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.

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 in 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.

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