Australian Government
Department of Agriculture, Water and the Environment

# National Recovery Plan for the White-throated Snapping Turtle (*Elseya albagula*)

December 2020

**Image credits**

Front Cover:
White-throated snapping turtle (*Elseya albagula*) in the Connors River, Queensland (© Stephen Zozaya and Jason Schaffer)

The Species Profile and Threats Database pages linked to this recovery plan is obtainable from: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl.

# Table of contents

**Figures and tables** .... **4**

**Acronyms** .... **5**

**1 Summary** .... **6**

1.1 White-throated snapping turtle *(Elseya albagula)* .... 6

1.2 Habitat critical for survival .... 6

1.3 Recovery plan objectives .... 6

1.4 Recovery strategies .... 6

1.5 Criteria for success .... 6

1.6 Criteria for failure .... 7

**2 Introduction** .... **7**

2.1 About the recovery plan .... 7

2.2 Conservation status .... 8

**3 Background** .... **8**

3.1 Species description .... 8

3.2 Distribution .... 8

3.3 Population trends and dynamics .... 9

3.4 Biology and ecology .... 12

*3.4.1 Longevity .... 12*

*3.4.2 Genetics .... 12*

*3.4.3 Diet .... 12*

*3.4.4 Movement patterns .... 13*

*3.4.5 Life history and breeding .... 13*

*3.4.6 Habitat .... 14*

*3.4.7 Habitat critical to survival .... 17*

**4 Threats** .... **17**

4.1 Historical causes of decline .... 17

4.2 Current threatening processes .... 18

*4.2.1 Predation and trampling at nesting sites .... 18*

*4.2.2 In-stream barriers .... 18*

*4.2.3 Degradation of habitat and water quality .... 19*

*4.2.4 Climate change .... 20*

*4.2.5 Fishing and boating activities .... 20*

**5 Populations under particular pressure** .... **22**

**6 Objectives and strategies** .... **22**

**7 Actions to achieve the specific objectives** .... **23**

7.1 Strategy 1 – Substantially improve the recruitment of hatchlings and juveniles into the population .... 23

7.2 Strategy 2 – Decrease adult/subadult mortality and injury rates, and reduce barriers to movement along riverine habitats ........ 26

7.3 Strategy 3 – Improve stream flow and habitat quality throughout the species' distribution ........ 28

7.4 Strategy 4 – Increase public awareness and participation in conservation of the species and its habitat ........ 31

7.5 Strategy 5 – Improve the collation and availability of data to inform recovery actions ........ 32

**8 Duration and cost of the recovery process ........ 33**

**9 Current management practices ........ 34**

9.1 Commonwealth ........ 34

9.2 Queensland ........ 34

9.3 Offsets ........ 35

**10 Effects on other native species and biodiversity benefits ........ 36**

**11 Social and economic considerations ........ 37**

**12 Affected interests ........ 37**

**13 Consultation ........ 37**

**14 Organisations/persons involved in evaluating the performance of the plan ........ 38**

**15 References ........ 39**

# Figures and tables

Figure 1: Indicative distribution of the white-throated snapping turtle (Elseya albagula) ........ 11

Table 1: Threatening processes and their priority ........ 21

Table 2: Summary of high priority recovery actions and estimated per unit costings for the first five years of implementation ........ 33

# Acronyms

| | |
|---|---|
| AMTD | Adopted middle thread distance (km) from the river mouth |
| DAF | Department of Agriculture and Fisheries (Queensland) |
| DAWE | Department of Agriculture, Water and the Environment (Commonwealth) |
| DES | Department of Environment and Science (Queensland), |
| DNRM | Department of Natural Resources and Mines (Queensland) |
| EPBC Act | *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) |
| IBRA | Interim Biogeographic Regionalisation for Australia |
| IUCN | International Union for Conservation of Nature |
| MNES | Matters of National Environmental Significance |
| NRM | Natural resource management |
| RLP | Regional Land Partnerships |
| SPRAT | Species Profile and Threats Database (Commonwealth) |
| TAP | Threat Abatement Plan (Commonwealth) |
| QTC | Queensland Turtle Conservation |

# 1 Summary

## 1.1 White-throated snapping turtle *(Elseya albagula)*

| | |
|---|---|
| **Family:** | Chelidae |
| **IBRA Bioregions:** | South east Queensland, Brigalow Belt South, Brigalow Belt North, Central Mackay Coast |
| **Current status of taxon:** | *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth): Critically Endangered, Criterion 1 A3<br>*Nature Conservation Act 1992* (Queensland): Endangered |
| **Distribution and habitat:** | The white-throated snapping turtle occurs in the Fitzroy, Mary and Burnett Rivers and associated smaller drainages in south-eastern Queensland. It mostly inhabits sections of stream with permanent water and habitat features that provide shelter, such as undercut banks, overhanging riparian vegetation, moderate to high densities of submerged boulders and/or log jams, and macrophyte beds. |

## 1.2 Habitat critical for survival

Habitat critical to the survival of this taxon is defined as:

- Parts of riverine systems with permanent water, including pools, within the species' distribution that contain shelter and refuges (e.g. bank overhangs, overhanging riparian vegetation, macrophyte beds, moderate to high densities of submerged boulders and/or log jams).
- All currently known and new aggregated nesting sites (all nesting sites should be considered to be part of an aggregation unless it can be demonstrated otherwise).

## 1.3 Recovery plan objectives

The objectives of this recovery plan are to:

- ensure a self-sustaining healthy population structure in all catchments in which the white-throated snapping turtle occurs; and
- enhance the condition of habitat across the white-throated snapping turtle's range to maximise survival and reproductive success.

## 1.4 Recovery strategies

The strategies to achieve the plan's objectives are to:

- Substantially improve the recruitment of hatchlings and juveniles into the population;
- Decrease adult/subadult mortality and injury rates, and reduce barriers to movement along riverine habitats;
- Improve stream flow and habitat quality throughout the species' distribution;
- Increase public awareness and participation in conservation of the species and its habitat;
- Improve the collation and availability of data to inform recovery actions.

## 1.5 Criteria for success

This recovery plan will be deemed successful if, within ten years, all of the following have been achieved:

- Population structure has been regularly monitored throughout the species' distribution, and shows an increasing shift towards a younger population distribution.
- Hatching success in the wild population has substantially increased.
- The number of juveniles recruiting into the population throughout the turtle's distribution has substantially increased.
- Mortality rates of adults/subadults have decreased to a level comparable to natural mortality.
- Appropriate measures have been put in place to manage key threats to the species.
- Understanding of the biology and ecology of the species, including survivorship and habitat use, has increased.

### 1.6 Criteria for failure

This recovery plan will be deemed to have failed if, within ten years, any of the following have occurred:

- There has been no shift in population structure towards a younger population distribution.
- Hatching success in the wild population has not increased.
- The number of juveniles recruiting into the population has not increased.
- Mortality rates of adults/subadults have not decreased.
- There has been no overall improvement in habitat quality for the species across its distribution.
- Appropriate measures to manage key threats to the species have not been implemented.

# 2 Introduction

### 2.1 About the recovery plan

This document constitutes the 'National Recovery Plan for the White-throated Snapping Turtle (*Elseya albagula*)'. The plan considers the conservation requirements of the species across its range, identifies actions to be taken to ensure the species' long-term viability in nature, and identifies the parties responsible for undertaking those actions. The Minister determined that a national recovery plan was required as the species is subject to a number of threats across a broad distribution, and management of these threats would benefit from a coordinated approach.

Principal threats to the white-throated snapping turtle include: the loss of eggs and hatchlings due to predation and trampling; in-stream barriers which obstruct movement and result in injury and death during over-topping and water releases; degradation of habitat and water quality; climate change; and fishing and boating activities.

This recovery plan describes the threats to the white-throated snapping turtle that have caused its decline and led to its threatened status. It sets out the research and management actions necessary to stop the decline, and support the recovery, of the white-throated snapping turtle in Australia. The overall goal of this recovery plan is to achieve a wild population that has a high likelihood of persistence in nature, and to put in place long-term management arrangements that ensure a healthy population structure and healthy habitat for the white-throated snapping turtle.

To achieve this goal a range of strategies will be employed, including: improving the recruitment of hatchlings and juveniles into the population; minimising the incidence of adult mortality and injury above natural rates; improving stream flow and habitat quality; and increasing public awareness and participation in conservation actions for the species.

Species Profile and Threats Database (SPRAT) pages provide further information on the biology, population status and threats to white-throated snapping turtle. SPRAT pages are available from: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl.

## 2.2 Conservation status

The white-throated snapping turtle was listed as Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in November 2014. It is listed as Endangered under the Queensland *Nature Conservation Act 1992* and has not yet been assessed by the International Union for Conservation of Nature (IUCN).

The Threatened Species Scientific Committee recommended listing the species as Critically Endangered as it has experienced a severe loss of eggs due to predation and nest bank trampling, resulting in a recruitment rate to the breeding population of only 1% each year. In the absence of appropriate management, a very severe population reduction of over 90% was projected to occur over the next three generation period, due to recruitment failure and loss of the existing adult cohort (DotE, 2014).

# 3 Background

## 3.1 Species description

The white-throated snapping turtle is one of the largest short-necked freshwater turtles in Australia. It had previously been regarded as part of the more common and widely distributed northern snapping turtle *Elseya dentata*, but was formally described as a separate species in 2006 (Thomson et al., 2006). It is the largest extant species of snapping turtle (*Elseya* spp.), with carapace lengths of up to 42 cm long in females and up to 30 cm in males (adults in the Mary River are smaller on average than their respective counterparts in the Burnett and Fitzroy rivers; Limpus, 2008). Adults are heavily built, with a large, robust head. Adult females commonly have irregular white or cream markings on the sides and under surfaces of the head and neck. Males are easily distinguished from mature females by their much larger tail. Hatchlings and small juveniles have strongly serrated shell margins (Thomson et al., 2006).

The species is one of a number of freshwater turtles in Australia which can absorb oxygen from both the air and water (Clark et al., 2008). The ability to respire aquatically allows these species to extend their dive duration, which may reduce overall energy expenditure and reduce exposure to threats (particularly for juveniles) by reducing surfacing frequency (Mathie & Franklin, 2006; Storey et al., 2008; Fitzgibbon & Franklin, 2010). Aquatic respiration in the white-throated snapping turtle primarily occurs via active ventilation of the cloacal bursae (Fitzgibbon & Franklin, 2010). Adults may obtain up to 40–60% of their total oxygen requirements from aquatic respiration, but in hatchlings this may be up to 100%, with younger turtles having a higher reliance on aquatic respiration than adults (Mathie & Franklin, 2006; FitzGibbon & Franklin, 2010). The greater ability of small/young turtles to utilise aquatic respiration is likely attributable to their higher mass-specific cloacal bursae surface area (Mathie & Franklin, 2006).

## 3.2 Distribution

The white-throated snapping turtle is endemic to the Fitzroy, Mary and Burnett Rivers, and associated smaller drainages, in south-eastern Queensland (Figure 1). It occurs across approximately 3300 km of riverine habitat: Fitzroy Catchment (~2,150 km), Burnett Catchment (~700 km) and Mary Catchment (<500 km) (Hamann et al., 2007). Its area of occupancy is estimated to be less than 500 $km^2$ (DotE, 2014). Adults are widespread and abundant within all three of these catchments, but immature turtles are poorly represented within populations.

Genetic analysis has shown that populations within catchments are well connected genetically. However,the Fitzroy Catchment contains a genetic lineage distinct from the Burnett and Mary catchments, reflecting the historical isolation of the Fitzroy and recent coalescence of the Burnett-Mary catchments during lowered sea levels in the Pleistocene (Todd et al., 2013a).

There are numerous areas within each catchment where the species is abundant. All areas with high abundance/densities represent important populations, as threats impacting them could result in high losses. These populations should therefore be given particular attention when assessing threats to the species. Any area of high quality habitat with the potential to support high numbers of the species should also be surveyed when assessing threats to populations in the area.

Populations and habitat within the species' distribution have been fragmented by the construction of multiple dam and weir structures. These structures have obstructed the upstream movement of turtles, and converted flowing stream reaches into impoundments that may have deeper, slower or more variable water levels compared to unmodified reaches. In the Burnett River, natural flowing stream reaches lie between the upper limit of brackish water at Ben Anderson Barrage (Adopted middle thread distance (km) from the river mouth [AMTD] 25.9) and the upper end of John Goleby Weir (AMTD 333.8). This habitat has been fragmented into six sections ranging from 7 km to 47 km in length (Hamann et al., 2007). Adults have been observed unsuccessfully attempting to climb Ned Churchward Weir (AMTD 74.5) from the downstream side (Limpus et al., 2011b). However, as individuals can be abundant in and successfully breed from impoundment areas, and some may move over or around such infrastructure, the species' distribution is not considered severely fragmented (DotE, 2014).

## 3.3 Population trends and dynamics

The numbers of individuals in each of the three catchments within the species' distribution are unknown. However, population trends can be inferred from the age structure of the population. Sampling at multiple sites in each catchment has demonstrated that there is generally a paucity of immature (juvenile) turtles in the population.

In the Fitzroy Catchment, Limpus et al. (2011, 2012) found a lack of immature turtles at sites sampled across the catchment, with the population primarily composed of ageing adults. The survey methods deployed captured turtles down to a straight carapace length of 7 cm and included snorkelling, dip netting, seine netting, trapping and muddling (hand searching) (Limpus et al., 2011b). Immature turtles comprised 15% of the 363 turtles recorded, ranging from 2% to 28% of the sample at each site. In a sample of 124 adult females that underwent gonad examination, only one first-time breeding female was identified as a new recruit into the breeding population (Limpus et al., 2011b).

In the Burnett Catchment, Hamann et al. (2007) also found a distinct paucity of immature and pubescent animals in the population. Sampling was undertaken in the Burnett River using snorkelling, dip netting, seine netting and trapping (with snorkelling and dip netting found to be the most effective survey methods). Of the 283 turtles recorded, immature turtles represented 4% of the males and 8% of the females, indicating low recruitment of immature turtles to adulthood (Hamann et al., 2007).

In the Mary Catchment, Limpus (2008) undertook a review of previous studies which employed various sampling methods including snorkelling, trapping, seine netting and muddling. The studies indicated a general paucity of juveniles across the catchment, with immature turtles comprising 18% of the 456 turtles recorded. The paucity was greatest in the lower reaches of the catchment, with the proportion of juveniles at each site progressively increasing with distance upstream (from 2% at the Mary Barrage to 35% downstream of Borumba Dam). This pattern could possibly be the result of decreasing mortality of eggs in the upper reaches of the catchment, where farm management may be reducing dog, fox and pig activity (Limpus, 2008).

Also in the Mary Catchment, Ecotone Environmental Services (2007) undertook snorkelling surveys as part of a survey for the proposed Traveston Dam. Age/sex class data collected in the downstream reaches indicated a severe paucity of juveniles; in the Gundiah reach the frequency of juveniles (0.3 individuals per km) was substantially lower than that of adult females (9.4) and adult males (5.1), while in the Netherby reach no juveniles were recorded. Further upstream in the below Traveston Crossing reach, field notes indicated that the three age/sex classes were all well represented, with juveniles accounting for over 75% of the individuals recorded with a frequency of 4.5 individuals per km.

Despite some sites having a good representation of juveniles/immature turtles, analysis of the data indicates a substantial failure to recruit new adults into the breeding population generally in each catchment (Limpus, 2009):

- Fitzroy: 0.5% of adults are new recruits to the breeding population (211 adult females examined);
- Burnett: 0.9% of adults are new recruits to the breeding population (an additional 0.9% of the adults were identified to be in their second breeding season) (331 adult females examined);
- Mary: 1.1% of adults are new recruits to the breeding population (175 adult females examined).

Overall, studies indicate that the present wild population is composed primarily of aging adults in each catchment. Given that this is a slow growing species estimated to reach maturity at about 15–20 years, the population structure indicates that excessive egg loss has been operating on these populations for at least 20 years (Limpus, 2008). Abundant evidence of nesting can be found in all three catchments, but almost 100% of eggs are predated or lost to trampling by stock, with none or very few hatchlings recorded in surveys and most nests showing evidence of predation (Hamann et al., 2007; Limpus, 2008; Limpus et al., 2011b). Additionally, survival rates of hatchlings are low (Hamann et al., 2007). These threats have likely led to a severe reduction in the adult population, which will continue in the future if recruitment failure is not addressed.

The population growth rate (or decline rate) in many freshwater turtles has been shown to be more responsive to changes in adult survivorship than proportional changes in egg or juvenile survivorship, as once adulthood is reached there are a potentially large number of breeding episodes (Heppell et al., 1996; Heppell 1998; Blamires et al., 2005; Spencer & Thompson, 2005). However, this tendency is overwhelmed by the high rates of nest predation experienced by the white-throated snapping turtle, and the population will crash if this threat is not addressed. Given its life history, a viable turtle population would be expected to have relatively high proportions of juveniles (Thompson, 1983). Hatchling and juvenile survivorship are important to population stability (Heppell, 1998; Blamires & Spencer, 2013) and in this case the loss of eggs is extreme. Nevertheless, because of the sensitivity of population growth to adult survival rates (and the known anthropogenic causes of additional mortality) it remains important to address sources of mortality across all life stages; a turtle species may quickly be decimated if there is depressed juvenile recruitment and increased adult mortality (Brooks et al., 1991).

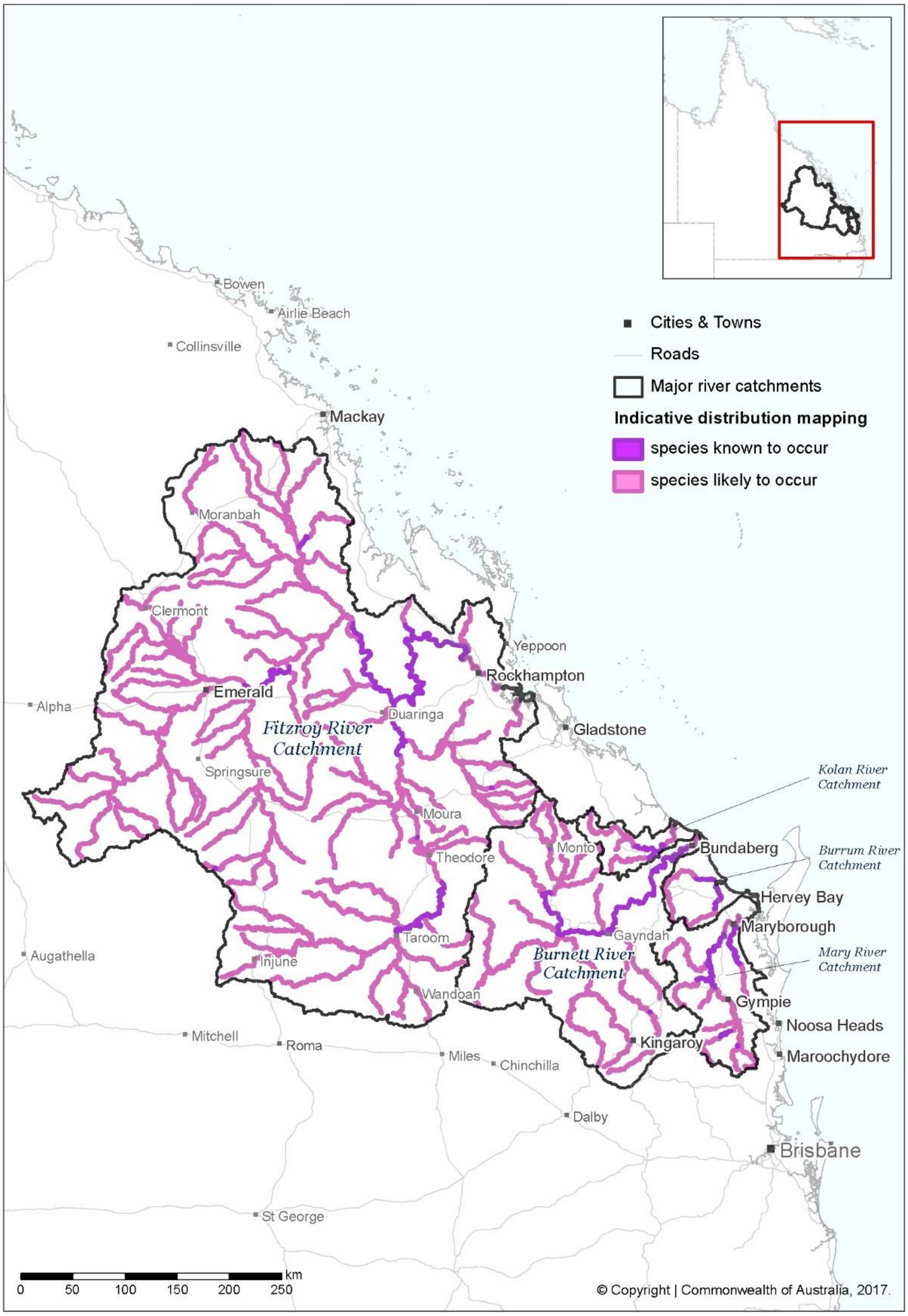


***Figure 1: Indicative distribution of the white-throated snapping turtle (Elseya albagula)*** *(Source: Environmental Resources Information Network (2018). Department of the Environment and Energy, Commonwealth of Australia, Canberra.)*

## 3.4 Biology and ecology

### *3.4.1 Longevity*

The life expectancy of the white-throated snapping turtle is unknown. However, the species is thought to reach maturity at around 15–20 years of age (Tucker 2000; Flakus 2002; Hamann et al., 2004; Limpus 2008).

### *3.4.2 Genetics*

Genetic analysis of the white-throated snapping turtle has found that there are two evolutionarily significant units (Fitzroy River basin and the Burnett/Mary River basins) (Todd et al., 2013).

### *3.4.3 Diet*

The white-throated snapping turtle is a benthic foraging species with a broad diet. Studies based on the analysis of stomach contents and faecal matter suggest that adults are primarily herbivorous, with a diet comprised of the fruit and buds of riparian vegetation that fall on the water (such as *Livistona, Ficus*, *Syzygium, Celtis chinensis* and *Castanospermum australe*), leaves and stems of terrestrial plants, tree roots, filamentous algae (including *Mougeotia* and *Spirogyra*), and instream macrophytes (such as *Vallisneria*, *Schoenoplectus* and *Nitella*) (Rogers, 2000; Armstrong & Booth, 2005; Thomson et al., 2006; Limpus et al., 2011b). It appears to change its diet from being largely carnivorous (feeding on benthic invertebrates) when young, to largely herbivorous as it gets older, with juveniles consuming plant material when carapace length reaches about 6 cm (Limpus, 2008; Limpus et al., 2011b). Animal material forms a small part of the diet of adults and includes freshwater sponges, carrion, cane toads and insect larvae (Thomson et al., 2006; Hamann et al., 2007). A strong correlation between turtle size (carapace length) and the proportion of plant material in the diet has been observed (Limpus, 2008).

In contrast to the above studies, however, stable isotope analysis found that adult females primarily feed on filamentous algae and crustaceans obtained from the muddy and vegetated shallow margins of deep water pools (Micheli-Campbell et al., 2017). This discrepancy with previous studies may be a result of examining dietary preference and habitat utilisation over a broad timescale (12 months), as opposed to single point-in-time observations (Micheli-Campbell et al., 2017). The study also showed that most dives were shallow (1-2 m in depth), and that home ranges centred on slow moving sections of river instead of riffles, which were previously thought to be important habitat and a source of abundant food for the species (Hamann et al., 2007; Limpus et al., 2011b).

The availability of within-river food resources is highly variable both seasonally and annually. Extended dry periods can result in the near total removal of extensive and dense macrophyte beds (Hamann et al., 2007; Limpus et al., 2011a), and floods can scour the river substrate, removing aquatic vegetation and invertebrate fauna (Limpus et al., 2002). Under adverse environmental conditions there may be insufficient food resources for reproduction. In areas of the Fitzroy River Basin where aquatic macrophytes were absent following prolonged drought, females were found to resorb the yolky developing/mature follicles instead of producing eggs, most likely because these served as an alternative nutrient supply (Limpus et al., 2011b). Filamentous algae, which regrow quickly, may be the only readily available food for the white-throated snapping turtle following flood events, although the species has also been observed foraging on submerged grass on inundated banks during flood conditions (Hamann et al., 2007).

The diet of the white-throated snapping turtle appears to differ significantly between impounded and non-impounded areas. Tucker et al. (2012) found that significantly different plant species were consumed between the two habitat types, and that windfall fruits and insects made up a greater proportion of the diet in impoundments compared to non-impounded areas.

Further research is required to clarify dietary sources and preferences in response to changing food availability in response to droughts and floods, particularly over different life stages, of the white-throated snapping turtle.

### 3.4.4 *Movement patterns*

The species has relatively small home ranges, commonly utilising stream lengths of less than 1 km (Hamann et al., 2007; Micheli-Campbell et al., 2017). Isolated long distance movements of up to 10 km have been recorded, with these larger movements potentially exceeding the length of the flowing stream fragments between dam and weir impoundments (Hamann et al., 2007). The species does not appear to have a home range that has separate breeding and non-breeding zones (Hamann et al., 2007), and does not appear to migrate to nest, with females nesting locally (Micheli-Campbell et al., 2017). However, more recent unpublished data within the Queensland Turtle Conservation (QTC) freshwater turtle database has recapture records of tagged individuals in the Burnett River moving upstream from below the Ned Churchward Weir for ~60 km to the downstream side of Paradise Dam (movement further upstream being prevented by the Paradise Dam wall), and records of downstream movements of gravid females from within Paradise Dam falling over the wall when it is not over-topping as they headed towards a “traditional nesting area” ~1 km downstream of the wall (Limpus pers. comm., 2018).

Dive times recorded for adult individuals are among the longest recorded for a diving vertebrate (Hamann et al., 2007). Under natural conditions, individuals undertake deep resting dives during the day before moving into shallower depths for the night (Gordos et al., 2007; Hamann et al., 2007).

The turtle is more active around dusk and dawn (as indicated by elevated surfacing frequencies), which is possibly associated with foraging (Gordos et al., 2007; Hamann et al., 2007). Tracking studies showed a frequent entry into shallow rapids habitat between adjacent deeper pools near dawn and dusk (Hamann et. al., 2007). Decreases in depth at night may be associated with foraging, given that the preferred diet (i.e. *Vallisneria*, filamentous algae and wind-fallen fruit) is generally restricted to shallow environments (Gordos et al., 2007). However, the importance of shallow habitats to the ecology of the white-throated snapping-turtle is unknown (Gordos et al., 2007). Movements between different depths may also occur in response to seasonal conditions, e.g. during dry periods the turtles move into deeper pools which function as dry season refugia (Limpus et al., 2011b).

### 3.4.5 *Life history and breeding*

The white-throated snapping turtle is slow growing, with adults growing at less than 0.5 cm per year (Hamann et al., 2007). It appears to reach sexual maturity at a relatively large size, with minimum sizes at maturity being 33.1 cm for females and 19.2 cm for males (Hamann et al., 2007). Age at first breeding is approximately 15–20 years (Tucker 2000; Flakus 2002; Hamann et al., 2004; Limpus, 2008).

Most adult females will breed in each successive year, unless the turtle has been injured or debilitated, or the riverine habitat has been severely depleted through severe drought or excessive water extraction. A single clutch of eggs is laid per annual breeding season, which varies from about 5 to 18 eggs per clutch, with an average of 14 per clutch (Hamann et al., 2007; Limpus, 2008; Limpus et al., 2011b). Eggs are laid in shallow nests typically 18−25 cm deep, in a range of soil types from bare sand to dark clay/loam (Hamann et al., 2007). While most nesting occurs on alluvial sand-loam banks deposited by floodwaters, nesting can also occur on well grassed loam slopes adjacent to the river (Limpus, 2008). Nests may be anywhere from 1 m to 65 m from the water’s edge and 0.8−8 m above the water level, however many nests are laid at the top of steep slopes within 20 m of the water’s edge (Hamann et al., 2007).

Breeding occurs during the dry season, when many individuals do not necessarily have access to flowing water habitat with its higher quality food availability (Limpus et al., 2011b). Breeding during periods of low and relatively stable stream flows may be advantageous, as this is when nesting habitats are least likely to be scoured out or flooded (Bunn & Arthington, 2002). The eggs employ embryonic diapause which continues after the eggs are laid, with resulting delays in embryonic development so that hatching occurs during the wet season (in spring and summer) when conditions are optimal for food resources and dispersal (Hamann et al., 2007).

The species aggregates at certain sites to nest, and may nest in the same general area of a riverbank across a decade or more (Hamann et al., 2007; Limpus et al., 2011b). Compared to most other freshwater turtles, it has an extended nesting season of around 7 months (Hamann et al., 2007). In the Fitzroy Catchment, the species aggregates to breed during May-December (Limpus et al., 2011b). In the Burnett Catchment, nesting occurs from Autumn to Spring (May-September), with hatching occurring during Spring and Summer (Thomson et al., 2006; Hamann et al., 2007). In the Mary Catchment, nesting occurs in Autumn and Winter, with aggregations recorded during April-May and most clutches deposited during May-June (Limpus, 2008).

Survivorship of adult turtles is high, while that of small juveniles is low (Blamires et al., 2005; Hamann et al., 2007). There are no estimates for the survivorship of hatchlings or small juveniles across the species' distribution. However, the Murray River turtle (*Emydura macquarri*) in Victoria, which also has high rates of nest predation and for which long-term (>20 years) data are available, has an estimated minimum first year survival rate of 0.12 and an annual juvenile survival rate of 0.69 (Spencer & Thompson, 2005). Iverson (1991), in a survey across a range of freshwater turtle species outside Australia, estimated an average survivorship across those species of approximately 0.2 per year for hatchlings up to one year of age, and approximately 0.8 per year for adults.

The low survivorship of hatchlings and small juveniles is probably largely due to predation. Micheli-Campbell et al. (2013) recorded 50% predation of tagged juvenile Mary River turtles (*Elusor macrurus*), a species that utilises the same habitat as the white-throated snapping turtle in the Mary River. Twelve juveniles were tagged at 5–16 months of age, over a 9 month tagging period. It was inferred from turtle movements that half the predators were likely fish (e.g. freshwater eel, Mary River cod, fork-tailed catfish, sooty grunter) and the other half likely birds or mammals (e.g. white-bellied sea eagle, water rat). Blamires and Spencer (2013), in a study on the Bellinger River snapping turtle (*Myuchelys georgesi*) in NSW, found hatchlings and juvenile turtles in the stomachs of catfish, particularly in larger catfish (>400 mm in length) where they were the most abundant item. Population viability analysis showed that shallow water increased the exposure of hatchlings and juvenile turtles to fish predation, which may cause the population to substantially decline (Blamires & Spencer, 2013).

#### *3.4.6 Habitat*

*Water quality and stream flow*

Habitat preferences of the white-throated snapping turtle are somewhat unclear. The species is considered by some to be a habitat specialist (Todd et al., 2013) and to prefer clear, flowing, well-oxygenated waters (Hamann et al., 2007). This preference is associated with its physiological adaptation to extract oxygen from water via cloacal (aquatic) respiration (Mathie & Franklin, 2006; Clark et al., 2008). A study on the cloacally-respiring turtle *Elseya irwini* (Irwin's turtle), which has a similar reliance on aquatic respiration to *Elseya albagula*, demonstrated that increased suspended-sediment concentrations affected its utilisation of dissolved oxygen, and significantly reduced diving duration and increased surfacing frequency (Schaffer et al., 2015). Decreased diving duration may expose turtles to increased predation, and decreased water quality is likely to have a greater impact on the survival of hatchlings and juveniles than adult turtles (Mathie & Franklin, 2006; Clarke et al., 2008). Storey et al. (2008) found that the average dive length of juvenile white-throated snapping turtles doubled as water depth increased from 50 to 150 cm, which may enable them to conserve energy via reduced surfacing, and decrease predation risk.

Clear, well-oxygenated waters are considered more important in winter (the dry season), when bimodally respiring freshwater turtles switch from being obligate air breathers to facultative air breathers, which likely enables them to conserve energy through extended periods of inactivity in refugia (deep pools) (Gordos et al., 2003; Fielder, 2012).

However, the white-throated snapping turtle has been observed to inhabit both clear and turbid waters, and sections of stream with varying flow rates and depths (Limpus et al., 2011b; Hamann et al., 2007). It occurs in abundance in the upstream reaches of the Fitzroy River Barrage (Hamann et al., 2007), which are chronically turbid (Schaffer pers. comm., 2015). In the Burnett River it has been found in both shallow flowing pools less than 1 m deep, and deeper, slow flowing, well-oxygenated pools at least 6 m deep (Gordos et al., 2007; Hamann et al., 2007). All of the individuals caught during sampling in the area of the Burnett River prior to construction of Walla Weir were from 2−6 m deep sections of the river, with individuals foraging or resting at the bottom of the stream when first encountered (Limpus et al., 2002). In the mid-upper reaches of the Mary River, individuals tended to be concentrated along the periphery of streams and to prefer shallow waters less than 2 m deep, but utilised any depth of water with good log cover or bank overhangs (Ecotone Environmental Services, 2007).

Based on distribution records in the Fitzroy catchment (Limpus et al., 2011b), the species appears to be suited to the aerobic margins of large slow-flowing reaches and large non-flowing pools. It has been recorded in many impoundments throughout its distribution, including:

- Fitzroy catchment: Fitzroy River Barrage, Glebe Weir, Eden Bann Weir and Emerald Town Weir (Hamann et al., 2007; Limpus et al., 2011b).
- Burnett catchment: Bingera Weir, Wuruma Dam, Kolan Barrage, Ben Anderson Barrage and Ned Churchward Weir (Hamann et al., 2007).
- Mary catchment: Mary River Barrage, Imbil Weir, Borumba Dam and Tallegalla Weir (Limpus, 2008).

Nevertheless, the species is unlikely to function well in the deeper habitats of larger pools if the pools have very low dissolved oxygen levels, especially under dry season conditions in standing water bodies (Limpus, 2008). Larger, deeper impoundments are associated with lower oxygen saturation, particularly at the bottom of the water column (Tucker et al., 2012), but the shallow upper reaches of impoundments are suitable for the species.

Although not a riffle specialist, some studies have indicated that the white-throated snapping-turtle prefers well-oxygenated reaches of calm water near riffle zones (Storey et al., 2008). In trapping surveys in the Burnett River, the species was often found in relatively deep pools in close proximity to riffle zones, or in shallow waters adjacent to the bank or within riffle zones (Hamann et. al., 2007). However, subsequent studies have shown that nesting is most abundant within the Ben Anderson Barrage with no association with riffle zones (McDougall et al., 2015). Capture records from the Mary and Fitzroy catchments indicate that the species is regularly associated with submerged log entanglements during the day and shallow riffle zones at night (Hamann et. al., 2007). In a survey of nesting locations in the lower Fitzroy catchment, the majority of white-throated snapping turtle tracks and nests were located on sand banks in close proximity to riffle zones (Tracey, 2017). However, records from the Queensland Turtle Conservation database does not support this conclusion (Limpus, pers. comm. 2018).

In the mid-upper reaches of the Mary River, stable isotope analysis revealed that home ranges of adult females of the species were centred on slow moving sections of river instead of riffles (Micheli-Campbell et al., 2017). During active searches, the species was most commonly observed in glides and shallow pools, particularly where high densities of submerged logs persisted (Ecotone Environmental Services, 2007). The presence of riffles did not appear to be a determinant of the occurrence of the species, although still water and eddies within and around riffle zones were utilized (Ecotone Environmental Services, 2007).

*Permanent and ephemeral water*

The species has been recorded almost exclusively in reaches of streams with permanent water. It has not been recorded where there are no permanent pools during the dry season and has not been recorded inhabiting ephemeral water bodies away from main watercourses, indicating that it has a limited capacity to cross dry paddocks or follow dry streambeds for extended distances. It does not appear to permanently inhabit brackish waters, and its dispersal between rivers via the ocean appears to be limited (Hamann et al., 2007).

*Microhabitat*

The white-throated snapping turtle exhibits a strong preference for sections of stream characterised by steep undercut banks (bank overhangs), areas of overhanging riparian vegetation providing heavy shade, and moderate to high densities of submerged boulders and/or log jams that are used for shelter (Hamann et al., 2007; Ecotone Environmental Services, 2007). It is also often found in areas with moderate to high cover of macrophytes, although macrophyte abundance and distribution is highly variable and dependent on water levels and flow rates (Hamann et al., 2007; Ecotone Environmental Services, 2007), and individuals have been found in areas without macrophytes (Limpus et al., 2002).

The species is rarely found in reaches without suitable refuges. However, it does occur in abundance in the upstream reaches of the Fitzroy River Barrage, which is not associated with habitat features such as rocks, logs and undercut banks (Hamann et al., 2007). In the Mary River, a number of juveniles were located in shallow water less than 1 m deep where there was typically no log cover available, however these locations always had macrophyte beds (Ecotone Environmental Services, 2007).

*Nesting sites*

Almost all nesting occurs on alluvial sand–loam banks deposited by floodwaters, which are often reworked with each significant flooding event (Limpus, 2008). Nests may occur in loose or compact soils, under a closed canopy or with less than 50% canopy cover, with either a dense covering of grasses or with low or no vegetation (Hamann et al., 2007; Limpus et al., 2011b).

In the Fitzroy Catchment, nests have been constructed on average around 17 m (with a range of 1−86 m) from the water's edge (Limpus et al., 2011b). Nests are shallow, with a mean depth of 23 cm, and most nesting occurs on sloped banks with an average slope of 27 degrees (Limpus et al., 2011b).

In the Burnett Catchment, nests have been located on average around 15 m (but up to 60 m) from the water's edge and at a height of 3 m (up to 8 m) above water level, with a mean depth of 22 cm and a width of around 10 cm (Hamann et al., 2007). The tops of steep sloping banks appear to be important nesting habitat, as do both sand and soil substrates (Hamann et al., 2007). The majority of nesting at the Ben Anderson Barrage during 2007−2011 occurred following rainfall events, and is thought to be closely associated with a decreasing water temperature in autumn (McDougall et al., 2015).

There have been no detailed nesting studies in the Mary Catchment (Limpus, 2008).

The species aggregates to breed at a restricted number of sites. Known aggregation areas include:

- Fitzroy Catchment − high density aggregations occur in the upper reaches of the Fitzroy River Barrage impoundment (Hamann et al., 2007).
- Burnett Catchment − nesting occurs throughout the middle and lower catchment, with 90% of observed nesting occurring in the upper reaches of the Ben Anderson Barrage impoundment (Limpus, 2008; Hollier, 2012). High densities have also been observed below Bucca Weir (Kolan River) and the Ned Churchward Weir (Burnett River) (Hamann et al., 2007).
- Mary Catchment − traditional high density nesting banks occur near Tiaro, and a series of nesting banks supporting a lower density of nesting have been identified in the upstream reaches between Traveston and Kenilworth (Limpus 2008).

However, while aggregations have been recorded in certain reaches, the location of breeding sites may change over time in response to river banks being re-modelled during major flooding events (Limpus pers. comm., 2015).

*Juvenile turtles*

Habitat requirements of juvenile turtles can be very different to those of adults. Micheli-Campbell et al. (2013) undertook a tracking study on juvenile Mary River turtles, a species which also utilises aquatic respiration. They released small juveniles (5–16 months) at the nesting bank where the eggs were laid (adjacent to deep, slow-flowing water), and found that all moved to shallow slow-flowing water within 400 m of a riffle, where they remained for the duration of the study (9 months). Habitat modelling suggested that the riffles themselves, characterised by fast-flowing water, were not suitable habitat for juveniles, nor were deep water and pools. Depth was the most significant factor predicting the location of the turtles, probably because less energy is expended when surfacing to breathe.

The habitat use and dispersal movements of hatchling and juvenile white-throated snapping turtles are unknown. It is possible that the vicinity of riffle zones is important habitat for these life stages. Invertebrates are known to form a greater part of their diet (Limpus, 2008; Limpus et al., 2011b), and riffle zones are areas of high vegetation and macroinvertebrate productivity (DNR 2000). Clear, flowing and well-oxygenated waters may also be more important for hatchlings and juveniles, which have a higher reliance on aquatic respiration than adults (Mathie & Franklin, 2006; FitzGibbon & Franklin, 2010). The highest density of nesting occurs within the shallow upper reaches of impoundments, suggesting that elevated levels of oxygen in the water column may not be critical for the species (Limpus, pers. comm. 2018). However, it is unknown where hatchlings move to following their emergence from the nesting site. If river reaches near riffle zones are important habitat for hatchlings and juveniles, the loss of these reaches due to habitat modification or impoundments may increase predation risk (see Section 3.4.5).

As the habitat requirements of hatchlings and juveniles are unknown, and may influence their survivorship and recruitment into the breeding population, the collection of these data to parameterise appropriate population models is a research priority. In the absence of such data, a precautionary approach should be taken to avoid activities that reduce the availability of riffle zones and habitat in their vicinity, and impacts on these areas should be minimised.

In the mid-upper Mary Catchment, aggregations of juvenile white-throated snapping turtles were encountered in some areas (Ecotone Environmental Services, 2007). Limpus (2008) showed a progressive increase in the proportion of immature turtles in the populations with increasing distance upstream from the Mary River Barrage to Yabba Creek. Investigation of this increasing proportion of immatures in the population in the upper Mary Catchment warrants investigation to determine the role of differences in land use/predator control on the adjacent properties, upstream migration of juveniles, or other as yet unrecognised factors (Limpus, pers. comm. 2018).

#### *3.4.7 Habitat critical to survival*

Although there are knowledge gaps regarding the species' habitat use, the following areas may be regarded as representing habitat critical to the survival of the species:

- Parts of riverine systems with permanent water, including pools, within the species' distribution that contain shelter and refuges (e.g. bank overhangs, overhanging riparian vegetation, macrophyte beds, moderate to high densities of submerged boulders and/or log jams).
- All currently known and new aggregated nesting sites (all nesting sites should be considered to be part of an aggregation unless it can be demonstrated otherwise).

Further research is required to more clearly define habitat critical to survival, particularly for hatchlings and juveniles.

# 4 Threats

## 4.1 Historical causes of decline

The white-throated snapping turtle is estimated to have lost more than 70% of its hatchling production and more than 70% of juveniles and sub-adults over at least 20 years (Limpus et al., 2011b). The populations in all catchments consist of older individuals with approximately 1% recruitment into the population of each catchment per year. This severe loss of juveniles can be attributed to loss of eggs due to predators, nest bank trampling and subsequent failure to produce immature age classes across the decades. Given the length of time over which this threat has operated, it is likely that it has already led to a severe reduction in the adult population (DotE, 2014).

The population size has also declined due to river regulation. Numerous barrages, dams and weirs have been erected along waterways in the Fitzroy, Burnett and Mary catchments to supply water for urban, agricultural and industrial uses. The Burnett River is particularly heavily regulated, containing over forty pieces of water infrastructure (Brizga et al., 2000). These structures have resulted in direct impacts on aquatic species (e.g. injury, mortality and obstruction of movement), and indirect impacts from altered flow regimes (e.g. changes to the volume, frequency, duration and seasonality of flows) which have led to the loss or degradation of in-stream, nesting and riparian habitat (Bunn & Arthington, 2002; DotE, 2014). Many of the impacts associated with flow regulation are likely to be further exacerbated under future climate change scenarios.

## 4.2 Current threatening processes

### *4.2.1 Predation and trampling at nesting sites*

The principal current threat to the white-throated snapping turtle is the excessive (near total) loss of eggs and hatchlings at the aggregated nesting areas in the Fitzroy, Burnett and Mary catchments. This is due to predation by feral (fox, dog, pig, cat) and native (e.g. goanna, water rat) predators, and trampling of nests by cattle. This egg loss is continuing and has been occurring for at least a generation, with the majority of the population comprised of older adults with very low recruitment into the adult breeding population. Spencer et al. (2016) suggest that a single fox can destroy more than 95% of freshwater turtle nests in one area; foxes were only introduced into Australia around 1870, and freshwater turtles have not had time to evolve to cope with this increased predation on top of natural predators. More knowledge is needed of the extent and nature of these threats impacting the species at the local and sub-catchment levels, as they may differ throughout the species' distribution.

Foxes are known to kill adult nesting females of smaller turtle species, such as the Murray River turtle (Spencer et al., 2005). Short-necked turtle species (e.g. *Emydura* spp., *Elseya* spp.) are more susceptible to fox predation as they are unable to fully retract their heads and limbs (Spencer et al., 2005). However, it is unknown whether foxes predate on subadult/adult white-throated snapping turtles. Raptors, which prey on immature and small adult freshwater turtles, may be significant predators on small white-throated snapping turtles when the depth of water in isolated pools become low during drought periods, but the extent of this impact is unknown.

### *4.2.2 In-stream barriers*

Impoundment structures can obstruct movement, and prevent turtles returning to a section of river after being displaced (mostly in the order of a few tens of kilometres) by a flood or overtopping event. Adults have been observed attempting to climb Ned Churchward Weir (Burnett Catchment) from the downstream side (Limpus et al., 2011b). Existing structures which facilitate fish passage past dams/weirs are not effective for facilitating the passage of the white-throated snapping turtle (Hamann et al., 2007; Limpus et al., 2011b). Road causeways can also impede the movement of turtles along waterways due to excessive flow velocities (Limpus et al., 2011b).

Turtles may be injured or killed on impoundment structures when they strike hard surfaces during over-topping (from flood events and water releases), drown in trash filter screens, or fall back onto hard substrate during attempts to climb infrastructure walls (Limpus et al., 2006; Hamann et al., 2007; Limpus et al., 2009; Limpus et al., 2011b). Dams and weirs featuring design characteristics such as stepped spillways (e.g. Bucca Weir and Paradise Dam, Burnett Catchment) and steep faces with shallow associated plunge pools (e.g. Ned Churchward Weir) are known to result in physical damage to the turtles as they move over these structures during flow events (Hamann et al., 2007). Turtles residing in pools on the downstream side of impoundment structures had a higher incidence of damage than turtles inhabiting free flowing sections of river (Hamann et al., 2004). In 2003 and 2006, mass mortalities of freshwater turtles (40−90 per year) were recorded on the two trash filters at Glebe Weir (Dawson River, Fitzroy Catchment) during water releases to meet downstream agricultural needs (Johnson, 2007). While the extent of impacts to white-throated snapping turtle populations caused by such barriers is unknown, it is likely to be locally significant given the species' low fecundity and severe lack of recruitment.

### *4.2.3 Degradation of habitat and water quality*

The white-throated snapping turtle relies on complex underwater habitat for shelter, aquatic vegetation for food, and riparian vegetation for both shelter and food (see section 3.4.6). This habitat has been degraded through various processes including the clearing of riparian vegetation, slumping of stream banks, increased sedimentation loads in rivers, damage to stream banks and shallow water macrophyte beds from cattle and vehicle crossings, and increased nutrient loads from agricultural runoff and faecal deposition from domestic stock (Brizga et al., 2000; Limpus et al., 2011b). Increased sedimentation and turbidity, due to erosion and runoff, can affect riverine productivity and the health and growth of aquatic plants (Hamann et al., 2007). Increased turbidity can also inhibit cloacal respiration in turtles, particularly juveniles, and reduced habitat availability and water quality is likely to expose juveniles to increased predation (Schaffer et al., 2015). The loss of riparian vegetation overhanging riverine habitat leads to a reduction in fruit as food for adult turtles, and reduces bank stability and refugia provided by undercut banks and roots (Limpus et al., 2011b). Elevated nutrients in waterways can increase the growth of invasive weeds, inhibiting the growth of native plants.

The construction of impoundments (water storages) has resulted in the conversion of flowing water reaches to still (ponded) water, a reduction in the natural riparian zone, and a loss of pool-riffle-pool stream structures (Brizga et al., 2000; Limpus et al., 2011b). Impoundments are a sediment deposition zone where sandy/gravel substrates tend to be replaced by silt/mud, with associated changes in benthic invertebrate and vegetation communities, and filling in of deep sections of the stream bed and microhabitat features (Limpus et al., 2011b). Water levels in impoundments are subject to a greater degree of variation than flow levels in natural pools, as a result of water extraction or releases (Brizga et al., 2000). Permanently flooded and fluctuating water levels make it difficult for submerged macrophytes and riparian communities to establish (Brizga et al., 2000; Tucker et al., 2012). The loss of shallow fast-water habitats leads to an overall loss of habitat diversity; shallow riffles and runs are regions of high productivity for macroinvertebrates and microscopic organisms, providing an important food supply for turtles and other animals (Brizga et al., 2000).

Altered flow regimes have reduced the frequency of flood events, which inhibits the replenishment of sandbanks, especially within impoundments. During long inter-flooding intervals, nesting banks can become overgrown with weeds, reducing the quality and availability of nesting habitat (Brizga et al., 2000; Hamann et al., 2007; Limpus et al., 2011b). Dense weeds, such as cat's claw creeper (*Macfadyana unguis-cati*), lantana (*Lantana camara*) and leucaena (*Leucaena leucocephala*), can reduce the food supply from key riparian plants (Limpus et al., 2011b).

Nests constructed on the banks of water storages may be inundated if storages are at a lower level when nesting occurs, and then fill to the supply level or higher during incubation. Research from sympatric chelid turtle species indicates that significant egg mortality (up to 100%) can be expected to occur with nest inundation (McDougall et al., 2015). In some areas this threat has been mitigated by implementing appropriate operating rules. At the Ben Anderson Barrage (Burnett Catchment), eco-hydraulic rules have been implemented to keep the maximum change in storage levels between the white-throated snapping turtle's nesting and incubation periods to 1.4 m (which is estimated to inundate no more than 20% of nests), by maintaining higher water levels in the impoundment throughout the turtle's reproductive period (McDougall et al., 2015).

The degree of upstream impact of dams, weirs or barrages varies depending on a range of factors, including: the length and depth of the impoundment, the extent and timing of variations in water level resulting from storage operation, the extent to which ponding persists under high flow conditions, and the relative proportion of flowing habitat versus pools pre-impoundment (Brizga et al., 2000). Deep water reaches of impoundments are largely cold and low in oxygen, which can be a particular issue if water is released from the bottom of a dam/weir (Gordos et al., 2007; Limpus et al., 2011b). Water allocation and regulated/unregulated extraction may lead to low or no flows in some reaches, which severs connections between pools for longer than natural periods of time, changes the composition and abundance of aquatic biota (Brizga et al., 2000), and may reduce oxygenation of the water and impede cloacal respiration (Limpus et al., 2011b). In large floods, flows in dam impoundments occur only at low velocity, but in weirs or barrages high velocity flows may still occur (Brizga et al., 2000).

#### *4.2.4 Climate change*

By 2030, average temperatures in the south-east of Queensland are projected to rise by 0.4-1.3 °C above the climate of 1986-2005, with a substantial increase in maximum temperatures, frequency of hot days and the duration of warm spells (Dowdy et al., 2015). Changes to rainfall and runoff are unclear, however heavy rainfall events are projected to increase in intensity (Dowdy et al., 2015).

Climate change may impact the white-throated snapping turtle in a number of ways, including the following:

- Higher water temperatures and associated decreased dissolved oxygen levels may decrease the species' diving duration, exposing it to increased predation pressure (Mathie & Franklin, 2006; Clarke et al., 2008). An increase in water temperature raises metabolic rate and oxygen demand; dives of juvenile turtles become significantly shorter (i.e. surfacing frequency increased) when water temperatures were increased from 20°C to 30°C (Storey et al., 2008).
- Higher ambient temperature may result in lower hatching success and hatchling fitness, which may decrease their survival and render them more vulnerable to predation. Laboratory incubation temperatures of 30°C results in much poorer hatching success, poorer swimming performance and greater proportions of scute abnormalities in the white-throated snapping turtle than incubation temperatures of 26°C or 28°C (Hamann et al., 2007; Eiby & Booth, 2011). In the wild, the extent of nest shading by vegetation cover is an important determinant of nest temperatures, which could influence hatching success; unshaded nest temperatures may approach the upper viable thermal limit for successful hatching for this species (Eiby & Booth, 2011).
- Extended drought periods, exacerbated by water extraction and storage and draw down water levels in some river reaches lower than would naturally occur, causes the river to cease to flow for longer time periods. Low or no flows are associated with a reduction in water quality; reductions in breeding rates due to an inability to access nesting banks, which is presumed to increase mortality of turtles (Limpus et al., 2011b); and a reduction in in-stream vegetation (Hamann et al., 2007).
- More intense flooding events are likely to result in a greater removal of aquatic vegetation and invertebrate fauna (Limpus et al., 2002), and flooding of nesting sites leading to a loss of eggs, particularly in impoundments (McDougall et al., 2015). More extreme weather events (i.e. droughts and floods) are likely to increase fluctuations in water levels in impoundments.

#### *4.2.5 Fishing and boating activities*

Direct impacts from recreational fishing result from hooking injuries to the mouth and throat, or mortality when turtles are cut loose from fishing lines, break away with ingested hooks, or drown in fish or crayfish traps (Limpus et al., 2008). The white-throated snapping turtle is commonly caught on fishing lines during fishing competitions in the lower Mary River (D. J. Limpus, unpublished data), and incidental captures have been reported from recreational fishers at a number of sites in the Fitzroy Catchment (Limpus et al., 2001). Indirect impacts are caused by stocking of fish (top end predators, e.g. sooty grunter) into dam impoundments, which increases predation pressure on juvenile turtles (Limpus et al., 2011b). Deaths from boat strikes and water skiing may also occur.

A summary of threatening processes facing the white-throated snapping turtle is outlined in Table 1. The priorities relate to the threatening processes discussed in sections 4.2.1−4.2.5 and guide the priorities assigned to recovery actions in section 7.

***Table 1: Threatening processes and their priority***

*Priority is based on the severity of the threat and the capacity for ameliorating the threat

| **Drivers** | **Threatening process** | **Impact on species (stress)** | **Priority*** |
|---|---|---|---|
| Prevalence of predators | Predation at nesting sites | • Excessive loss of eggs and hatchlings | 1 |
| Livestock, people and vehicles accessing nesting banks | Trampling and crushing at nesting sites | • Loss of eggs and hatchlings | 1 |
| Land use activities and riparian management | Loss/ degradation of riparian and in-stream habitat | • Reduced water quality (increased turbidity, higher nutrient loads, altered pH)<br>• Loss of shading, in-stream habitat structures, aquatic and riparian vegetation<br>• Loss of nesting habitat | 2 |
| River regulation | Construction and existence of dams and weirs | • Injury and mortality at impoundment structures<br>• Obstruction of movement<br>• Loss of riparian vegetation | 2 |
| | Operation of dams and weirs, and water flow management | • Changes to in-stream habitat, nesting habitat and water quality due to altered flow regimes<br>• Inundation of nesting banks downstream of impoundments with water releases | 2 |
| | Extended drought periods exacerbated by water storage and extraction | • Reduction in water quality, breeding rates and increased mortality<br>• Reduction in access to nest banks, breeding partners and habitat for juvenile turtles | 2 |
| Climate change | Increased temperatures and extreme weather events | • Lower hatching success and hatchling fitness<br>• Reduced diving duration and increased predation risk<br>• Lower flows<br>• More intense flooding events | 3 |
| Cattle and vehicles crossing rivers | Trampling and crushing in-stream | • Injury and mortality of adults | 3 |
| Prevalence of invasive plants<br>Spread of weeds through people and animals | Aquatic weeds | • Obstruction of access to nesting habitat<br>• Loss of nesting habitat<br>• Reduction in food supply from native plants<br>• Invasive macrophytes affecting food supply<br>• Changed water quality | 3 |
| Recreation | Recreational fishing and boating | • Injury and mortality<br>• Increased in-stream predation pressure from stocked fish | 3 |

# 5 Populations under particular pressure

The actions described in this recovery plan are designed to provide increased protection for the white-throated snapping turtle and its required habitat throughout its range. Insufficient data are available to discern demographically separate populations within the catchments. However, a sustained lack of recruitment due to predation and trampling at nesting sites present significant challenges for the species' recovery and exert strong pressure on its survival in the wild. Given these challenges all aggregated nesting areas for the white-throated snapping turtle require protective measures. Additionally, given the slow rate at which the species reaches sexual maturity and its low fecundity, all populations and locations where there is a high incidence of turtle mortality/injury are also exposed to increased pressure.

# 6 Objectives and strategies

The objectives of this recovery plan are to:

- ensure a self-sustaining healthy population structure in all catchments in which the white-throated snapping turtle occurs; and
- enhance the condition of habitat across the white-throated snapping turtle's range to maximise survival and reproductive success.

The objectives are long-term and may not be achieved during the life of the plan. However, recovery actions should go towards achieving these objectives. The plan will be reviewed every five years.

The strategies to achieve the plan's objectives are to:

- Substantially improve the recruitment of hatchlings and juveniles into the population;
- Decrease adult/subadult mortality and injury rates, and reduce barriers to movement along riverine habitats;
- Improve stream flow and habitat quality throughout the species' distribution;
- Increase public awareness and participation in conservation of the species and its habitat;
- Improve the collation and availability of data to inform recovery actions.

The first three recovery strategies directly address the threats to the white-throated snapping turtle across all life stages. The fourth strategy contributes to the species' recovery, as increased public awareness of threats to the species will help mitigate these threats at public areas such as nesting beaches and recreational fishing sites. Reported sightings by the public will aid in the collection of distribution data, and the involvement of volunteers in implementing recovery actions (e.g. turtle nest surveys and nest protection) is valuable, particularly given the broad distribution of the species. The fifth strategy is important for tracking changes in the status of the species, assessing progress against the recovery actions, and adaptive management.

# 7 Actions to achieve the specific objectives

Actions identified for the recovery of the white-throated snapping turtle are described below. There are two tables under each strategy – one table lists research actions, and the other lists on-ground actions. Actions are cross-referenced where required.

Priorities assigned to actions should be interpreted as follows:

| | |
|---|---|
| **Priority 1:** | Taking prompt action is necessary in order to mitigate the key threats to the white-throated snapping turtle, and/or to provide valuable information to help identify long-term population trends. |
| **Priority 2:** | Action would greatly assist, and provide a more informed basis for, the long-term management and recovery of the white-throated snapping turtle. |
| **Priority 3:** | Action is desirable, but not critical, to the recovery of the white-throated snapping turtle or the assessment of trends in that recovery. |

It should be noted that the indicative costs for Priority 1 actions are not funding commitments, but serve as a guide to the approximate cost of implementing these actions should funding become available (through, for example, government or research grants). Interested parties can use these cost estimates as a guide when developing project proposals. A more detailed breakdown of the costings are provided in Section 8. Whilst only Priority 1 actions are costed in this recovery plan, this should not deflect from any proposal to undertake Priority 2 or 3 actions. All actions are important steps towards ensuring the long-term survival of the species.

## 7.1 Strategy 1 – Substantially improve the recruitment of hatchlings and juveniles into the population

### Research actions

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| **1a** | Design a hatchery or nest protection program to release large numbers of hatchlings into the rivers | 1 | • A hatchery program is developed which includes:<br>- Estimated numbers, frequency, timing and locations for egg collectionand hatchling release;<br>- an investigation into the feasibility of head-starting turtles in captivity. | Research community; Queensland Department of Environment and Science (DES) | $25,000 |
| **1b** | Determine the survivorship of hatchlings from wild nests and captive incubated nests | 1 | • The survivorship of hatchlings and young juvenile turtles from wild nests are determined.<br>• The survivorship of hatchlings and young juvenile turtles from the hatchery program are determined. | Research community; DES; catchment groups | $60,000 |

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| **1c** | Evaluate the success of the hatchery program | 1 | • The success of the hatchery program developed under Action 1a and implemented under Action 1i has been evaluated, including:<br>- an assessment of whether the survivorship of turtles released from the hatchery program are significantly greater than the survivorship of turtles from wild nests;<br>- an assessment of whether the survivorship of young turtles can be increased via a head-starting project, and by how much;<br>- (if head-starting is feasible) determination of the optimal age for releasing captive bred turtles into the wild which maximises survivorship. | Research community; DES | $25,000 |
| **1d** | Search for and map nesting sites in each catchment | 1 | • Key nesting sites are identified and mapped in all catchments. Stream banks should be checked for signs of nesting, particularly after rainfall. | Research community; DES; catchment groups | $100,000 |
| **1e** | Identify the extent and nature of threats to nests and hatchlings at the local and sub-catchment levels | 1 | • A strategy to improve understanding of the threats to nests and hatchlings, and how these threats vary throughout the turtle's distribution, has been developed.<br>• Research to identify the nature, level and extent (undertaken synchronously) of threat to nests and hatchlings has been undertaken at key nesting areas.<br>• Risk assessments have been undertaken at impoundments (on a per site basis) to identify the risk of turtle nest inundation under current operating rules (Burnett and Fitzroy catchments). | Research community; DES; catchment groups; infrastructure operators | $200,000 |
| **1f** | Develop an effective means to control predators of eggs over a catchment scale | 1 | • A range of options (e.g. taste aversion, baiting, den fumigation, sniffer dogs, aerial shooting) for predator control have been explored and their relative effectiveness evaluated. Control options should target predators which have a significant impact at the population level, as identified by Action 1e.<br>• Changing predator species have been monitored in response to environmental change and land management practices. | Research community; DES; regional bodies | $70,000 |
| **1g** | Determine the impact of introduced or translocated stocked fish on the turtle | 2 | • Predation rates of stocked fish on hatchlings/juveniles are quantified.<br>• The impact of stocked fish on turtle populations is determined.<br>• If found to have a substantial impact, a review of fish stocking | Research community; recreational fishers and fish stocking groups | |

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| | | | activities is undertaken and options to reduce their impact developed. | | |
| **1h** | Monitor trends in population structure and abundance | 1 | • Trends in population structure and abundance have been regularly monitored across the species' distribution, using an appropriate sampling design and index of abundance.<br>• These trends are reported to the Commonwealth Department of Agriculture, Water and the Environment (DAWE) and used to evaluate the success of the recovery plan. | Research community; DES | $250,000 |

### On-ground actions

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| **1i** | Implement the hatchery program (developed under Action 1a) | 1 | • The hatchery program developed under Action 1a is implemented.<br>• Hatchlings are released into the wild, at locations and ages which maximise their chances of survival.<br>• Outcomes of the hatchery program (as demonstrated by Action 1c) are reported to DAWE and made publicly available. | Research community; DES | $180,000 |
| **1j** | Protect nests and nesting banks from predation, trampling and other disturbance | 1 | • A program is implemented to erect and maintain physical structures around nests (e.g. 70-100 cm square plastic mesh covers, 10 cm grid-size, over nests) and key nesting reaches (e.g. with fencing) in all catchments.<br>• Access to key nesting banks and adjacent stream reaches by livestock, people and vehicles is restricted; and closed during the breeding season.<br>• Hatching success from protected nesting banks are monitored, and the effectiveness of nest protection actions evaluated.<br>• At least 70% of managed clutches produce hatchlings every year (depending on external factors such as floods, which may impede the measurement of hatching success). | DES; community groups; regional bodies; landholders | $540,000 |
| **1k** | Implement a predator control program in key areas of each catchment | 1 | • A predator control program is implemented in key nesting areas of each catchment, as informed by Actions 1e and 1f.<br>• Hatching success in areas with predator control are monitored, and | DES; community groups; regional bodies | $180,000 |

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| | | | the effectiveness of control programs evaluated.<br>• Production of hatchlings entering the water is increased. | | |
| **1l** | Manage water releases and water levels to avoid inundation of nesting banks during the incubation period | 2 | • Inundation of nesting banks during the incubation period is avoided at high risk areas and times, as informed by Action 1e. This may include:<br>- reducing water level fluctuations in storages, taking into account requirements of water resource planning subordinate legislation and processes administered by the Queensland Department of Natural Resources and Mines (DNRM). | DNRM; infrastructure operators | |
| **1m** | Reduce predation rates of juveniles from stocked fish | 2 | • If predation rates of hatchlings/juveniles from stocked fish are found to be substantial (as per Action 1g), implement options to reduce the impact of fish stocking activities. | Research community; recreational fishers and fish stocking groups | |

## 7.2 Strategy 2 – Decrease adult/subadult mortality and injury rates, and reduce barriers to movement along riverine habitats

### Research actions

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| **2a** | Determine rates and sources of mortality and injury | 1 | • Rates of natural mortality in the adult/subadult population have been determined.<br>• Rates of mortality and injury associated with infrastructure, recreational fishing/boating, and other causes have been determined and their impact on the recovery of the turtle evaluated. | Research community; DES; catchment groups | $100,000 |
| **2b** | Identify high risk (existing) water infrastructure and explore options to facilitate safe passage | 2 | • A risk assessment has been undertaken to identify existing infrastructure with high turtle mortality/injury, or which pose a high barrier to the passage of turtles.<br>• The design features of infrastructure which contribute to turtle mortality/injury have been identified.<br>• Cost-effective options for facilitating the safe passage of turtles past these infrastructure (downstream and upstream movements) are explored − e.g. catch and carry, turtleways, operational changes. | Research community; DES; infrastructure providers and operators | |

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| | | | • If feasible and practicable options for safe passage are identified, these are trialled and their effectiveness assessed. | | |
| **2c** | Design (new) water infrastructure to allow the movement of turtles upstream and downstream with minimal injury and mortality | 1 | • Practical guidelines for the design of water infrastructure to minimise turtle mortality and injury, and to facilitate safe passage, are developed − e.g. the cessation of stepped weir designs, suitable design of trash filters to reduce mortality, turtleways. May be informed by Action 2b.<br>• Where feasible, the guidelines should include costs estimates for incorporating different design features (e.g. ballpark cost per metre of elevation for different turtleway types). | Research community; DES; infrastructure providers | $240,000 |
| **2d** | Monitor changes in turtle injury/mortality rates in response to management actions | 1 | • A monitoring program is implemented which enables the assessment and reporting of injury and mortality rates of turtles at existing high risk and new water infrastructure, and connects this with infrastructure design/ modification/ operation.<br>• Injury and mortality rates of turtles are reported to DAWE and DES. | Research community; DES; infrastructure providers and operators | $150,000 |
| **2e** | Monitor the movement of the species near in-stream barriers. | 2 | • Movements of turtles in downstream pools are monitored using acoustic telemetry.<br>• The scale and cues for movement are understood.<br>• An assessment of whether turtles are moving upstream past barriers is undertaken, and used to inform infrastructure design/ modification.<br>• Possible cumulative impacts of water infrastructure on the fragmentation of habitat and populations are investigated. | Research community; DES | |

### On-ground actions

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| **2f** | Implement options, where feasible and practicable, to allow safe passage of turtles past (existing) infrastructure | 2 | • In accordance with Action 2b, options for facilitating the safe passage of turtles past high risk water infrastructure have been implemented.<br>• The rates of injury and mortality of adult/subadult turtles at high risk infrastructure have substantially | Infrastructure providers and operators | |

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| | | | decreased, as demonstrated by Action 2d. | | |
| 2g | Remove all redundant infrastructure which pose a high risk to turtles | 2 | • Any existing infrastructure identified in Action 2b found to be redundant is removed. | Infrastructure providers | |
| 2h | Construct (new) water infrastructure in accordance with the guidelines developed at Action 2c | 1 | • The guidelines developed at Action 2c are widely adopted and incorporated into a formal process for designing and constructing water infrastructure.<br>• Turtles are moving past water infrastructure with minimal injury/mortality, as demonstrated by Actions 2d and 2e. | Infrastructure providers and operators | $1,600,000 |
| 2i | Reduce the extent of turtle injury and mortality from recreational fishers and boaters | 3 | • Position statements on the following are prepared by the recreational fishing industry and presented to the Queensland Department of Agriculture and Fisheries (DAF):<br>- the impact of stocked fish on the turtle;<br>- avoiding the use of barbed and stainless steel fish hooks.<br>• Guidelines for reducing the injury to (or mortality of) turtles from fish or crayfish traps, fish hooks, boat strikes and water skiing are developed.<br>• These guidelines are disseminated to recreational fishers and boaters.<br>• The injury to (or mortality of) turtles from fish or crayfish traps, fish hooks, boat strikes and water skiing is monitored.<br>• The injury to (or mortality of) turtles from each of the following is substantially reduced: fish traps, crayfish traps, fish hooks, boat strikes, water skiing. | Recreational fishers and boaters; fishing clubs; DAF | |

## 7.3 Strategy 3 – Improve stream flow and habitat quality throughout the species' distribution

### Research actions

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| 3a | Identify habitat requirements and movement patterns | 1 | • Environmental flow requirements for the species, including flows required to maintain in-stream habitat and to produce and maintain nesting banks, are determined. | Research community; DES | $200,000 |

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| | | | • Habitat use/requirements of hatchlings and young juvenile turtles, including the importance of riffle habitat and clear flowing water, are identified.<br>• Habitat requirements for adults, including water quality parameters and suitability/unsuitability of impoundments, are clarified.<br>• Tracking studies are undertaken to understand movements of juveniles and adults.<br>• The relationship between cloacal respiration, diving ecology and prevailing environmental conditions is determined.<br>• 'Habitat critical to survival' is further defined. | | |
| 3b | Determine the impact of river regulation on the survivorship of hatchlings and juveniles | 2 | • Impacts of regulation (e.g. impoundments, reduction in shallow fast-flowing reaches) and unregulated extraction (e.g. through water pumping) on survival rates of hatchlings and small juvenile turtles are determined.<br>• Synergies between habitat alteration and predation on juveniles from stocked fish are investigated. | Research community; DES; infrastructure operators | |
| 3c | Identify and locate areas of optimal or sub-optimal habitat* | 2 | • Areas of optimal and sub-optimal habitat, including foraging reaches and reaches with suitable refuges, are mapped in each catchment.<br>• The presence/absence of any habitat-related limitations to breeding and foraging are documented.<br>• Impacts on areas of optimal habitat are identified.<br>• The mapped habitat areas are provided to DES for incorporation into a central database (Action 5a). | Research community; DES; regional bodies; community groups | |

* *Optimal habitat:* having characteristics that are preferred by the white-throated snapping turtle (e.g. banks suitable for nesting, in-stream refuges, intact riparian vegetation); see sections 3.4.6 and 3.4.7.
*Sub-optimal habitat:* areas having characteristics that are less than desirable for the turtle, or which are slightly degraded.

### On-ground actions

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| 3d | Ensure that water releases maintain adequate water quality | 2 | • Impoundments which may release cold water with low dissolved oxygen are identified.<br>• These impoundments are monitored, and appropriate management measures implemented, to ensure that the | DNRM; infrastructure operators | |

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| | | | temperature and oxygen levels of water released do not impact on the turtle. | | |
| **3e** | Review water management plans to ensure environmental flow requirements for the turtle are met | 2 | • Water management plans for all catchments are reviewed and include minimum environmental flow requirements for the turtle, as informed by Actions 3a and 3b. These may include the need for:<br>- provision of baseflow to maintain adequate shallow fast-water habitat<br>- review of waterhole drawdown rules to maintain refugial quality of key waterholes<br>- maintenance of geomorphological flows that enable nesting banks to form and limit vegetation encroachment on these banks<br>- risk assessments (i.e. social impacts) for high flow events required to replenish sandbanks. | DNRM; infrastructure operators | |
| **3f** | Reduce the impact of pest/exotic plants on nesting and aquatic habitats | 3 | • Weed control (particularly cat's claw, lantana, leucaena) in key nesting and foraging reaches (preferably using selective strategic herbicide application) is undertaken where required. | Regional bodies; community groups | |
| **3g** | Reduce the incidence of riparian clearing | 2 | • Riparian clearing is minimised through engagement with landholders and other key stakeholders, and through increased compliance with relevant legislation. | DNRM; regional bodies; landholders | |
| **3h** | Reduce the extent of cattle and vehicles accessing stream banks and rivers | 3 | • Funding is provided to landholders to undertake riparian fencing and offstream watering, in order to reduce access of livestock to stream banks and river reaches utilised for nesting.<br>• Vehicle crossings are regulated to minimise impacts on river beds and stream banks. | Regional bodies; community groups; landholders | |
| **3i** | Restore the health of riparian vegetation | 2 | • Riparian management and/or restoration measures have been implemented in sub-optimal habitat where required, including the establishment of food plants for the turtle.<br>• Management measures are linked to other existing NRM programs. | Regional bodies; community groups | |
| **3j** | Restore and maintain nesting banks | 1 | • Where necessary, nesting banks are rehabilitated to ensure adequate sand/loam substrate and low-density vegetation (while ensuring adequate | Regional bodies; community groups | $210,000 |

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| | | | cover to buffer nests from impacts of extreme temperatures). | | |
| **3k** | Improve in-stream habitat | 2 | • The abundance and diversity of native in-stream vegetation and microhabitat features have increased in areas of sub-optimal habitat.<br>• Impacts to areas with important habitat and habitat critical to survival, as identified in Action 3a, are appropriately managed.<br>• Work with landholders is undertaken to reduce the input of nutrients into waterways. | Regional bodies; community groups; catchment groups; landholders | |

## 7.4 Strategy 4 – Increase public awareness and participation in conservation of the species and its habitat

### On-ground actions

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| **4a** | Develop and implement a broad strategy to raise awareness and educate the general public about conservation for the species | 2 | • Articles about white-throated snapping turtle conservation, including threats and recovery actions, are published in community newsletters, local bulletins and newspapers.<br>• Informative displays and web-based social media are developed to educate the broader community about conservation of the turtle, particularly at nesting and recreational fishing sites.<br>• Public awareness before and after implementation of the strategy is measured.<br>• Public awareness about conservation of the species has increased. | DES; community groups; catchment groups | |
| **4b** | Develop and implement a targeted strategy to promote the use of citizen science in relation to conservation for the species. | 3 | • Articles are published in community newsletters and magazines to advertise the central repository for white-throated snapping turtle observations and encourage citizen scientist involvement in conservation of the species.<br>• Citizen scientists and community groups are involved in implementing on-ground management actions.<br>• Promote the use of TurtleSAT (an online database and mapping tool where people can submit sightings of turtles) by management agencies and the general public. | Catchment groups; DES; research community; community groups | |

| Action | Description | Priority | Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| | | | • A central database is developed and used to record all sightings of the species. | | |
| **4c** | Establish proactive ongoing roles for Traditional Owners in conservation and management actions for the species | 2 | • Protocols for ongoing liaison with the Burnett Mary Caring for Country Alliance, and other Indigenous groups, are developed.<br>• Ongoing consultation with Indigenous communities is undertaken to facilitate their participation in on-country management actions.<br>• Traditional owners are involved in implementing on-ground management actions.<br>• Training and capacity building activities for Traditional owners are undertaken where required. | NRM bodies; Indigenous groups; local councils; DES; DAWE | |

## 7.5 Strategy 5 – Improve the collation and availability of data to inform recovery actions

### Research actions

| Action | Description | Priority | • Performance Criteria | Potential implementation agencies/groups | Indicative Cost *priority 1 only |
|---|---|---|---|---|---|
| **5a** | Collate all population information in a database and maintain long-term | 1 | • A database is maintained which provides a central repository of data on the distribution and abundance of turtles and nesting sites, population dynamics data, tagging-recapture data, incubation success, rates of turtle mortality and predation.<br>• The database is updated annually and available for population assessment. | DES | $150,000 |
| **5b** | Maintain a register of research, monitoring and management actions and resulting reports | 1 | • A register of recovery actions, and progress against the actions, is established and updated as required.<br>• Project reports are available for access by the general public. | DES, research institutions, community groups, management agencies | |
| **5c** | Undertake all research and monitoring with Animal Ethics approval and relevant permits under the *Qld Nature Conservation Act, 1992.* | 1 | • Approval by an Animal Ethics Committee is reported in project reports. | DES, research institutions, community groups | |

# 8 Duration and cost of the recovery process

It is anticipated that the recovery process will not be achieved prior to the scheduled five-year review of the recovery plan. The *National Recovery Plan for the White-throated Snapping Turtle* (Elseya albagula) will therefore remain in place until such time as the Australian populations of the white-throated snapping turtle have improved to the point at which the populations no longer meet threatened species status under the EPBC Act.

The cost of implementation of this plan should be incorporated into the core business expenditure of the affected organisations, and through additional funds obtained for the explicit purpose of implementing this recovery plan. Additionally, it is expected that state and Commonwealth agencies will use this plan to prioritise actions to protect the species' and enhance their recovery, and that projects will be undertaken according to agency priorities and available resources. In order to maximise the conservation outcomes and cost-effectiveness of this plan, it is intended that the proposed recovery actions complement, where possible, those of other protected matters.

Cost estimates for Priority 1 actions for the first five years of this recovery plan are provided in Table 2. Costings have been derived in consultation with species experts, catchment groups and infrastructure operators, using estimates provided in 2018 and 2019.

***Table 2: Summary of high priority recovery actions and estimated per unit costings for the first five years of implementation*** *(these estimated costs do not take into account inflation over time)*

| **Action** | **Scale** | **Estimated cost ($000's) per unit** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** | **Total** |
| **Strategy 1 – recruitment** | | | | | | | |
| 1a Design a hatchery program to release large numbers of hatchlings into the rivers | hatchery | 25 | | | | | **25** |
| 1b Determine the survivorship of hatchlings from wild nests and captive incubated nests | hatchery | | 30 | 30 | | | **60** |
| 1c Evaluate the success of the hatchery program | hatchery | | | | | 25 | **25** |
| 1d Search for and map nesting sites in each catchment | 200km of river | 60 | 10 | 10 | 10 | 10 | **100** |
| 1e Identify the extent and nature of threats to nests and hatchlings at the local and sub-catchment levels | catchment | 100 | 100 | | | | **200** |
| 1f Develop an effective means to control predators of eggs over a catchment scale | catchment | 50 | 5 | 5 | 5 | 5 | **70** |
| 1h Monitor trends in population structure and abundance | catchment | 50 | 50 | 50 | 50 | 50 | **250** |
| 1i Implement the hatchery program (developed under Action 1a) | hatchery | 100 | 20 | 20 | 20 | 20 | **180** |
| 1j Protect nests and nesting banks from predation, trampling and other disturbance | 200km of river | 320 | 55 | 55 | 55 | 55 | **540** |
| 1k Implement a predator control program in key areas of each catchment | 200km of river | 100 | 20 | 20 | 20 | 20 | **180** |
| **Strategy 2 – adult mortality/injury** | | | | | | | |
| 2a Determine rates of mortality and injury | report | 50 | 50 | | | | **100** |
| 2c Design (new) water infrastructure to allow the movement of turtles upstream and downstream with minimal injury and mortality | report | 120 | 120 | | | | **240** |

| Action | Scale | Estimated cost ($000's) per unit | | | | | |
|---|---|---|---|---|---|---|---|
| | | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Total |
| 2d Monitor changes in turtle injury/mortality rates in response to management actions | site | | | 50 | 50 | 50 | **150** |
| 2h Construct (new) water infrastructure in accordance with the guidelines developed at Action 2c | site | | | 1,200 | 200 | 200 | **1,600** |
| **Strategy 3 – habitat quality** | | | | | | | |
| 3a Identify habitat requirements and movement patterns | catchment | 100 | 100 | | | | **200** |
| 3j Restore and maintain nesting banks | 200km of river | 130 | 20 | 20 | 20 | 20 | **210** |
| **Strategy 5 – data management** | | | | | | | |
| 5a Collate all population information in a database and maintain long-term | all catchments | 30 | 30 | 30 | 30 | 30 | **150** |
| 5b Maintain a register of research, monitoring and management actions and resulting reports | all catchments | | | | | | |
| 5c Undertake all research and monitoring with Animal Ethics approval and relevant permits under the *Qld Nature Conservation Act, 1992.* | all catchments | | | | | | |
| **TOTAL** | | **1,235** | **610** | **1,490** | **460** | **485** | **4,280** |

# 9 Current management practices

## 9.1 Commonwealth

As the white-throated snapping turtle is protected under the EPBC Act, it is an offence to kill, injure, take, trade, keep, or move any individual without a permit on Commonwealth lands. In addition, all listed threatened species are considered matters of national environmental significance (MNES), and any action that may have a significant impact on MNES must be referred to the Minister of the Environment for approval. The Department of Agriculture, Water and the Environment, as the Australian Government department responsible for administering the EPBC Act, maintains a suite of interactive tools that allow users to search, find and generate reports on information and data describing MNES. The conservation values atlas shows the location and spatial extent of conservation values (where sufficient information exists), and is available at: www.environment.gov.au/coasts/marineplans/cva/index.html.

The Commonwealth has developed threat abatement plans (TAPs) for feral cats, foxes and feral pigs:

- Threat abatement plan and background document for predation by the European red fox (DEWHA 2008a,b)
- TAP and background document for predation by feral cats (DotE 2015a,b)
- TAP and background document for predation, habitat degradation, competition and disease transmission by feral pigs (DoEE 2017a,b).

## 9.2 Queensland

In Queensland, the white-throated snapping turtle is listed as Endangered under the Queensland *Nature Conservation Act 1992*. It is also ranked as a high priority species under DES's Back on Track species prioritisation framework, which prioritises species based on those which face the greatest risk of extinction and have the greatest potential for recovery. The framework identifies common threats affecting a range of species, and identifies where to focus management actions and investment in order to maximise outcomes (Qld DEHP 2012). A range of action documents have been developed based on this framework. Two – the Burnett Mary Actions for Biodiversity, and Fitzroy Actions for Biodiversity – include the white-throated snapping turtle (Qld DERM 2010a,b).

The Queensland DES undertakes long-term research, monitoring and conservation management of marine and freshwater turtles via the Queensland Turtle Conservation (QTC) project, which was created in 1975. A significant proportion of this work with freshwater turtles focuses on turtle populations within the Burnett, Mary and Fitzroy catchments. Research and monitoring activities and nest protection are undertaken by DES staff and the QTC volunteer program. The data collected are collated within a central database, summarised in annual reports, and used to guide conservation management planning (DES 2011).

The Queensland government developed the 'Management plan for the conservation of *Elseya sp.* [Burnett River] in the Burnett River Catchment' (Hamann et al., 2007), which is a comprehensive management plan for the white-throated snapping turtle. Many of the actions in the 'National Recovery Plan for the White-throated Snapping Turtle (*Elseya albagula*)' are based on actions in the Burnett River plan. The Queensland government also developed "Management strategies for the conservation of *Elseya albagula*" in the Fitzroy Catchment' (Limpus et al., 2011b), which provides a comprehensive summary of management needs for the white-throated snapping turtle in the Fitzroy Catchment.

Industry groups have developed some turtle management measures to meet conditions imposed for approval to implement water infrastructure projects. The 'Fitzroy River turtle *(Rheodytes leukops*) species management program' (GHD 2015) was developed as part of the Lower Fitzroy River Infrastructure Project. Informal guidelines for the design of water infrastructure to minimise turtle mortality and injury have also been developed, but have not been formally adopted (SunWater pers. comm., 2015).

The Burnett Catchment Care Association received a grant under the Commonwealth's 20 Million Trees Program (no further funding is available under this program, which finishes in 2020) to revegetate high priority riparian habitat for the white-throated snapping turtle and Australian lungfish (*Neoceratodus forsteri*) in the Burnett catchment. The project will involve landholders and local job-seekers in revegetation activities, and work with local schools to set up monitoring programs and raise community awareness of these species. More information on this project (ID: 20MTR2-228, 20 Million Trees Competitive Grants Round Two) can be found at: http://nrm.gov.au/national/20-million-trees

The Burnett Mary Regional Group, and Fitzroy Basin Association Inc, have also been successful tenderers for delivering the Regional Land Partnerships (RLP) component of the National Landcare Program's second phase, with potential for receiving funding to assist recovery of the white-throated snapping turtle. More information on the RLP is available at: http://nrm.gov.au/national-landcare-program

The Queensland DES provides training and authorisation of landowners and community groups, including Indigenous rangers, to undertake nest protection projects to enhance white-throated snapping turtle hatchling production in all three catchments.

The 'National Recovery Plan for the White-throated Snapping Turtle (*Elseya albagula*)' will complement these current management practices, and encourage all threats to the white-throated snapping turtle to be adequately identified, prioritised and addressed across the species' distribution.

## 9.3 Offsets

When balancing social and economic impacts with the protection and conservation of the white-throated snapping turtle (see section 11), it may not always be possible to avoid significant impacts on the turtle. In these instances, the Minister for the Environment, or the Queensland Coordinator-General, may approve an action on the condition that offsets are implemented.

Offsets are defined as measures which aim to compensate for the residual adverse impacts of an action on the environment. Offsets may include direct offsets such as the protection and/or enhancement of habitat, or other compensatory measures such as the contribution of funds towards monitoring or research that benefit the species. As the ecological outcomes of offsetting activities are generally uncertain, offsetting should only be proposed as an attempt to compensate for impacts that are deemed unavoidable, and must provide a net benefit for the threatened species.

With regard to any proposed actions involving offsets for the white-throated snapping turtle, the aims are to:

- Ensure that offsets are consistent with the wording and intent of the EPBC Act Environmental Offsets Policy (DSEWPaC 2012), including:
  - where possible, tailoring the proposed offsets to the aspect of the turtle that is impacted, for example population numbers, nesting habitat or foraging habitat; and
  - how proposed offsets will address key priority actions outlined in this recovery plan and any other relevant recovery plans, threat abatement plans and any other Commonwealth management plans.
- Reduce pressures on the turtle or its habitat, such as implementing predator control measures, protecting nesting sites from predators and disturbance, or reducing barriers to movement.
- Improve the condition and ecological function of the remaining extent of the species' habitat by enhancing riverine water quality and riparian zone condition, to ensure that any offset sites add additional value to the remaining extent.

# 10 Effects on other native species and biodiversity benefits

The adjacent Fitzroy, Burnett and Mary catchments of central and southeast Queensland support three species of locally endemic freshwater turtles, all of which are listed as threatened under the EPBC Act. These species are: the Mary River turtle (*Elusor macrurus*) which is listed as Endangered; the Fitzroy River turtle (*Rheodytes leukops*) which is listed as Vulnerable; and the white-throated snapping turtle (*Elseya albagula*) which is listed as Critically Endangered. The Burnett and Mary catchments also support the Australian Lungfish (*Neoceratodus forsteri*) which is listed as Vulnerable, and the Mary catchment supports the Mary River Cod (*Maccullochella mariensis*) and Giant Barred Frog (*Mixophyes iteratus*) which are both listed as Endangered.

Reducing anthropogenic impacts from water regulation and recreational fishing activities, and supporting work to improve water quality in the Fitzroy, Burnett and Mary catchments, will likely benefit other EPBC-listed threatened species including freshwater turtles. Implementation of the white-throated snapping turtle recovery plan will also have positive outcomes for other species which utilise riverine habitats, such as species which may suffer mortality/injury from stepped weir designs, and species which have been negatively impacted by degradation of riparian habitat. In the Fitzroy catchment, implementation of a concurrent nest protection program for both the Fitzroy River turtle and the white-throated snapping turtle, as an extension of the current long-running conservation program for the Fitzroy River turtle centred on nest protection, would result in funding efficiencies and improved outcomes for both species.

# 11 Social and economic considerations

The Fitzroy, Burnett and Mary catchments are heavily regulated to supply cities, towns, industrial developments (e.g. mines, power stations) and agricultural production with water. However, water regulation threatens the white-throated snapping turtle by altering flow regimes, reducing water quality, altering riverine habitat, obstructing movement along rivers, and increasing injury and mortality. Implementation of this recovery plan is expected to impose additional obligations on water infrastructure providers, with costs associated with modifications to the design or operation of infrastructure potentially passed onto users. However, as the recovery actions incorporate assessments of risk to the turtle and analyses of cost-effectiveness in determining when infrastructure modifications should be made, these obligations are likely to apply to only a small proportion of water infrastructure (i.e. those identified to have significant impacts on the turtle, and where modifications are feasible and practicable). The recovery plan is also expected to have benefits to water supply, as implementation of recovery actions should improve water quality.

As habitats critical to the survival of the species are identified, there is potential for the construction of water infrastructure to be restricted under the EPBC Act development assessment and approval process. In determining whether to approve new developments, the Minister for the Environment will consider the extent to which the proposal is likely to have a significant impact on the turtle, and balance this with possible social and economic impacts, as required under the EPBC Act.

Recreational fishing and boating activities also threaten the white-throated snapping turtle due to the species being caught and injured on fishing lines, from propeller and boat strikes, or drowned in lost redclaw cray traps (Limpus et al., 2011b). The actions outlined in this recovery plan in relation to recreational fishing focus on reducing mortality and injury to turtles by changing fishing practices. Implementation of the plan is expected to have small short-term impacts on recreational fishing activities, but negligible impacts in the long-term once the industry has adopted new fishing practices.

The parties involved for implementing each recovery action should work closely with each other, in order to ensure protection and conservation of the white-throated snapping turtle, while at the same time minimising any social and economic impacts.

# 12 Affected interests

Organisations and groups likely to be affected by the actions proposed in this recovery plan include: Australian and state government agencies, particularly those with environmental and water regulation responsibilities; private and government owned corporations responsible for water supply; water users (mining and agricultural industries, riparian landholders, general public); recreational fishers; local Indigenous communities; researchers; catchment groups; conservation groups; and wildlife interest groups. This list, however, should not be considered exhaustive, as there may be other interest groups that would like to be included in the future or need to be considered when specialised tasks are required in the recovery process.

# 13 Consultation

The ‘National Recovery Plan for the White-throated Snapping Turtle (*Elseya albagula*)’ has been developed through extensive consultation with a broad range of stakeholders. The consultation process included a workshop in Brisbane that brought together key species experts and conservation managers, from a range of different organisations, to categorise ongoing threats to species and identify knowledge gaps and potential management options. Workshop participants included representatives from DAWE, DES, DNRM, SunWater, SEQWater, catchment groups, Greening Australia and university researchers. A public consultation period was held from 22 February 2017 to 26 May 2017, and comments received during this period were carefully considered in later iterations of the draft plan. During the drafting process and the finalisation of this recovery plan, DAWE continued to work closely with key stakeholders.

# 14 Organisations/persons involved in evaluating the performance of the plan

This plan should be reviewed no later than five years from when it was endorsed to determine the success of the plan and assess:

- whether the plan should continue unchanged or be varied to remove completed actions or to include new conservation priorities;
- whether a recovery plan is no longer necessary for the species as either a Conservation Advice will suffice, or the species is removed from the threatened species list.

The review will be coordinated by DAWE in association with relevant Australian and state government agencies, and key stakeholder groups likely to be affected by the actions proposed in this plan.

# 15 References


Armstrong, G., & Booth, D. T. (2005). Dietary ecology of the Australian freshwater turtle (*Elseya* sp.: Chelonia: Chelidae) in the Burnett River, Queensland. *Wildlife Research 32*, 349-353.

Blamires, S.J., & Spencer, R-J. (2013). Influence of habitat and predation on population dynamics of the freshwater turtle *Myuchelys georgesi*. *Herpetologica 69(1)*, 46-57.

Blamires, S.J., Spencer, R-J., King, P., & Thompson, M.B. (2005). Population parameters and life-table analysis of two coexisting freshwater turtles: Are the Bellinger River turtle populations threatened? *Wildlife Research 32*, 339-347.

Brizga S., Arthington A., Choy S., Duivenvoorden L. J., Kennard M., Maynard R., & Poplawski W. (2000). Burnett basin WAMP: current environmental conditions and impacts of existing water resource development. Department of Natural Resources Report, Queensland.

Brooks, R. J., Brown, G. P., & Galbraith (1991). Effects of a sudden increase in natural mortality of adults on a population of the common snapping turtle (*Chelydra serpentina*). *Canadian Journal of Zoology 69 (5)*, 1314-1320.

Bunn S. E., Arthington A. H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management 30*, 492–507.

Clark N. J., Gordos M. A., & Franklin C. E. (2008). Diving behaviour, aquatic respiration, and blood respiratory properties: a comparison of hatchling and juvenile Australian turtles. *Journal of Zoology (London) 275*, 399-406.

Department of the Environment (DotE) (2014). Conservation Advice *Elseya albagula* White-throated snapping turtle. Available on the Internet at: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl.

Department of the Environment (DotE) (2015a). Threat abatement plan for predation by feral cats. Canberra: DotE. Available on the Internet at: http://www.environment.gov.au/biodiversity/threatened/publications/tap/threat-abatement-plan-feral-cats.

Department of the Environment (DotE) (2015b). Background document for the threat abatement plan for predation by feral cats. Canberra: DotE. Available on the Internet at: http://www.environment.gov.au/biodiversity/threatened/publications/tap/threat-abatement-plan-feral-cats.

Department of the Environment and Energy (DoEE) (2017a). Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*). Canberra: DAWE. Available on the Internet at: http://environment.gov.au/biodiversity/threatened/publications/tap/feral-pig-2017

Department of the Environment and Energy (DoEE) (2017b). Background document for the threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*). Canberra: DoEE. Available on the Internet at: http://environment.gov.au/biodiversity/threatened/publications/tap/feral-pig-2017

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2008a). Threat abatement plan for predation by the European red fox. Canberra: DEWHA. Available on the Internet at: http://www.environment.gov.au/biodiversity/threatened/publications/tap/predation-european-red-fox.

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2008b). Background document for the threat abatement plan for predation by the European red fox. Canberra: DEWHA. Available on the Internet at: http://www.environment.gov.au/biodiversity/threatened/publications/tap/predation-european-red-fox

Department of Natural Resources (2000). *Burnett Basin WAMP: Current Environmental Conditions and Impacts of Existing Water Resource Development, Vol. 1*. Department of Natural Resources. Queensland: DNR.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2012). *Environment Protection and Biodiversity Conservation Act 1999* Environmental Offsets Policy. Canberra: DSEWPaC. Available on the Internet at: http://www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy

Dowdy, A. et al. (2015). *East Coast Cluster Report*, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. *et al.,* CSIRO and Bureau of Meteorology, Australia. Available on the internet at: https://www.climatechangeinaustralia.gov.au/en/publications-library/cluster-reports/

Ecotone Environmental Services Pty. Ltd. (2007). *Traveston Crossing Dam project: Ecological study: Terrestrial fauna and freshwater turtles. Final Report.* Ecotone Environmental Services Pty Ltd, No. 2007/06, Tenterfield, NSW.

Eiya, Y. A., & Booth, D. T. (2011). Determining the optimal incubation temperature for a head-start program: the effect of incubation temperature on hatchling Burnett River snapping turtles (*Elseya albagula*). *Australian Journal of Zoology 59*, 18-25.

Fielder, D. P. (2012). Seasonal and diel dive performance and behavioural ecology of the bimodally respiring freshwater turtle *Myuchelys bellii* of eastern Australia. *Journal of Comparative Physiology. A. Neuroethology, Sensory, Neural, and Behavioural Physiology 198*, 129-143.

FitzGibbon, S. I., & Franklin, C. E. (2010). The importance of the cloacal bursae as the primary site of aquatic respiration in the freshwater turtle, *Elseya albagula. Australian Zoologist 35*, 276-282.

Flakus S (2002). The ecology of the Mary River turtle, *Elusor macrurus*. M.Sc. thesis, Department of Zoology and Entomology, The University of Queensland, Brisbane.

GHD (2015). Fitzroy River turtle (*Rheodytes leukops*) species management program. Report for Gladstone Area Water Board and SunWater – Lower Fitzroy River Infrastructure Project.

Gordos, M., Franklin, C. E., & Limpus, C. (2003). Seasonal changes in the diving performance of the bimodally respiring freshwater turtle *Rheodytes leukops* in a natural setting. *Canadian Journal of Zoology 81*, 617-625.

Gordos et al (2007). Diving ecology of an undescribed freshwater turtle, *Elseya* sp. [Burnett River], from a pristine and hydrologically altered habitat. *Journal of Zoology 272*, 458-469.

Hamann, M., Schäuble, C. S., Limpus, D. J., Emerick, S. P., & Limpus, C. J. (2004). The Burnett River snapping turtle, *Elseya* sp. [Burnett River] in the Burnett River Catchment, Queensland, Australia: Biological Report, 2004. Unpublished report to Queensland Environmental Protection Agency, Brisbane.

Hamann, M., Schäuble, C. S., Limpus, D. J., Emerick, S. P., & Limpus, C. J. (2007). Management plan for the conservation of *Elseya* sp. [Burnett River] in the Burnett River Catchment. Queensland Environmental Protection Agency.

Heppell S. S. (1998). Application of life-history theory and population model analysis to turtle conservation. *Copeia 2*, 367-375.

Heppell S. S., Crowder L. B., & Crouse, D. T. (1996). Models to evaluate headstarting as a management tool for long-lived turtles. *Ecological Applications 6*, 556-565.

Hollier, C. (2012). Effects of experimental flooding on egg survival of Krefft's River Turtle: Implications for freshwater turtle conservation. Thesis for Master of Environment, University of Melbourne

Iverson, J. B. (1991). Patterns of survivorship in turtles (order Testudines). *Canadian Journal of Zoology 69*, 385-391.

Johnson R (2007). Report on freshwater turtle deaths, Glebe Weir, upper Dawson River. pp. 1–7. Unpublished report to Queensland Environmental Protection Agency.

Limpus, C. J. (2008). Freshwater turtles in the Mary River, Queensland. Review of biological data for turtles in the Mary River, with emphasis on *Elusor macrurus* and *Elseya albagula*. Environmental Protection Agency Brisbane.

Limpus, C. J. (2009). Threatened species nomination of *Elseya albagula*. Department of Environment and Resource Management, Queensland.

Limpus, C. J. (2015). Personal communication at the White-throated snapping turtle (*Elseya albagula*) recovery plan workshop, 5 November 2015. Chief Scientist, Department of Environment and Heritage Protection, Queensland.

Limpus, C. J. (2018). Personal communication by email, 18 October 2018. Chief Scientist, Department of Environment and Heritage Protection, Queensland.

Limpus, C, Limpus, D., & Hamann, M. (2002). Freshwater turtle populations in the area to be flooded by the Walla Weir, Burnett River, Queensland: Baseline study. *Memoirs of the Queensland Museum 48*, 155-168

Limpus C. J., Limpus D. J., Hollier C., Savige M., McAllister D. (2011a). *Survey Of Freshwater Turtle Populations and Nesting Habitat: Tartrus Weir Turtleway Project, 25 September - 1October 2011*. Conservation Technical and Data Report 2011 (3), 1-33.

Limpus, C. J., Limpus, D. J., Parmenter, C. J., Hodge, J., Forest, M., & McLachlan J. (2011b). The Biology and Management Strategies for Freshwater Turtles in the Fitzroy Catchment, with particular emphasis on *Elseya albagula* and *Rheodytes leukops*: A study initiated in response to the proposed construction of Rookwood Weir and the raising of Eden Bann Weir. Department of Environment and Resource Management, Brisbane.

McDougall, A. J., Espinoza, T., Hollier, C., Limpus, D. J, Limpus, C. J. (2015). A risk assessment approach to manage inundation of *Elseya albagula* nests in impounded waters: a win-win situation? *Environmental management 55*, 715-724.

Mathie, N. J., & Franklin, C. E. (2006). The influence of body size on the diving behaviour and physiology of the bimodally respiring turtle *Elseya albagula*. *Journal of Comparative Physiology B 176*, 739-474.

Micheli-Campbell, M. A., Campbell, H. A., Cramp, R. L., Booth, D. T., and C. E. Franklin, (2011). Staying cool, keeping strong: incubation temperature affects performance in a freshwater turtle. *Journal of Zoology*, *285(4)*, 266-273

Micheli-Campbell, M. A., Campbell, H. A., Connell, M., Dwyer, R. G., & Franklin, C. E. (2013). Integrating telemetry with a predictive model to assess habitat preferences and juvenile survival in an endangered freshwater turtle. *Freshwater Biology 58*, 2253-2263.

Micheli-Campbell, M. A., Connell, M. J., Dwyer, R. G., Franklin, C. E., Fry, B., Kennard, M. J., Tao, J., & Campbell, H. A. (2017). Identifying critical habitat for freshwater turtles: integrating long-term monitoring tools to enhance conservation and management. *Biodiversity and Conservation*, *26*(7), 1675-1688.

Queensland Department of Environment and Heritage Protection (Qld DEHP) (2011). Marine and freshwater turtle monitoring. Viewed 8 April 2016. Available on the internet at: https://www.ehp.qld.gov.au/water/monitoring/assessment/turtle_monitoring.html

Queensland Department of Environment and Heritage Protection (Qld DEHP) (2012). Back on Track species prioritisation framework. Viewed 8 April 2016. Available on the internet at: https://www.ehp.qld.gov.au/wildlife/prioritisation-framework/index.html.

Queensland Department of Environment and Resource Management (Qld DERM) (2010a). Fitzroy Natural Resource Management Region Back on track Actions for Biodiversity. Brisbane.

Queensland Department of Environment and Resource Management (Qld DERM) (2010b). Burnett Mary Natural Resource Management Region Back on track Actions for Biodiversity. Brisbane.

Rogers, V. M. (2000). Dietary ecology including dietary resource partitioning of four species of chelid turtle in a tributary of the Fitzroy River, central Queensland. Rockhampton: Unpublished B.Sc.Hon. thesis, School of Biological and Environmental Sciences, Central Queensland University, Rockhampton.

Schaffer, J. R., Hamann, M., & Rowe, R. (2015). Muddy waters: the influence of high suspended-sediment concentration on the diving behaviour of a bimodally respiring freshwater turtle from north-eastern Australia. *Marine and Freshwater Research*.

Spencer, R.-J., & Thompson, M. B. (2005). Experimental analysis of the impact of foxes on freshwater turtle populations. *Conservation Biology 19(3)*, 845-854.

Spencer, R.-J., Van Dyke, J. U., & Thompson, M. B. (2016). The 'Ethological Trap': Functional and numerical responses of highly efficient invasive predators driving prey extinctions. *Ecological Applications*. Accepted Author Manuscript. doi: 10.1002/eap.1375. Available on the internet at: http://onlinelibrary.wiley.com/doi/10.1002/eap.1375/full.

Storey, E. M., Kayes, S. M., De Vries, I., & Franklin, C. E. (2008). Effect of water depth, velocity and temperature on the surfacing frequency of the bimodally respiring turtle *Elseya albagula 22*, 840-846.

SunWater (2015). Personal communication at the White-throated snapping turtle (*Elseya albagula*) recovery plan workshop, 5 November 2015.

Thomson, S., Georges, A., Limpus, C. J. (2006). A new species of freshwater turtle in the genus Elseya (Testudines: Chelidae) from central coastal Queensland, Australia. *Chelonian Conserv Biol 5(1)*,74-86.

Todd, E. V., Blair, D., Farley, S., Farrington, L., Fitzsimmons, N. N., Georges, A., Limpus, C. J., & Jerry, D. R. (2013a). Contemporary genetic structure reflects historical drainage isolation in an Australian snapping turtle, *Elseya albagula*. *Zoological Journal of the Linnean Society 169*, 200-214.

Todd, E. V., Blair, D., Limpus, C. J., Limpus, D. J., & Jerry, D. R. (2013b). High incidence of multiple paternity in an Australian snapping turtle (*Elseya albagula*). *Australian Journal of Zoology 60*, 412-418.

Tracey, C. (2017). Final Report White-throated snapping turtle recovery actions in the Fitzroy Basin 2017. Report for the Fitzroy Basin Association, Rockhampton.

Tucker, A. D. (Compiler) (2000). *Cumulative effects of dams and weirs on freshwater turtles: Fitzroy, Burnett and Mary catchments*. Queensland Parks and Wildlife Service. Report to Department of Natural Resources, Brisbane.

Tucker, A. D., Guarino, F., & Priest, T. E. (2012). Where lakes were once rivers: contrasts of freshwater turtle diets in dams and rivers of southeastern Queensland. *Chelonian Conservation and Biology 11(1)*, 12-23.