

**ECOLOGY OF THE EASTERN LONG-NECKED TURTLE (*CHELODINA  
LONGICOLLIS*) ALONG A NATURAL-URBAN GRADIENT, ACT, AUSTRALIA**

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## **Statement of Contribution**

The thesis entitled *Ecology of the eastern long-necked turtle (Chelodina longicollis) along a natural-urban gradient, ACT, Australia* includes a published manuscript (Chapter two), a manuscript in review (Chapter three), and two manuscripts prepared for publication (Chapter four and five), which were written under the supervision of my thesis supervisors Prof. Arthur Georges (Institute for Applied Ecology, University of Canberra) and Assist. Prof. John H. Roe (Department of Biology, University of North Carolina).

These people provided guidance throughout the conception, analysis, writing and scope of these chapters, and they are included as authors in the associated publications. I have not received other assistance than stated above.

As chair of the supervisory panel I agree with the above statement.

A handwritten signature in black ink that reads "Arthur Georges". The signature is written in a cursive style with a large initial 'A' and 'G'.

**Prof. Arthur Georges**

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## Abstract

Urbanization is one of the leading causes of biodiversity loss worldwide. Many species living within natural-urban gradients are in contact with urban stressors and ecological studies are needed to understand biological responses of susceptible species. Semi-aquatic reptiles engaging dispersal and large distance movements within the city can be susceptible to road mortalities and predation. Freshwater turtles are no exception, as females engage in movements for nesting, males move large distance during the breeding season to search for mating opportunities, and both sexes can disperse to reach different ponds in response to prey availability and wet-dry cycles. In Australia, the eastern long-necked turtle (*Chelodina longicollis*) is a common species inhabiting a range of bodies of water, including suburban wetlands. Previous studies in a suburban area and an adjacent natural reserve during drought in the Australian Capital Territory demonstrated that the *C. longicollis* suburban population was more abundant, grew faster, moved longer distances, and did not exhibit aestivation behavior compared to their nature reserve counterparts, while both populations exhibited similar survivorship. This previous study also demonstrated that the movement dynamics of this species was influenced by wet-dry cycles. When the nature reserve ponds dried, the suburban ponds maintained water levels, and attracted turtles from the nearby reserve. After five years, many conditions had changed at the study site, including an increase in rainfall compared to the previous study, in addition to an increase in urbanization and associated infrastructure. A predator-proof fence was constructed around the nature reserve to protect against encroaching suburban hazards and feral predators. These changes created a unique opportunity to study the response of this turtle over time to an increase in suburban stressors in addition to climatic conditions. I considered three areas with different levels of suburban stress to evaluate *C.*

*longicollis* responses – a nature reserve with a low anthropogenic impact isolated by the enclosure fence, a rural site with an intermediate anthropogenic impact, including agriculture, low level of urban development and exposure to feral predators, and an suburban site with a high anthropogenic impact, including urbanization and exposure to feral predators. The goal of the thesis was to investigate responses of the turtles to dramatic habitat change brought about by urbanization, under a wetter climatic regime than occurred in earlier studies. Specifically, the objectives of this investigation was to evaluate the effects of a predator-proof fence on a reptile community and determine if there is a species-specific impact and the magnitude of the impact at the population level; to evaluate the spatial ecology and survivorship of female *C. longicollis* within the suburban area compared to females inside of the fence enclosure in the nature reserve, with the use of radio-telemetry; to investigate demographic responses, fecundity and vital rates of *C. longicollis* through a capture-mark-recapture study; and to evaluate the nesting ecology of *C. longicollis* in order to document incubation period and nesting success in natural nests, and investigate the possibility of overwintering in the nest by hatchlings.

I registered 1052 records of six species of reptiles along the predator-proof fence, but impacts, including number of records and mortality, were larger for *C. longicollis* than lizards and a snake species (Chapter two). I observed several *C. longicollis* recaptures at the fence and many were found dead later at the fence, indicating a persistent attempt to navigate past the fence. I conservatively estimated that the fence resulted in the death of 3.3% and disrupted movements of 20.9% of the turtle population within the enclosure. The most common cause of turtle mortality was overheating, especially on turtles trying to enter the reserve, followed by predation, vehicular collision and entanglement.

Considering the spatial ecology attributes, suburban and nature reserve female *C. longicollis* had similar movements and spatial metrics, except for suburban turtles moving longer total distances (Chapter three). There was no observation of prolonged terrestrial aestivation in any of the study sites. Turtles from smaller ponds used more wetlands than turtles from larger ponds, exposing them to increased risks from vehicular mortality during overland movements, a fact that was observed in the suburban site, as they showed reduced annual survivorship estimates (0.67), according to known fate models, compared to the nature reserve turtles (1.00) owing to the high number of vehicular collisions in the sample.

The capture-mark-recapture study revealed that turtles from the three study sites with different levels of anthropogenic impact had similar growth rates, abundances, sex ratios, and fecundity (Chapter four). Despite increasing urbanization, there was evidence of recent recruitment at all sites and survivorship estimates were similar among study areas, according to Cormack-Jolly-Seber models. In addition, some of the turtles were recaptured over long distances (6 km) from their initial encounter, underscoring the importance of movements in suburban landscapes. These findings contrast with the previous study during drought where nature reserve turtles grew slower, were less active and less vagile than suburban turtles owing to the fluctuating resources and water levels in the nature reserve compared to the more stable environment in the suburbs.

I was also able to confirm that *C. longicollis* hatchlings overwinter in the nest, spending on average 320 days from the date eggs were laid until emergence (Chapter five). In addition, I also observed two strategies from the same population, with hatchlings from one nest emerging in autumn and spending their first winter in the aquatic environment, and hatchlings from three nests overwintering in the nest and emerging in spring.

Together, these findings indicate that *C. longicollis* is a resilient species within suburban landscapes and its demography and behavior is strongly influenced by rainfall. The observations of turtles trying to migrate back to the nature reserve following flooding of ephemeral ponds in the reserve, in addition to the long distance movements and the fact that the current design of the fence did not allow turtles to reach the reserve ponds underscore the importance of allowing turtles to freely move between habitats in response to stochastic events such as drought. Even though the nature reserve turtles are now protected against nest predation by foxes inside the enclosure, the fact that the fence caused adult mortalities and did not allow immigrations suggests the population inside of the fenced enclosure would likely decline over the long-term if no action is taken. I suggest the construction of water under-passages along hotspots of turtle movements, which were clustered in areas with more wetlands and less urban development. The efficacy of this mitigation measure should be tested and a longer-term monitoring of the turtle population inside of the fence enclosure and within the suburbs should be encouraged to understand population responses over longer periods of time (i.e., decades), which are more reflective of turtle life spans. In conclusion, this work helps to demonstrate how the population dynamics of a nominally aquatic turtle is influenced by and regulated in space and time by populations from a range of habitats differing in anthropogenic impact. The remarkable capacity for overland movements in *C. longicollis* is what connects such unique and sometimes distant populations, and possibly helps in the persistence of this species in challenging environments.

## Table of Contents

	Page
<b>Chapter 1: General Introduction</b> .....	1
Urbanization and wildlife.....	1
Freshwater turtles and urban challenges.....	2
Study species.....	6
Study system and knowledge gap.....	6
Thesis aims and structure.....	11
<b>Chapter 2: Reptile bycatch in a pest-exclusion fence established for wildlife reintroductions</b> .....	13
Abstract.....	13
Introduction.....	14
Method.....	16
Study area.....	16
Fence monitoring.....	18
Pond sampling.....	19
Data analysis.....	19
Results.....	22
Encounters and mortalities.....	22

Spatial correlates of encounters.....	24
Temporal correlates of encounters.....	24
Size-frequency distributions.....	27
Magnitude of disruption.....	27
Discussion.....	30
General impacts on reptiles.....	30
Management, mitigation and non-target species.....	33
Conclusion.....	36
<b>Chapter 3: Urban hazards: spatial ecology and survivorship of female turtles in an expanding suburban environment.....</b>	<b>37</b>
Abstract.....	37
Introduction.....	38
Methods.....	40
Study area.....	40
Water levels and urban growth.....	42
Capture and radio-transmitter attachment.....	42
Radio-telemetry data collection.....	43
Data analysis.....	44
Results.....	46

Water levels.....	46
Movements.....	48
Survivorship.....	53
Discussion.....	55
<b>Chapter 4: Responses of an Australian freshwater turtle to drought-flood cycles along a natural to urban gradient.....</b>	<b>61</b>
Abstract.....	61
Introduction.....	62
Methods.....	64
Study area.....	64
Trapping and marking.....	67
Anthropogenic impact.....	67
Primary and secondary productivity.....	68
Reproduction.....	69
Growth rates and movements.....	69
Demographic parameters.....	70
Data analysis.....	70
Results.....	72
Anthropogenic impact.....	72

Primary and secondary productivity.....	73
Reproduction.....	73
Growth and movements.....	75
Demographic parameters.....	80
Discussion.....	84
Conclusions.....	89
<b>Chapter 5: First record of hatchling overwintering in the nest in a Chelid turtle.....</b>	<b>93</b>
Abstract.....	93
Introduction.....	94
Methods.....	95
Results.....	96
Discussion.....	100
<b>Chapter 6: Synthesis.....</b>	<b>105</b>
Management implications.....	108
<b>References.....</b>	<b>111</b>

## List of Figures

	Page
<b>Figure 1.1.</b> Study sites along a natural-urban gradient in Gungahlin region, Australian Capital Territory, southeastern Australia. Mulligans Flat Nature Reserve.....	6
<b>Figure 1.2.</b> Adult and juvenile <i>Chelodina longicollis</i> , and the habitats they were studied in a nature reserve, rural site and suburban site in Gungahlin region, Australian Capital Territory, Australia.....	7
<b>Figure 1.3.</b> Fence monitoring in the nature reserve and some reptiles found along the fence. <i>Chelodina longicollis</i> nest with an i-button inserted to record nest temperatures and the same nest covered with a metal mesh to avoid predation and monitor the incubation period.....	8
<b>Figure 2.1.</b> Pest-exclusion fence at Mulligans Flat Nature Reserve, Australian Capital Territory, Australia.....	17
<b>Figure 2.2.</b> Spatial distribution of encounters for <i>Chelodina longicollis</i> , <i>Tiliqua rugosa</i> and <i>Pogona barbata</i> along the pest-exclusion fence at Mulligans Flat Nature Reserve, Australian Capital Territory, Australia.....	25
<b>Figure 2.3.</b> Temporal patterns of reptiles records from Jan 2012 to Apr 2013 in the pest-exclusion fence at Mulligans Flat Nature Reserve, Australian Capital Territory, Australia.....	26
<b>Figure 2.4.</b> Size-frequency distributions of <i>Chelodina longicollis</i> captured in ponds compared to those moving along a pest-exclusion fence, and those that were found inside of the pest-exclusion fence compared to those outside at Mulligans Flat Nature Reserve, Australian Capital Territory, Australia.....	29

**Figure 3.1.** Water level fluctuation relative to the beginning of the study (January 2012) in nature reserve and suburbans ponds, Australian Capital Territory, Australia.....47

**Figure 3.2.** Relationship between response and predictor variable in linear regression analysis in *Chelodina longicollis* inhabiting nature reserve and suburban ponds in Gungahlin, Australian Capital Territory, Australia.....51

**Figure 3.3.** Deaths of female *Chelodina longicollis* monitored by radio-telemetry in the Gungahlin suburb during wet period, Australian Capital Territory, Australia.....52

**Figure 4.1.** Nature reserve, rural and suburban study sites in Gungahlin, northern Canberra, Australian Capital Territory.....66

**Figure 4.2.** Gravid females *Chelodina longicollis* inspected through X-ray in nature reserve, rural and suburban sites, in Australian Capital Territory, Australia.....76

**Figure 4.3.** Relationships of growth and initial carapace length in *Chelodina longicollis* inhabiting nature reserve, rural and suburban habitats, during 2006-2014 and 2011-2014 period, Australian Capital Territory, Australia.....79

**Figure 4.4.** Size-frequency distributions of *Chelodina longicollis* among study sites, Australian Capital Territory, Australia.....81

**Figure 5.1.** Incubation period and nest emergence of *Chelodina longicollis* from Gungahlin, Australian Capital Territory, Australia, during 2013-2014 nesting season.....99

## List of Tables

	Page
<b>Table 2.1.</b> Live and dead reptile encounters in the pest-exclusion fence at Mulligans Flat Nature Reserve, Australian Capital Territory, Australia.....	23
<b>Table 2.2.</b> Logistic regression model base for timing of <i>Chelodina longicollis</i> deaths along the pest-exclusion fence at Mulligans Flat Nature Reserve, Australian Capital Territory, Australia.....	28
<b>Table 3.1.</b> Spatial ecology and movements of female <i>Chelodina longicollis</i> in nature reserve and suburban habitats comparing a previous and the present study in Gungahlin, Australian Capital Territory, Australia. ....	50
<b>Table 3.2.</b> Road mortality and pond characteristics of radiotracked female <i>Chelodina longicollis</i> in Gungahlin suburbs, Australian Capital Territory, Australia.....	54
<b>Table 3.3.</b> Models of survivorship probability ( <i>S</i> ) of female <i>Chelodina longicollis</i> between sites (site) over monthly time intervals (time), Australian Capital Territory, Australia.....	54
<b>Table 4.1.</b> Primary and secondary productivity measurements in ponds inhabited by <i>Chelodina longicollis</i> among study sites, Australian Capital Territory, Australia .....	74
<b>Table 4.2.</b> Clutch size and egg measurements of gravid female <i>Chelodina longicollis</i> (through X-ray evaluation) from different study sites, Australian Capital Territory, Australia.....	77
<b>Table 4.3.</b> Growth rates of eastern long-necked turtles ( <i>Chelodina longicollis</i> ), after controlling for carapace length, and recaptures for juveniles and adults, spanning long-term (drought-wet) and short-term (wet) conditions, Australian Capital Territory, Australia.....	78

**Table 4.4.** Models of survivorship ( $\Phi$ ) and capture probability ( $\rho$ ) of *Chelodina longicollis* over time, among sites (nature reserve, rural, and suburb), and among groups (adult male, adult female, and juvenile) in the Australian Capital Territory, Australia, 2011-2014.....82

**Table 4.5.** Estimates of survivorship ( $\Phi$ ) and capture probability ( $\rho$ ) for *Chelodina longicollis* among different sites and groups in the Australian Capital Territory, Australia, 2011-2014.....83

**Table 5.1.** *Chelodina longicollis* nests monitored during three reproductive seasons in Gungahlin, Australian Capital Territory, Australia.....98