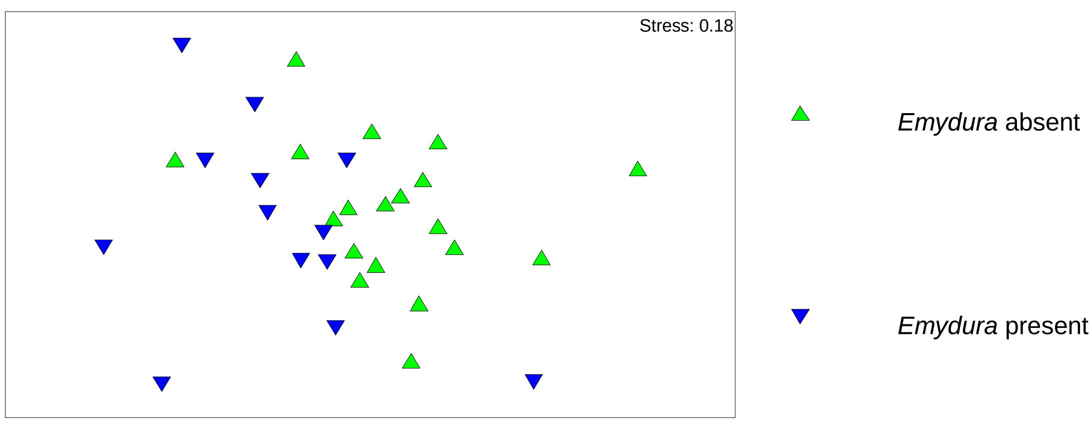


Fig. 7. nMDS plots based on waterholes with (upside down triangle) and without (triangles) *Emydura macquarii*. This figure represents the relationship between each site in space. Points that are closer together have more closely related habitat than points that are further apart.

Table 4. SIMPER analysis of dissimilarity of habitat variables between waterholes with and without *Emydura macquarii*. The average value for each variable at waterholes with turtles absent (Absent Average) and present (Present Average). The contribution of each variable to describing variance or differences between factors (ie. turtles present or absent at a waterhole is shown by Contrib%.

	Absent Average	Present Average	Av.Diss	Diss/SD	Contrib%
Dist. To Bridge (m)	394.21	244.62	6.28	1.33	20.07
Waterhole Length (m)	214.21	369.23	3.84	1.42	12.27
Substrate Rocks (%)	29.89	51.23	3.09	1.46	9.89
Substrate Gravel (%)	18.58	19.46	2.40	1.22	7.69
Substrate Sand (%)	31.21	15.85	2.31	1.35	7.38
Substrate Bedrock (%)	19.21	13.31	2.07	1.27	6.63
Veg. Cover (Hydrilla)(%)	6.32	10.77	1.51	1.25	4.84
Number of Elseya	6.63	11.46	1.49	1.49	4.77

Waterholes with and without *El. georgesi* differed significantly (R= 0.21 p=0.006- Fig. 8). *Elseya georgesi* was more likely caught in waterholes with a rocky substrate; with a reasonable vegetation cover of *Hydrilla*; and with a medium level of basking habitat (rocks and logs) (Table 5). *Elseya georgesi* was captured less in waterholes that were far from bridges and with a gravel or sandy substrate (Table 5).

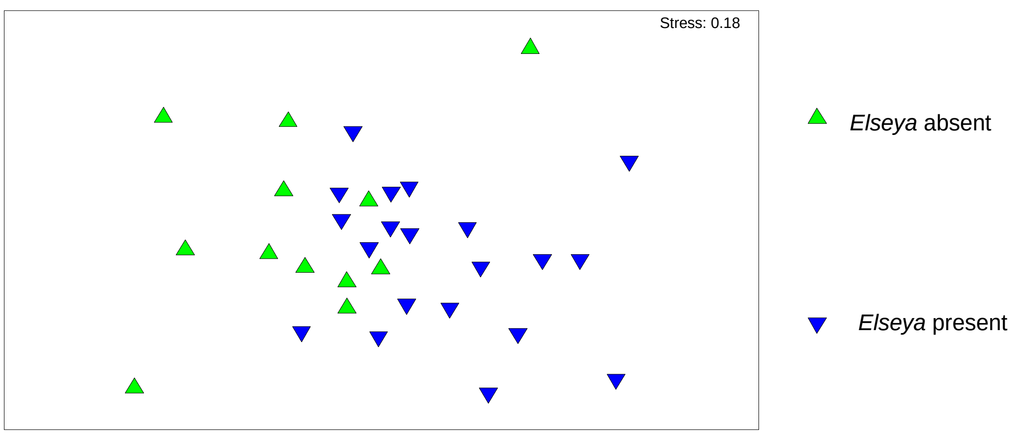


Fig. 8. nMDS plots based on waterholes with (upside down triangle) and without (triangles) *Elseya georgesi*.

Table 5. SIMPER analysis of dissimilarity of habitat variables between waterholes with and without *Elseya georgesi*.

	Absent Average	Present Average	Av.Diss	Diss/SD	Contrib%
Dist. To Bridge (m)	422.50	280.00	2.50	0.96	9.75
Substrate Gravel (%)	30.25	12.15	2.44	1.39	9.55
Substrate Rocks (%)	21.92	48.55	2.44	1.24	9.53
Substrate Bedrock (%)	12.50	19.40	2.02	1.18	7.90
Substrate Sand (%)	33.58	19.80	2.01	1.13	7.85
Veg. Cover (*Hydrilla*)(%)	4.17	10.50	1.88	1.30	7.36
Veg. Cover (*Vallisneria*)(%)	5.00	5.55	1.59	1.16	6.20
Basking Habitat (1-4)	1.08	2.10	1.20	1.41	4.68
Waterhole Length (m)	229.17	306.00	1.20	1.36	4.67

Hybrid and Other Turtles

We considered hybrids as turtles with morphological features of both *E. macquarii* and *El. georgesi*. Seven turtles with morphological feature of both *El. georgesi* and *E. macquarii* were captured during the survey. Four hybrids were captured in the Kalang (WH3 and X). An *El. latisternum* (not native to the area) was also captured in the Kalang (WH3) (Appendix 2). A hybrid was also captured at Tutts waterhole in the downstream stretches of the Bellinger (Fig. 1). Two hybrids were captured in the upper stretches of the Bellinger River at Barn waterhole (Fig. 1). All turtles were adults with plastron lengths greater than 130mm (>15 years of age). No *Chelodina longicollis* were caught during the survey.

DISCUSSION

With less than 20 *E. macquarii* captured from previous studies that date back to the 1970's, the capture of 76 individuals in this survey represents a major increase in ecological knowledge and information for the managing the species and catchment. It is unlikely that there has been a major recovery of the species in the catchment; the high capture rate relates more to the mode of capture and better understanding of their habitat preferences. Previous surveys have concentrated on snorkelling and trapping as methods for turtle capture (Cann 1993, Spencer and Thompson 2000, Blamires et al. 2005), however dip-netting from a boat was highly successful and important for focusing snorkelling efforts to particular habitats and locations. Snorkelling focuses on the deeper parts of waterholes, whereas *E. macquarii* were generally captured in shallower regions and prefer waterholes with rocky substrates with large clumps of vegetation, in particular, *Hydrilla verticillata*. In clear water conditions, like the Bellinger River, both *Emydura* spp. and *Elseya* spp. throughout eastern Australia are omnivorous. Ribbon weed (*Vallisneria gigantea)* is an important dietary source for both genera and so too might *Hydrilla* be with the Bellinger River *Emydura*. Both genera in clear water conditions tend towards carnivory, with a high proportion of their food coming from benthic macro-invertebrate communities associated with aquatic vegetation (Spencer et al. 2007).

Although far higher numbers of *E. macquarii* were captured during the present study than any previous study, densities of *E. macquarii* are still extremely low. Few waterholes contain more than 10 individuals, with most containing 2-4 turtles, and densities were less than 10 *E. macquarii* per hectare for both the upper and lower stretches of the Bellinger River (Fig. 2). Even in relatively oligotrophic conditions of the Fraser Island lakes, densities of *E.* kreffti are over 80 turtles per hectare (Georges 1982). Murray River *E. macquarii* occur at higher densities of over 200 turtles per hectare (Spencer 2001). The Bellinger River *Emydura* were captured at only 47% of sites sampled during the survey, whereas *El. georgesi* were captured at over 78% of waterholes (Appendix 1). Despite low densities, the age and size structures of *E. macquarii* suggest that recruitment may be occurring throughout the catchment. A large proportion of *E. macquarii* are either juvenile (<5years) or sub-adult (5-10 years) in the Bellinger River and growth annuli suggests that significant recruitment occurred six years ago, possibly after the floods of 2001. The floods scoured much of the riparian vegetation, probably creating open areas for nesting, which is preferred habitat by *E. macquarii* (Spencer and Thompson 2003). Very few juveniles exist in Murray River populations of *E. macquarii* and foxes account for nest predation rates of over 95%, yet in areas of remnant forests in the Riverland, where fox densities are lower than in agricultural regions of the Murray, nest predation rates due to native predators are less than 50% (Spencer unpubl. data). Goannas and foxes are the major predator of turtle nests in the Bellinger River and nest predation rates are 72% (Blamires et al. 2005). At this level of predation, population models predict that 95% of adult females and 65% of juveniles must survive annually to maintain population stability (Fig. 9). Unfortunately we do not have information about the survival rate of any life history stage of *E. macquarii* in the Bellinger River. *Emydura macquarii* have survival rates at these levels in the Murray River (Spencer and Thompson 2005), however survival rates of adult and juvenile *El. georgesi* in the Bellinger River are 0.86 and 0.58 respectively (Blamires et al. 2005. At those levels of survival, populations of the Bellinger River *Emydura* would be at less than 30 by 2040 (Fig. 9).

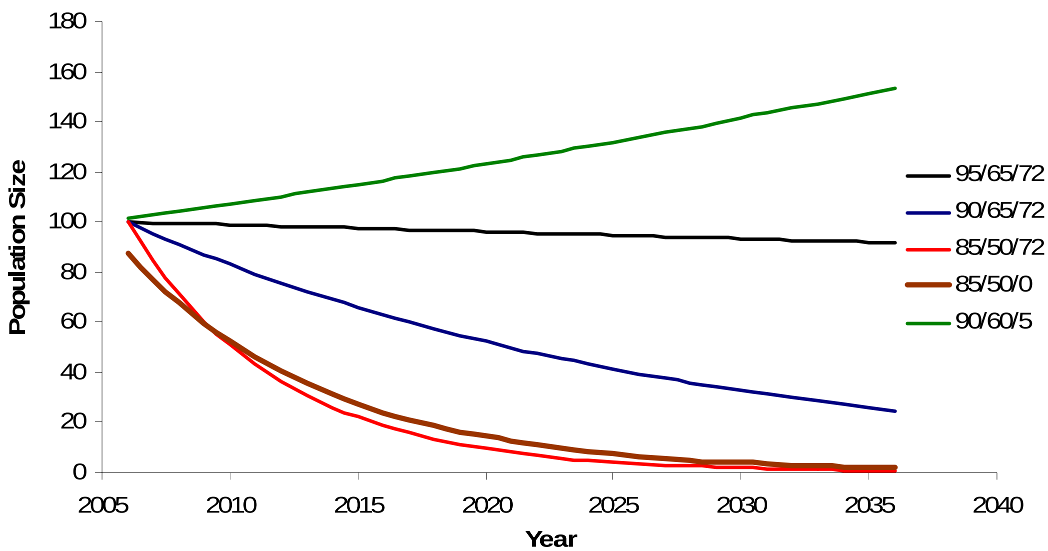


Fig. 9. Population predictions of the Bellinger River *Emydura*. A 3-stage (eggs, juveniles, adults) population matrix was developed and we simulated survival scenarios using POPTOOLS.

- The 95/65/72 scenario is based on *E. macquarii* adult (95%) and juvenile (65%) survival in the Murray River (Spencer et al. 2005), as well as 72% predation rates of nests in the Bellinger Valley (Blamires et al. 2005).
- The 90/65/72 scenario is based on estimates of adult survival at 90% with other parameters remaining the same
- The 85/50/72 scenario represents lower estimates of adult (85%) and juvenile (50%) survival, with nest predation rates steady.
- The 85/50/0 scenario represents a population prediction if nest predation rates were 0% at these lower estimates of adult and juvenile survival
- The 90/60/5 represents a conservative estimate of adult and juvenile survival with an implemented fox removal or headstarting program

Like most populations of freshwater turtles, *E. macquarii* relies heavily on adult survival for population stability (see Spencer et al. 2005). For example, completely eliminating nest predation has little impact on the population rate of decrease if adult and juvenile survival estimates are 0.85 and 0.50 respectively (Fig. 9). Slight increases in survival of other life history stages, in particular adult survival, have much greater impacts on population stability and management of most freshwater turtle populations should focus on these parameters for population recovery.

There are two strategies for managing freshwater turtle populations. Management focusing on recovery of a population should direct resources to minimise external factors that impact on adult survival, whereas options to provide population resilience should focus on increasing egg and juvenile survival. The problem in designing a management plan for the Bellinger River *Emydura* is that most population parameters derived for population models have been developed for *El. georgesi* or *E. macquarii* in other catchments (Blamires et al. 2005, Spencer and Thompson 2005). However life history patterns of freshwater turtles have generally remained conservative throughout Australia and the world (Shine and Iverson 1995). We now have a good understanding of the densities and distribution of *E. macquarii*, as well as potential breeding and nesting areas, but the population is at risk of extinction simply because less than 100 individuals have ever been captured. But should we conserve the Bellinger River Emydura?

Screening of control region variation revealed a surprising level of mitochondrial genetic diversity (six haplotypes) in the Bellinger drainage basin. This high diversity and the presence of three of the four major haplotypes in neighbouring drainage basins suggests that at least some of this diversity has been derived by either natural or human-mediated dispersal from the adjacent drainages (Georges et al. 2007). Furthermore, the single major haplotype that was unique to the Bellinger River under our sampling occurred in a single waterhole in the vicinity of the Bellingen township. Given that the system is essentially continuous, this haplotype is likely to have been introduced. Despite the Bellinger River Emydura being unremarkable genetically, the question of whether it is native to the Bellinger, or it has been introduced from neighboring drainages must remain an open question. However, the presence of hybrid *E. macquarii* and *El. georgesii* turtles opens the possibility of such introgression and the contamination of the genotype of *Elseya georgesi* by horizontal transfer of genes from *Emydura macquarii*. This is of conservation concern, and of high priority should it be found that the *E. maquarii* are introduced to the Bellinger River.

El. georgesi is restricted to, but common in, the Bellinger River. Its restricted distribution and habitat requirements make it a species potentially at risk to human induced or natural perturbations, despite relatively large densities in some sections of the River. *Elseya georgesi* are highly adapted to exploit the up-stream regions of the Bellinger River, preferring deeper waterholes with a rocky substrate that is surrounded by bedrock (Table 5). Like many *Elseya* spp. on the east coast of Australia, *El. georgesi* consume live prey associated with aquatic vegetation, such as caddis-fly larvae (Trichoptera) (Allanson and Georges 1999; Spencer et al. 2007). *El. georgesi* were severely affected by major floods in the Bellinger River catchment in March 2001, which removed much of the upper river aquatic vegetation. In some waterholes, 100% of plant beds were removed after the floods and consequently, dietary analyses revealed that the guts of five *El. georgesi* and one *E. macquarii* were empty (Spencer et al. 2007). There were also indications that reproduction did not occur throughout the catchment, with no gravid female *El. georgesi* captured in October-November 2001 (8 months after the flood).

Densities of *El. georgesi* are higher upstream of Thora than downstream, but like *E. macquarii*, a significant proportion of the population throughout the catchment were juveniles and sub-adults. Although capture method did not affect which sex was captured, it does influence which species or size classes are captured; important criteria for assessing the status of a species and developing population models. Many population and conservation studies of freshwater turtles are limited by capture methods. Turtles inhabit a range of habitats and water quality and snorkelling and dip-netting would be impossible in some of these environments, nevertheless, models that are developed for these populations or species are potentially confounded because of capture technique.

Blamires et al. (2005) suggest that *El. georgesi* populations are relatively stable or increasing and our results concur with the conclusion that the population has a relatively healthy mix of juvenile and adult turtles. *Elseya georgesi*, however, has a highly restricted distribution, specific habitat requirements and a highly specialised diet (Spencer et al. 2007) and should be considered for listing as a vulnerable species under the NSW Threatened Species ACT (1995). The key threatening processes for both species are the same and hasten the extinction of both species in the short-medium terms. Two key threatening processes are particularly relevant:

1. Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands. Any changes in river flow (eg. Introduction of European Carp, dams, dredging, mining etc) may affect turbidity and nutrient cycles, which in turn will affect the aquatic vegetation and river substrates. Sand and silt run-off from unsealed roads up-stream of Thora is a threat that immediately threatens both species. Turbidity increases dramatically and much of the silt that enters the River is deposited on patches of aquatic vegetation and rock substrates. Both of these factors are key parameters that limit the distribution of both species in the Bellinger River.
2. Predation by the European Red Fox *Vulpes Vulpes* (Linnaeus, 1758). Both species are greatly affected by predation from foxes. Both nest predation and the killing of nesting adult females by foxes and wild dogs (or pet dogs) affects population status and will lead to the extinction of *E. macquarii* within 15-20 years.

Hybidization must also be considered a key threatening process to *El. georgesi*. The concern is maintaining the genetic integrity of *El. georgesi* and possibly endemic *E. macquarii* that may still occur in the Bellinger River (Haplotypes 7 and 8; Georges et al. 2007). Although a natural process that may have historically occurred in other catchments throughout the east coast of NSW, it is not known whether the 7 potential hybrids captured during the survey are capable of breeding. Hybridsation between similar species occurs in other species of turtle. Population stability of yellowbelly turtles (*Trachemys scripta*) in South Carolina is threatened by hybridisation with red-eared sliders (*Trachemys scripta elegans*), a related subspecies from the Mississippi Valley. Red-eared sliders were sold in South Carolina pet stores for many years and continue to be sold through other venues, such as flea markets and exotic animal trade shows. This non-native species is often released in South Carolina by well-meaning, but ill-informed people. The release of *E. macquarii* collected on roads from neighbouring catchments may have similar impacts.

Although now well established as a flagship “species” upon which a range of conservation initiatives hang, the Belliner River Emydura is difficult to justify the conservation status currently accorded this form. This presents a particular problem for management. We recommend that the emphasis on the Bellinger Emydura be broadened to encompass also the endemic *Elseya georgesi*. This shift in focus should be easy to achieve without putting at risk valuable community support for fox control and restoration of riparian vegetation. The key threats identified for *E. macquarii*, equally apply to *El. georgesi*, plus the threat of hybridization could potentially lead to the extinction of the species. Subsequently, the emphasis can be further shifted to the local endemic *Elseya georgesi*, should this be required as more definitive information comes to hand.

RECOMMENDATIONS

1. The lack of any unique and widespread haplotypes (Georges et al. 2007) opens the very real possibility that the Bellinger River Emydura population is not native to the river. More extensive sampling of adjacent drainages, and the addition of nuclear genetic markers to the study for population assignment, is required to provide a definitive answer as to whether Bellinger River Emydura is native or a recent introduction to the Bellinger River, and to identify the sources of introductions.
2. Further work is required using nuclear gene markers to confirm these suspected instances of hybridization and introgression and to address the issue of whether the Bellinger population of Emydura should be conserved or whether it should be eradicated to conserve the genetic integrity of the endemic *Elseya georgesi*.
3. *Elseya georgesi* should be considered a vulnerable species because of its extremely limited distribution, specific habitat requirements, and issues with introgression with introduced *E. macquarii.*
4. We recommend that the emphasis on the Bellinger Emydura be broadened to encompass also the endemic *Elseya georgesi*. The key threats identified for *E. macquarii*, equally apply to *El. georgesi* and this shift in focus should be easy to achieve without putting at risk valuable community support for fox control and restoration of riparian vegetation.

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APPENDIX 1

(a) Diving

SubRegion	Waterhole Name	Survey Date	Time Start	Time (hours)	# People	Person Hours	Elseya	Emydura
Bell_up	Bel_1	1/04/07	10:00	1.00	7	7.00	20	1
Never_Never	Keoh_Reserve_Bridge	2/04/07	10:00	0.50	3	1.50	0	0
Bell_down	Happy_Run	2/04/07	11:00	0.50	3	1.50	0	0
Bell_down	Emydura_paradise	2/04/07	13:00	2.00	6	12.00	30	4
Bell_up	Darcys_Bridge	3/04/07	10:15	0.75	5	3.75	4	0
Bell_up	Darcy2	3/04/07	11:10	0.30	5	1.50	9	1
Bell_up	DS_The_Plains_Crossing	3/04/07	12:00	1.00	4	4.00	3	0
Bell_up	Justins_Bridge	3/04/07	15:30	1.00	5	5.00	6	2
Bell_up	Barn	4/04/07	13:30	0.75	3	2.25	10	1
Bell_up	Joyces	5/04/07	13:30	1.50	4	6.00	9	1
Kalang	Kalang_Site_X	5/04/07	08:45	0.75	4	3.00	0	0
Kalang	Brians	5/04/07	10:50	0.25	4	1.00	0	0
Bell_up	Ralphs	6/04/07	14:00	1.00	3	3.00	3	2
Bell_down	Gordonville_Cutting	7/04/07	09:15	1.75	3	5.25	13	6
Bell_up	US_Leans_Bridge	9/04/07	16:15	1.00	3	3.00	4	0
Bell_down	Terrys#1	10/04/07	09:30	1.50	4	6.00	33	0
Bell_down	Terrys#2	10/04/07	13:30	1.50	4	6.00	19	1
Bell_down	Jasons#1	11/04/07	11:00	1.50	5	7.50	33	0
Bell_down	Jasons#2	11/04/07	13:00	1.00	4	4.00	23	0
Bell_down	Celtic_Hole#1	12/04/07	09:00	1.00	4	4.00	21	2
Bell_down	Emydura_paradise	12/04/07	11:45	1.50	3	4.50	27	8
Kalang	Kalang_WH#3	14/04/07	09:30	1.00	2	2.00	0	0
Kalang	Kalang_WH#4	14/04/07	11:15	0.75	2	1.50	0	0
Kalang	Kalang_WH#5	14/04/07	12:15	0.50	2	1.00	0	0
Bell_up	Scraggy_Creek_WH	15/04/07	11:00	0.20	2	0.40	0	0
Bell_up	Woods_Creek_WH	15/04/07	11:40	0.25	1	0.25	0	0
Bell_up	Youngs_WH#3	15/04/07	12:00	0.20	2	0.40	0	0
Bell_up	Anges_Bridge	15/04/07	13:20	0.20	2	0.40	0	0
Bell_up	Winch_Flat	15/04/07	13:50	1.25	2	2.50	10	2
Bell_up	Justins_Bridge	16/04/07	09:00	0.67	4	2.67	12	2
Bell_up	Fiona_top	16/04/07	10:10	0.50	4	2.00	18	0
Bell_up	Barn	16/04/07	10:45	0.50	4	2.00	6	0
Bell_up	Mega_hole_DS	16/04/07	14:30	1.00	3	3.00	16	2
Bell_up	US_Mega_hole	16/04/07	15:30	1.00	2	2.00	12	4
Bell_up	Joyces	17/04/07	12:30	1.00	2	2.00	1	0
Bell_up	Darcys_Bridge	17/04/07	15:00	0.75	2	1.50	4	0
Bell_up	Darcy2	17/04/07	15:50	0.50	2	1.00	2	0
					Total	**116.37**	**348.00**	**39.00**

(b) Boating

SubRegion	Waterhole Name	Survey Date	Time Start	Time (hours)	Elseya	Emydura
Bell_down	Happy_Run	5/04/2007	18:30	1.50	1	3
Bell_down	DS_Bellingen_Bridge	6/04/2007	18:30	1.00	0	1
Bell_down (tidal)	Fernmount_to_Hydes_Creek	7/04/2007	18:00	1.50	0	0
Bell_down	Terrys#2	10/04/2007	19:30	1.00	0	0
Bell_down	US_Bellingen_Bridge	10/04/2007	21:00	0.50	0	0
Bell_down	Happy_Run	12/04/2007	18:45	2.00	2	9
Bell_down	Happy_Run	14/04/2007	17:50	1.50	2	9
Bell_down (tidal)	US_Hydes_Creek	15/04/2007	19:00	1.50	0	0
Bell_down	Tutts	17/04/2007	18:15	2.00	7	4
			Total	**12.50**	**12.00**	**26.00**

(c) Trapping

SubRegion	Waterhole Name	Survey Date	Time Start	Time (hours)	# Traps	Trap Hours	Elseya	Emydura
Kalang	Brians	8/04/07	10:00	7	6	42	0	4
Kalang	Brians	8/04/07	17:00	16	6	96	0	1
Kalang	Brians	9/04/07	10:00	24	11	264	0	3
Kalang	Brians	10/04/07	10:00	24	11	264	0	1
Kalang	Brians	11/04/07	10:00	24	11	264	0	1
Kalang	Kalang_WH#3	18/04/07	11:45	22	4	88	0	1
Kalang	Kalang_Site_X	18/04/07	12:30	20	4	80	0	0
					Total	**1098**	**0**	**11**

Appendix 2

SubRegion	Waterhole Name	Technique	Genus	Species	Sex	Plastron Length (mm)
Bell_up	Barn	Diving	Emydura	macquarii/georgesi	M	155.0
Bell_up	Barn	Diving	Emydura	macquarii/georgesi	M	162.3
Kalang	Kalang_Site_X	Trap	Elseya	georgesi/macquarii		
Kalang	Kalang_WH#3	Diving	Elseya	georgesi/macquarii	M	140.7
Kalang	Kalang_WH#3	Trap	Elseya	georgesi/macquarii	F	187.8
Kalang	Kalang_WH#3	Trap	Elseya	georgesi/macquarii	F	193.5
Kalang	Kalang_WH#3	Diving	Elseya	unknown/latisternum	M	130.1
Bell_down	Tutts	Boat	Emydura	macquarii/georgesi	F	166.0