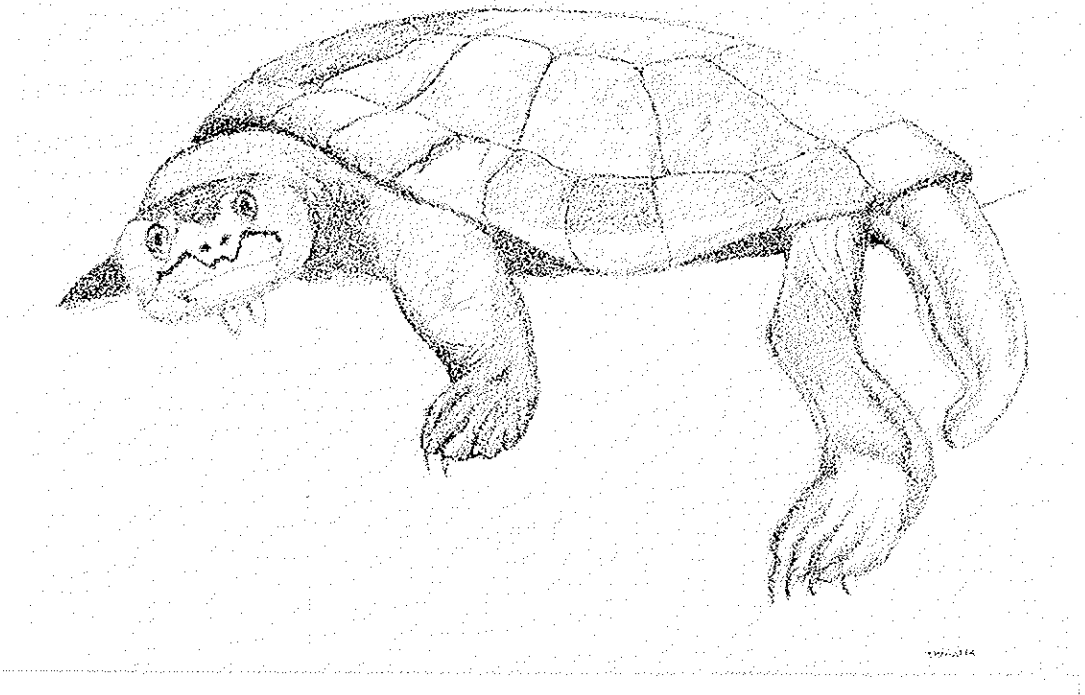
UNIVERSITY OF QUEENSLAND
DEPARTMENT OF ZOOLOGY AND ENTOMOLOGY

# Ecology of the Mary River Turtle, *Elusor macrurus*



Prepared and Written by:

**Samantha Pauline Flakus**

Master of Science (zoology) – 2002

## DECLARATION

I declare that the material submitted herein has not been used in the same context for any other award at any university or other institution of tertiary education. A small proportion of the earlier data presented in this thesis was used for an award of Post Graduate Diploma in 1998, however, its content and meaning were different. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Samantha Flakus
December 2002

## PERMITS

This research was partly funded by the Queensland Parks and Wildlife Service and was conducted under existing permits used by QPWS staff. The field component was conducted under a general fisheries permit **(PRM00152J)** issued to QPWS staff by the Queensland Fisheries Management Authority. Authorisation to capture, handle and tag freshwater turtles under this permit was also obtained from Dr Colin Limpus (QPWS). An animal experimental ethics certificate was also granted from the Animal Ethics Committee of the University of Queensland, St Lucia **(AECC approval number: ZOO/414/98/DOE/MSc)**.

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## ABSTRACT

*The Mary River turtle,* Elusor macrurus*, is a species of high conservation concern. Results from nesting surveys indicate that its breeding population has significantly declined by 95% since 1974. Today, high levels of goanna and fox depredation have been identified as the primary cause of low recruitment rates. Past commercial egg harvest, however, has also contributed to this and a delayed impact on the population structure is now obvious with very few sub-adult turtles in the population.*

E. macrurus *is a temperate-zone species. They breed during spring and summer. During the nesting season* E. macrurus *can move up to 2km to nest on 'preferred' sandy banks rather than vegetated banks. As a juvenile,* E. macrurus *is primarily carnivorous, but shift to a more herbivorous diet as an adult.*

*The data presented within clearly show the need for future active management. Recommended conservation and management strategies include the reassessment of the status of* E. macrurus *from vulnerable to endangered, the development of a species recovery program, further research on other aspects of* E. macrurus' *life history such as growth and survivorship and diving physiology, and the introduction of an incubation and head-start program to maximize incubation success and hatchling survivorship.*

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# Chapter 1: Introduction

## 1.1 General Introduction

Many people in today's society are perplexed or fascinated by what our natural environment offers, but are often unaware of the diversity of species that really exists. For many of us, our knowledge base extends only to a broad taxonomic level where a turtle is just a turtle, and likewise with many other animals. In a lot of ways, this unintentional ignorance has seriously impeded the conservation efforts of many species. Changing land use practices, continued habitat alteration and exploitation are prime examples of how our nonchalant attitudes have been responsible for the demise of many species, some even before they are properly described and studied.

The Mary River turtle, *Elusor macrurus*, is no exception. Known only through the pet trade until 1990, this species eluded discovery in its natural environment for almost 30 years, during which time the population was exploited for trade in the pet industry. With more than a decade of little or no recruitment into the population and more recent influences of increased depredation on nests, there has been a dramatic decrease in the size of *E. macrurus'* population (Flakus, 1998). Coupled with its restricted distribution, the long-term survival of this species is now questionable if left to its own devices.

Like many other Australian freshwater turtle species, little is known about the biology and ecology of *E. macrurus.* After its discovery and description by Cann and Legler (1994), only one study, on temperature sex determination, has been undertaken (Georges and McInnes, 1998). Without a basic understanding of certain aspects of its ecology such as habitat use, movement, dietary requirements, reproduction and population structure, the development of conservation and management strategies will prove to be ineffective and will not guarantee the future of this unique species.

This first detailed study on *E. macrurus* provides a basic understanding of its ecology so that effective land use practices can be employed for the long-term management and conservation of the species. In undertaking this study, the current trends in how the population is functioning are quantified and the vulnerable status of the species is re-evaluated.

## 1.2 The Australian Freshwater Turtle Fauna

The need for a better understanding of the taxonomy of Australian freshwater turtles has become particularly important in the last decade as a result of wide-spread changes in land use practises and increasing pressures on our waterways. These influences have affected the way in which turtle populations function and, in some species, have significantly altered the stability of the populations. Consequently, conservation efforts are now deemed a higher priority, but there is still considerable confusion about the taxonomy of this group (Georges, 1993).

Numerous studies have been undertaken in an attempt to redefine the taxonomy of Australian freshwater turtles through the use of traditional morphological data and/or serological data (Burbidge *et al.,* 1974; Gaffney, 1977; Georges and Adams, 1992; Legler and Georges, 1993; Georges, 1996; Manning and Kofron, 1996; Georges *et al.,* 1998). These studies have only led to further different interpretations.

As recently as the 1990s, Australia's waterways were thought to support only 16 species in six genera; three being monotypic (Gaffney, 1977; Legler and Cann, 1980; Burbidge *et al.,* 1974; Legler, 1982). Today, however, 30 species of freshwater turtles have been identified (Table 1.1).

## 1.3 Evolution and Taxonomy

Turtles are ancient and unique animals with an interesting evolutionary history. Dating back approximately 230 million years to the Triassic period (Goode, 1967), turtles are one of four reptilian groups that survived beyond the Mesozoic era (Carroll, 1969; Capula, 1989). During this time early reptiles have undergone considerable evolutionary changes that have given rise to new reptilian groups that are better adapted to living in both aquatic and terrestrial environments (Gaffney, 1990). Having said that, however, some reptilian fossils indicate that the order of turtles, the Testudines, has changed very little in appearance from their ancestors of the early Mesozoic era and display similar morphological features to present day turtles (Ernst and Barbour, 1989).

About 257 species of turtle exist worldwide, in two suborders, Cryptodira and Pleurodira (Ernst and Barbour, 1989), a dichotomy based primarily on the mechanism of head withdrawal (Goode, 1967; Georges and Adams, 1992; Legler and Georges, 1993). The Cryptodira withdraw their head by a vertical flexure of the neck into an S (Cogger, 1992). This group of turtles consists of 10 families and about 203 species and are believed to more efficient and superior to their predecessors – the Pleurodirans. The Pleurodira, consisting of two families and about 54 species, withdraw their head into the shell by a lateral flexure of the neck (Carroll, 1969), hence the term 'side-necked turtles'.

Pleurodiran turtles are found only within the southern continents including parts of Indonesia, South America, Australia and Papua New Guinea (Goode, 1967; Georges and Adams, 1992, 1996). It is thought that the Cryptodira displaced Pleurodiran turtles from the Northern Hemisphere. In Australia, with the exception of one Cryptodiran species, *Carettochelys insculpta* (family Carettochelydae), our waterways are dominated by one family of Pleurodiran turtles; the Chelidae.

Chelids can be separated into two broad morphological and ecological groups (Goode, 1967; Cann, 1978), the long-necked turtles and the short-necked turtles. As mentioned previously, currently 30 species of chelids have been formally described in Australia (6 long-necked; 24 short-necked), though many more are yet to be classified (Georges and Adams, 1996; Cann, 1998). Table 1.1 summarises the total number of species that are found in each state of Australia. Note that the total number of species per state is not an indication of the total number of described species within Australia, as the distribution of some species overlap states.

Table 1.1: Number of Australia freshwater turtle species by state.

| | Family | Australian State | | | | | |
|---|---|---|---|---|---|---|---|
| | | QLD | NSW | VIC | NT | WA | SA |
| Chelidae | *Chelodina* (6 species) | 4 | 2 | 2 | 2 | 3 | 1 |
| | *Elseya* (8 species) | 5 | 4 | - | 2 | - | - |
| | *Emydura* (12 species) | 7 | 5 | 1 | 4 | - | 1 |
| | *Elusor* (1 species) | 1 | - | - | - | - | - |
| | *Pseudoemydura* (1 species) | - | - | - | - | 1 | - |
| | *Rheodytes* (1 species) | 1 | - | - | - | - | - |
| Carretochelidae | *Carretochelys* | - | - | - | 1 | - | - |
| | TOTAL | 18 | 11 | 3 | 8 | 3 | 3 |

NB: Shaded rows indicate monotypic species. (Cann, 1998)

## 1.4 *Elusor macrurus*

*E. macrurus* is a species of high conservation concern (QPWS, 1997). In the past its population has been subjected to intense harvesting for trade in the pet shop industry. Up to 12 000 eggs were collected from the banks of the Mary River between Tiaro and Gympie and sold annually to pet shops throughout Australia for a period of twelve years (Appendix 1). During this time, it is suspected that there was little or no recruitment of hatchlings back into the population.

Initially identified and sold as *Elseya latisternum,* the common saw-shelled turtle, this unknown species (referred to as 'short-neck alpha') sparked great interest among turtle biologists. At the time of distribution through the trade, the geographic source of 'short-neck alpha' was unknown. In the following years, its origin was sought with

no success, and the pet trade's 'code of ethics' prevented distributors from revealing their source of supply.

In 1974, legal trade in turtles ceased with the introduction of the Fauna Conservation Act in Queensland, Australia; yet the search for the origin of this turtle still continued. After 25 years of long and arduous expeditions in river systems throughout Australia, Torres Strait and Papua New Guinea (Georges, 1995), this turtle was discovered in the Mary River by John Cann.

In late 1990, Cann obtained the first four adult specimens from the Mary River in southeast Queensland (Cann and Legler, 1994). In 1994, 'short-neck alpha' was described as not only a new species, but also as a new genus because of unique characteristics that distinguished it from all other taxa. It was named *Elusor macrurus; Elusor* reflecting its secretive nature by eluding discovery and *macrurus* because of its unusually large and laterally compressed tail (Cann and Legler, 1994).

During the years of egg collection, it was presumed by the collectors that *E. macrurus* used the same nesting sites annually. Reports of mass nesting events were also recorded for this species (Greenhalgh, pers.comm.; Appendix 1).

*E. macrurus* is endemic to the Mary River and its breeding population has been subjected to major impacts over time. Years of egg collection and increased levels of depredation have resulted in a population dominated by adults. Its discovery and description has led to further studies (including the present one) to define aspects of its biology and ecology.

### 1.5 Morphology, Distribution and Status

*Elusor macrurus*, is the largest Australian short-necked chelid (female≈34cm; male≈42cm; this study). It has a low domed, streamlined shell that is dull in colour and unpatterned in appearance. Adult males and females differ slightly in external morphology, with the female's shell being variable in cross-section and wider posteriorly than anteriorly. In contrast, the males' shells are depressed, being narrow and nearly straight-sided. Adult males are also distinguished by a large tail that, when stretched, extends to 70% of the carapace length.

Cann and Legler (1994) stated that coloration of the plastron is chiefly greyish to darker slate in adults, with skin parts almost totally grey. However, data from this study indicate that the plastron is cream to yellow in colour, skin parts of inguinal areas are pinkish-white and the dorsal surface of the skin is grey, suffused with pink on the transverse lamellae scales.

Like *Rheodytes leukops* (Priest, 1997) and *Elseya* sp. (Fitzgibbon, 1999), *E. macrurus* supports an extensive cloacal gill system that aids in respiration (Limpus, pers. comm.).

Hatchlings of this species show similar characteristics to other juvenile chelids, having a smooth shell that is unserrated and indistinctly keeled. At an immature size (approx. 20cm), marginal serrations develop and, by maturity, the mid-dorsal keel and marginal serrations are lost completely. Juveniles and hatchlings are darker in colour than adults with greater contrast between ventrally and dorsally coloured surfaces. Hatchling coloration is dark olive to almost black, flecked with fawn (Cann & Legler, 1994). The plastron is pale grey with a bluish tinge and skin parts are pale grey suffused with pink. After three weeks, hatchling coloration changes dramatically, becoming lighter in shade. In juveniles there is extensive dark coloration ranging from solid smudges to mottling on the inframarginal surfaces. The carapace and dorsal skin parts are dull and slightly brownish in colour and the plastron ranges from pale slate grey to neutral cream, which may be suffused with various amounts of rosy pigment (Cann & Legler, 1994). From personal observations throughout the study, coloration of ventral skin parts of juveniles was similar to that of the adults.

Since the early research by Cann and Legler (1994), many freshwater turtle surveys have been undertaken in major river systems throughout southeast Queensland (Albert river: Manning, 1994, Burnett River: DoE, 1995/8, Fitzroy River: Priest, 1997, QPWS, 1997/8, Mary River: QPWS 1997/8). Along with Cann and Legler's (1994) research, these surveys confirmed the extent of *E. macrurus'* distribution. *E. macrurus* is endemic to the Mary River catchment and occurs from Kenilworth (20°35'S, 152°46'E) in the upper reaches of the river through to the tidal reaches

upstream from the saltwater barrage at Tiaro (25°44.418'S, 152°31.554'E). *E. macrurus* has also been observed at various localities along Tinana and Yabba Creeks, two major tributaries which run parallel to the main stream in its northern and southern reaches respectively (see Figure 2.2). Because of its limited distribution, *E. macrurus* is listed vulnerable under state legislation and as critically endangered in the 1996 IUCN Red data book (IUCN, 1996).

## 1.6 Aims and Objectives

The aim of this study was to increase our knowledge and understanding of the ecology of the Mary River turtle to guide effective management through long-term conservation and/or recovery plans.

The objectives of this study were primarily to:

1. Determine the reproductive biology and capabilities of *E. macrurus* by recording nesting patterns and reproductive cycles.
2. Determine the movement and/or home range of individual *E. macrurus.*
3. Determine the dietary requirements of *E. macrurus.*
4. Determine growth rate and survivorship of *E. macrurus.*
5. Identify threatening processes that may affect the long-term viability of the species.
6. Recommend suitable management strategies for the conservation of this species.

## Chapter 2: General Methods and Site Description

### 2.1 General Methods

#### *2.1.1 Capture Techniques*

The sampling of freshwater turtles in the Mary River commenced in July 1997. Sampling was undertaken mostly during the day in all months and seasons of the year. Turtles were captured by one of three methods; 1) snorkelling, 2) baited funnel traps and 3) seine netting. Sampling effort for all methods of capture is listed in appendix 3.

Turtles captured by snorkelling were hand captured in depths of up to 5m and stored in mesh drawstring bags until processed. The riverbed was searched in mid-stream, amongst submerged logs and vegetation and in rock crevices. Most turtles seen were captured. Snorkelling was the most effective method of capture, although it was time consuming and dependent on the clarity of the water.

Collapsible, baited funnel traps and/or conventional crab pots were also used to capture turtles. The traps were set either fully or partially submerged and were checked at 2-3 hourly intervals. Pierced cans of tinned sardines, fresh liver, fruit or beef heart, were used as bait. Old bait was usually replaced by fresh bait after each trapping session. Traps were set either along banks among overhangs and fallen, submerged trees or in mid-stream if the current was not too strong.

In shallow areas of the river, up to 3m depth, a seine net (30m length, 3m fall, 15cm mesh size) or bait net was used. The nets were dragged through the water and along the bottom in either a semi-circle out from one bank or in a straight line (extending from both banks) along the river. This form of sampling was particularly suitable when water was turbid and where there was little aquatic vegetation and few snags. Sampling was restricted to capturing animals larger than the mesh size used.

### 2.1.2 *Data Collection*

All turtles were tagged, measured and weighed in accordance with Queensland Turtle Research methodologies (Limpus *et al.,* 2002). Two types of tagging were used in this study. Numbered self piercing, self locking, monel tags (style 898; 1.5cm x 0.4cm), originally designed as chicken wing bands (National Band and Tag Company, USA), were applied to the webbing of each turtle's right hind foot between the fourth and fifth digits (Limpus *et al.*, 2002). Carapace notching of marginal scutes was used as a secondary measure for tagging. Each marginal scute was assigned a letter of the alphabet from the right anterior end of the carapace, in a clockwise direction excluding the nuchal scute (Figure 2.1). Each notch had a depth of approximately one third of the width of the scute to provide a series of single, double and occasionally, triple notching combinations (e.g. a, b, c, …. z, ab, ac, ad, …. az, bc, bd, …. abc) (Limpus *et al.*, 2002). Each scute received only one notch for any combination.

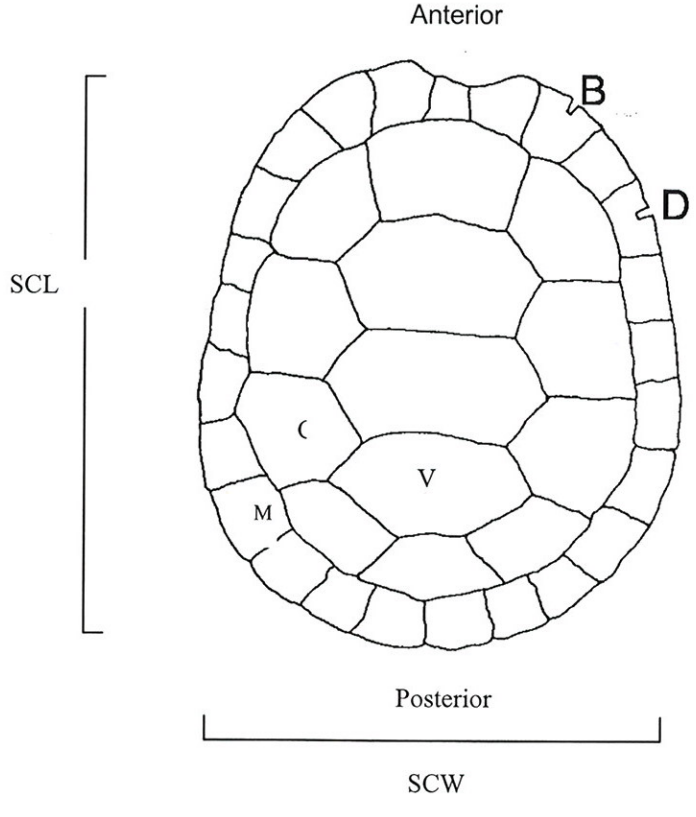



Figure 2.1: double combination carapace notching - combination BD; M=Marginal scute; C=Costal scute; V=Vertebral scute; SCL=Straight carapace length; SCW=Straight carapace width.

Standard measurements of each turtle were also taken (as used by QPWS Queensland Turtle Research Program). Straight carapace length (SCL) was measured along the midline from the nuchal scute at the anterior end of the carapace to the posterior margin of the carapace at the junction between post ventral scutes. Straight carapace width (SCW) was measured at the widest part of the carapace. Plastron length (PL) was measured along the midline from the anterior to posterior surfaces and plastron width (PW) was measured at the anterior margin of the bridge. Head length (HL) was measured from the anterior tip of the nose to the posterior projection of the supra-occipital process and head width (HW) was measured at the quadrate bones. Three tail measurements, anterior vent to tip (TV), plastron to tip (TP) and carapace to tip (TC) were also taken. In addition, tail circumference of male *E. macrurus* was measured using a flexible measuring tape. This measurement was taken around the base of the tail, at the posterior margin of the carapace. A carapace scute count and plastron curvature (convex, concave, flat) was also determined. All measurements were taken using 250mm, 300mm or 600mm Vernier callipers (±0.01mm) and all turtles were weighed using a Wedderburn electronic balance (5000g x 1g) or 10kg Salter spring balance. Data collected on sex and maturity from laparoscopic examination, was made available by the Queensland Turtle Research program run by the Queensland Parks and Wildlife Service. The data collected from this sampling was added to the above mentioned research program database.

The Average Middle Thread Distance (AMTD) was used to reference capture sites, movement patterns of individual turtles and to describe the position of sites during the study. AMTD is defined as the distance from the mouth of the river in kilometres (Water Resources Commission, 1984).

The water clarity was measured at each site by using a Secchi disk.

## 2.2 The Study Area

### *2.2.1 General Background*

The Mary River falls within a region that is characterised by relatively small coastal catchments compared to the inland regions of Queensland (DEH and DNR, 1999), having a catchment area of approximately 9700km$^2$ and a streambed length of about 300km (Johnson, 1997) (Figure 2.2). The Mary River originates in the Conondale ranges in the south and drains north, paralleling the eastern coastline to Maryborough (25° 31'05"S 152° 42'40"E) before changing its course northeast towards the coast at Hervey Bay (25° 15'29"S 152° 49'13"E). The eastern watershed is formed by the Tagigan, Beeham, Wapunga and Blackall Ranges and the western watershed by the Kandanga, Amamoor and the coastal ranges (Bridges *et al.,* 1990). A number of large tributaries drain into the Mary River including Tinana, Wide Bay, Yabba, Six Mile and Obi Obi Creeks. Within the catchment there are eleven water storages (weirs/dams) that provide both irrigation and urban water supplies to the surrounding communities (1 in Mary River; 10 in creeks) (Johnson, 1997).

The Mary River falls within a sub-tropical climate that is usually subjected to summer rains and dry winters. Toward the south and coastal ranges, the climate is predominantly moist sub-tropical (Pointer, 1998). The western ranges experience a dry sub-tropical climate (Pointer, 1998). The average rainfall varies within the catchment area and is the major factor determining where and when various agricultural land uses are carried out (Pointer, 1998). Rainfall ranges from about 2000mm annually in the upper catchment area around Maleny to 900mm in the middle to lower catchment area at Kilkivan and the western side of the catchment (Willcocks and Young, 1991; Bureau of Meteorology, 2000).

Land degradation in the Mary River catchment is widespread. A significant part of the catchment has been cleared of its natural vegetation for agricultural and other purposes (Pointer, 1998). This has resulted in varying degrees of land degradation mainly in the form of soil erosion and landslips, leaving the

soils low in nutrients, unstable, clear of vegetation and prone to weed infestations.

Development and commercial activity within the Mary River catchment began as early as 1840, with the transport of wool and timber along it (Pointer, 1998). Soon after, cotton, sugarcane and cattle industries were established along its banks. Since then, forestry, mining, dairy farming and other agricultural industries (including pineapple, macadamia, banana, vegetable crops) have been established, along with residential areas. These industries are responsible for extensively clearing the surrounding land (Johnson, 1997; Cann, 1998), and now only about 10% of the land is left in its original state (Johnson, 1997).

Mining and extractive industries also operate along certain reaches of the Mary River. Substantial deposits of sand and gravel can be found in the banks and in off stream alluvium (Johnson, 1997). At present there are thirteen registered sand and gravel mining operations along the main stream of the Mary River (NRM, 2001). In addition to this, there are a number of illegal mines operating. One of particular interest is sand and gravel extraction at Tiaro. Legally established in 1984, this mining operation was very small, removing only $100m^3$ of sand over a ten-year period. In 1999 a one hundred year flood saw large quantities of sand and gravel being deposited along this area. Since then, large-scale extraction has been occurring illegally on this 100-year old flood plain (Plate 2.1).

Plate 2.1: Sand and gravel extraction, Tiaro 1998.

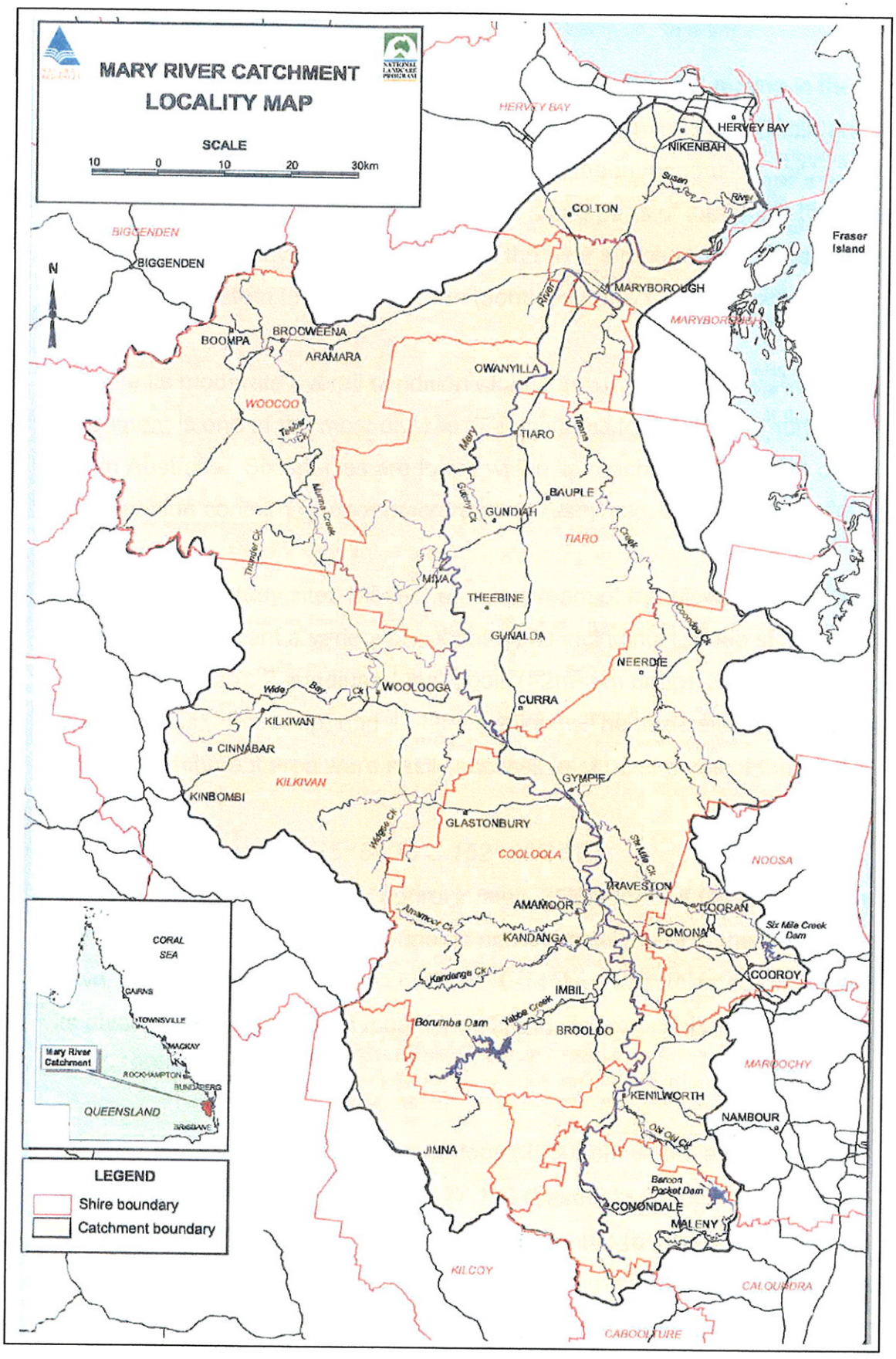



Figure 2.2: The Mary River catchment area.

In addition to sand and gravel extraction, some alluvial gold mining in the Chinaman Creek area and gold-bearing ore is being mined at Gympie and Kilkivan. Over the years, these industries have been responsible for increased turbidity as well as bank erosion along parts of the Mary River. Major operations have had an impact on the river structure, changing it from a meandering system to a braided form (Johnson, 1997).

Despite its moderate overall condition (Johnson, 1997), the Mary River catchment is one of the most diverse river systems for freshwater turtles within Australia. Six species are found within its reaches and two are of high conservation concern (*Elusor macrurus* and *Elseya* sp. *aff. dentata*).

Three different study sites within the main stream of the Mary River were chosen, to represent a variety of habitat types including 1. deep slow flowing pools (>6m deep), 2. medium depth pools (>2m<6m deep), 3. shallow fast flowing pools (>2m deep) and 4. riffle sections. The three sites in the middle to lower catchment area were easily accessible at most times of the year.

### 2.2.2 *Site 1: Gunalda (25° 54'36"S 152° 33'24"E)*

The small town of Gunalda is approximately 25km north of Gympie (Figure 2.3). The Mary River passes Gunalda approximately 5km to the west of the town. The Gunalda study site (AMTD 140-145km) was selected because of its diverse range of habitat types (types 2,3,4), its exceptional clarity (during 1997-1998).

Statistics from the Bureau of Meteorology (2000) show that average air temperatures range from 13.5°C to 27.1°C (based on Gympie records). Average rainfall for the area is 891.6mm per annum (based on Gunalda records). During 1999 the La Nina weather pattern created unusual weather conditions and an annual total of 1398mm of rainfall was recorded. During this weather cycle the Mary River flooded several times, increasing water levels and reducing the water clarity to zero. This caused difficulties for the present study.

The survey area covered a streambed length of approximately 4km (derived by the extent in which radio tracked turtles moved). Lying in the middle catchment area, this section of river is predominantly characterised by medium depth pools (>2m<6m deep), shallow fast flowing pools (<2m deep) and riffle sections that varied in width from approximately 10m to 50m. In these sections, water depth varied from 10cm to 6m, though typically was 1-2m deep. Two small creeks flow into the river at an Average Middle Thread Distance (AMTD) from the mouth of the river of 139km and 143.5km.

The riverbed is predominantly sand and gravel, with many boulders and logs lining the edges of the stream. Submerged aquatic vegetation and logs are abundant in most areas. However, during the 1999 floods all aquatic vegetation was scoured out due to the extended periods of high flow and turbidity.

The surrounding land has been cleared for agriculture (sugarcane and macadamia nuts) and cattle grazing. The eastern and western banks are mostly steep-sided. The riparian vegetation is poor (ie 20-40% cover) with some banks having little or no vegetation (Department of Natural Resources, 1996). As a result of this, bank erosion and landslips are common. There are no mining operations along this stretch of the river.

Within this stretch there is one sandbank that is known to be a nesting area because of the number of turtle tracks found each breading season. This nesting bank is also used by cattle as an access point to the river.

From October 1997 to December 1998 water clarity usually exceeded 2-3m. During February 1999 a 100-year flood reduced the water clarity to zero. Since January 1999, subsequent high rainfall has kept the water from clearing.

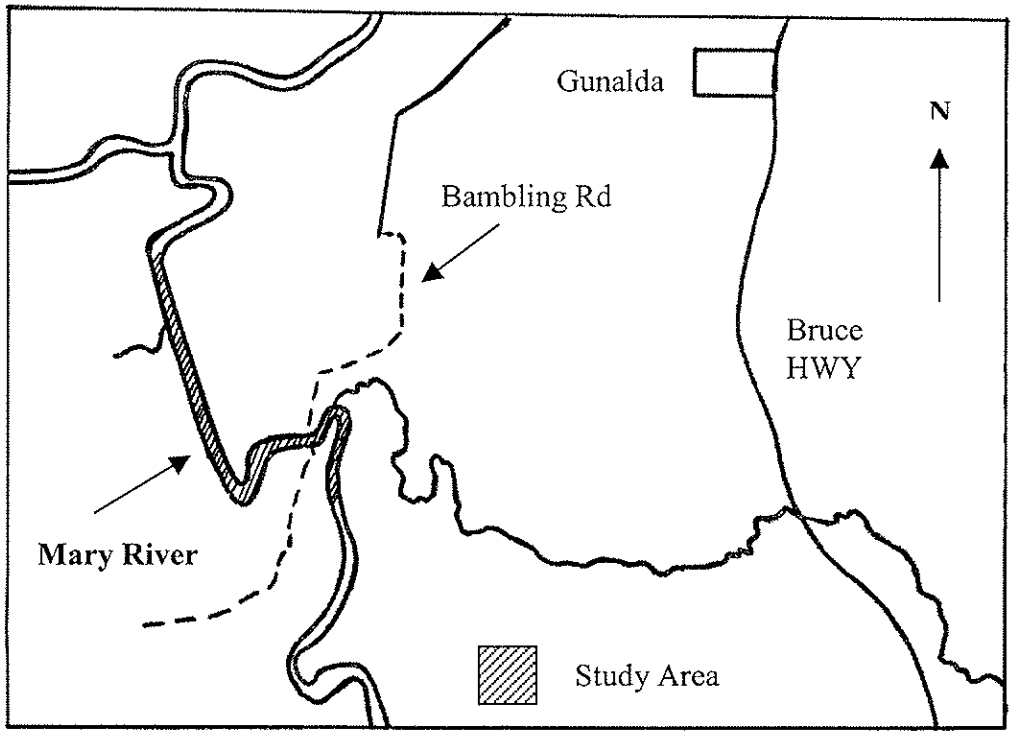



Figure 2.3: Study site 1 – Gunalda.

2.2.3 *Site 2: The Woolooga Bridge Crossing (25°53'191"S 152°28'281"E)*
The Woolooga bridge crossing is approximately 10km west of the Bruce Highway at Gootchie (Figure 2.4). It falls within the Biggenden area. This study site was selected because of its clarity and excellent in-stream habitat.

The climate of this area is similar to Gunalda with average temperatures of 27.1°C and rainfall of approximately 900mm per year (Bureau of Meteorology, 2000). Here too, the 1999 floods caused an increase in average water depth and turbidity.

The survey area covered a streambed length of approximately 2.5km (derived by map distance, AMTD 112km). Lying in the middle to lower catchment area this section of river is characterised by shallow fast flowing pools (<2m deep) and riffle sections. The width of the stream varies from 10m to 40m. Munna Creek enters the Mary River along this stretch of river at an AMTD of 110km.

The riverbed is mainly sand and gravel with submerged logs lining the edges. Aquatic vegetation is usually abundant on the edges of the stream. During the 1999 floods, extended periods of high flow scoured the vegetation.

The surrounding land has been cleared and is used predominantly for cattle grazing. The western bank is mainly steep-sided, whereas the eastern bank has a more gradual slope. The riparian vegetation is poor to moderate (ie 20-60% cover) according to Department of Natural Resource standards (Johnson, 1997).

There are two sand-gravel banks that are possibly used by turtles for nesting. They both have a gradual slope and are used regularly by cattle to access water.

From September 1997 to December 1998 water clarity was excellent, usually exceeding 5m. After the 1999 February floods water clarity fell to zero. As with the Gunalda study site, since January 1999 subsequent high rainfall has kept this section of river from clearing.

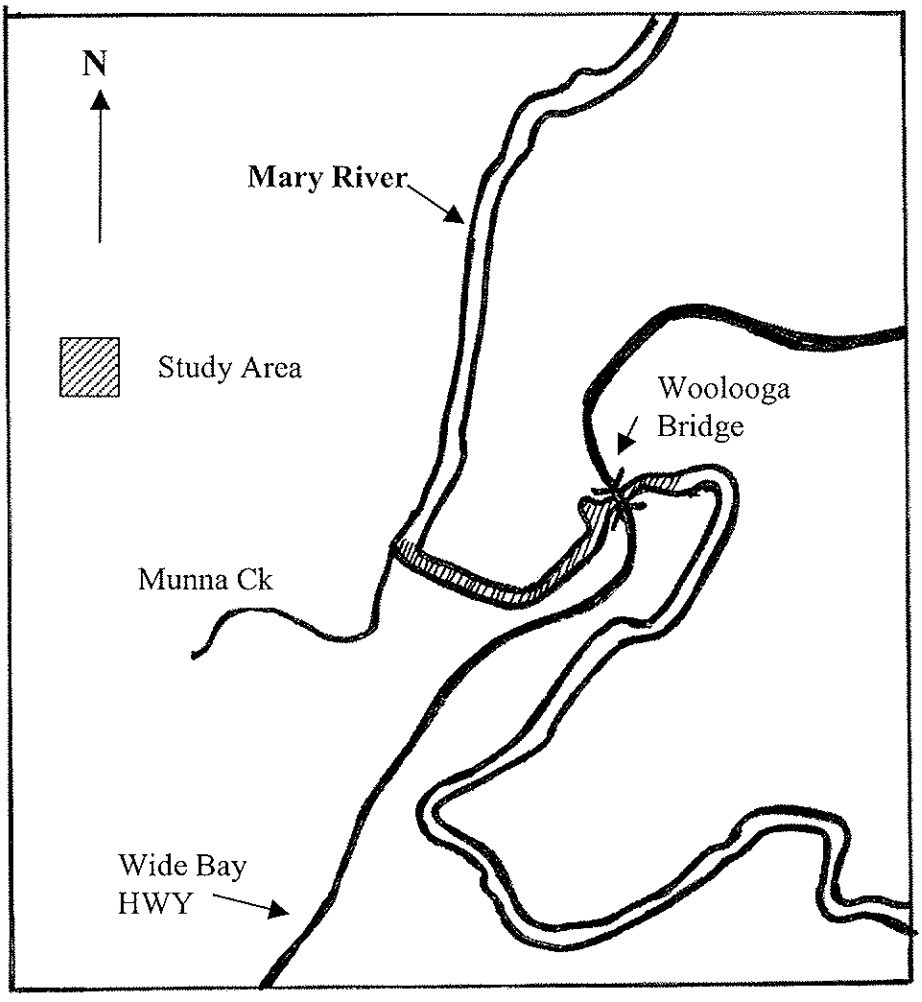



Figure 2.4: Study site 2 – The Woolooga Bridge Crossing.

2.2.4 *Site 3: Tiaro (25° 43'25"S 152° 34'31"E)*

The town of Tiaro is approximately 25km south of Maryborough (Figure 2.5). The river runs along the western side of town varying in distance from 0.5km to 5km. The Tiaro study site was selected because of its close proximity to several known nesting areas for the Mary River turtle.

Average minimum and maximum temperatures range from 15.2°C to 26.9°C and average rainfall is 1148.25mm per annum (Bureau of Meteorology, 2000).

The survey area covered a streambed length of approximately 2.5km (AMTD 88). Lying in the lower catchment area, this section of river is characterised

predominantly by large deep (>6m), slow flowing pools and few riffle sections. One creek flows into the main stream along this stretch at AMTD 88km.

The riverbed is mainly sand with overlying silt and has some boulder areas nearer riffle sections. Aquatic vegetation is sparse, probably as a result of depth and turbidity and submerged logs are uncommon. Undercut banks are common within this section of river and have been observed to provide a safe haven for turtles and other animals. There are few basking sites for turtles.

The surrounding land has been cleared mainly for cattle grazing, however, a number of farms have been established producing citrus fruits, sugarcane and corn. The riparian vegetation is fair, that is, 40-60% of its original state as defined by the Department of Natural Resources (1996). Large-scale gravel and sand extraction is occurring along the flood plain within this area. This operation is adjacent to a major nesting area that is used by the Mary River turtle.

There are four identified nesting areas in the Tiaro study site. Historically, these nesting banks have been identified as the most productive nesting areas for the Mary River turtle during the pet shop trade era (Greenhalgh, pers. comm.). Two of these banks are very steep sided with little or no vegetation. The other two have a shallow incline with vegetation lining some of the edges. All of the banks are predominantly sand, though the last flooding event deposited large quantities of gravel. Regular use by cattle to access water has introduced weed species on to these banks.

Water clarity is usually poor within the deep, slow flowing pools. Nevertheless, from July 1997 to December 1998 clarity in shallow areas near riffle zones usually exceeded 3m. Since major flooding in February 1999 water clarity has been reduced to zero.

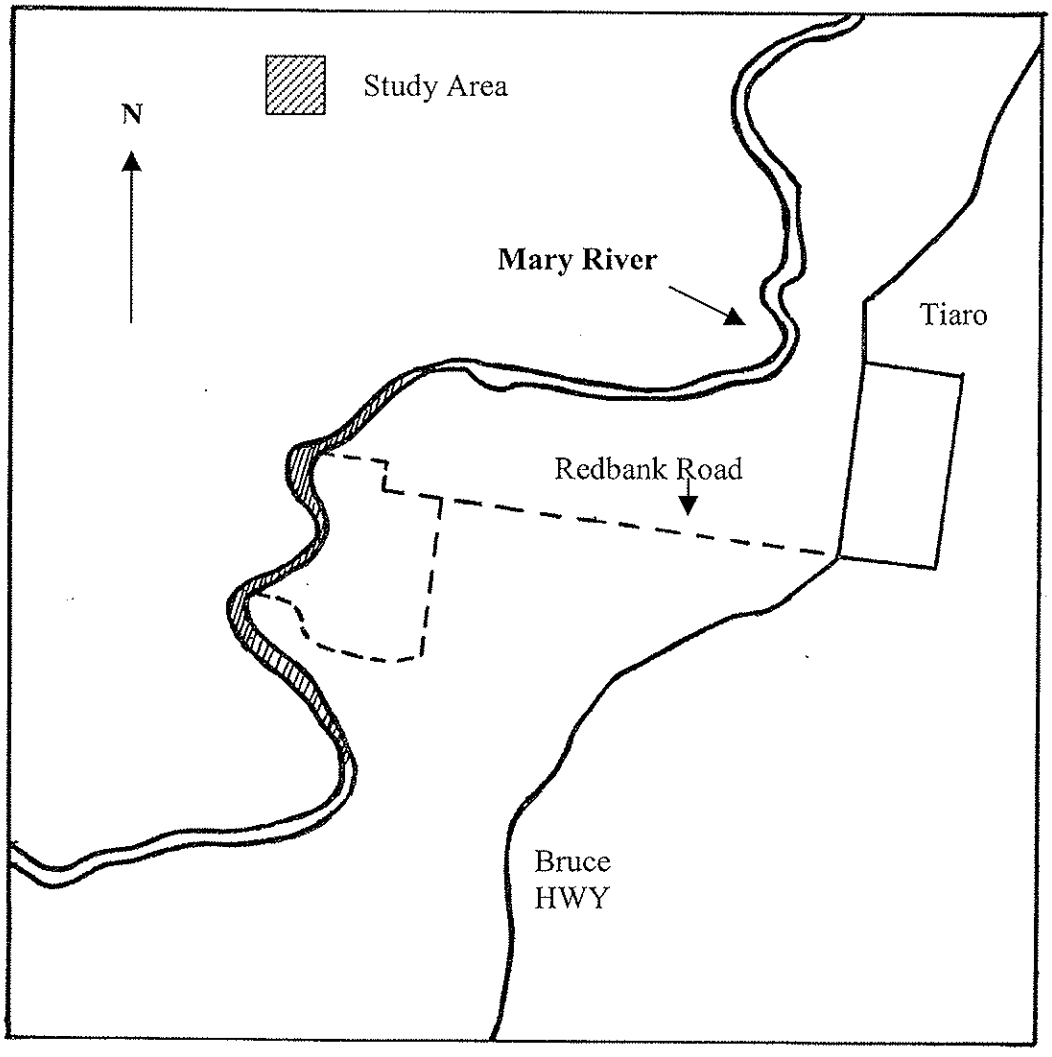



Figure 2.5: Study site 3 – Tiaro.

## Chapter 3: Movement Patterns

### 3.1 Introduction

Over the last 50 years, habitat modification for various purposes has played a major role in shaping today's society (Dodd, 1990). In particular, river systems throughout the world have been altered in accordance with our increasing needs for municipal water and agricultural development (Dodd, 1990). As a result of this, habitat fragmentation and alteration, changes in flow regimes, and food availability have threatened populations of both fish and riverine turtles throughout the world (Ono *et al.,* 1983; Meffe and Vrijenhoek, 1988; Dodd, 1990; Moll, 1997). All of these studies have identified that changes due to impoundments have hindered movements of these species and, in some cases, have threatened the population.

Little is known about the movement patterns of Australian freshwater turtles and what effect habitat alteration has on their daily activities of foraging, reproduction and sheltering. For a species like *E. macrurus*, that has displayed strong tendencies to use specific habitats for nesting and foraging (Cann, 1998) and to possibly move between these areas regularly, the impact of major habitat alterations could be significant on the population.

Together with the need to learn more about the biology of Australian freshwater turtles, comes the obvious need for further research and understanding into the habitat use and movement patterns of many species. Such information is essential for the long-term management and conservation of a species and for the development of effective management strategies.

This study examines the movement patterns and home range of *E. macrurus* in its natural environment. In particular, it focuses on the breeding population to determine if movement is a necessary function of their breeding ecology and if the use of specific habitats are needed for the long term survival of the species.

In general, the movement pattern and home range of an animal is shaped by many biotic and abiotic influences within its environment. To a large extent the spatial availability of resources such as food, mates and shelter determine an animal's use of space (Waser and Wiley, 1979; Macartney *et al.,* 1988).

For a freshwater turtle, the continual natural changes within its environment could also influence its daily movements. In a lotic system there are many stresses and demands such as changing water velocity, depth and substrate which can substantially influence the daily activities of individual freshwater turtles (Pluto and Bellis, 1988).

The movement patterns of several American riverine turtles have been studied. These include *Pseudemys scripta* (Moll and Legler, 1971), *P. concinna* (Jackson and Walker, 1997), *Trionyx muticus* (Plummer and Shirer, 1975), *Graptemys ouachitensis, G. pseudogeographica* (Vogt, 1980), *G. geographica* (Pluto and Bellis, 1988), *Chrysemys picta* (MacCulluch and Secoy, 1983), *Trachemys scripta* (Schubauer *et al.,* 1990), *T. spiniferus* (Plummer *et al.,* 1997) and *Phrynops rufipes* (Magnusson *et al.,* 1997). A number of these studies have shown that the linear distance used by an individual ranges from 200-500m and are similar for both males and females (Moll and Legler, 1971; Pluto and Bellis, 1988; Jackson and Walker, 1997). Other studies have shown individual turtles to occupy a linear distance of 2-6km with males having a significantly larger linear range than females (MacCulluch and Secoy, 1983; Schubauer *et al.,* 1990; Magnusson *et al.,* 1997). All of these studies concluded that home range size or range length was determined by the availability of food resources rather than other factors such as social structure.

Within Australia, the movement patterns of a number of species have been studied including *Rheodytes leukops* (Tucker *et al.,* unpublished 1999), an undescribed species of *Elseya* (Flakus *et al.,* unpublished 1999) and *Chelodina longicollis* (Kennett and Georges, 1990). The studies on *R. leukops* and *Elseya* sp. indicated that linear distances of up to 50-700m and 300-1700m respectively, were occupied by individuals of each species.

In most studies of movement patterns the term 'home range' is used to define the area which an individual uses. This term is very broad and in the past its definition has been somewhat unclear. In 1943 Burt defined home range as an area traversed by an individual in going about its normal activities of foraging, mating and caring for young. This definition gives no explanation of the 'area' and 'activities outside the area' and defines the home range of an animal with no reference to time in days, months, years or even seasons (Powell *et al.*, 1997).

The term home range has been applied predominantly to terrestrial animals where their movements are recorded using methods of analysis such as Minimum Convex Polygon, Cluster Analysis and Kernel Analysis (Kendward, 1987; Harris *et al.*,1990; Funston *et al.*, 1994; Ryser, 1995). All of these methods use various ways to calculate the area used by an individual, by connecting the outer tracking fixes to form a polygon. In a linear system, these methods have obvious limitations. By creating a polygon, areas that are not used by the turtle (ie the land) will be included into the home range. Thus giving a false estimate of the area the turtle is using.

Instead of applying the term 'home range' to riverine turtles, the term 'range length' has been used, to describe the stretch of river that turtles use in going about their normal day to day activities (Pluto and Bellis, 1988).

For the purpose of this study, the term range length will be used to describe the linear range that an individual turtle uses during the breeding and non-breeding seasons. By definition, this area includes where an individual carries out activities such as foraging, mating, nesting and sheltering (Pluto and Bellis, 1988).

The linear range will be calculated by using the Average Middle Thread Distance (AMTD). The Average Middle Thread Distance (AMTD) is defined as the distance from the mouth of the river in kilometres (Water Resources Commission, 1984). This method accounts for the river meanders, thus estimating the range for a riverine species more accurately than other methods used in determining home ranges in terrestrial species.

## 3.2 Methods and Study Site

### 3.2.1 *Radio Telemetry and Mapping*

Between October 1997 and June 2000 the movements of 10 adult *E. macrurus* were tracked using radio telemetry. As described by Flakus (1998) custom made radio transmitters were attached to the carapace of ten adults (7 female; 3 male). During the study one male and female were 'lost' and it is suspected a transmitter became detached from another female. The data from 9 turtles (3 males; 6 females) were used to determine range lengths and seasonal patterns in movement.

Each transmitter was bolted to the right, rear marginal scutes of the carapace using 1/8"x25mm stainless steel threads (Plate 3.1). The nuts were secured with Selleys five-minute Araldite and gaps between the transmitter and carapace were filled with Selleys universal co-polymer sealant or 3-5mm neoprene. After attachment, each turtle was released at its site of capture.

The radio transmitters were manufactured by Titley Electronics, powered by a Varta 3V lithium battery and had an estimated life of 7-8 months. In reality, the life of the battery was approximately 24 months. The entire package, encased in resin, measured 4.3cm x 3cm x 1.7cm and weighed 28g (less than 5% of the turtle's body weight). Each transmitter had a whip antenna of approximately 27.5cm in length, which trailed beyond the rear of the carapace. They transmitted in the 151mHz-frequency band and turtles were tracked with a 3-element hand held collapsible Yagi antenna and a Regal 2000 receiver. The range of each transmitter was approximately 500-600m if in line of site.

On one occasion turtles were tracked from the air. In this instance, precise locations of the turtles were not determined. On other occasions, tracking position along the riverbank did not allow for the precise location of the turtles, and it could not be determined whether the turtle was in mid-stream or at the

bank. On most occasions, however, the turtle's positions was located and recorded using a Garmin GPS 12XL.

A mark/recapture program (described in Chapter 2) also provided a potential source of data on the movements of some individual turtles.

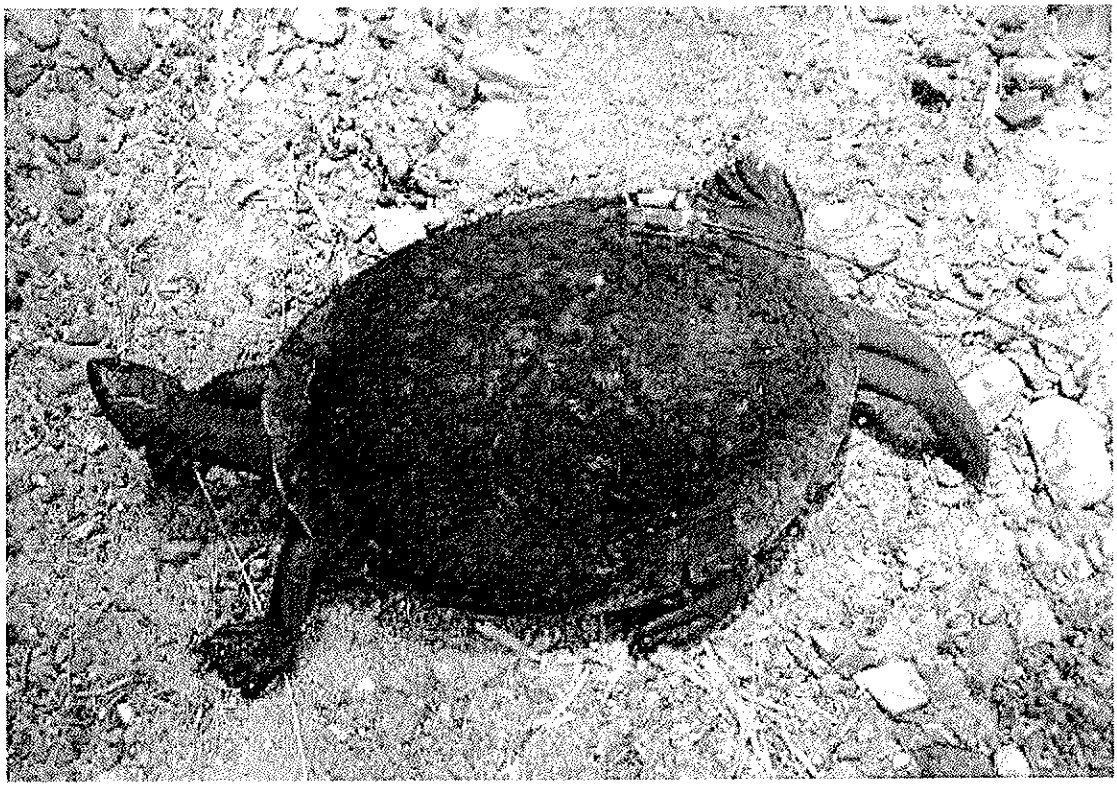


**Plate 3.1: Attachment and placement of radio transmitter to *E. macrurus***

Aerial photographs of each study site were used to plot tracking fixes and determine range lengths of individual turtles. Each aerial photograph was enlarged by 200% or 400% to produce maps for plotting fixes (Figures 3.1, 3.2). Aerial photographs used included Gympie 9445, 1:40 000, 01/08/1996 and Maryborough 9446, 1:25 000, 29/04/1999.

Field notes and latitude and longitude bearings were used to plot turtle locations on each map. The position of each turtle was numbered in chronological order. An overlay of Average Middle Thread Distance (AMTD) was used to derive the linear distance in metres that the turtle occupied (Figures 3.1a, 3.2a).

### 3.2.2 *Data Analysis*

Data was analysed using AMTD information from maps provided by Queensland Water Resources Commission (1984). Estimates of range length were split into two categories, the total range length and the range length of core activity. The total range length of each individual was estimated by using 100% of tracking fixes. The AMTD of the outermost fixes were determined and subtracted from each other to estimate the total distance used by an individual including both the breeding and non-breeding seasons. The range length of core activity was estimated by subtracting the AMTD of the two outer most fixes recorded during the non-breeding season. The non-breeding season is defined as those months of the year other than October and November (ie from December to September inclusive).

In addition, movement patterns in relation to a focal zone were also recorded for each individual (if applicable). A focal zone related to an area where activity was centred during the breeding and non-breeding seasons.

The average distance an individual moved between subsequent fixes was also determined using AMTD data.

### 3.2.3 *Study Area*

The Gunalda and Tiaro study sites (see Chapter 2 for details) were used for this part of the study. Aerial photographs of the two study sites are shown below (Figures 3.1 and 3.2).

## 3.3 Results

### 3.3.1 *Tracking History*

The tracking histories of nine *E. macrurus* ranged from 132-757 days with a range of 3-38 fixes being recorded (Figure 3.1). Flooding conditions often restricted access to the river, explaining the large gaps between some fixes. In addition, there were a number of times when an individual turtle could not be located. These attempts are not included in Figure 3.1 but, like the

flooding events, help account for some of the large time gaps between subsequent fixes. For a given individual, the number of times a turtle could not be located ranged from 1-11 (mean=4.3), however, approximately 80% of the time the targeted turtle was located.

Plate 3.2: Gunalda study site aerial photograph used for plotting fixes

Plate 3.3: Tiaro study site aerial photograph used for plotting fixes

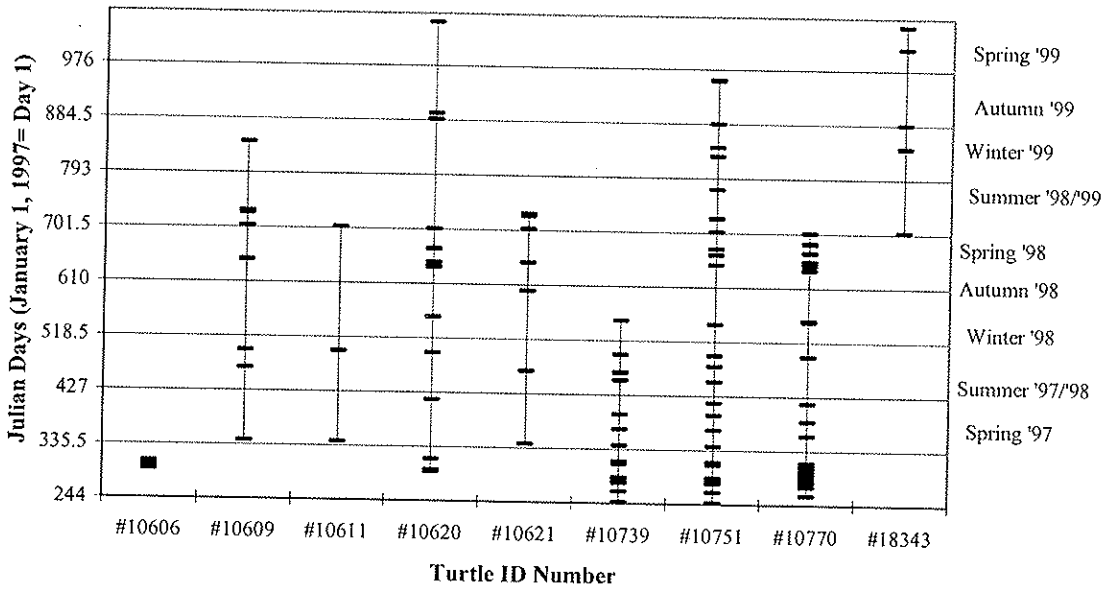



**Figure 3.1: Tracking histories of nine *E. macrurus* in the Mary River from 1997-2000. Cross bars indicate confirmed fixes of turtles. Julian days represent the number of consecutive days turtles were tracked from 1 January 1997.**

### 3.3.2 *Linear Range*

The total linear range of *E. macrurus* was variable and ranged from 100m to 2km (Table 3.1). The linear range during the non-breeding season was considerably smaller ranging from 200-600m (Table 3.1). The range lengths of four female turtles that were tracked during the breeding and non-breeding season were compared to identify any seasonal differences in the length of river it used during these periods. A one-way analysis of variance indicated that there was a significant difference (P=0.03) between total range length and the length of river used only during the non-breeding season. This indicates that some females are moving to a designated nesting area (i.e. traditional nesting bank) during the nesting season.

There was no significant difference between male and female range lengths (P=0.37) during the course of the study. Estimates of total range length ranged from 250m-2km for females and 100m-1.1km for males. During the

non-breeding season only female turtles were tracked. Estimates of range length for females during this period were 200-650m (Table 3.1).

**Table 3.1: Range length estimates of nine *E. macrurus* in the Mary River**

| Turtle ID | | Began tracking | Number of fixes | Mean inter-fix distance | Estimated Range Length in metres | | Notes |
|---|---|---|---|---|---|---|---|
| Female | Male | | | | Total | Non-Breeding | |
| 10606 | | Oct-97 | 10 | 84m | 950 | - | Only tracked in breeding season |
| 10620 | | Oct-97 | 18 | 300m | 2000 | 200 | |
| 10770 | | Sep-97 | 34 | 102m | 600 | 550 | Living and breeding in same pool |
| 10751 | | Oct-97 | 38 | 320m | 1250 | 650 | |
| 10739 | | Sep-97 | 24 | 312m | 1750 | 650 | |
| 18434 | | Dec-98 | 5 | 100m | 250 | - | |
| | 10609 | Dec-97 | 8 | 138m | 1100 | - | |
| | 10611 | Dec-97 | 3 | 333m | 900 | - | |
| | 10621 | Dec-97 | 7 | 41m | 100 | - | |

### 3.3.3 *Movement Rates*

Table 3.1 also shows the movement of individual male and female *E. macrurus* between subsequent tracking fixes. Overall, the average distance moved by both male and female turtles between tracking fixes was 192m. Female turtles moved on average 139m per between recorded fixes and, male turtles moved an average of 137m. A one-way analysis of variance indicated that the movements between tracking fixes for both males and females were not significantly different (P=0.73). Variation in average inter-fix distance was relatively high, reflecting the irregularity in tracking.

### 3.3.4 *Focal Activity and Seasonal Movements*

The movement of four female *E. macrurus* with respect to a known nesting bank (focal zone) is shown in Figure 3.2. The nesting bank was considered to be a focal zone where nesting activity was centred during the nesting period. Figures 3.2a/b represent female turtles from the Tiaro study site.

Figures 3.2c/d represent female turtles from the Gunalda study site. Figures 3.2b/c/d indicate that female turtles move to and from a focal area (ie nesting bank) during the spring and summer months (October to December). These months coincide with the breeding season. In addition, the three listed figures indicate that during the non-breeding season the turtles remain in a small section of river. One female turtle from Tiaro (10620) did not show movement to a nesting bank during spring and summer (Figure 3.2a), which may indicate that this particular turtle was not in breeding condition during the survey period.

The transmitter attached to female 10739 from Gunalda (Figure 3.2c) was suspected to have detached from the turtle. During the latter part of the study this female (or transmitter) was found in the same place for an extended period of time. Extensive underwater surveys were conducted on several occasions to capture the turtle or retrieve the transmitter. All attempts were unsuccessful. Therefore, the movement pattern of this female (Figure 3.2c) does not represent the turtle's true movement during winter and spring 1998.

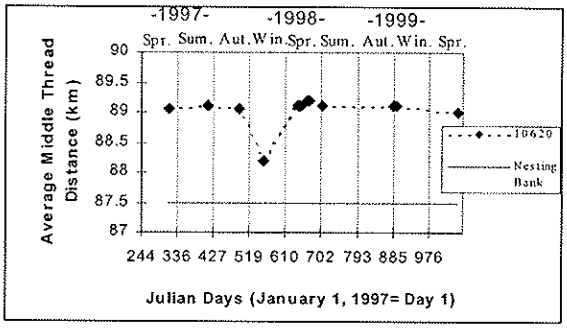
Figure 3.2 also shows that each individual turtle resides in pools that vary in distance from a focal zone (ie nesting bank). Therefore, some turtles move greater distances than other turtles to find nesting banks during the breeding season. The average distance travelled between pools and focal zones for three females in Figure 3.2 include 525m (10751), 475m (10606) and 783m (10739).

Table 3.2 lists the minimum, maximum and mean distances a turtle travelled to a nesting site (focal zone).

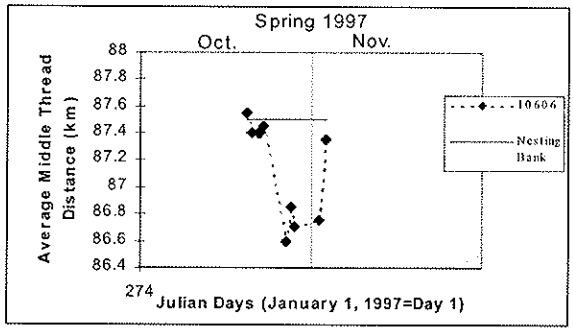
The data indicate male turtles 10609 and 10621 to have only one focal area, however, the data is insufficient in describing any seasonal movement. It is evident that their movements were less extensive than the females shown in Figure 3.2. There was no apparent overlap in the normal home ranges of these male and female turtles.

**Table 3.2: Minimum, maximum and mean distance to a focal zone of 9 *E. macrurus*.**

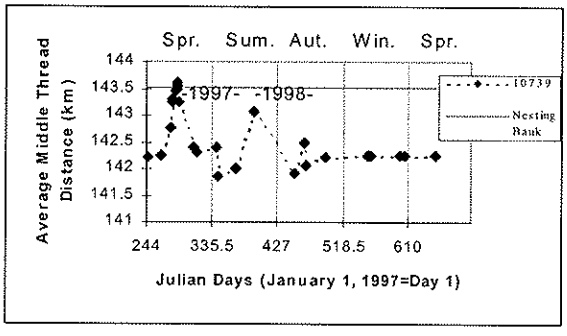
| Turtle ID | | Number of fixes | Capture site (AMTDs) | Mean distance to focal zone (m) | Minimum distance to focal zone (m) | Maximum distance to focal zone (m) |
|---|---|---|---|---|---|---|
| Female | Male | | | | | |
| 10606 | | 10 | 87.5 | 475 | 50 | 900 |
| 10620 | | 18 | 87.5 | 900 | 100 | 1700 |
| 10770 | | 34 | 87.5 | 225 | 50 | 400 |
| 10751 | | 38 | 143 | 525 | 25 | 1025 |
| 10739 | | 24 | 143 | 783 | 25 | 1540 |
| 18434 | | 5 | 141 | 2150 | 2025 | 2275 |
| | 10609 | 8 | 141 | 2075 | 1825 | 2325 |
| | 10611 | 3 | 141 | 2475 | 2025 | 2925 |
| | 10621 | 7 | 141 | 2075 | 2025 | 2125 |



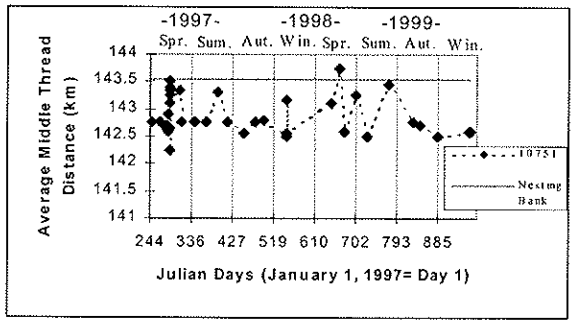

a.




b.




c.




d.

**Figure 3.2: Linear movements of four female *E. macrurus* in relation to a focal zone within Tiaro and Gunalda. 3(A) Tiaro – 10620; 3(B) Tiaro – 10606; 3(C) Gunalda – 10739; 3(D) Gunalda – 10751.**

### 3.3.5 *Upstream Movements*

Flow data was obtained from the Department of Natural Resources water monitoring stations 138001A – Miva (Gunalda) and 18014A – Home Park (Tiaro). Observational data indicate that *E. macrurus'* upstream movements were mirrored by increases in flow velocity. Figures 3.3 and 3.4 are an extract of the tracking and flow data collected in September and October 1997. The flow data (summarised in Mega litres) indicate peaks in discharge that are correlated to rainfall and flooding events. The associated turtle movements are tracking histories of three female turtles (1 Tiaro, 2 Gunalda). Graphically, this data indicates that turtle movements are correlated to increases in the flow intensity (Figures 3.3, 3.4).

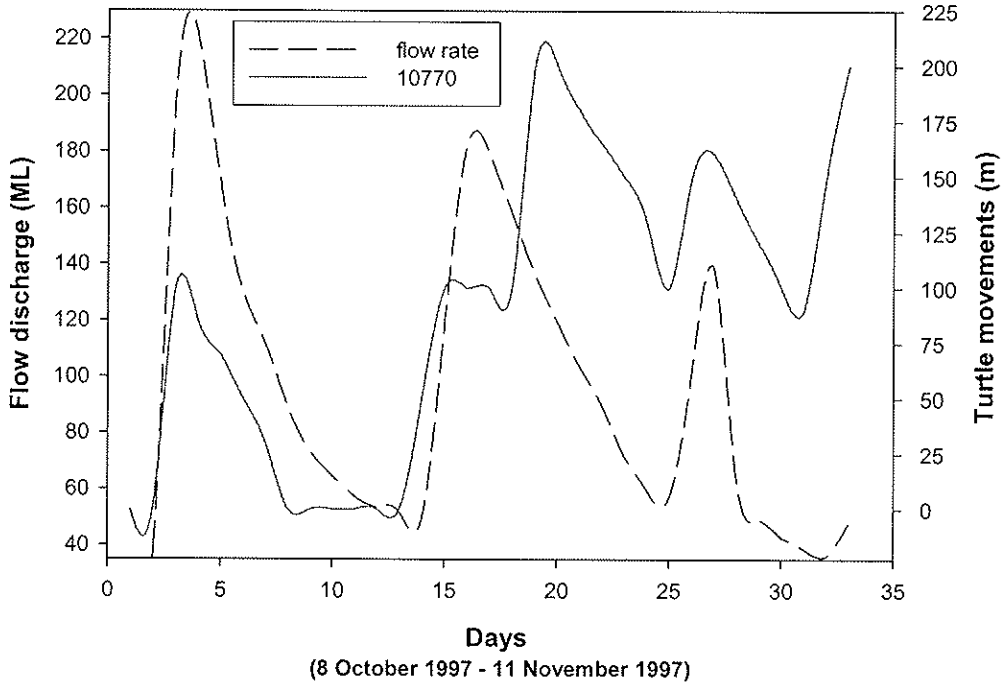



Figure 3.3: Correlation between river flow intensity and turtle movements at Tiaro, 1997.

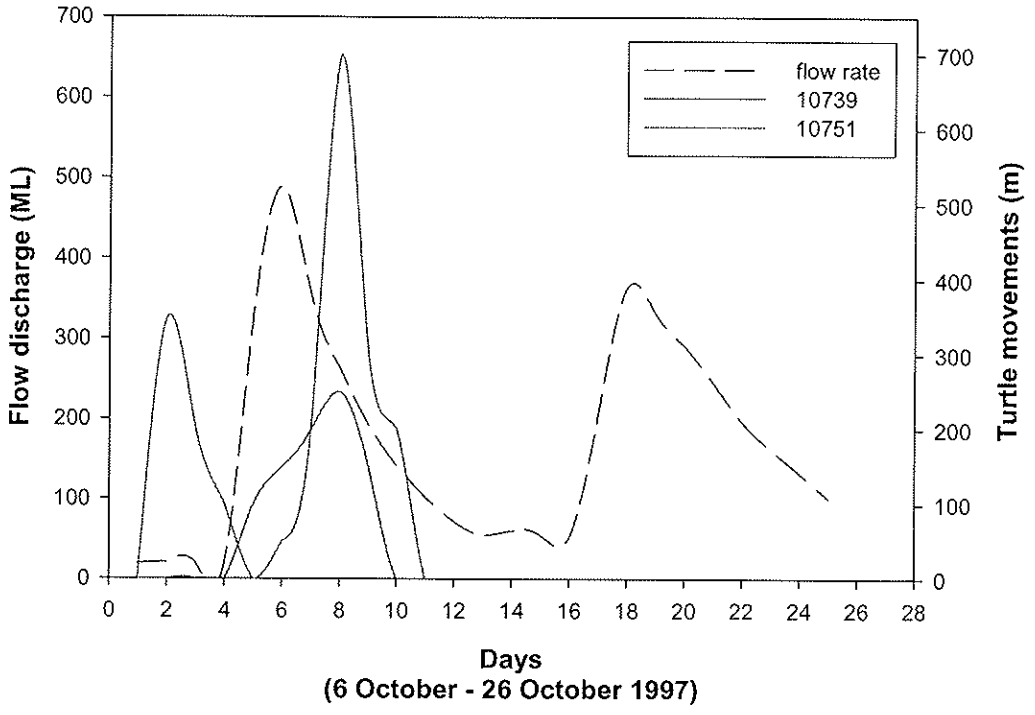



Figure 3.4: Correlation between river flow intensity and turtle movements at Gunalda, 1997.

## 3.4 Discussion

The movement pattern and range length for each individual turtle differed greatly, which was expected. For female turtles, however, there appeared to be a general trend of movement to and from an identified nesting area during the spring and summer months (nesting season). Nesting migrations or movements have been identified in other species of freshwater turtles including *Pseudemys scripta* (Moll and Legler, 1971), *Chelydra serpentina* (Obbard and Brooks, 1980) and possibly *Graptemys geograpica* (Pluto and Bellis, 1988) and are common in sea turtles (Limpus and Reed, 1985; Limpus *et al.*, 1992; Musick and Limpus, 1997). Historic records of *E. macrurus* strongly suggest that female turtles are using and re-using the same sand banks for nesting (Cann, 1998). Because substantial sand banks are uncommon along the river, turtles need to move some distance to find suitable nesting habitat. In this study, the proximity of a sand bank to an individual female's foraging area determined the extent to which they moved

during the breeding season. It was noted that if a sand bank was not available to them within the pool that they lived in then they moved to nearby areas where sand banks could be found. A female's range length was, therefore, determined by the proximity of a suitable nesting area.

In addition, it was found that female turtles confined their movements to a small area during the non-breeding season or winter months. The scant data collected on male turtles suggests that movements are not centred around a focal area throughout the year and that, like the females, they too are using only a small section of river. In this study, male and female turtles had similar range lengths. Studies on *Trachemys scripta* (Schubauer *et al.,* 1990) and *Trionyx spiniferus* (Plummer *et al.,* 1997) suggest, however, that males use larger areas than females. The small sample size used in this study and the lack of information on male turtles may in fact bias the results, thus it cannot be concluded that there is not a significant difference in range length between male and female turtles.

In comparison to other studies on freshwater turtle home ranges, the range length of *E. macrurus* was quite large. Most riverine species, with the exception of *Trionyx muticus* (Plummer and Shirer, 1975), *Rheodytes leukops* (Tucker *et al.,* 1999) and *Elseya* sp. (Flakus *et al.,* 1999), seem to occupy an area of less than 4ha (Table 3.3). It is unknown whether the range length of *E. macrurus* was determined by resource availability, such as food, as has been found in other studies (MacCulluch and Secoy, 1983; Schubauer *et al.,* 1990; Magnusson *et al.,* 1997). Continued research needs to be undertaken to determine if a correlation exists between the availability of food and shelter and the patterns in movement and the extent of range lengths.

Upstream movements of *E. macrurus* closely reflected increases in flow intensity, which were recorded during periods of flooding. Field observations and tracking data show that during high flow events, after upstream movement, *E. macrurus* positioned themselves in backwaters or eddies until

the flow had peaked. In most cases, the subsequent return of females to their former positions was recorded as the flow intensity decreased.

Upstream movements as a response to increases in flow intensity, commonly known as positive rheotaxis, have also been recorded in other aquatic fauna including larvae and juvenile sole (*Solea solea*) and salmonid species (Taylor and Larkin, 1986; Champalbert *et al.,* 1994; Champalbert and Marchand, 1994). In these species, such environmental cues assist in orientation and dispersal. This display of rheotactic behaviour in *E. macrurus* indicates that they are using external cues for orientation and to avoid displacement in the stream.

**Table 3.3: Summary of home range areas of riverine turtles (Plummer *et al.*, 1997). Home ranges for *E. macrurus, R. leukops* and *Elseya* sp. were calculated using 90% Kernel analysis.**

| Species | Mean Width of Stream (m) | Home Range | | Area (ha) | Reference |
|---|---|---|---|---|---|
| | | Length (m) | Length (m) AMTD | | |
| *Chelydra serpentina* | 13 | 426 | | 0.6 | Sharber, 1973 |
| *Trachemys scripta* | 90<br>24 | 287<br>274 | | 3.6<br>0.7 | Moll & Legler, 1971<br>Florence, 1975 |
| *Pseudemys concinna* | 175 | 340 | | 1.4 | Buhlmann & Vaughan, 1991 |
| *Graptemys flavimaculata* | 100 | 1644 | | 3.8 | Jones, 1996 |
| *Mauremys japonica* | 3 | 74 | | 0.02 | Yabe, 1992 |
| *Trionyx muticus* | 175 | 797 | | 11.6 | Plummer & Shirer, 1975 |
| *Trionyx spiniferus* | 5 | 1567 | | 0.8 | Plummer *et al.*, 1997 |
| *Elusor macrurus* | 78 | 602.77 | 916.66 | 5.6 | This study |
| *Rheodytes leukops* | 100 | 1181 | 1050 | 16.9 | Tucker *et al.*, 1999 |
| *Elseya* sp. | 78 | 502 | | 8.25 | Flakus *et al.*,1999 |

With this in mind, changes to flow regimes, water quality and food resources by the construction of weirs or dams present serious implications for many species of aquatic fauna. For animals such as fish and some turtles,

successful reproduction and dispersal rely on their ability to move up or downstream. In particular, for a species like *E. macrurus* that requires a specific habitat for nesting, such hindrances could significantly affect the reproductive success and continued survival of localised populations.

## Chapter 4: Diet

### 4.1 Introduction

During the last 30 years numerous studies have been undertaken to determine the diets of many different freshwater turtles throughout the world (Table 1; Appendix 2). Despite the number of studies that have been undertaken, detailed dietary information is lacking for threatened species with restricted distributions or low or declining populations (Allanson and Georges, 1999). This problem stems from the fact that many of these species have only recently been described (*Elusor macrurus, Rheodytes leukops* and a number of *Elseya* species) (Legler and Cann, 1980; Cann and Legler, 1994; Allanson and Georges, 1999), or are yet to be described (Georges and Adams, 1996).

The studies that have been undertaken identify a number of dietary strategies and feeding patterns amongst the different species or populations of freshwater turtles. The dietary requirements obviously vary among species, though feeding regimes usually fall into two categories; dietary generalists (omnivores), and dietary specialists (herbivores or carnivores) (Zug, 1993).

Dietary generalists such as *Chelodina longicollis* (Parmenter, 1976; Chessman, 1978; Georges *et al.*, 1986), *Emydura australis* (Legler, 1976), *E. krefftii* (Georges, 1982), and *E. macquarii* (Spencer *et al.*, 1998) are opportunistic feeders, taking advantage of readily available food resources. Herbivorous species such as *Elseya dentata* (Legler and Cann, 1980; Kennett, 1994; Kennett and Tory, 1996), and carnivorous species such as *C. expansa* (Parmenter, 1976; Chessman, 1978; Georges *et al.*, 1986), *C. rugosa* (Kennett, 1994; Kennett and Tory, 1996), *E. latisternum* (Legler and Cann, 1980), *Psuedoemydura umbrina* (Burbidge, 1981), and *Rheodytes leukops* (Legler and Cann, 1980) are dietary specialists.

Along with these variations in feeding patterns between species, individual dietary changes occur within species. The feeding habits of juvenile turtles often differ from those of adults. Dietary shifts have been observed in many American emydid turtles including *Chrysemys picta* (Ernst and Barbour, 1972; Moll, 1976), *Graptemys pseudogeographica* (Moll, 1976), *Pseudemys scripta* (Ernst and Barbour, 1972; Moll, 1977; Hart, 1983), *Trionyx* species (Plummer and Farrar, 1981) and *Sternothaerus carinatus* (Berry, 1975; Tinkle, 1958) and generally involve a shift from a carnivorous diet in juveniles to a more herbivorous or omnivorous diet in adults. Such studies have speculated that these dietary changes are associated with the changing energetic demands of an animal as it grows (Parmenter and Avery, 1990; Georges, 1982; Parmenter, 1980; Wood, 1974; Clark and Gibbons, 1969; Marchand, 1942).

Dietary shifts with age have also been noted in a few Australian chelids. *E. krefftii* and *E. macquarii* both shift from a carnivorous to a more omnivorous diet with size (Georges, 1982; Chessman, 1986). *E. dentata* shifts its diet from carnivory in juveniles to herbivory in adults (Kennett, 1994; Kennett and Tory, 1996). Other studies have shown species such as *C. rugosa* (Kennett, 1994) and *C. longicollis* (Parmenter, 1976; Chessman, 1978; Georges *et al.*, 1986) not to undergo such dietary changes during their life. The diets of many other Australian chelids have been described, however, dietary changes with respect to size have generally been overlooked.

Changes to the environment can, therefore, have a direct effect on a species by changing the quality or abundance of its food resources. For species management and conservation, knowledge of an animal's diet can improve the understanding of consequences associated with habitat modification or alteration (Dodd, 1990; Moll, 1997) and also identify the potential for declines.

*E. macrurus* is a species of conservation concern, though little is known about its dietary requirements. Early studies by Cann and Legler (1994) describe *E.*

*macrurus'* diet as predominantly carnivorous consisting mainly of freshwater mussels.

This chapter investigates the dietary habits of *E. macrurus* by describing the components of its diet across a variety of size classes, looking for any dietary shifts that may occur in relation to size and gender. Furthermore, it determines if *E. macrurus* has specialised dietary needs and defines how major changes to their food resources/environment could affect their long-term survival.

## 4.2 Methods

### 4.2.1 *Capture Method*

Turtles were captured, tagged and measured using techniques described in Chapter 2. Where possible, surgical laparoscopy was used to determine or confirm the sex and reproductive status of turtles used in this study. Surgical procedures were the same as those described by Limpus (1984) and Limpus *et al* (2002).

### 4.2.2 *Stomach Flushing*

The stomach contents of 32 *E. macrurus* were examined using a stomach flushing method similar to that described by Legler (1977). The stomach contents of each animal were removed within approximately 3 hours of capture. The animal was held in an inverted position and a steady flow of water was pumped into the stomach of the turtle via a flexible plastic tube connected to a submersible, battery operated bilge pump. Varying sizes of plastic tubing were used to accommodate differences in turtle size. The stomach contents were collected in a sieve and preserved immediately in 70% ethyl alcohol for later analysis under a stereo microscope.

### 4.2.3 *Data Analysis*

Stomach contents were separated into categories comprising plant, animal and unidentified material. Where possible, dietary items were identified to genus or species, and the remaining food items were identified to Order.

Samples obtained may not represent 100% of the turtle's stomach contents, as animals were not dissected after flushing. However, it is presumed they provide a reliable indication of the food types they were feeding on. Sand particles were presumed to be ingested accidentally and were not included in the analysis of food items.

As used in various other diet studies (Kennett, 1994; Georges, 1986, 1982; Chessman, 1986, 1984, 1983), percent occurrence and percent by mass were used to evaluate the proportion of dietary items eaten. Percent occurrence was calculated as the number of turtles that had eaten a particular food item expressed as a percent of the total number of turtles examined. Percent by mass was determined by expressing the wet weight of a particular food type as a percent of the combined wet weight of food items from all turtles.

Percent abundance could not be used as a means for analysing stomach contents as plant material constituted a large proportion of the diet and was not identified as discrete units.

To examine differences in dietary composition with respect to gender, specimens collected from adult turtles were grouped into male and female components. The raw data was classified into four groups: aquatic plants; terrestrial plants; aquatic invertebrates and other material including roots, stems and bark. The data was analysed using a two-way analysis of variance.

To examine differences in dietary composition with respect to increasing body size, specimens were grouped according to juvenile or adult age classes. Turtles

with a straight carapace length less than 20cm were classified as juveniles. Turtles with a straight carapace length greater than 26cm were classified as adults based on results from laparoscopic examination. The age class of one female turtle (22.44cm) was not determined, therefore, she was omitted from this part of the analysis.

## 4.3 **Results**

### 4.3.1 *Dietary Composition*

The food items found in *E. macrurus'* diet and the relative importance of each item are listed in Table 4.1. *E. macrurus* is largely herbivorous as an adult with 79% of the food items consumed (by mass) (Figure 4.1b) being aquatic plant material. The most common aquatic vegetation consumed by *E. macrurus* included filamentous algae, *Vallisneria* sp., and other plant material such as root, stems, bark, and unidentified material (Table 4.1).

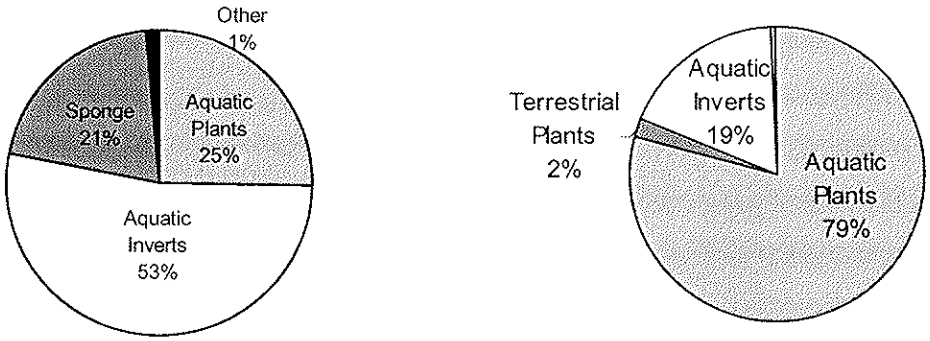
### 4.3.2 *Adult vs Juvenile*

Comparisons between adult and juvenile food types consumed by *E. macrurus* revealed a striking shift in diet with age (Figure 4.1). Juvenile turtles fed predominantly on aquatic invertebrates (53%) and sponge (21%) with only a small proportion of plant material being consumed (25%) (Figure 4.1a). Adult turtles relied upon an herbivorous diet (79% aquatic plants; 2% terrestrial plants) (Figure 4.1b) and only 19% of animal matter was consumed. Despite the presence of aquatic insect larvae in the adult diet (19%) (Figure 4.1b), the occurrence of such items was insignificant and appeared to be incidentally ingested rather that selectively consumed.

Table 4.1 shows the relative importance of food items eaten by *E. macrurus.* 76.97% of turtles had aquatic plant material in their diet, 20.61% ate aquatic invertebrates and the remaining 2.42% was made up of terrestrial plants and other unidentified material. The percent occurrence of each of these food types can be interpreted as the percent of turtles that ate a particular food item,

therefore, the percentage figures are non additive. In addition to the food items listed in Table 4.1, fragments of the freshwater mussel shell, *Velesuio ambiguus* (Walker, 1981), and seeds from the plant *Waterhousia florobunda* (Pickersgill and Wedlock, pers. comm.) were found in the faecal material of one adult female and male respectively. These items were not included in the analysis, but can be identified as components of *E. macrurus'* diet.

A two-way analysis of variance indicated that there was a statistically significant difference between the adult and juvenile diet (P=<0.001) of *E. macrurus.* There was a significant difference in the amount of aquatic invertebrates (P=<0.001), aquatic plant material (P=<0.001), and terrestrial plant material (P=<0.017) consumed by adult and juvenile turtles. There was no significant difference in the consumption of roots, stems and bark between the two age groups (P=0.594).




a b

Figure 4.1: (a) dietary composition (% by mass) of juvenile *E. macrurus*; (b) dietary composition (% by mass) by adult *E. macrurus*.

Figure 4.2 illustrates the differences in dietary composition between adult male and female *E. macrurus.* The proportion of plant material in the female diet (94%) was slightly greater than the proportion of plant material found in the male diet (72% aquatic plants; 3% terrestrial plants), though overall there was no significance between the two groups (P=0.542).

Table 4.1: The relative importance of food items consumed by juvenile and adult *E. macrurus* from the Mary River, SE Queensland.

| Food Type | Occurrence | % Occurrence | % By mass |
|---|---|---|---|
| Aquatic plant material: | **71** | | **76.97%** |
| *Cabomba caroliniana* (Fanwart) | 1 | 3.13 | 0.07 |
| *Elodea canadensis* (Elodea) | 7 | 21.88 | 2.02 |
| filamentous algae | 17 | 53.13 | 42.61 |
| *Hydrilla verticulata* | 1 | 3.13 | 0.04 |
| *Myriophyllum* sp. | 7 | 21.88 | 10.64 |
| *Nitella* sp. (stoneworts) | 1 | 3.13 | 0.06 |
| *Vallisneria* sp. | 16 | 50.00 | 17.30 |
| other plant material (roots, bark) | 17 | 53.13 | 4.11 |
| unidentified plant material | 4 | 12.50 | 0.12 |
| Terrestrial plant material (buds/fruits/seeds) | **2** | | **2%** |
| *Eucalyptus teritecornis* buds | 1 | 3.13 | 0.43 |
| *Castanospermum australe* seeds | 1 | 3.13 | 1.57 |
| Aquatic invertebrates: | **91** | | **20.61%** |
| Coleoptera (beetle larvae) (L) | 5 | 15.63 | 0.50 |
| Diptera (two-winged flies) (L) | 15 | 46.88 | 1.49 |
| Ephemeroptera (mayflies) (L) | 6 | 18.75 | 0.13 |
| Lepidoptera (moth larvae) (L) | 12 | 37.50 | 3.42 |
| Mecoptera (scorpion flies) (L) | 2 | 6.25 | 0.02 |
| Mollusca (gastropoda) (A) | 2 | 6.25 | 0.03 |
| Neuroptera (lacewings) (L) | 2 | 6.25 | 0.01 |
| Odonata (dragonflies) (L/N) | 4 | 12.50 | 0.23 |
| Porifera (freshwater sponge) | 13 | 40.63 | 13.58 |
| Trichoptera - Heliocopsychidae (L) | 19 | 59.38 | 1.05 |
| - Hydropschidae (L) | | | |
| unidentified larvae | 11 | 34.38 | 0.15 |
| Other material: | **9** | | **0.42%** |
| unidentified egg clusters | 5 | 15.63 | 0.06 |
| unidentified material | 4 | 12.50 | 0.36 |
| RAW TOTAL | | 32 turtles | 202.19g |

L=larvae; N=nymph; A=adult

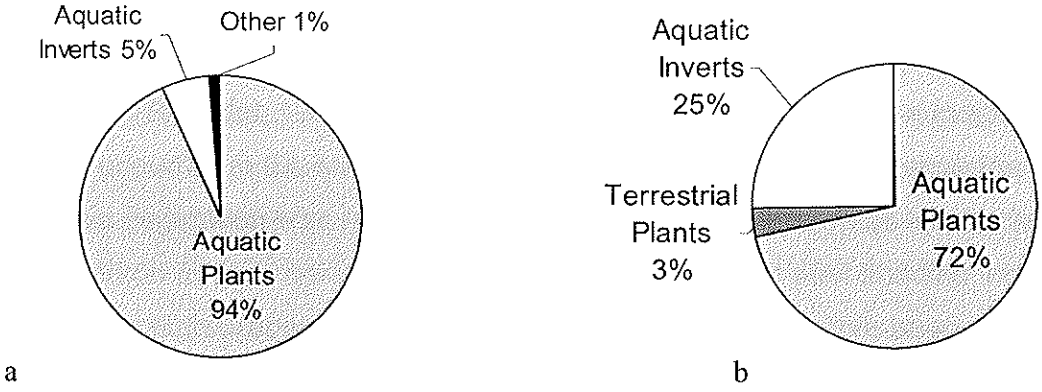



Figure 4.2: (a) dietary composition (% by mass) of adult female *E. macrurus*; (b) dietary composition (% by mass) of adult male *E. macrurus*.

## 4.4 Discussion

Apart from its carnivorous tendencies as a juvenile, *E. macrurus* feeds predominantly on an herbivorous diet as an adult, but does show signs of omnivory. Taking into consideration the local variations in habitat, this study found that adult *E. macrurus* fed predominantly on filamentous algae, *Vallisneria* sp., *Elodea canadensis* and other plant material such as roots and stems from aquatic plants and bark from submerged terrestrial plants. Unfortunately, the limited number of samples meant that seasonal changes in diet could not be observed in this study. Earlier observations by Cann and Legler (1994) suggested that *E. macrurus* was a mussel-feeder. Their analysis of diet was based on the stomach contents of only four adult specimens, hardly a reliable interpretation of the species dietary regime.

Within the Mary River, the availability of these foods change due to seasonal variations in weather patterns and also change as a result of altering land use practises. Currently, in 75% of the Mary River catchment, the aquatic vegetation is in a very poor state (Johnson, 1997). In such a fluctuating environment, the loss of major dietary components can and does have ill effects on species like *E.*

*macrurus* because of its herbivorous tendencies. Nutritional disadvantages can affect the reproductive output of the animal and, in extreme cases, jeopardise reproduction for the year (Kuchling, 1998). It can also slow growth and offset maturity (Bjorndal, 1997). Earlier in this report, it was noted that a major flooding event occurred in the Mary River during the study period. Major scouring of aquatic vegetation was recorded post flooding. It is unknown as to what affect this had on *E. macrurus* as no food samples were taken post flooding, however, there is a high probability that breeding and growth would have been compromised due to the loss of their major source of food.

In the true sense of the word 'specialist', *E. macrurus* is not a specialist feeder. It does not rely on one particular aquatic plant for its nutrition rather, it feeds on all aquatic plants within its habitat. In some studies of diet choice and optimal foraging models, the question of why some species are dietary specialists is often raised (Pennings, 1990; Holbrook and Schmitt, 1992). The diets of specialist feeders consist of items that are specifically chosen over more readily available resources. Some species such as the long-neck chelids, *C. expansa* and *C. longicollis* (Legler and Georges, 1993), and an American species, *Podocnemis unifilis* (Belkin and Gans, 1968), have even adopted specialised feeding strategies to accommodate their specialised dietary requirements. *C. expansa* are sit and wait predators that ambush highly motile prey (Chessman, 1983). *C. longicollis* (Legler , 1976) and *P. unifilis* (Belkin and Gans, 1968) have been noted to display neustophagia, a form of surface feeding behaviour that has been observed in very few species.

Apart from these adaptations, it has been shown that food items in specialist diets are less likely to be nutritionally balanced, are more likely to have more patchy distribution and lower abundance, and are more likely to exhibit wide fluctuations in nutrient content, distribution and abundance over time (Real, 1980). So why aren't all freshwater turtles omnivorous in order to take advantage of the wider range of dietary items available and prosper from a more nutritionally

balanced diet? The answer to such a question would identify the potential nutritional effects of an animal, if the availability of their food resources changed from major habitat modifications.

For a species like *E. macrurus* with preferred dietary needs (as opposed to species that have broader dietary needs), the nutritional effects of a changing environment are far greater (Kennett and Smith, 1996). A specialised or preferred diet, together with the potential for loss of major dietary components can, therefore, impose serious conservation implications for freshwater turtles such as *E. macrurus*.

Along with the major dietary components of the adult diet of *E. macrurus*, a small amount of aquatic invertebrate material was recorded in most samples (19%). This animal component of their diet was always associated with large quantities of vegetation and it is suspected that such food items were ingested accidentally along with aquatic plant material rather than being chosen selectively.

Indirectly, the incidental occurrence of such a mixed diet can be advantageous nutritionally and in the digestive capabilities of an animal. Bjorndal (1991) found that the associated effects of a mixed diet in freshwater turtles were far more beneficial than a strict herbivorous or carnivorous diet in terms of digestive efficiency. Therefore, the incidental ingestion of animal material by *E. macrurus* may indirectly benefit its digestive capabilities, more than if it were feeding strictly on an herbivorous diet.

As a juvenile, *E. macrurus* feed predominantly on aquatic insect larvae such as Diptera, Trichoptera, Lepidoptera and Coleoptera, as well as freshwater sponges, Porifera (see Figure 4.1). Similar to juveniles of other species, *E. macrurus* presumably rely on a carnivorous diet in order to meet energy requirements and obtain essential nutrients such as protein and calcium for rapid growth

(Parmenter and Avery, 1990; Wood 1974) and shell hardening (Clark and Gibbons, 1969).

In the past, differences in dietary composition of freshwater turtles have been explained in terms of energetic efficiency, such as increasing body size and the onset of sexual maturity (Georges, 1982). Marchand (1942) and Parmenter (1980) have both suggested that such a shift in diet can be attributed to the inability of large turtles to satisfy their metabolic demands by pursuing small active prey, thus tending toward a more herbivorous diet. In this study, such changes were obvious and a significant shift from a predominantly carnivorous diet in juveniles to one that was more herbivorous in adults was apparent.

With the knowledge that most freshwater turtles forage at multiple trophic levels, it may be possible to use a species like *E. macrurus* as a useful model in monitoring change at specific ecological niches in many aquatic environments (Tucker *et al.*, 1999). By assessing the abundance and availability of food resources throughout the river, generally the population density of turtles could be estimated. That is, a high availability of food resources will usually coincide with a higher turtle density than areas where there is limited food (Tucker *et al.*, 1999).

The limited number of turtles used in this study meant that intermediate size classes were not fully represented and that the size at which diet shifted could not be defined precisely. Additional studies are required to determine the timing of such shifts and also to investigate the seasonal changes in diet that may occur with fluctuations in food availability.

## Chapter 5: Reproduction

### 5.1 Introduction

Of the many adaptive features incorporated into the life history of a species, the pattern of reproduction is paramount in respect to ultimate survival (Harless and Morlock, 1979). In Australia, a number of temperate-zone species such as *Emydura krefftii* (Georges, 1988), *E. macquarii* (Goode and Russell, 1968; Chessman, 1978), *Elseya dentata* (Kennett, 1994), *Chelodina expansa* (Goode and Russell, 1968; Goode, 1965, 1966, 1967), *C. longicollis* (Goode, 1965, 1966, 1967; Vestjens, 1969; Parmenter, 1976; Chessman, 1978, Legler and Cann, 1980), *C. oblonga* (Kuchling, 1988) *and Pseudemydura umbrina* (Burbidge, 1981; Kuchling, 1993), have been subjected to detailed studies on reproduction. In addition, a study by Legler (1985) discussed the reproductive patterns in a number of taxa of Australian chelid turtles. Despite these studies, knowledge on the reproductive strategies of many species in the family Chelidae still remains poorly known (Georges, 1983).

*E. macrurus* falls into this category, and data collected on reproduction (among other aspects of its ecology) is inadequate for guiding future management. Some reproductive aspects have been described for this species, though mainly from observational data recorded during the period of commercial trade, which is documented in the type description (Cann and Legler, 1994). Only one study examining temperature sex determination has been undertaken (Georges and McInnes, 1998). Observations on nesting habits of *E. macrurus* suggest they are unique (J.Greenhalgh pers.comm.) and warrant further study.

This study describes the nesting patterns and reproductive cycles of *E. macrurus* through intense sampling and identifies and discusses what effects commercial harvest and depredation has had on the population.

Before discussing the reproductive cycles and patterns of *E. macrurus,* it is first necessary to describe and define relevant terminology of chelonian reproductive biology for a better understanding.

In most reptiles, reproduction occurs seasonally and the mechanisms used to regulate these events are synchronized with seasonally occurring external cues (Whittier, 1994). In most freshwater turtles, the reproductive cycle is dependent on seasonal variations in weather patterns (Moll, 1979). Examples of this have been shown in studies on the reproductive success of turtles affected by drought. *Pseudemydura umbrina* and *Emydura krefftii* are two species in which egg production is significantly reduced in times of drought (Burbidge, 1981; Limpus, unpublished data). On a broad scale, however, reproductive synchrony of male and female gonadal cycles ensure that breeding, nesting and hatching occurs (Moll, 1979; Georges, 1993) when conditions are favourable for hatchling development and survival (Harless and Morlock, 1979; Heatwole and Taylor, 1987).

In temperate-zone species, the optimal time for breeding is during the warmer months of the year, when food resources are abundant and allow for hatchling growth before the following winter (Harless and Morlock, 1979). Generally the reproductive period for species in the temperate-zone is relatively short and is often followed by a period of complete sexual inactivity (Licht, 1972).

The female reproductive cycle consists generally of four basic phases; vitellogenesis, ovulation, nesting and quiescence. Vitellogenesis is the process of the accumulation of yolk within ovarian follicles (Moll, 1979). In most birds, crocodiles and squamates, individual follicles accumulate yolk and grow to a mature size in times spans of days or weeks. The growth of individual follicles of turtles typically takes many months, often two-thirds of a year (Kuchling, 1998).

In adult females, the ovary often contains previtellogenic and vitellogenic follicles, corpora lutea, corpora albucantia and atretic follicles. Previtellogenic follicles appear as small white spots or discs on the ovaries (Kuchling, 1998). These are the follicles that will be used in future breeding seasons. Vitellogenic follicles are bright yellow spheres with clear red blood vessels (Kuchling, 1998) and are generally those follicles that will be used to produce eggs in the upcoming breeding season. Corpora lutea are white ovarian scars formed after the follicle has erupted from the ovary during vitellogenesis (Kuchling, 1998). Atretic follicles are those follicles that were not used in egg production and are subsequently being reabsorbed back into the blood stream. They are dark yellow to orange in colour with diffuse blood vessels, and often are not perfectly spherical (Kuchling, 1998).

When follicles reach a maximum size (generally 14-15mm in diameter for most freshwater turtles), the ovum is released from the ovary into the body cavity by the rupture of the follicle wall at its apex (Guraya, 1989; Kuchling, 1998). The presence of ovarian scars (corpora lutea) is a good indication that the process of ovulation has taken place. After ovulation, the ova are quickly transported from the body cavity into the oviducts (Kuchling, 1998) where fertilisation, albumin and shell deposition occur. Fertilisation presumably occurs immediately before the albumin is secreted around the yolk prior to shelling (Kuchling, 1998).

The oviducal period is variable among species, individuals and even clutches and often depends on favourable nesting conditions (Kuchling, 1998). *Chrysemys picta, Clemmys insculpta, Terrapene ornate* and *Sternotherus odoratus* have been known to retain their eggs for approximately 3-8 weeks before nesting (Cagel and Tihen, 1948). *Trachemys scripta* and *Kinosternon subrubrum* have the ability to retain their eggs for a maximum of 39 days and 50 days respectively (Kuchling, 1998). *P. umbrina* have been known to retain their eggs up to 49 days (Kuchling and Bradshaw, 1992).

If nesting conditions are suitable, then nesting or oviposition occurs. Oviposition in most chelonians involves emerging from the water and using the terrestrial environment. Generally, this process involves a well-defined sequence of behaviours that favours incubation and possibly hatchling survivorship. Factors such as soil type, exposure to sunlight, distance from water and the presence of predators all appear to influence the selection of a nesting site (Harless and Morlock, 1979).

At the completion of the breeding season it is common in most chelonian species for the ovaries to regress and become inactive. During this period of reproductive quiescence, the hormones used to stimulate follicular development in vitellogenesis are down-regulated (Johnson, 1996). Follicular atresia becomes apparent in those preovulatory follicles that were not used for egg production.

The male reproductive cycle, as described by Moll (1979), is relatively complex consisting of five basic phases; germinal quiescence, gonial proliferation, spermatocytogenesis, spermiogenesis and spermiation. For the purpose of this study, it is only necessary to briefly describe the broad functions of spermatogenesis and germinal quiescence.

In male turtles, sexual maturity is reached with the first production of spermatozoa (Kuchling, 1998). The spermatogenic cycle begins as the seminiferous tubules enlarge to maximum diameter so accumulation of feather-like branches of sperm can be attained (Moll, 1979; Legler, 1960; Kuchling, 1998). The testes are enlarged during sperm production and become bright yellow in colour. The epididymis becomes pendulous and the seminiferous tubules become distended and are white in colour.

Similar to the female reproductive cycle, a period of quiescence is a feature of the male reproductive cycle. During the quiescent period testicular activity

ceases and both the testis and the seminiferous tubules decrease to minimum diameter becoming inactive (Legler, 1960; Kuchling, 1998).

## 5.2 Methods

During the nesting season (October – December, 1997 – 1999) known nesting sites were monitored for turtle nesting activity from dusk until dawn to determine the size of the nesting population and to compare current population levels with past statistics. The banks were checked at hourly intervals for the presence of nesting females. Nesting females were tagged, measured and weighed after oviposition in accordance with Queensland Turtle Research methodologies (see Chapter 2). If turtles were missed, nests were located by examining sand disturbances from turtle tracks. Clutch size was recorded for all nests and eggs were removed for weighing and measuring. Eggs were measured carefully without rotation. The length and width of each egg was measured using 300mm Vernier calipers and weighed on Wedderburn electronic scales (5000g x 1g). Dimensions of nests were recorded including nest depth to top and bottom of eggs and straight-line distance from water. The location of each nest was measured to existing star pickets for future reference. Predation by goannas and/or foxes was recorded from either direct observation or by track identification.

In the 1997 nesting season, 5 nests were protected with flat mesh cages (1$m^2$ at 50x50mm mesh size) from predators while 4 nests were left unprotected. The mesh cages were placed over the nest and were held in place by four tent pegs. On one of the protected nests, a cage was placed over the nest site to capture any hatchlings that emerged so that hatchling morphometrics could be recorded. This cage was made from the same material that the flat mesh cages were made from, however, it was modified using shade cloth so hatchlings were unable to escape through the holes and to prevent desiccation.

Sand temperatures were recorded (at a depth of 20cm) at hourly intervals in December 1997 using a Tiny Tag temperature data logger manufactured by Gemini. Sand temperatures were recorded to obtain baseline information for studies on artificial incubation. Water temperatures during 1997 and 1998 were also recorded every two hours at two locations (Tiaro and Gunalda) using Vemco Minilog temperature data loggers. Water temperatures were recorded to determine if any relationship existed between ambient water temperatures and turtle activity.

In the 1998 nesting season, 4 clutches of eggs were artificially incubated in Qualtex Solidstat incubators to collect information on hatchling morphometrics and to increase hatchling recruitment. Using average daily sand temperatures recorded in December 1997 as a guide to incubating *E. macrurus* eggs, incubators were set at 29°C and 31°C respectively. Eggs were transported by vehicle and were cooled to approximately 3-5°C in a car fridge to slow development during transportation. Eggs were weighed and measured in the lab before incubation. The temperature of the incubators was recorded daily and adjusted if necessary to keep the temperature constant throughout the incubation period. Eggs were incubated in sterilized sand collected from the nesting banks at Tiaro. To prevent the eggs dehydrating during incubation, distilled water was used occasionally to moisten the sand.

Hatchling weight and length were recorded immediately after hatching. All hatchlings were notched on marginal scutes using a leather punch (see Chapter 2 for details on notching) before being released into the Mary River.

Data collected on sex and maturity from laparoscopic examination, was made available by the Queensland Turtle Research program run by the Queensland Parks and Wildlife Service. The data presented here obviously has its limitations, as laparoscopy is intended as a qualitative tool for examining the reproductive status of turtles rather than providing quantitative information on

gonads. In this study, 45 *E. macrurus* were examined throughout the study (20 adult female; 15 adult male; 9 immature; 1 unknown). Procedures for laparoscopic examinations are described by Limpus (1984) and Limpus *et al.* (2002). All laparoscopic examinations were performed by Dr C. Limpus.

## 5.3 Results

### 5.3.1 *Female Reproductive Cycle*

Table 5.1 summaries the reproductive cycle of 20 female *E. macrurus* from results obtained from laparoscopic examination. From September to November vitellogenic follicles, at varying stages of development (4-5mm to 15mm), were present in individual ovaries. The presence of only a small number of mature sized, pre-ovulatory follicles in any female indicated that only one clutch of eggs would be laid in a breeding season. The associated enlarging follicles (<15mm) were too small for ovulation in the current breeding season and appeared to be follicles for future nesting events rather than multiple clutches. All females examined during July and September were preparing for the coming breeding season. Oviducal eggs were present only during the nesting season in October and November. One size of corpora lutea (ovarian scars) in all females sampled during January indicated that ovulation had occurred and one clutch of eggs had been laid. The combined presence of vitellogenic follicles less than mature size (<15mm) and only one size of corpora lutea may suggest that the females examined were not preparing to lay multiple clutches of eggs within that particular breeding season. Mature follicles that remained in the ovary after ovulation (during January) became atretic. There was no evidence of a quiescent period for female *E. macrurus.* Size of breeding females ranged from 27.22cm to 34.78cm.

In addition to the adult females, four immature females were examined internally. All had a white straight oviduct indicating their immaturity.

### 5.3.2 *Male Reproductive Cycle*

Table 5.2 summaries the reproductive cycle of 15 male *E. macrurus.* The data suggest that spermatogenesis occurs from around May and continues through to September each year. Gaps exist between January and April, and during November, therefore, it is unknown when these cycles change over. Throughout December, both testes and seminiferous tubules were at their smallest, consistent with reduced sperm production or storage. Due to the lack of data, it is unknown how long the quiescent period lasts and at what time of year the reproductive status changes. Size of breeding males ranged from 29.04cm to 42.02cm.

Table 5.1: Reproductive cycle of female *E. macrurus* determined through laparoscopic examination.

| Month | n | Vitellogenic follicles | Oviducal eggs | Atretic follicles | Corpora lutea |
|---|---|---|---|---|---|
| January | 2 | 2 | - | - | - |
| February | 0 | | | | |
| March | 0 | | | | |
| April | 0 | | | | |
| May | 0 | | | | |
| June | 0 | | | | |
| July | 6 | 6 | - | - | - |
| August | 5 | 5 | - | - | - |
| September | 3 | 3 | - | - | - |
| October | 4* | - | 4 | - | - |
| November | 1 | 1 | - | - | - |
| December | 3** | 2 | - | 3 | 3 |

* Turtles found on nesting bank – not examined internally.

** Only three turtles examined; 2 with small vitellogenic follicles, large atretic follicles and corpora lutea in ovaries and 1 with only large atretic follicles and corpora lutea. This explains why columns do not add up.

Table 5.2: Reproductive cycle of male *E. macrurus* determined through laparoscopic examination.

| Month | n | Spermatogenic | Quiescent |
|---|---|---|---|
| January | 0 | | |
| February | 0 | | |
| March | 0 | | |
| April | 0 | | |
| May | 3 | 3 | |
| June | 0 | | |
| July | 3 | 3 | |
| August | 3 | 3 | |
| September | 2 | 2 | |
| October | 0 | | |
| November | 0 | | |
| December | 5 | 1 | 4 |

### 5.3.3 *Nesting*

Rainfall and nesting data show that nesting in *E. macrurus* was often associated with rainfall events (Figures 5.1, 5.2). Locally, it was observed that rainfall hardened the sand banks and allowed for more successful nest construction. In drier periods, soft sand prohibited the construction of a nest, hence the high number of tracks (119 tracks) compared to nests (26 nests) (Table 5.3). Over the three nesting seasons monitored, all records of nests were associated with nocturnal nesting activity. No evidence of diurnal nesting activity was found.

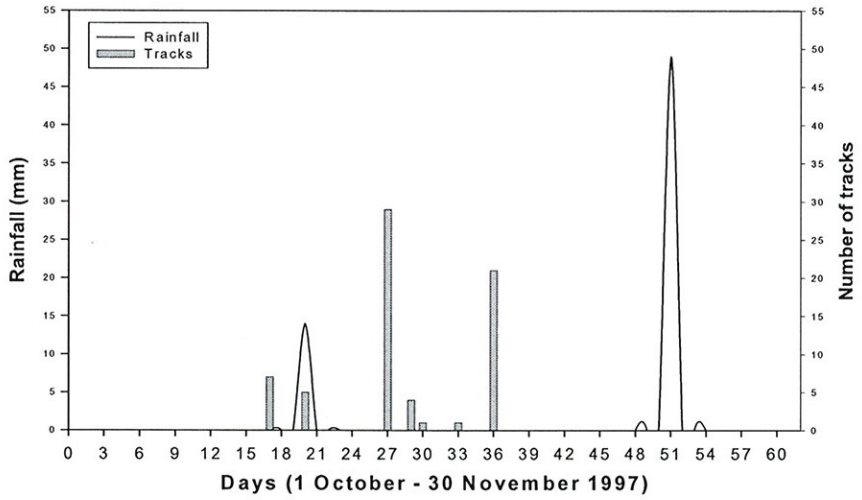
In the current study fewer than ten individuals were recorded nesting at the same site (Table 5.3). Compared to nesting data collected in the 1960s and 1970s (up to 2000 eggs at Tiaro), the nesting population at Tiaro has significantly declined by approximately 95% (P=4.25E-05). The egg data collected in 1997-1999 represent a nesting population of dozens rather than hundreds.

Surprisingly, a one-way analysis of variance indicated that the nesting numbers in wet and dry years were significantly different (P=0.03), however, this is contrary to the belief that nesting is triggered by the onset of rain because the results show that more eggs were laid in the dry year.

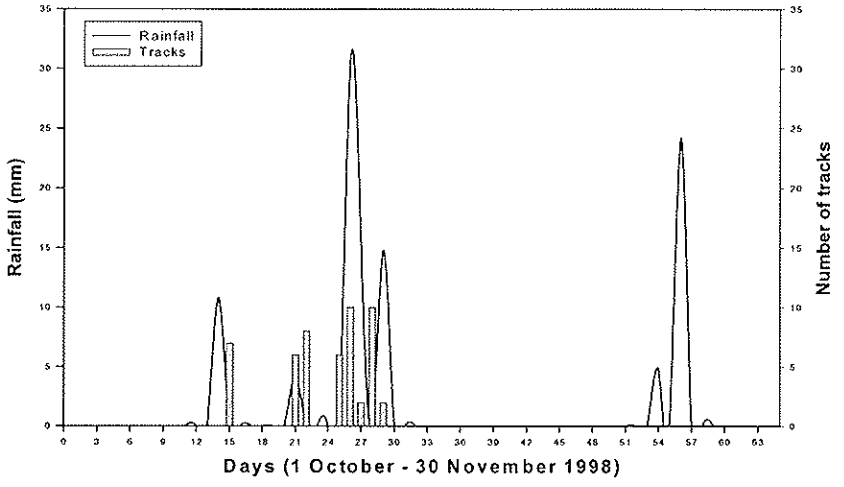
Table 5.3: Summary of nesting data collected over three consecutive seasons at Tiaro. Dry and wet years reflect rainfall during the nesting season (October-December).

| Season | Number of tracks | Number of nests | Number of eggs |
|---|---|---|---|
| 1997; dry | 54 | 8 | 112 |
| 1998; wet | 29 | 9 | 99 |
| 1999; dry | 36 | 9 | 100 |
| **TOTAL** | **119** | **26** | **311** |

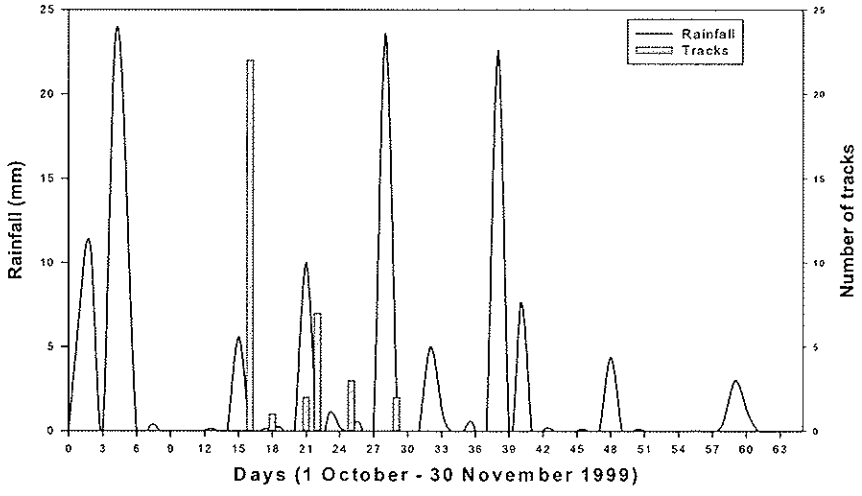
In 1997, two females were captured after oviposition and radio transmitters were attached to the carapace for tracking studies. Sampling effort for nesting studies are listed in Appendix 3 along with total sampling and catch effort for the data collection phase.




a.

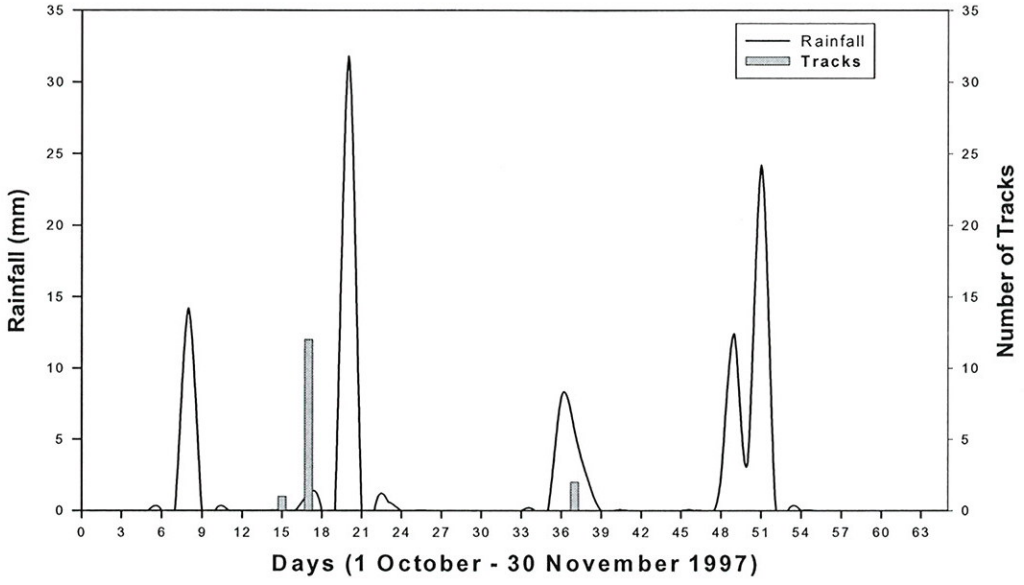



b.

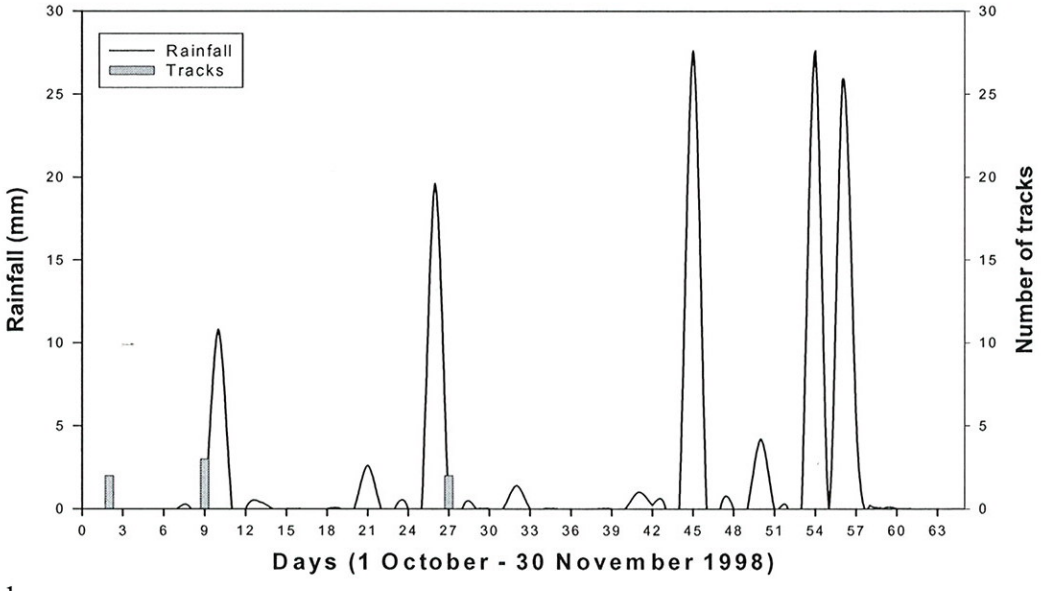



c.

Figure 5.1: Nesting and rainfall data through time for Tiaro nesting site (a) 1997 data; (b) 1998 data (banks flooded during November 1998); (c) 1999 data (banks flooded during November due to onset of 100 year flood).




a.




b.

Figure 5.2: Nesting and rainfall data through time for Gunalda nesting site (a) 1997 data; (b) 1998 data (banks flooded during November 1998); 1999 banks flooded due to 100 year flood.

### 5.3.4 *Nesting areas*

*E. macrurus* nested on sparsely vegetated sand banks that were often steep sided. Historically, these nesting areas have been identified as traditional sites. As discussed in Chapter 3, individual turtles moved to and from these areas if a suitable bank was not in close proximity to the pool that they lived in. Nest site selection seemed random on a sand bank with nests ranging from 1.95m to 45m (mean = 10.8m ± 11.53m) from the water (straight line distance), either on steep or shallow slopes, protected or unprotected from vegetation. Most nests were laid 2.32m ± 1.28m above the level of water. Nest depth varied among individuals ranging between 17-23cm deep (n=18) (to bottom of nest) and having an average depth of 19.94cm ± 1.59cm. The depth of eggs from the surface ranged from 5-19cm. Average depth below the surface was 11.73cm ± 3.73cm (n=15). Due to lack of data on individual turtles these measurement cannot be correlated to body size.

The presence of cattle on nesting banks was also observed throughout the study period. Cattle trampling over nests and nest sites was common on all nesting banks monitored, however, no eggs were damaged from this.

### 5.3.5 *Eggs/Incubation*

*E. macrurus* has hard shelled (calcareous) eggs that are elongate in shape and relatively uniform in size. Average egg sizes were 3.50cm x 2.26cm in length and 11.6g in weight (Table 5.4). An analysis of variance indicated that individual egg mass varied significantly between some clutches ($p$=3.68E-11, F=7.771, df=12). Average clutch size was 12.2±3.66 eggs (n= 20). Clutch size ranged from 4-17 eggs (Table 5.4).

Table 5.4: Egg morphometrics of *E. macrurus* from Tiaro.

| Parameter | Mean ± SD | Range | N |
|---|---|---|---|
| Egg length (cm) | 3.50±0.14 | 3.09-3.82 | 244 |
| Egg width (cm) | 2.26±0.08 | 1.96-2.43 | 244 |
| Egg weight (g) | 11.6±1.20 | 8-14 | 165 |
| Clutch size | 12.2±3.66 | 4-17 | 20 |

The limited availability of equipment meant that sand temperatures could not be recorded for all nests across years. General sand temperatures were, therefore, recorded only during the 1997 nesting season so that incubation times could be correlated to sand temperatures. Sand temperatures (at 20cm) during December 1997 at Tiaro ranged from 25.5°C to 40.2°C and averaged at 31.07°C. Due to 100% loss of all eggs in 1997 (see section 5.3.7 on predation) the duration of natural incubation was not recorded.

Four clutches (43 eggs) were artificially incubated in 1998. All eggs were successfully transported approximately 160km at 3-5°C from the nesting bank to the lab. Eggs recommenced development when placed in the incubators. One clutch of eggs (16 eggs) desiccated from lack of hydration during incubation. There was 95% hatching success of the remaining clutches. The duration of artificial incubation at 29°C and 31°C were 46 and 47 days respectively (approximately 8 weeks).

### 5.3.6 *Hatchlings*

Hatchling morphometrics were recorded immediately after hatching. Mean size of hatchlings (straight carapace length) was 3.30cm ± 0.05 (Table 5.5). Mean weight was 6.8g ± 0.0004 (Table 5.5).

Table 5.5: *E. macrurus* hatchling morphometrics.

| Parameter | N | Mean ± SD | Range |
|---|---|---|---|
| Hatchling length (SCL) (cm) | 19 | 3.30 ± 0.05 | 3.21-3.35 |
| Hatchling weight (g) | 19 | 6.8 ± 0.0004 | 6.1-7.5 |

### 5.3.7 *Predation*

Figure 5.3 represents the level of predation on *E. macrurus* nests in two consecutive breeding years at Tiaro. In 1997, 25% of the nests recorded were destroyed by foxes (17%) or goanna's (8%). It is suspected that the remaining 75% of nests were collected illegally. On inspection of these nests, there were no signs of nest predation or empty eggshells to indicate that hatchling emergence had occurred. This data indicates that there was zero recruitment into the population during the 1997 breeding season. 1998 data show that 55% of nests were destroyed (22% goanna; 33% unknown source) while 45% of the nests were artificially incubated with the subsequent release of hatchlings. In 1999, all nesting banks were inundated by floodwaters resulting in zero recruitment of hatchlings.

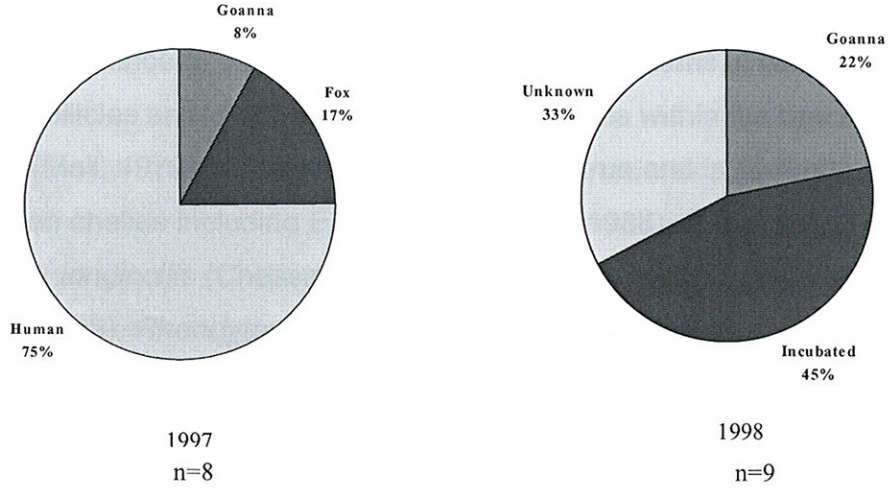



Figure 5.3: Egg predation in 1997 and 1998 nesting season.

## 5.4 Discussion

The reproductive strategy of *E. macrurus* was similar to reproduction in other temperate-zone chelonians. However, several aspects of its nesting ecology were unique among the family chelidae. In many temperate-zone chelonians vitellogenesis starts in late summer or autumn and continues until spring when ovulation occurs. It is not unusual for some turtles, including *Pseudemys scripta* (Gibbons and Greene, 1990), *Sternotherus minor* (Cox and Marion, 1978) and *E. krefftii* (Georges, 1983), to become reproductively inactive after the breeding season. In female *E. macrurus* there was no evidence of a period of quiescence. The maturation of follicles appeared to take up to twelve months, indicating that vitellogenesis was continuous throughout the year with the ovaries showing numerous sizes of vitellogenic follicles year round. The long and continuous period in which the follicles took to mature in *E. macrurus* is not uncommon in other chelonian species. The Loggerhead musk turtle, *Sternotherus minor minor*, in north Florida (Iverson, 1978), displays the same type of continuous

reproductive cycle. All species of sea turtles experience the same lengthened process of vitellogenesis, though not continuous (Kuchling, 1998).

With the presence of different sized follicles in the ovaries, it could be interpreted that the follicles are to be used for multiple clutches within the one breeding season (Moll, 1979). In many instances, this is true and is common in many Australian chelids including *E. krefftii* (Georges, 1988), *E. macquarii* (Chessman, 1978), *C. longicollis* (Chessman, 1978; Parmenter, 1985) *Elseya latisternum* (Legler, 1985), *Rheodytes leukops* (Legler and Cann, 1980) and *C. oblonga* (Kuchling, 1988). Contrary to the historic reports of *E. macrurus* producing two clutches of eggs annually, there was no evidence in ovarian activity to suggest that the females sampled produced more than one clutch per year. That is, the presence of only one size of corpora lutea and follicles less than mature size (<15mm) post oviposition, indicated that the production of only one clutch of eggs was possible.

In temperate-zone Australian chelids, vitellogenesis of individual follicles is generally completed in one year (Kuchling, 1998) and those pre-ovulatory follicles that are not used in egg production and that are not carried over to the next breeding season, typically become atretic and are reabsorbed back into the blood stream (Chessman, 1978; Georges, 1983; Parmenter, 1976, 1985; Kuchling, 1988, 1998). *E. macrurus* showed comparable patterns in atresia with all large mature-sized follicles remaining after oviposition, becoming atretic. Similarly, in numerous American species such as *Chrysemys picta* (Powell, 1967), *Pseudemys scripta* (Web, 1961), *Terrapene ornata* (Legler, 1960) and *Trachemys carolina* (Altland, 1951) atresia has been observed. However, in all of these cases, small to medium sized follicles became atretic. In no case was the incidence of atresia sufficient to account for complete loss of enlarged follicles that did not ovulate (Gibbons and Green, 1990).

Therefore, if 100% of adult females bred each year, having a vitellogenic cycle of about twelve months, each female would have to commence preparation for the next breeding season as they were resorbing left over follicles and healing corpora lutea from the previous season.

The reproductive cycle observed in male *E. macrurus* was generally similar to other temperate-zone turtles, having a distinct period of quiescence after the breeding season. The timing of their cycle, however, was slightly different. In the families of some American temperate-zone turtles (Emydidae, Chelydridae, Trionychidae and Kinosternidae) spermatogenesis begins in the spring, peaks in late summer, and ends in autumn as spermatozoa leave the testes to overwinter in the epididymides (Hildebrand, 1929; Risley, 1938; Cagle, 1950; Legler 1960; Tomko, 1972). In *E. macrurus* spermatogenic males were recorded from late autumn through to mid summer. It is presumed that towards the end of summer sperm production had ceased.

Unlike other freshwater turtles, historical information suggested that *E. macrurus* used "traditional" sites for nesting, with the same females recorded nesting each year (Appendix 1). In addition to this, reports of synchronised or 'mass' nesting events were recorded. Current data confirm that *E. macrurus* are using selected nesting areas (typically un-vegetated sand banks) and are moving large distances to get to these sites (see Chapter 3). However, the lack of data on individual turtles using these sites means that conclusions cannot be drawn on site fidelity without further research.

Evidence of 'mass' nesting was not apparent in *E. macrurus* during the 1997, 1998 and1999 nesting seasons, presumably as a result of low nesting numbers and/or due to the significant reduction in the nesting population. With current population levels it is unlikely that such a nesting event will be observed, therefore, the observations of mass nesting and site fidelity in the 1960s and

1970s, cannot and probably will not be proven or disproven until the population levels increase.

Apart from these nesting parameters, the onset of oviposition in female *E. macrurus* was associated with rainfall events. This pattern of nesting is not unusual and has been observed in many Australian chelids (Goode, 1965; Clay, 1981; Kuchling, 1993). Presumably, *E. macrurus* responded to rainfall for increased nesting success. Observations from Greenhalgh (pers. comm.) indicate that *E. macrurus* 'tests' the nesting bank prior to nesting, suggesting that each individual will oviposit on its second emergence from the water. There is no solid data supporting these observations, however, the high number of tracks recorded compared to nests in this study may suggest that this is the case.

The variability in both egg and clutch size of *E. macrurus* nests were quite large. Variances in these nesting parameters are common in most turtles and may be explained by differences in maternal body size (Gibbons, 1982). Gibbons (1982) suggests that body size alone dictates the number and size of eggs an individual will lay per clutch. As the female grows, so does her capacity for bigger eggs and larger clutches (Gibbons, 1982). Unfortunately, correlations between body size and clutch size for *E. macrurus* were not recorded during this study. From the information presented, however, it is expected that the variability in clutch size may be significantly correlated to female body size as has been shown in many other species of freshwater turtle (eg. *E. dentate, C. rugosa, P. scripta, C. serpentina, T. scripta*) (Congdon and Gibbons, 1983; Congdon *et al.*, 1987; Gibbons and Greene, 1990; Kennett, 1994; Iverson *et al.*, 1997).

In all nests monitored, high levels of predation were responsible for low levels of hatching success and subsequent recruitment back into the population. Other studies have shown that predation of freshwater turtle nests may be high, often with over 95% of nests being destroyed (Petokas and Alexander, 1980; Thompson, 1983; Congdon *et al.,* 1987; Robinson and Bider, 1988). In *E.*

*macrurus,* most nests were destroyed within 24 hours of being laid, either by foxes (*Vulpes vulpes*) or goannas (*Varanus gouldii, Varanus varanus*). Studies have reported that during the first 24 hours olfactory cues are stronger and allow for easy detection of nests (Congdon *et al.,* 1987). In 1997, a large proportion of nests were presumably illegally collected. Further investigation into this matter is required, as a continued decrease in the levels of recruitment will have a very serious and negative affect on the population.

## Chapter 6: Population dynamics

### 6.1 Introduction

Among reptiles, small, relatively short-lived species (such as lizards) have set the standard for generating and testing life history theories (Milstead, 1967; Huey *et al.*, 1983). Very little work has focused on the demography of long-lived reptiles, particularly turtles (Iverson, 1991). Turtles are among the longest-lived vertebrates (Gibbons, 1967; Gibbons and Semlitsch, 1981) and, primarily for this reason, accumulation of demographic and life history data is lacking (Congdon *et al.,* 1987). In recent years, a number of long-term population studies have commenced, though mainly in American species (see Iverson, 1991). Few studies have been initiated to investigate the life history parameters of Australian freshwater turtle species (Parmenter, 1976, 1985; Georges, 1993; Kennett, 1994; Limpus *et al.,* 2002).

Knowledge of several life history characteristics is critical in understanding the demography of a population (Iverson, 1991) and in assessing the effect that anthropogenic impacts have on a population (Congdon *et al.*, 1987). Generally, reproduction, growth, survivorship, age at maturity, diet and movement are important parameters for studying the demography of a population.

Chelonians, when compared with many other reptiles of similar size, are characterized by extended longevity and delayed maturity. Their juvenile and sub-adult phase lasts several years and, in some of the largest forms, even decades (Kuchling, 1998). Subsequently, a change in the population dynamics and life history traits can often go undetected for many years. Therefore, to be successful and informative, studies of such nature must continue long enough to address both the within-individual variations and the within-population variations.

This study presents preliminary data on a number of life history traits, such as population structure, sex and maturity ratios and sexual size dimorphism in the population of *E. macrurus* from the Mary River.

By studying such parameters and analysing the temporal changes in abundance and spatial structure, the response to natural and human induced disturbances can be determined (Chaloupka and Musick, 1997). More data needs to be collected, however, in order to quantify growth and survivorship of both juveniles and adults in the population.

## 6.2 Methods

### 6.2.1 *General methods*

A two-year mark/recapture study commenced in mid 1997 in the Mary River. The Mary River turtle, *E. macrurus* was targeted, though data on all other species were recorded for the Queensland Parks and Wildlife Service freshwater turtle monitoring program. Turtles were captured by one of three techniques; snorkeling, trapping or seine netting (see Chapter 2 for details). All turtles were tagged, measured and weighed using methodologies described in Chapter 2. Maturity and gender were determined and/or confirmed by laparoscopy (see Limpus, 1984; Limpus *et al.,* 2002).

### 6.2.2 *Statistical analysis*

The sex ratio of *E. macrurus* was evaluated using a Chi-Square test to determine if the occurrence of male to female captures was significantly skewed. A Fisher exact test was used to determine if maturity ratios were significantly different between sexes. A standard *t*-test was used to compare the mean carapace lengths of adult male and female turtles in determining significant differences in sexual size dimorphism. The same test was used to compare tail lengths of adult male and female turtles.

## 6.3 Results

### 6.3.1 *Mark/Recapture*

A total of 808 turtles (six species) were tagged during the study period. Each species was easily identified. The breakdown of numbers per species is listed in Table 6.1. There were only 18 recaptured animals in total, 6 *E. krefftii*, 7 *Elseya* sp. and 5 *E. macrurus.*

Table 6.1: Statistics of tag/recapture program

| Species | Number caught | Number recaptured |
|---|---|---|
| *Chelodina expansa* | 1 | 0 |
| *Chelodina longicollis* | 0 | 0 |
| *Elseya latisternum* | 16 | 0 |
| *Elseya* sp. | 302 | 7 |
| *Elusor macrurus* | 131* | 5 |
| *Emydura krefftii* | 358 | 6 |
| **TOTAL** | **808** | **18** |

* including 19 incubated hatchlings

### 6.3.2 *Population structure*

Size classed distribution of *E. macrurus* was determined using the straight carapace length of each individual. Turtle sizes ranged from 3.59cm to 42.02cm (excluding incubated hatchlings). The population structure of *E. macrurus* in this study was clearly bimodal (Figure 6.1), showing the majority of individuals in the size ranges 9-17cm and 28-42cm respectively. In addition to this, there was a significant absence of sub-adult sized individuals in the population. Adult male and female turtles were sexually dimorphic in size (see section 6.3.4), shown by two peaks in the adult size range (28-42cm).

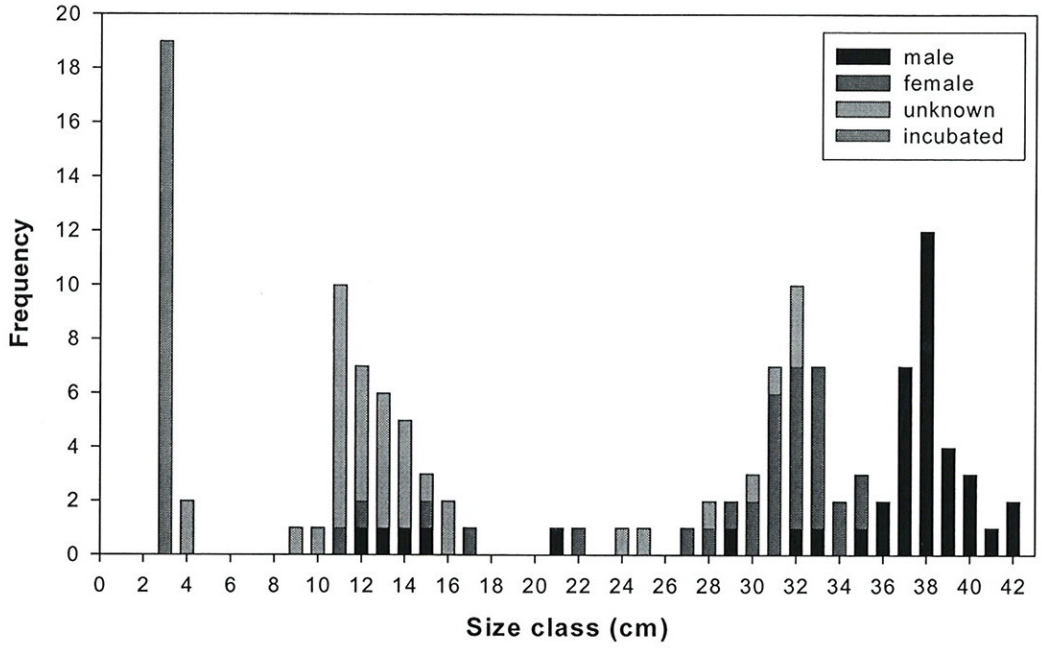



Figure 6.1: Size class distribution of *E. macrurus*.

### 6.3.3 *Sex and maturity ratios*

Of 112 *E. macrurus* captured during this study, 41 were male, 32 were female and for the remaining 39, sex was not determined due to size. The sex ratio of male:female turtles was 1.28:1 for *E. macrurus,* 1:1.14 for *E. krefftii* and 1:2.76 for *Elseya* sp (Table 6.2). A Chi-Square test indicated that sex ratios for *E. macrurus* were not significantly different from a ratio of 1:1 (P=0.241). There was also no significant difference between male and female maturity ratios (P=0.7222). A Fisher Exact test indicated that the maturity ratios of male and female *E. macrurus* were significantly skewed toward adult turtles (P=0.005: males; P=0.001: females) (Table 6.2).

Table 6.2: Sex and maturity ratios for *E. macrurus* and two other Australian chelids from the Mary River.

| SPECIES | SEX RATIO | | MATURITY RATIO | | | |
|---|---|---|---|---|---|---|
| | | | MALE | | FEMALE | |
| | ♂:♀ | n | Imm:Adult | n | Imm:Adult | n |
| *E. macrurus* | 1.28:1 | 73 | 1:7.2 | 41 | 1:5.4 | 32 |
| *E. krefftii* | 1:1.14 | 158 | 1:2.2 | 67 | 1:1.8 | 75 |
| *Elseya* sp. | 1:2.76 | 169 | 1:4.8 | 39 | 1:5.6 | 126 |

### *6.3.4 Growth*

Figure 6.2 represents the projected growth rate of juvenile *E. macrurus* based on growth rings (y=2.8894x + 4.2738). Due to the small number of recaptured individuals in this study, the data are inadequate to predict size at maturity and the rate of adult growth.

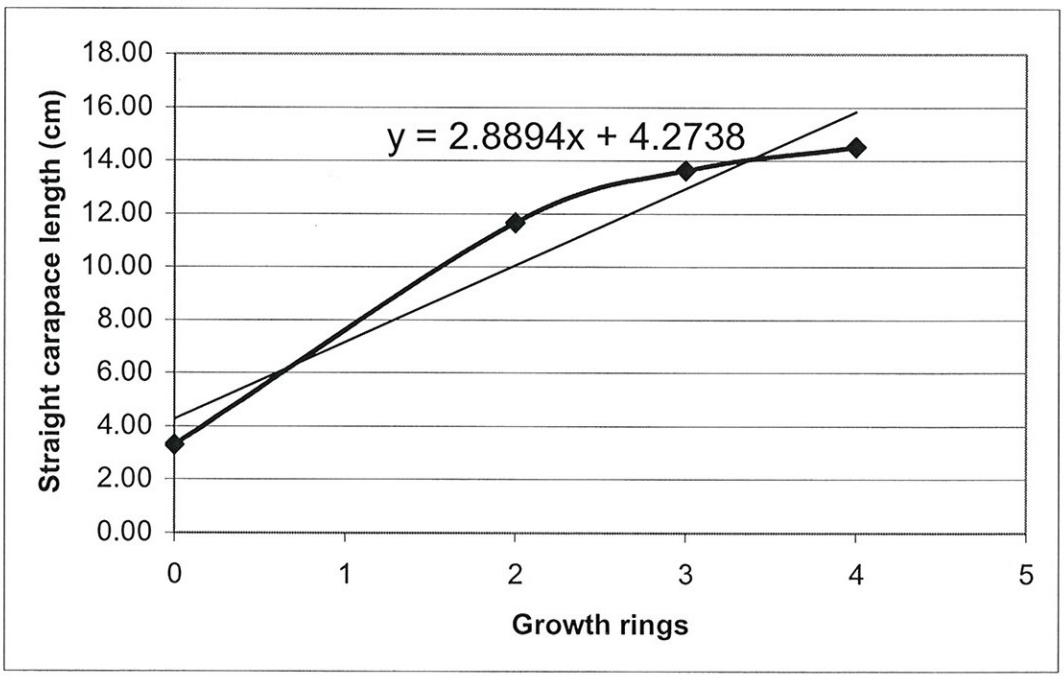



Figure 6.2: Projected juvenile size of *E. macrurus* using growth rings.

### 6.3.5 *Sexual size dimorphism*

As seen in Figure 6.1 and 6.3 adult male and female turtles displayed obvious differences in carapace length. The straight carapace length of adult female *E. macrurus* averaged 31.83cm (n=27, range=27.22cm – 34.78cm, SD=1.92). Adult males attained an average size of 37.69cm (n=35, range=29.04cm – 42.02cm, SD=2.46). A standard *t*-test indicated that the size difference between sexes was significant ($t$=3.725, $p$<0.0003, df=100).

Figure 6.4 indicated that 25cm is the pivotal size range for juvenile and adult turtles. At sizes less than 25cm you would expect individual *E. macrurus* to be immature. Conversely, individuals greater than 25cm in carapace size would be reproductively mature. (Note that the broken lines indicate approximate values as few turtles were caught in the sub-adult size ranges).

In addition to *E. macrurus* displaying sexual size dimorphism in carapace length and width, tail length from the carapace was also significantly different for male and female turtles ($t$=22.776, $p$=0, df=58). Figure 6.5 illustrates the pivotal size of carapace and tail lengths for both adult male and female turtles. It can be interpreted that any individual larger than 35cm and with a tail length longer than 7cm, is an adult male and vice versa for females. The average tail length for female *E. macrurus* was 3.40cm (n=27, range=1.68cm – 6.15cm, SD=1.14). The average tail length for male *E. macrurus* was 13.89cm (n=38, range=7.73cm – 18.35cm, SD=2.16).

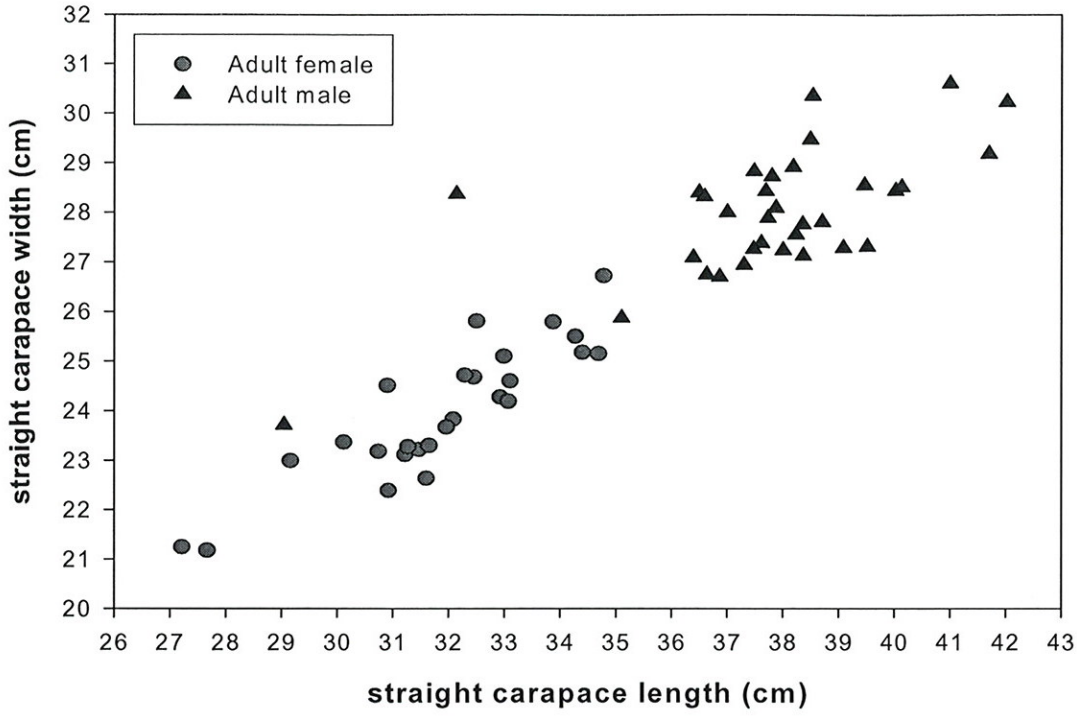



Figure 6.3: Correlation between adult male and female straight carapace length and width.

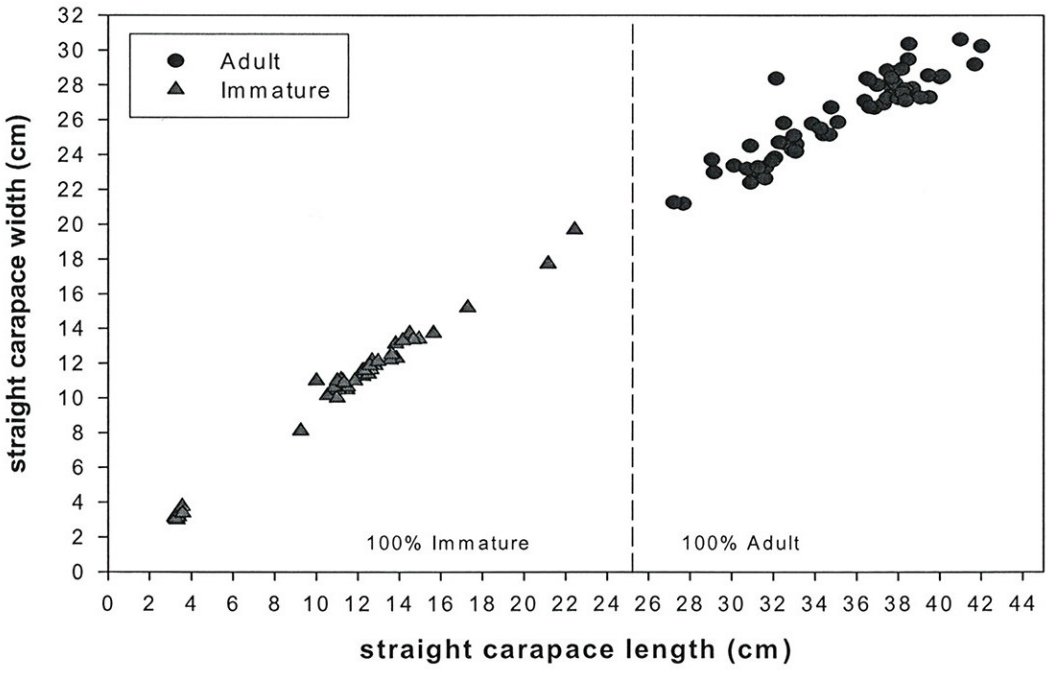



Figure 6.4: Correlation between adult and juvenile straight carapace length and width.

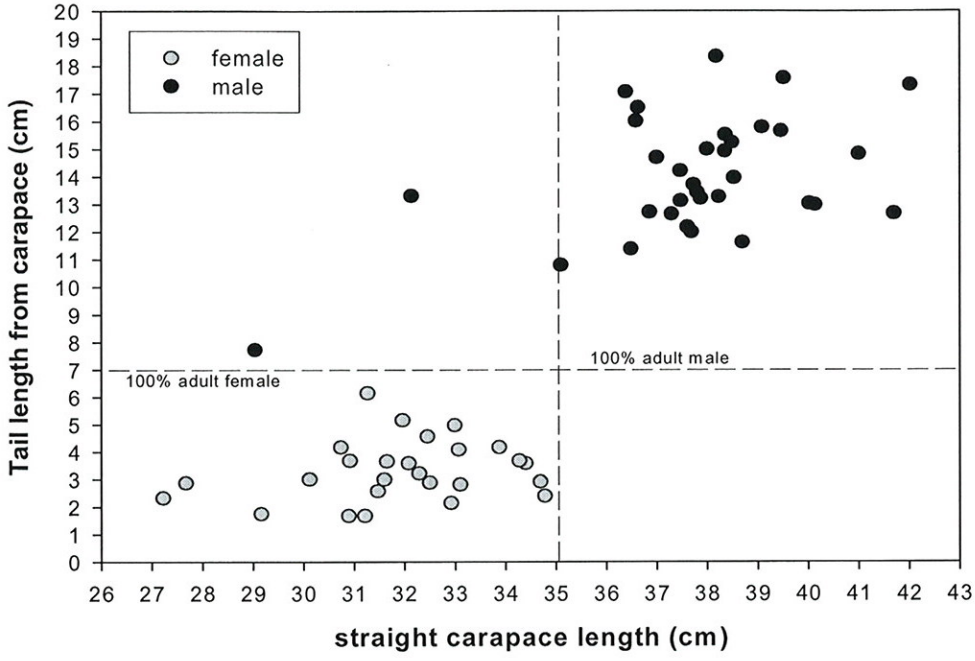



Figure 6.5: Correlation between tail length and straight carapace length of adult male and female *E. macrurus.*

## 6.4 Discussion

The sampling effort summarised in Appendix 3 indicates that a large proportion of the turtles were caught during the warmer months of the year, presumably when turtles were most active. During these periods, sampling was more regular due to warmer water temperatures for divers, though sampling in winter months did result in fewer turtles per catch effort in comparison. Other sampling biases resulted from periods of flooding, which hindered sampling effort in certain months of the year due to increased flow and turbidity. With this is mind, other studies have shown that such seasonal patterns in activity are common for chelonian species and reflect the period of breeding and foraging (Ernst, 1978; Burbidge, 1981; Brown and Brooks, 1993; Kuchling, 1993; Souza and Abe, 1997).

Based on the data presented here, the population structure of *E. macrurus* was typically bimodal, indicating peaks in the juvenile and adult phases. In some Australian freshwater turtle populations this structure represents a healthy population (Limpus, unpublished data). In other species, this type of population structure is uncommon and generally a gradual increase in the number of turtles throughout the size range, peaking in adult size classes is seen (Tucker *et al.*, 1998). The latter population structure represents a population with high juvenile mortality offset by high adult survivorship (Thompson, 1983; Iverson, 1991; Kennett, 1994; Souza and Abe, 1997).

From data collected in this study Tucker *et al.* (1998), estimated the age at maturity for *E. macrurus* to be 25-30 years. The reliability of this estimate is unknown as recapture data used was minimal. Compared to other species, however, the estimated age at maturity for *E. macrurus* is delayed (Tucker *et al.,* 1998). American species including *Emydoidea blandingii* (Congdon *et al.,* 1993) and *Gopherus agassizi* (Turner *et al.*, 1987) were estimated to reach maturity between the ages of 12 and 20 years. Age at maturity for *Kinosternon flavescens* varied across its range from 6-15 years (Iverson, 1991). *Trachemys scripta* attained maturity at an age of 5-8 years (Mitchell and Pague, 1990). In those Australian species that have been studied, *Pseudemydura umbrina* and *Emydura krefftii* matured between 7 to 10 years (Burbidge, 1981; Georges, 1982), *E. macquarii* between 6-8 years (Chessman, 1978), *Chelodina longicollis* between 8-12 years (Goode, 1967; Chessman, 1978; Parmenter, 1976, 1985), *C. expansa* between 9-12 years (Chessman, 1978), *C. rugosa* between 4-7 years and *Elseya dentata* between 8.5-13.5 years (Kennett, 1994).

Generally, in all of these studies male turtles reached maturity 2-5 years prior to their female counterpart. In the projected maturity rates for *E. macrurus*, females were estimated to mature faster than males (25 years as opposed to 30 years for males).

In terms of delayed maturity, some studies have identified that life history traits can increase the quality of young produced and the size of clutches produced as well as decrease the risk of mortality due to size (Gadgil and Bossert, 1970; Tinkle *et al.*, 1970; Wiley, 1974; Bell, 1977; Stearns and Koella, 1986). The costs associated with delaying sexual maturity, however, include increased risk associated with death prior to first reproduction and lengthened generation time (Congdon *et al.*, 1993), which may substantially delay population growth in a declining population. For *E. macrurus* the later has created major implications in sustaining the population after the period of intense egg harvest.

From 1962 to 1974, 100% of *E. macrurus* eggs were removed from nesting banks and presumably little recruitment occurred. Almost 30 years later, you would expect to see a large proportion of sub-adult and adult turtles in the population. *E. macrurus* live in sympatry with five other species of freshwater turtles, all reaching sizes that are equivalent to its sub-adult phase. So why is there an absence of sub-adult turtles in the species *E. macrurus*? The scarcity of sub-adult turtles in *E. macrurus'* population can partly be attributed to twelve years of total egg collection. Egg collection may have continued after the introduction of the Fauna Conservation Act in 1974, though at the same time, the presence of foxes within Australia dramatically increased (Limpus, pers. comm.). In the late 1970s and early 1980s, increased fox depredation levels to marine turtle nests were recorded on mainland nesting beaches along the Queensland coast (Limpus and Reimer, 1994). The combination of these impacts almost certainly account for the absence of small post-hatchling turtles (< 15cm) and sub-adult turtles in this population. The possibilities of sampling bias, however, cannot be eliminated.

In other studies, low numbers of juvenile were due to: 1. juveniles occupying habitats different to those that were sampled; 2. juveniles being very secretive and eluding capture and 3. juveniles being rare and representing actual numbers of recruitment into the population (Gibbons, 1968; Graham and Doyle, 1977;

Petokas, 1986). During this study, a range of micro-habitats were sampled and recruitment rates were observed through studies on nesting and reproduction.

The sex ratio of *E. macrurus* was not significantly skewed in this study, however, the maturity ratios leaned significantly toward an adult population. It has been suggested in other studies, that the sampling methods and the timing and location of collection can have a significant effect on both the sex and maturity ratio of a population (Ream and Ream, 1966; Gibbons, 1990; Pilgrim *et al.,* 1997). It has also been proposed that male/female, adult/immature turtles may have different spatial or temporal patterns of activity that can also alter sex and maturity ratios (Pilgrim *et al.,* 1997). Therefore, such ratios do not always accurately reflect the true population structure of a species. Long-term sampling in a variety of habitats would be necessary to eliminate seasonal and spatial sampling biases.

Sexual size dimorphism (SSD) was evident in *E. macrurus* with male turtles attaining significantly greater sizes in both carapace and tail length compared to females. In most chelonian species SSD is common, however, in highly aquatic species like *E. macrurus* females are generally larger in size (Berry and Shine, 1979; Gibbons and Lovich, 1990). Such differences is body size have given rise to a number of theories which relate predominantly to the mating strategies of males. Basically, larger body size in males is correlated with the presence of male combat in a population and female choice (Darwin, 1979 (1874); Berry and Shine, 1979). These strategies suggest that aggression in males and forcible insemination during mating is a direct display of fitness which, hence, increases the individual's chance of copulation or being 'chosen' by a female. Alternatively, smaller sizes in males suggest that dispersal is far greater and reflects their ability or success in copulating with a greater number of females (Ghiselin, 1974). Conversely, larger female sizes have been correlated to increased fecundity and survivorship from predators during nesting (Berry and Shine, 1979).

A study by Berry and Shine (1979) showed that in 97% of aquatic turtles females attained a larger carapace size than males. In all but two species of Australian chelids (*E. macrurus* and *Pseudemydura umbrina*), females are larger than males. Why *E. macrurus* displays different traits in SSD are unknown and may be consistent with the hypotheses listed above. Mating behaviour has not been observed in the wild for *E. macrurus,* however, aggression and territoriality has been observed in captive specimens (Cann, 1998).

Simulation studies based on life history data collected in long-term studies indicate that turtle populations with delayed maturity fare poorly in the face of increased mortality rates of any age class in the population as a result of their life history characteristics (Congdon *et al.*, 1993, 1994). For *E. macrurus* the low level of nest survival (see Chapter 5) represents a substantial problem to the population and reflects the abnormality in their population structure. Further studies are needed to quantify growth and survivorship in all stages of *E. macrurus'* life cycle. In addition, further research needs to be undertaken to clarify the age at which *E. macrurus* reaches maturity. More importantly, the threats hindering juvenile recruitment must be eliminated so that the population can, in time, function normally.

## Chapter 7: Conclusions and Management Recommendations

### 7.1 General discussion and Management Implications

The population of *E. macrurus* has declined significantly over the last 30 years, presumably as a result of human predation, loss of nesting habitat (Greenhalgh, pers.comm..), increased predation of both native and exotic species and environmental degradation. Similar threats have been identified in many other chelonian species worldwide (Kuchling, 1998), though most conservation efforts for chelonians within Australia have been directed towards sea turtles and only a few concern freshwater species.

In some countries, including Australia, the removal of many eggs, adults and juvenile turtles for the pet trade has seriously depleted some populations to the extent that recruitment has been reduced significantly (Ernst and Barbour, 1989). Together with their relatively slow rate of maturation, turtles cannot withstand such activities and maintain their populations.

Fortunately in Queensland, the introduction of the Fauna Conservation Act, 1974 ceased the collection and trade of reptiles. These days, other influences such as the introduction of exotic species, cattle trampling, flooding and land degradation are the major issues some populations are faced with.

In many ways *E. macrurus* is similar to other temperate-zone species, and display comparable breeding cycles and nesting rituals. Like *Rheodytes leukops* (Priest, 1997) and *Elseya* sp. (Fitzgibbon, 1999), *E. macrurus* has been identified as a species that uses a certain type of habitat and displays tendencies towards a preferred food source. Similar to the abovementioned species, *E. macrurus* are often found inhabiting highly oxygenated waters associated with riffle sections. A stream characteristic that is preferred for cloacal ventilation. In *R. leukops,* cloacal ventilation has been shown to be extremely important in respiration (Priest, 1997). *E. macrurus* display the same physiological features

and have the capability for cloacal respiration (Limpus, Pers. Comm.). The extent to which they are using these bursae for respiration is unknown. Without such information, the effects of altered stream flow regimes and changes in water quality, cannot be determined.

Likewise, having an herbivorous diet (see Chapter 4) means that changes to the quantity and quality of food resources can have a major effect on the reproductive potential and ultimately, the survival of a species. In at least some chelonians, breeding cycles seems to be sensitive to stress (Kuchling, 1998). For some species, stresses may include changes in food availability or even changes to their environment. A good example of stress related change is the transfer of wild *Pseudemydura umbrina* into captivity. Initially, a major change to their environment seriously disturbed ovarian cycles in females to the point where they either would not initiate breeding or the existing vitellogenic follicles were reabsorded (Kuchling and Bradshaw, 1993). Relying on a more herbivorous diet, *E. macrurus* is unlikely to adjust to major changes in their environment and, may undergo similar 'stresses' if faced with the pressures of habitat degradation and loss of food resources.

In other life history traits, *E. macrurus* has displayed relatively unique requirements. Historical data suggested that *E. macrurus* mass nested on traditional sand banks. Mass nesting was not observed in this study, probably as a result of a significant reduction in the number of turtles nesting, but certainly the preference in using sand banks (as opposed to vegetated banks) was affirmed.

Through tracking studies, some individuals were recorded to move up to 2km during the breeding season to use these 'preferred' sand banks for nesting. The extent of movements in individual female's seemed to be linked to the presence of a nearby sand bank.

Movement of female turtles is not a unique trait and has been recorded in other species of turtles. Migratory movements are common in sea turtles during the breeding season (Limpus and Reed, 1985; Limpus *et al.*, 1992; Musick and Limpus *et al*, 2002) and in some freshwater turtles (Jackson and Walker, 1997; Magnusson *et al.*, 1997; Plummer *et al.*, 1997).

The use of restricted areas for nesting, however, is unique and the implications of habitat loss or alteration are far greater. The loss of nesting habitat through flooding (e.g. weirs and dams), infestation of exotic plant species, sand mining and cattle trampling would all have a significant effect on the long-term viability of *E. macrurus*. Over the years, human activities such as those listed above, have altered habitat and predator-prey relationships.

Subsequently, a significant reduction in nesting numbers has occurred. These days, the nesting population of *E. macrurus* is functioning at a level that represents only 5% of their former population. Figure 7.1 shows the number of nesting females in recent years compared to historic data collected in the 1960s and 1970s (Greenhalgh, pers. comm.). Note that present sampling methods and sampling intensity varied from those used for egg collection, so the later data may be underestimated. Sampling for egg collection was more rigorous and destructive and resulted in entire banks being dug up.

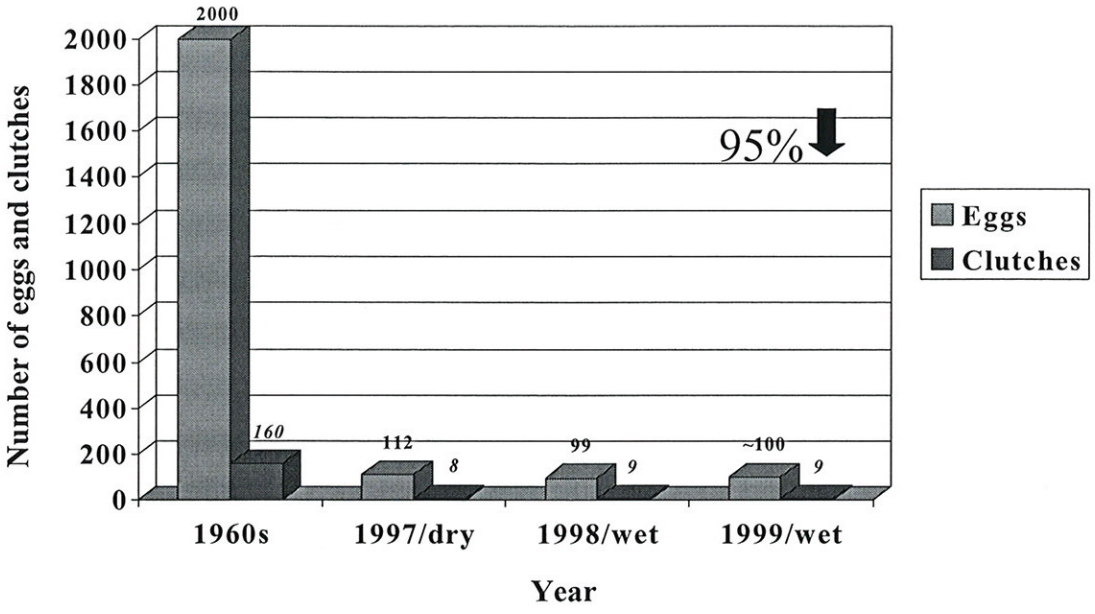



Figure 7.1: Trend in egg production and nesting numbers of *E. macrurus* at Tiaro across years.

The level of predation recorded during this study was very high resulting in extremely low levels of recruitment. Both native and exotic species preyed upon *E. macrurus* eggs, not to mention the suspected illegal harvest by humans.

Coupled with high egg mortality, low fecundity was recorded for *E. macrurus* (one clutch per year). Such life history constraints limit the ability of turtle populations to recover from other human impacts such as habitat degradation. In addition, their estimated age at maturity (25-30 years) is also delayed compared to other species of freshwater turtles (Tucker *et al.,* 1998) meaning there can be extended periods before new individuals are entering the adult population.

The threat of sand mining was also prevalent in what used to be the most productive nesting sites for *E. macrurus*. The removal of sand adjacent to these nesting banks has raised serious concerns about the potential to mine these areas. In other countries, sand mining has been identified as the greatest potential threat to freshwater turtle populations (Moll, 1997), and in some cases, the loss of sand banks to mining has resulted in entire populations being depleted (Moll, 1997).

The consequential changes of flooding, streambed alteration, nutrient loading, siltation and inappropriate land use practices, have the potential to substantially affect an already vulnerable species. The remaining population of *E. macrurus* and its habitat must be actively managed to ensure their long-term survival. Continued long-term studies will help determine other life-history traits that were not identified or only touched upon in this study.

## 7.2 Recommendations for Conservation and Management

Development of conservation programs often must proceed without adequate data on life history trait values of target species. Reasons for lack of data include technical and logistic problems related to obtaining life history data on some species, and the difficulty of obtaining reliable data from populations that are already reduced or in decline (Congdon *et al.*, 1993). Reasons for lack of data relate directly to the levels of funding or suitably qualified or "inspired" personal that are available for such research and the perceived priorities for conservation. One might ask the question, which is the higher cost? The cost of managing a species or the cost of losing a species?

This study raises concerns about the long-term viability of the population of *E. macrurus.* Throughout this document, the threats to *E. macrurus* have been discussed and it has been identified that without urgent action, this species is subject to further decline. *E. macrurus* is listed as Vulnerable under state legislation (Endangered under Federal legislation) and in such context, the species is recognised to be threatened of extinction. This alone, warrants the need for further research and monitoring of this species.

In considering the priorities for conservation and related research, it is first important to determine the level of threat a species is faced with. Georges (1997) identified that priorities for conservation should be determined using a

number of criteria based on the rarity, distinctiveness and intrinsic vulnerability of a species and the level of threat faced by a species.

With a relatively low abundance (particularly the nesting population) throughout its restricted range, *E. macrurus* meets the criteria of rarity. As a monotypic species, having unique morphological features that set it apart from all other Australian freshwater turtles, its distinctiveness is quite clear. Its vulnerability to decline and level of threat from predation and other influences has been shown in the low levels of recruitment recorded during the breeding season, its skewed size class distribution and its gradual decrease in nesting numbers over the last 30 years.

With this knowledge, *E. macrurus* clearly requires further management to ensure its long-term survival. The recommended conservation and management strategies for *E. macrurus* should include:

1. *Reassess the status of E. macrurus, up-grading its priority for conservation by listing it as Endangered.*

2. *The development of a species recovery program which would broadly include:*
    a. The immediate protection of known habitat areas (both aquatic and terrestrial) from alteration and/or degradation.
    b. The continued research and monitoring of the species.
    c. The introduction of a public education and awareness program.

3. *Further scientific research on aspects of its life history including:*
    a. Growth and survivorship.

4. *The introduction of an incubation program and a head-start program for increased hatchling survivorship.*

### 7.2.1 *Development of a recovery program*

The development of a species recovery program would aim to reduce detrimental impacts to the population of *E. macrurus* and promote their recovery in the wild. It would aim to reduce the current threats of habitat degradation and predation, and modify the human activities that influence habitat alteration and population declines in all stages of its life cycle. The specific objectives would include:

- The development of on-going research programs to monitor trends in the population (see section 7.2.2 for details).
- Identification of critical habitat used by *E. macrurus* and the protection and management of these habitats from further human related impacts.
- Involvement of sand mining leases in the protection of critical nesting habitat.
- The introduction of predator control programs to reduce the mortality of eggs and hatchling turtles.
- Community education through newsletters, media and workshops.
- Community involvement through community nature conservation (e.g. land for wildlife) and in monitoring and research, particularly school groups, local landowners and conservation groups.

### 7.2.2 *Continued research and monitoring*

It is clear that further research on other aspects of *E. macrurus'* life history is necessary to gain a better understanding on the overall biology and ecology of the species. In addition, the need to continue current research seems imperative for this long-lived animal in order to gain long-term data on population trends. Further research on this species should:

- Identify potential nesting sites throughout the entire Mary River catchment.
- Monitor these nesting sites to identify trends in the nesting population.
- Determine the extent of predation at other nesting sites.
- Control the level of predation on eggs and juvenile turtles.

- Continue data collection on reproductive cycles.
- Determine growth, age at maturity and survivorship.
- Define the diving physiology and the associated habitat requirements.

Obviously, continued research should eliminate any sampling and habitat biases that may have been experienced in this study or through short-term studies in general. Not only will such data be extremely valuable scientifically, but, it would be invaluable for future conservation and management of the species.

### 7.2.3 *Introduction of a head-starting program*

Head-starting is a broad term used for the captive hatching and rearing of turtles through an early part of their life cycle (Heppell, *et al.,* 1996). As a management tool, head-starting has long been subject to major criticism for returning individuals back into a degraded environment without addressing the initial cause of the decline. It has also raised concerns that such supplementation of individuals into a population serves as an attempt to relieve humans of the consequences of their actions (Frazer, 1997). Used properly, however, head-starting has its advantages and can be very beneficial to a population that is in decline.

On its own, incubation and head-starting is seen as a short-term solution to the problems of recruitment by instantaneously increasing the number of juveniles entering the population. Used in conjunction with other management strategies (such as those listed here) that will (a) maximize incubation success and (b) maximize hatchling survivorship, head-starting would be an effective tool in assisting overall population growth.

Some management strategies that would complement a head-starting program would include:

- Reducing predators.

- Relocating clutches of eggs prone to flooding to safer incubation locations.
- Artificially incubating eggs in control environments.
- Creating artificial sand banks to encourage nesting.
- Releasing hatchlings into suitable habitat that will increase survivorship.
- Replanting in-stream vegetation after flood scouring.
- Providing better in-stream habitat through the introduction of snags.

In considering these programs for management and conservation, it is important that certain aspects of a species ecology is defined. In particular, the factors affecting sex determination and orientation (i.e. magnetic orientation used in sea turtles) need to be considered for some species of turtles. In most Australian chelids, incubation would not affect sex ratios because the determination of gender is not reliant on temperature (Georges and McInnes, 1998). Alternatively, the factors affecting orientation in freshwater turtles have not yet been studied and the long-term effects of these programs are unknown. In short, the success of any of these management tools relies heavily on the extent of knowledge that is available for a species and the combined implementation of threat based management strategies.

The abovementioned strategies aim to protect all aspects of the turtle's lifecycle, rather than focusing on one area. Used in conjunction with each other, the long-term outcomes of these strategies would positively influence the population of *E. macrurus*.

## Chapter 8 - References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## APPENDIX 1:

Historical information on egg collection: Interview with John Greenhalgh 30.05.2002.

| **1. In what years did you collect turtle eggs from the Mary River?** |
|---|
| Eggs were collected from 1962-1974. They stopped collecting eggs when they became protected. |
| **2. Where in the Mary River did you collect eggs from? (mark on map)** |
| John searched the river downstream from Gympie in the first year. He never found any nests around the Gympie area. In fact, from Gympie to Miva very few nests were ever found. They did launch their boat at Bell's bridge, but until they reached Miva they never really found anything. This stretch of river wasn't payable. After the first year, they never looked upstream from Bell's bridge.<br><br>Because they never found nests around Gympie, John never looked for nests further upstream.<br><br>John looked in the Burnett river in the early 1970s, however, no suitable nesting banks were found. This was a failure. They planned on going to the Murray river, but never got there. They didn't think they could cope with another river; the Mary river kept them busy.<br><br>The Mary river was John's supply of turtles for the entire time he collected eggs. He only ever collected eggs from the main stream of the Mary river. He only went to one creek (T-bar creek - do not know whether this is a tributary of the Mary river) and found that turtles were laying in the fields (unknown species).<br><br>There were a number of banks that were productive and between 1200-1500 eggs were collected from them. Most of the eggs came from a bank at Miva, upstream from the Dickabram bridge. One of the biggest banks was on Robinson's property near Tiaro. Banks on Armstrong's and Tony Connors property were also very productive. Another bank upstream from Gundiah (Emery's bridge) was also quite large and good for turtle eggs. Sand mining is now being undertaken adjacent this nesting bank. |

At Reibels crossing near Gunalda, some turtle nests were found just below the old bridge. This bank is now vegetated.

100-200 eggs were collected on less productive banks.

**3. How did you find the eggs?**

John used to follow the tracks on the banks and prod the sand with his finger until he found the 'soft spot'. It was difficult at times because the tracks would overlap.

After the last laying for the season, they would manually dig up entire banks from top to bottom with their hands. They would do this to find any nests that they missed earlier. By this time, the eggs were quite robust and they would get 100% survival.

When the eggs were collected they were packed into old margarine containers. Eggs were carefully placed into containers without changing the orientation. One nest fit perfectly in each margarine container. He would stack the containers into an esky. Each layer had foam in between to stop the movement of the eggs.

On the steeper banks it was sometimes difficult to find the nests and eggs would get missed. In drier times the sand would fall down the face of these banks and clear the tracks making it difficult to find and dig nests.

**4. When did you collect eggs? (night after, 1 week after, 2 weeks after)**

John recalls that *Elusor's* only laid after rain in October and November. He believed that they nested twice a year (30 days apart) and that if individuals were marked you would see the same ones coming back each year.

The biggest mistake John remembers was collecting the eggs the night they were laid. He learnt that by transporting them at this time, the incubation success would be quite low. The jerking and jumping around in the boat as they passed over rapids killed the eggs.

John tried different collection methods and over the years hatching success increased. He found that by collecting the eggs one week after they were laid, the embryo was stronger and would withstand a lot of the movement involved in transporting them. By collecting the eggs one week after they were laid, John got 99% hatching success.

In his experience, John only ever recorded nesting during the night time. They would monitor one bank and as soon as they found nests they would collect from other banks through to Miva.

**5. Were there other people collecting eggs at the same time?**

No. Only John and his son collected eggs from the Mary river. They guarded this very well, and they dreaded farmers coming down to spot them. They used to be very quiet and sneak around the banks, so as not to attract attention to themselves.

They learnt not to collect eggs over the weekend as more people were using the river. They never had a farmer come to question what they were doing.

**6. Did you keep records of the number of eggs that were collected? If so, can we please get copies?**

John kept records of the number of eggs he collected, but unfortunately does not have those records still today. John talks of collecting up to 12 000 eggs in a season. He believes that he would have got over 4000 more hatchlings if they didn't collect them as soon as they were laid in the first few years.

On his first trip, he got 1200 eggs and carried them home in a bucket. This was a big mistake as only 700 eggs hatched.

**7. How long did the eggs take to incubate?**

The eggs took exactly 8 weeks to incubate (all species). On emergence they were predated on by birds, foxes, goannas and toads. With the first lot of hatchlings that emerged, he found that cane toads had climbed the cages that he had around the area, to get the hatchlings.

The hatchlings would emerge on Christmas eve always around 3pm. The pet shops always wanted them prior to Christmas, but they never hatched earlier than Christmas eve. Because of this, the hatchlings could not be transported for 3 or 4 days.

The area John incubated the eggs was about 21x21feet. The eggs were incubated in dirt.

John would hold them in tanks in about 2inches of water.

**8. Were all the hatchlings of one species?**

No. Often they would get up to seven or eight hatchlings of a different species. He would get some *Emydura kreffti* and others with a serrated edge (*Elseya latisternum?)*.

In John's experience 90% of the eggs collected were Elusor eggs. He describes the others as Krefft's and turtles that had a yellow edge around the shell, a short neck and white cheeks. These were found at the same time of year as *Elusor* eggs. No eggs were found 8 weeks prior to *Elusor* nesting.

**9. What did you feed hatchlings prior to distribution?**

The hatchlings were fed tubafish worms prior to being sent to the pet shops. About 300 hatchlings were kept to a tank. A small ball of tubafish worms a day would be sufficient for the hatchlings. The tanks never needed cleaning out when they were fed on worms.

On one occasion sewerage came through the pipes and killed all the tubafish worms, so the hatchlings were fed on first grade mince. This made a mess of the tanks and they had to be cleaned daily.

The turtles were fed daily. They wouldn't feed if they were out of water.

| **10. How were the hatchlings transported to pet shops?** |
| --- |
| The hatchlings were transported in boxes which were divided into a couple of layers. There were 300 hatchlings to a box. A ball of tubafish worms were also put into the boxes for the hatchlings to feed on whilst in transit. |
| **11. How much were the hatchlings sold for to pet shop owners?** |
| For the first two years John sold the hatchlings for 30c each. He then put the price up to 50c each because of a high demand for the turtles. Any hatchlings sold locally were sold for $1 to local aquariums.<br><br>He adds that now they are sold for about $19 to the southern pet trade and $25 to the public.<br><br>Allen (pet shop dealer) protected John from researchers inquiring about the origin of the hatchlings. |
| **12. How much were the hatchlings sold for in the pet trade?** |
| John never knew how much the hatchlings were sold for through the pet trade. Now they are sold for $25. |
| **13. Do you have invoices from the pet trade? If so, can we please get a copy or a sample?** |
| John never go invoices from the pet trade. |
| **14. Did you ever sell hatchlings to overseas dealers?** |
| No. Most of the hatchlings were sold to Allen, a dealer in Sydney. John is unsure whether any of these went overseas.<br><br>John sold only a few hatchlings locally (only on demand) to aquariums he dealt through. |

**15. What were your observations of these nesting areas? (what did they look like, how big etc)**

The banks were large sand banks with no weeds. Most were very steep. They were about 50yards longs and about 100feet high. All banks had cattle tracks around them where turtles would nest.

John talks about the banks being 'tracked all over'. He speaks of *Elusor's* coming up to test the sand prior to nesting, digging half holes to see if the sand was moist enough to hold its structure.

After flooding events, banks would be scoured, some would have a lot of gravel others a lot of sand. This would vary after each flood event. No sand mining was observed along the banks.

Drought years affected the number of turtles that laid. During these times they would come up and lay after only a shower, as long as the sand was hard enough.

**16. Where were turtles most likely to nest? (close to waters edge, on slope, distance from water, under vegetation, out in the open)**

Turtles would nest up to 200yards back from the water. They would lay on any patch of sand in these areas. Some laid in the grass. They would tear the grass away. Initially they would walk past without noticing, but after a few days the grass would die. If you had sharp eyes you could pick it up.

The turtles would only ever come up over sand banks. John talks of lots of turtles basking in front of these banks prior to the nesting season. The turtles would wait in front of these banks for the first rains to come before they nested.

Turtles would nest on the slope and over the top of the bank. It was often difficult to find the eggs if the turtles nested on top of the banks because the tracks would be lost. The turtle would also nest along cattle tracks. John used to dig these tracks up and find a lot of nests.

| **17. Were there signs of nest predation by foxes or goannas during the years of collection? Was there any differences between the 1960s and 1970s?** |
|---|
| Fox predation was not a big problem in the 1960s and 1970s. Only the odd nest would be destroyed by foxes. It is only recently that foxes have become a problem. John says only one out of every hundred nests would survive these days. John says that goanna predation was never recorded when he was collecting the eggs.<br><br>Since shooting stopped the foxes bred up. About 12 months ago, he and John Cann visited Armstong's and only found one nest. He says all the rest were destroyed by foxes. |
| **18. Were there signs of cattle trampling on nesting banks?** |
| No eggs were crushed by cattle trampling over nesting banks, however, they were a menace. They would access the water across banks and trample out all the tracks. Some of the nests laid along cattle tracks near banks would be displaced by cattle as they walked over them, but never were any eggs destroyed. |
| **19. Have any nesting banks been flooded by the barrage?** |
| There were a few banks around the Tiaro area (that are now flooded by the barrage). Most of these banks were not very productive and only a few nests were found each year. They got quite a few nests from the gravel pit (near Petrie Park), but this area has been flooded by the barrage.<br><br>There were no nesting banks downstream of where the barrage is now. |
| **20. Do you have any photographs of nesting banks and/or turtles nesting? If so, can we please have copies?** |
| No photographs taken. |

| **21. Do you know of anyone bringing turtles back to release in the river?** |
| --- |
| There may have been some people that released unwanted pet turtles back into the river, but John is unaware of any. |
| **22. Have you ever recorded any fish with baby turtles in the stomach?** |
| Never. |
| **Other comments** |
| John's interest in turtles was sparked when he visited his niece down south. She found a turtle nesting in her yard and told John about it. On his visit, John collected the eight eggs (packing them in an old beer carton filled with soil) and transported them back to his place. He put them in the ground to incubate and regularly checked them so he wouldn't loose any hatchlings when they hatched. These turtles were long necks with red underneath (*Chelodina longicollis*?). There was a lot of interest in these hatchlings and John thought to himself this would be a way of making money. So him and his son looked at maps of the Mary river and divided the river into day trips. They would have two vehicles, one at the start and one at the end.<br><br>John often saw turtles basking on logs and rocks. He believed that the only reason the researchers were unable to find them was because they were too noisy when approaching the river and they would scar all the basking turtles.<br><br>John never went diving for turtles or saw turtles nesting on banks. He would only ever see signs of turtles (eg tracks, basking).<br><br>John was aware that there were different species of turtles in the river. He finds it a mystery how he never got two of the types of turtles that John Cann caught.<br><br>John encountered crocs in the river. He was unsure whether they were freshwater or saltwater crocs, though remembers a really large croc around the Miva area (this is before the barrage was up).<br><br>John led Allen (the pet shop dealer) to believe that he had the breeders in his back yard, so as not to give away the location of where he was collecting the |

eggs.

John Cann caught his first *Elusor* at Armstrong's. He also caught another one from Miva.

John used a small punt with a 4hp motor to travel down the river. He put a false floor made from bond wood under the hull to protect it from rocks and rapids. He capsized a few times, loosing tools, knives and raincoats. He never capsized with a load of turtle eggs on board.

*Egg collection day trips:*

1. Bell's bridge to Scotchy Pocket
2. Scotchy Pocket to Miva (Dickabram bridge)
3. Miva to Gundiah
4. Gundia to Armstrong's
5. Armstrong's to Tiaro

## APPENDIX 2:

Table 1: Freshwater turtle dietary studies since 1968

| Year | Author/s | Species | Focus of study |
|---|---|---|---|
| 1968 | mahmoud | *Kinosternon subrubrum hippocrepis*<br>*K. flavescens flavescens*<br>*Sternothaerus odoratus*<br>*S. carinatus carinatus* | Feeding behaviour |
| 1969 | Clark & Gibbons | *Pseudemys scripta* | Dietary shift from carnivory to herbivory in first year of growth |
| 1975 | Berry | *Sternotherus minor*<br>*S. odoratus* | Resource partioning |
| 1976 | Legler | *Emydura spp.*<br>*Elseya dentata* | Feeding habits in short necked turtles |
| 1976 | Moll | *Graptemys pseudogeographica ouachitensis* | Diet and feeding strategies |
| 1978 | Chessman | *Chelodina expansa*<br>*C. longicollis*<br>*Emydura macquarii* | Seasonal and dial variation in foraging activity |
| 1980 | Parmenter | *Chrysemys scripta* | To identify preferred food types of turtles |
| 1981 | Vogt | *Graptemys geographica*<br>*G. ouachitensis*<br>*G. psuedogeographica* | Resource partitioning amongst three species |
| 1981 | Williams & Christiansen | *Trionyx muticus*<br>*T. spiniferus* | Niche overlap of two species |
| 1981 | Plummer & Farrer | *Trionyx muticus* | Dietary differences not related to size |
| 1982 | Georges | *Emydura krefftii* | Dietary shift – prey item size to body size |
| 1983 | Chessman | *Chelodina expansa* | Dietary analysis |
| 1983 | Hart | *Pseudemys scripta* | Relationship between diet and body size |
| 1984 | Chessman | *Chelodina longicollis* | Dietary differences amongst different habitats |
| 1985 | Sidis & Gasith | *Mauremys caspica rivulata* | Diet and feeding habits |
| 1986 | Chessman | *Emydura macquarii* | Diet and dial feeding variation |
| 1986 | Georges *et al.* | *Chelodina longicollis* | Geographic distribution |
| 1988 | Vogt & Guzman | *Kinosternon leucostomum*<br>*Stauroypus triporcatus*<br>*Trachemys scripta* | Resource partitioning amongst three species |
| 1989 | Geoges & Kennett | *Carettochelys insculpta* | General study on pig-nosed turtles |
| 1989 | Moll | *Dermatemys mawei* | Diet |
| 1990 | Heapht | *Carettochelys insculpta* | Foraging ecology |
| 1990 | Moll | *Trachemys scripta*<br>*Kinosternon scorpioides*<br>*K. leucostomum* | Resources partitioning amongst three species |
| 1991 | Bjorndal | *Trachemys scripta* | Diet mixing in an omnivorous species |
| 1993 | Bjorndal & Bolten | *Pseudemys nelsoni*<br>*Trachemys scripta scripta* | Digestive efficiencies in herbivores and omnivores |
| 1995 | Tucker *et al.* | *Malaclemys terrapin* | Resource partitioning amongst sub-groups of a species |
| 1996 | Kennett & Tory | *Chelodina rugosa*<br>*Elseya dentata* | Diet analysis |
| 1997 | Perez-Eman & Paolillo O | *Peltocephalus dumerilianus* | Diet |
| 1998 | Spencer *et al.* | *Emydura macquarii* | Diet and digestive energetics |
| 1999 | Allanson & Georges | *Elseya purvisi*<br>*Elseya georgesi* | Diet |
| 1999 | McCauley & Bjorndal | *Trachemys scripta elegans* | Dietary dilution; implications of ontogenetic dietary shifts |

Table 2: Bomb calorimetry results for plant tissue; Date:2/9/99; calibration standard: benzoic acid 26442 J/g; I unit = 257.048J (Wick:1 unit) (Tucker *et al.*, 1999)

| Sample Type | Sample No. | Mass (g) | Heat Units | Energy (J) in sample | J/g |
|---|---|---|---|---|---|
| Small fig (Ficus) | 1 | 0.1019 | 8.30 | 2133.5 | 20937 |
| | 2 | 0.1313 | 10.67 | 2742.7 | 20888 |
| | 3 | 0.1332 | 10.00 | 2570.5 | 19298 |
| | | | | **average** | **20374** |
| Large fig (Ficus) | 1 | 0.1095 | 7.82 | 2010.0 | 18356 |
| | 2 | 0.1293 | 11.00 | 2827.5 | 19027 |
| | 3 | 0.1095 | 9.90 | 2544.8 | 19773 |
| | | | | **average** | **19052** |
| Eucalyptus seed/pod | 1 | 0.1225 | 9.36 | 2406.0 | 19641 |
| | 2 | 0.1398 | 11.24 | 2889.2 | 20666 |
| | 3 | 0.1291 | 10.00 | 2570.5 | 19911 |
| | | | | **average** | **20073** |
| Eucalyptus leaves | 1 | 0.1419 | 12.67 | 3256.8 | 22951 |
| | 2 | 0.1444 | 13.00 | 3341.6 | 23192 |
| | 3 | 0.1293 | 11.24 | 2889.2 | 22345 |
| | | | | **average** | **22829** |
| Un-ripe berries | 1 | 0.1345 | 10.73 | 2758.1 | 20506 |
| | 2 | 0.1065 | 8.51 | 2187.5 | 20540 |
| | 3 | 0.1229 | 9.36 | 2406.0 | 19577 |
| | | | | **average** | **20207** |
| Ripe berries | 1 | 0.1407 | 11.10 | 2853.2 | 20729 |
| *average corrected to allow | 2 | 0.1243 | 9.90 | 2554.8 | 20473 |
| for oil leeched out of sample | 3 | 0.2058 | 16.40 | 4215.6 | 20434 |
| | | | | **Average** | ***22546** |
| Hornwort | 1 | 0.1171 | 4.70 | 1208.13 | 10317 |
| Moderate amount of non- | 2 | 0.0917 | 2.65 | 681.18 | 7428 |
| Combustible material | 3 | 0.1112 | 4.10 | 1053.9 | 9477 |
| | 4 | 0.1091 | 4.40 | 1131.0 | 10366 |
| | 5 | 0.1261 | 5.40 | 1388.0 | 11007 |
| | | | | **average** | **10292** |
| Vallisneria | 1 | 0.1102 | 6.0 | 1542.3 | 13995 |
| NC 0.0153g 13.9% | | | | | |
| 0.0111g 9.8% | 2 | 0.1128 | 7.0 | 1799.3 | 15951 |
| 0.0176g 14.1% | 3 | 0.1251 | 7.0 | 1799.3 | 14383 |
| | | | | **average** | **14776** |
| Elodea | 1 | 0.1115 | 5.24 | 1346.9 | 12080 |
| NC 0.0299 26.8% | | | | | |
| 0.0287 26.8% | 2 | 0.1072 | 5.18 | 1331.4 | 12420 |
| 0.0350 25.5% | 3 | 0.1374 | 6.65 | 1709.4 | 12441 |
| | | | | **average** | **12314** |
| Algae | 1 | 0.1070 | 8.62 | 2215.8 | 20708 |
| NC 0.0072 6.7% | | | | | |
| 0.0155 12.6% | 2 | 0.1234 | 7.87 | 2023.0 | 16394 |
| 0.0170 11.4% | 3 | 0.1487 | 11.0 | 2827.5 | 19015 |
| | | | | **average** | **19015** |
| Sponge | 1 | 0.1691 | 5.0 | **1285.2** | **7600** |
| NC 0.0990 58.5% | | | | | |
| 0.1488 58.8% | 2 | 0.2530 | 9.51 | **2445.5** | **9662** |
| 0.1042 56.5% | 3 | 0.1843 | 6.31 | **1692.0** | **9181** |
| | | | | average | 8814 |
| | | | | | |
| Plain white copying paper | | 0.1038 | 6.8 | **1747.9** | **16839** |

NC = mass and percent of sample that was non-combustible. NC portion of hornwort, Vallisneria, algae and elodea appeared to be siliceous, whereas NC portion of sponge was pollibly silica or calcium. Spicules might also be proteinaceous.

## APPENDIX 3

Approximate hours sampled for freshwater turtles in the Mary River and tributaries.

| Capture Method | Date | Approx. Hours Sampled | Number of turtle caught | Catch/Hour Sampled |
|---|---|---|---|---|
| Snorkelling | 04.08.97 | 3 | 12 | 4 |
| Snorkelling/Trapping | 09.08.97 | 7 | 0 | 0 |
| Snorkelling | 10.08.97 | 0.5 | 0 | 0 |
| Snorkelling/Seining | 12.08.97 | 3 | 5 | 1.67 |
| Snorkelling | 13.08.97 | 0.5 | 0 | 0 |
| Snorkelling/Trapping | 23.08.97 | 2.5 | 0 | 0 |
| Snorkelling | 24.08.97 | 4 | 11 | 2.75 |
| Snorkelling | 29.08.97 | 0.5 | 1 | 2 |
| Snorkelling | 30.08.97 | 2 | 21 | 10.5 |
| Snorkelling | 04.09.97 | 6 | 4 | 0.67 |
| Snorkelling | 05.09.97 | 2 | 7(1 Dead) | 3.5 |
| Snorkelling/Trapping | 20.09.97 | 3.5 | 11 | 3.14 |
| Snorkelling | 21.09.97 | 4 | 6 | 1.5 |
| Snorkelling | 22.09.97 | 4 | 5 | 1.25 |
| Snorkelling | 28.09.97 | 1 | 12 (1 Dead) | 12 |
| Snorkelling | 30.09.97 | 4 | 8 | 2 |
| On Bank | 01.10.97 | - | 1 (Dead) | - |
| Snorkelling | 07.10.97 | 0.5 | 1 | 2 |
| On Bank | 10.10.97 | - | 1 (Dead) | - |
| Snorkelling | 11.10.97 | 1 | 2 | 2 |
| Snorkelling | 16.10.97 | 0.5 | 1 | 2 |
| Snorkelling | 18.10.97 | 0.5 | 0 | 0 |
| Trapping | 19.10.97 | 6 | 0 | 0 |
| On Bank (nesting) | 20.10.97 | 5 | 2 | 0.4 |
| Snorkelling/Trapping | 28.10.97 | 2.5 | 6 | 2.4 |
| Snorkelling | 29.10.97 | 1.5 | 4 | 2.67 |
| On Bank (nesting) | 05.11.97 | 4 | 1 | 0.25 |
| Snorkelling | 08.12.97 | 4.5 | 4 | 0.89 |
| Snorkelling/Trapping | 09.12.97 | 5.5 | 3 | 0.55 |
| Seining | 21.12.97 | 5 | 82 | 16.4 |
| Snorkelling | 23.12.97 | 2 | 6 | 3 |
| Snorkelling | 28.12.97 | 4 | 10 | 2.5 |
| Snorkelling | 02.01.98 | 3 | 36 | 12 |

| Capture Method | Date | Approx. Hours Sampled | Number of turtle caught | Catch/Hour Sampled |
|---|---|---|---|---|
| Snorkelling | 08.01.98 | 3 | 63 | 21 |
| Snorkelling | 11.01.98 | 1 | 7 | 7 |
| Seining/Trapping | 20.01.98 | 8 | 17 | 2.13 |
| Snorkelling | 02.02.98 | 0.5 | 1 | 2 |
| Basking | 19.02.98 | 0.25 | 1 | 4 |
| Snorkelling | 28.03.98 | 4.5 | 11 | 2.44 |
| Trapping | 10.04.98 | 4.5 | 4 | 0.89 |
| Seining | 09.05.98 | 4 | 1 | 0.25 |
| Dip netting | 10.05.98 | 0.25 | 1 | 4 |
| Trapping | 28.05.98 | 3 | 2 | 0.67 |
| Snorkelling | 01.07.98 | 0.5 | 0 | 0 |
| Snorkelling | 02.07.98 | 0.5 | 3 | 6 |
| Snorkelling | 07.07.98 | 4.5 | 20 | 4.44 |
| Snorkelling | 08.07.98 | 3.5 | 11 | 3.14 |
| Snorkelling | 09.07.98 | 2.5 | 1 | 0.4 |
| Snorkelling | 13.07.98 | 3.5 | 5 | 1.42 |
| Snorkelling | 14.07.98 | 2 | 15 | 7.5 |
| Snorkelling | 16.07.98 | 0.5 | 1 | 2 |
| Snorkelling | 23.08.98 | 3.75 | 16 | 4.27 |
| Snorkelling | 29.08.98 | 5 | 18 | 3.6 |
| Snorkelling | 03.09.98 | 6 | 34 | 5.67 |
| Snorkelling | 04.09.98 | 4.5 | 51 | 11.3 |
| Snorkelling | 09.09.98 | 3 | 73 | 24.3 |
| Snorkelling | 11.09.98 | 2 | 2 | 1 |
| On Bank | 20.10.98 | - | 1 (Dead) | - |
| On Bank | 25.10.98 | - | 1(Dead) | - |
| On Bank (nesting) | 31.10.98 | 6 | 1 | 0.17 |
| Snorkelling | 04.12.98 | 2.5 | 12 | 4.8 |
| Snorkelling | 05.12.98 | 5.5 | 10 | 1.82 |
| Snorkelling | 07.12.98 | 3.5 | 10 | 2.86 |
| Snorkelling | 09.12.98 | 2 | 9 | 4.5 |
| Snorkelling | 13.12.98 | 2 | 33 | 16.5 |
| Snorkelling | 14.12.98 | 1 | 9 | 9 |
| Trapping | 20.12.98 | 6 | 11 | 1.83 |
| Trapping | 29.12.98 | 6.5 | 2 | 0.31 |
| Trapping | 30.12.98 | 2.5 | 0 | 0 |
| Snorkelling | 31.12.98 | 3.5 | 8 | 2.3 |

| Capture Method | Date | Approx. Hours Sampled | Number of turtle caught | Catch/Hours Sampled |
|---|---|---|---|---|
| Trapping | 11.01.99 | 6 | 17 | 2.8 |
| Snorkelling | 21.01.99 | 3 | 11 | 3.67 |
| On bank | 15.10.99 | 3 | 1 (nesting) | 0.33 |
| Trapping | 17.11.99 | 3.5 | 6 | 1.71 |
| Trapping | 18.11.99 | 4.5 | 2 | 0.44 |
| Trapping | 14.01.00 | 4.5 | 12 | 2.6 |
| Snorkelling/Trapping | 22.09.00 | 12 | 16 | 1.33 |
| **TOTALS** | **65 days** | **241.25** | **789** | |