Aquatic and terrestrial habitat use of the Australian freshwater turtle, *Chelodina expansa*

Ellyn Ercolano

Academic Director: Tony Cummings

Advisor: Deborah Bower, PhD Candidate
Institute for Applied Ecology, University of Canberra

Home institution: Bucknell University, Lewisburg, PA

Major: Biology

Location: Berri, South Australia, Australia

Submitted in partial fulfillment of the requirements for Australia: Natural and Cultural Ecology, SIT Study Abroad, Spring 2008

Title page photo credit: Ellyn Ercolano, April 2008

ABSTRACT

Organisms select habitats that provide the best possible resources necessary to their survival. Organisms may occupy and utilize a home range which requires specific selection of components in their available habitat. Monitoring the threats to a species within their habitats is a crucial tool in conservation and management practices. The Murray-Darling Basin of south-eastern Australia has suffered alterations to its hydrology, flow regime, catchment size and usage, flooding cycles, as well as from vast removal of vegetation in the floodplains since European settlement in Australia in the mid-nineteenth century. Knowledge of the habitat use of a focal species can guide efforts to improve the health of systems vital to the plants, animals, and people of Australia.

This study investigated habitat use of the Australian freshwater turtle, *Chelodina expansa*, in two backwaters of the Lower-Murray River in South Australia. Little is known about the ecology of this cryptic carnivore that inhabits only permanent waters. Habitat use of female *C. expansa* was located within the terrestrial vegetation of Lake Bonney. We collected qualitative information based on the nest and track selection of the nesting females. Aquatic habitat use was determined by locating animals with radiotelemetry in Horseshoe Lagoon. Habitat availability was determined by the percentage of vegetation cover of each habitat type, and the usage of each habitat type was determined by the location of tracked animals.

This species of turtle displayed a preference for areas of undisturbed and moderate vegetative cover in which to excavate nests, and the majority of aquatic habitat use was in structured vegetation, including emergent reeds, aquatic macrophytes and submerged logs, dead trees and root systems. Future conservation and restoration of modified systems, especially of the Lower Murray, should consider both terrestrial and aquatic habitats for threatened species suffering from habitat loss, invasive species, and other dangers.

Keywords: *Chelodina expansa*, habitat selection, conservation and management, Murray-Darling Basin

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Deborah Bower, my advisor, for providing me with the opportunity to study broad-shelled turtles with her for an entire month. I will be forever grateful for our unique moments and fond memories of the beginner's luck; camping on 'Old Mate's' property; waking up in time for an overnight tracking shift; the heap of canned food for dinners and Mars Bars for dessert; classic tunes in our endless car rides; and the ability to somehow push forward, even when the rains were not forecast for weeks; the blisters burned; and the keys were missing. Thank you for the endless time and energy put forth to enhance my educational experience.

Thank you to Amanda O'Malley and Scott Waugh for their enthusiasm during field work, regardless of the kilometers walked and the hours passed by. For the knowledge of vegetation identification, special thanks to Phil Reddy; and for GPS resources, to Claire Treilibs. I would still be collecting data if it were not for their help.

I would also like to thank Kate Hodges, Carla Eisemberg, and flat mates for their hospitality during my whirlwind stay in Canberra. Thank you, John Bannear, for providing your insight on nesting at Lake Bonney.

And finally, thank you SIT Wet 2008 (and Tony), for the fun and excitement shared from the start to finish of this project. Your guidance and motivation kept the workload enjoyable.

LIST OF FIGURES

1. INTRODUCTION

1.1 Habitat selection

A suitable habitat for any given organism will possess the resources required for its survival. Habitats with better resources, including adequate food supplies and safer shelter, may give an individual a selective advantage and improved fitness over others (Mysterud and Ims, 1998). Differences in habitat use are thought to develop as a result of physiological, morphological or bionomical interspecific differences, adaptation to a habitat based on independent evolution in different areas, or specialization to optimal habitats because of competition (within or) between species (Storch and Frynta, 1999; Rosenzweig, 1981). Regardless of how habitat selection occurs, certain locations will be perceived as preferable and inhabiting these areas may provide a selective advantage.

Selection of a habitat can be ordered at the macro and micro levels. First, a physical or geographical location in which to inhabit will be selected as a macrohabitat. Then the animal, or social group, will secure a home range, limiting their movement spatially. Further selection will occur as an animal makes use of the different habitat components, or microhabitats, in the home range. The usage of feeding locations, if chosen as a specific area of the home range, may correlate directly to efforts of acquisition. Habitat availability, relative to the proportions at the macro level, may decrease at the micro level because an animal is selecting for an area where its habitat of preference dominates. Usage by the animal at the micro level can therefore increase relative to the total availability of habitat types (Johnson, 1980).

It is often assumed that all habitats in a study area are available to each individual, and that a home range, dominated by a distinct area of habitat, is defined for each animal (Arthur *et al.*, 1996). It is therefore important to note that habitat composition will change over time, on both short and long term scales. The link between habitat usage and spatial or temporal scales must be taken into consideration when analyzing the habitat selection of an animal. Habitat availability will change with yearly growth cycles of vegetation and stochastic events, including those naturally and human influenced. Fluctuations in water level, nutrients and other resources will also impact the abundance and distribution of habitat types. Movement of an animal between habitats will occur, based on availability and requirements of an animal at a certain point in time (Arthur *et al*., 1996; Bodie and Semlitsch, 2000).

1.2 Implications of habitat use

Habitat selection of vagile species can be indicative of important resources because individuals choose areas that they perceive to have better access to resources. These selected regions can be used in the management of modified systems to prioritize areas for conservation and those which need restoration. The status and trend of a focal species, if determined accurately, can also indicate change in a broader set of species and ecological function (Regan *et al.*, 2008). Species diversity, abundance and distribution represent a healthy functioning ecosystem. As the knowledge of species known to associate primarily with a specific range of habitat types increases, the health status of an ecosystem can be assessed. Decreases in the abundance and distribution of a species in a region can indicate a lack in the availability of the habitat and thus decline in the health of an ecosystem (Walker *et al.*, 1992; Walker, 1992; Walker, 2006).

Habitat types should be monitored for a focal, or indicator, species based on the threats a species faces within its habitat, not the threats on the habitat itself. Such threats may consist of a decrease in food resources as habitat complexity decreases, or overall shelter from danger in vegetative cover, as well as competition from invasive species; alterations to fire regimes; disturbances from humans; and altered hydrology. If threats for a species inhabiting a particular area become more prevalent, the fitness of the animal will decrease due to possible declines in food availability, areas of protected shelter, delayed reproductive maturity (and success). Physiological stress can further affect the response of an animal to its environment. Although much can be interpreted from monitoring habitat alterations and changes to species abundance and distribution in a region, it is important to monitor the threats a species faces within its preferred habitat over time (Regan *et al.*, 2008).

The Murray-Darling River Basin is a highly modified river system occurring through five states of south-eastern Australia. Since European settlement in the mid-nineteenth century, its rivers have been used as avenues for commerce, and their surrounding floodplains have been cleared for the pastures of livestock and fields of crops. About two thirds of the mean annual discharge of the basin is diverted (Walker, 2006). There are 200 storages located in the basin, storing over 94% of the total capacity of the system (Walker, 2006). The basin hosts nearly two million people, and supports one quarter of the nation’s cattle and dairy farms, half the sheep and half the cropland (Walker, 1992). Irrigation has occurred on a large-scale, to provide water for citrus, vines and stone-fruit crops. Between 90%-95% of annual water consumption is due to irrigation (Walker, 2006; Walker, 1992).

To regulate water levels and flow, there are four major dams and sixteen weirs on the Murray River. The flow is regulated from its source in the Snowy Mountains, and the annual average flow reaching South Australia is at least 42% less than under natural conditions (Walker, 1992). Salinity levels of surrounding soils and waters of the Murray River are currently increasing as a result of rising water tables. Water tables have risen due to the removal of vegetation; lack concentration of salt due to low flows; and inadequate irrigation, land and water management. Turbidity of the waters has increased due to sediment settling or transport between weirs and increased chemical runoff from agricultural activity (Walker, 1992). Habitat fragmentation is occurring throughout the Lower Murray region, affecting large populations of native fishes and waterbirds. The loss of complex vegetative structures has consequentially had a negative impact on species abundance and diversity; this is particularly evident in highly sensitive taxa, such as macroinvertebrates (Walker *et al.*, 1992).

1.3 Habitat use of reptiles

A habitat adequate to support a nest of any organism should maintain conditions necessary for successful development, as well as limit threats from predators. Oviparous reptiles deposit their eggs in a nest in the ground, abandoning them soon after. The desiccation of eggs can occur if the nest is subject to a drastic decrease in moisture over time, while an increase in moisture may lead to fungal infestations or reductions in gas exchange. Additionally, high temperatures may be lethal to the embryos, and low temperatures can halt or prevent stages in the development process (Warner and Andrews, 2002).

The ultimate fitness of an animal will relate to those components of a home range utilized the most. Most reptiles will live on the ground, inhabitating vegetative cover such as logs or other fallen debris, and some will climb trees as well. The abundance of food resources (insects, plants, small animals), structures for basking, and shelter from predators are dominant habitat requirements of reptiles. Migration between ranges of habitat use, or hibernation, will result with changes in environmental conditions, including the cycles of ephemeral water bodies, seasonal availability of food, and as mating between sexes begins (Chessman, 1988; Warner and Andrews, 2002; Greer, 2006).

Turtles are a suitable organism for habitat selection studies because they utilize both aquatic and terrestrial habitats throughout their lives. They are uniquely adapted vertebrates for river and wetland systems. Aquatic habitats are important for the feeding, basking, mating and overwintering of many turtles. Terrestrial habitats are used by males for emigration, to search for females, and possible overwintering, while many females travel large distances from the water to oviposit (Cann, 1998; Greer, 2006). Alterations to river systems can impact the availability of habitat types that turtles rely on. Evaluation of the effects on turtle populations is useful for the development of mitigation measures, and to predict the impact and severity of future management decisions (Reese and Hartwell, 1998).

1.4 Freshwater turtles of Australia

The broad-shelled turtle, *Chelodina expansa*, is a freshwater turtle occupying the Murray-Darling Basin in south-eastern Australia. It is listed as ‘threatened’ in Victoria (Flora and Fauna Guarantee Act 1988) and ‘vulnerable’ in South Australia (National Parks and Wildlife Act 1972). Few studies have investigated population dynamics, nesting behavior and impacts from disturbances of *C. expansa*. This lack of knowledge has limited the understanding of their ecology, and in turn, restricted the ability to predict the impacts of management processes. These turtles are cryptic, do not bask, and are often trapped in much lower numbers than other freshwater turtles found in the same areas (Spencer and Thompson, 2005; Legler, 1978; Chessman, 1988). Ongoing and future research will continue to expand knowledge of the distribution, ecology, behavior and natural life history of *C. expansa* in Australia, furthering knowledge of conservation biology and encouraging management and restoration initiatives.

This species is predominantly found in turbid waters at a depth greater than three meters (Chessman, 1988). It will occur in rivers, backwaters, oxbows, anabranches, ponds in floodplains, swamps, and lagoons (Cann, 1998; Chessman, 1988; Legler, 1978). Dependence on permanent waters by *C. expansa* is most likely associated with its higher rate of evaporative water loss under desiccating conditions, infrequent emigration between water bodies, and the lack of terrestrial (or aquatic) aestivation (Chessman, 1988). Past studies have shown *C. expansa* is found in the uppermost level of dense vegetation cover in the water column (Legler, 1978). Food availability and shelter from predators may influence the specific microhabitat preference of these turtles, as well as seasonal changes affecting water levels and flow.

This species will select specific nesting conditions and respond to pressures, such as predation and vegetative cover. Females will travel up to one kilometer from the water's edge to lay her eggs in a nest. Nests have often been found at the tops of ridges or where a slope has leveled off (Georges, 1984). The threat of predation on nests of *C. expansa* by the red fox (*Vulpes vulpes*) can be high (Spencer and Thompson, 2005). It is thought that turtles are aware of predators, mainly through olfactory and visual clues (Spencer and Thompson, 2005; Spencer, 2002). Preference for nest site selection on terrestrial areas with substantial vegetative cover and little disturbance may increase hatchling success. Although nests can be far from the water, moisture requirements of the nest are insignificant until hatchlings are to emerge from the nest, in which case soils softened by rainfall are desired. In addition, nests of *C. expansa* are often subject to much colder temperatures during winter months. Direct sunlight on the nests will increase temperatures, which can slightly impact the development process of the hatchlings (Goode and Russell, 1968; Greer, 2006).

1.5 Study aims

This study investigated the use of aquatic and terrestrial habitats along the Murray River in South Australia by the freshwater turtle, *C. expansa*. The aquatic habitat selection by this freshwater turtle was determined, as well as the destination for females nesting terrestrially, to establish an understanding of habitat importance to the species. Analysis of habitat type and abundance provides further understanding of distribution and ecology of an animal, and can imply the potential impact of habitat loss, change or destruction to the species. This has application for the development of conservation and management practices, in addition to the turtles, of broader river floodplain habitats.

2. METHODS

2.1 Study species

The broad-shelled turtle, *Chelodina expansa*, is a pleurodire freshwater turtle in the family Chelidae. It is found in permanent waters throughout the Murray-Darling Basin of south-eastern Queensland, New South Wales, Victoria and South Australia. *Chelodina expansa* occurs in broad sympatry with *Chelodina longicollis* and *Emydura macquarii.* The species is primarily active from spring (October) to early autumn (April), while its metabolism, movement and feeding decrease over colder winter months (Greer, 2006).

These highly specialized and selective carnivorous predators feed primarily on crustaceans, aquatic insects, and small fish. Broad-shelled turtles are the largest of the long-necked turtles. Carapace lengths can reach 48 cm in females, which obtain larger sizes than males. The neck, when extended, can exceed the length of the carapace size (Greer, 2006).

Females construct nests during daylight hours following rainfall from mid-March to August, laying clutches of 5-28 eggs. The eggs are white and ellipsoid shaped, with a hard, calcareous shell. Duration of incubation averages between 324 and 360 days, and the developing embryo enters two distinct diapauses (primary diapause occurs when inside the mother; once the egg is laid, after a short period of growth, secondary diapause is triggered by a drop in temperature and will resume with a corresponding rise in the spring). Major predators of hatchlings are spotted barramundi, while nests are often predated by foxes (*Vulpes vulpes*) and ravens (*Corvus* spp.) (Greer, 2006; Legler, 1978; Georges, 1984; Phillot and Parmenter, 2000).

2.2 Study areas

The Murray River is one of the largest river systems in Australia, extending more than 2350 km through the continent's southeast. Flow regimes and catchments have been dramatically altered by European settlers for the past century, including the construction of ten weirs and associated locks on the Lower-Murray River. Changes to the hydrology have subsequently affected the vegetation of the riparian and littoral zones. River red gum (*Eucalyptus camaldulensis*) and black box (*Eucalyptus largiflorens*), which previously dominated flood plains, suffered wide scale death in response to the permanent water levels. Furthermore, many wetland species of aquatic macrophytes and grasses previously confined to backwater billabongs were able to colonize the main river channel. In South Australia, the Riverland stretches from the border of New South Wales, Victoria and western South Australia to Waikerie, further along the river. The Riverland has broad floodplains which extend up to 9 km beyond the Murray channel. Unsuitable land practices such as land clearing and wide scale cropping has caused problems, and has decreased the quality of habitats in both the littoral zone and main river channel (Walker *et al.*, 1992). This is evident through the removal of vegetation for agriculture (mainly citrus orchards and vineyards) and grazing of livestock, as well as altered water levels throughout the river channel.

Beyond its convergence with the Darling River, weir pools extend over two thirds of the Murray's course. Areas of permanent waters, or a lack of water altogether, are present in regions of floodplain where periodic flooding and drying has historically occurred (Walker, 2006). The change from impermanent to stable bodies of water within the floodplains of the Murray River has hindered the reproduction cycle and recruitment of many native plant and animal species (Walker, 1992; Walker, 2006), and the loss of complexity due to the removal of tree snags increases erosion, decreases habitats and the abundance of species (Walker *et al.*, 1992). These outcomes have dramatically affected the extensive floodplains of the Riverland.

Two sites located along the Murray River in South Australia were used in this study. Lake Bonney, situated in the township of Barmera, was subject to periods of drought and flooding before the construction of Lock 3 on the Murray in 1925 (34°12.446' S, 140°26.776'

E), which created a stable water body. However, the channel connecting the lake to the Murray has recently been closed off (October 2007), a response from government authorities to manage insufficient water availability in the region. Horseshoe Lagoon is located in Murtho State Forest (34°5.379' S, 140°46.773' E), and it retains two small water passes connecting to the main river channel. This water body was also subject to flooding and drying cycles, but is now permanent as a result of water level alterations. Both sites have high turbidity levels, characteristic of the Lower-Murray.

Lake Bonney, with a 19 km perimeter and oval shape, encompasses an area of 16.5 square km. We classified the terrestrial vegetation habitats surrounding the water based on four major zones, the edges of which were traced on foot with a GPS on 23 April 2008 to an accuracy of one meter. The first zone included the water’s edge to the semi-aquatic vegetation growth (*Cynodon dactylon, Typha domingensis*), and was called the beachfront zone. The second zone was measured at the opposite edge this growth, called the semi-aquatic vegetation zone. The third zone was measured past any disturbance (foot path or dirt vehicle road) such that the vegetation cover beyond the edge was fairly consistent in density and diversity. This outer zone was subject to further disturbance, including a paved roadway, vineyard or residential development, a few meters further out; however, distinct vegetation cover allowed for the classification of a zone.

On the west and north sides of the lake, the dominant vegetation types of the outer zone were small-fruited samphire (*Halosarcia* spp.), tangled and short sclerolaena (*Sclerolaena dicantha, S. cuneata*), and pigface inland (*Carpobrutus modestus*). The vegetation of the outer zone on the east side of the lake was dominated more heavily by saltbush (*Mariana* spp.), Old Man saltbush (*Atriplex nummularia*) and eucalypt trees (*Eucalyptus* spp.). The south side was dominated by an introduced species of grass, kikuyu (*Pennisetum clandestinum*). The soil of the floodplain of the lake is characterized by undulating sand ridges over clay. In many areas dead river red gum trees (*Eucalpytus camaldulensis*) are present on the exposed beachfront, and some trees of the *Acacia* spp. were developing past the outside edge.

Horseshoe Lagoon is curved, with a characteristic horseshoe shape, and approximately 6 km in total length with a water area of 1.2 square km. Aquatic vegetation was traced by GPS between 20 and 30 April 2008. Reeds (*Typha domingensis, Phragmites australis, Juncus* spp.) located along the bank that extended out into the water were traced from a boat to an accuracy of one meter. Submerged trees and dead trees visible and accessible from the boat were marked by waypoint or traced if the area was larger than three meters in diameter, again to an accuracy of one meter. Areas of plant cover in the water were traced to within 500cm. Aquatic plant species in the lagoon include ribbon weed (*Vallisneria* spp), curly pond weed (*Potamogeton crispus*), native primrose (*Ludwigia pepliodies*), floating pond weed (*Potamogeton sulcatus*), and *Arizola* spp. The vegetation mapped (Figure 3) is representative only of what was visible by the unaided human eye, so cover for each habitat type is most likely an underestimate of actual availability. However, this is appropriate for the conditions of this study as waters were too turbid to permit underwater observation.

2.3 Data Collection

2.3.1 Track and nest observations

Tracks of female *C. expansa* individuals were counted along the shore of Lake Bonney on 10 and 14 April 2008. Chelodina expansa tracks were distinguished by their large size relative to other species and because they nest at a different time. Tracks were followed from the edge of the water up through vegetation, as far as detection allowed. Zones of vegetation included in the track route were described for each individual track. Nests were identifiable by digging marks, disturbances in vegetation, and sometimes by the presence of predated eggs. When nests were identified, the locations and corresponding vegetation type were recorded. Some tracks were not distinguishable as distance from the lake edge increased due to drier and more compact soils, but ending locations were approximated to within one meter. In cases where the nest was not located, the habitat in which the turtle walked proved adequate to describe ultimate terrestrial habitat conditions.

2.3.2 Radiotelemetry

Radio transmitters (Holohil 150 MHz with exposed antennae) were externally affixed to the rear right of the carapace of eight female and five male turtles in December 2006. Turtles were initially located by listening with a receiver (Telonics TR-4 at 150 MHz) and a hand-held antenna at approximately 300 m intervals. Signals were usually audible at distances of 200-500 m, although reception declined for individuals in thick covers of vegetation or moving in open water. Specific location fixes were estimated based on signal strength within 2 to 3 m of the turtle's position. Turtles were tracked from a small motor boat to the closest point without vegetation, preventing us from disturbing turtles into moving.

Tracking data was collected over six days on 15 April, 19 April, 24-25 April, 1 May and 2 May 2008 in Horseshoe Lagoon. On all days, except 24-25 April, turtles were located once during the day. On 24-25 April, the turtles were tracked for a twenty-four hour period, and fixes were collected every two hours. Vegetation type and density, location, approximate water depth, and time of day were recorded for all fixes. Density was recorded on a scale of 1-3; (1 corresponded to sparse cover, while 3 corresponding to very dense, vegetation cover).

Low quality fixes, associated with diminished signals, were usually a result of thick vegetation cover or movement of the animal in open water. For the purposes of this study, however, approximate location to (or in) a particular vegetation type is appropriate, and low quality fixes were included in all data analysis.

2.4 Data Analysis

2.4.1 Maps

Latitude and longitude was collected in decimal degrees from a Garmin Map 60, Datum WP84. The coordinates were imported into maps accessed using OziExplorer, which was also used for morphometric calculations, such as land area. Vegetation cover was shaded using Photoshop in order to provide a visual representation of the proportion of described habitat types available.

2.4.2 Vegetation cover

At Lake Bonney, the location and vegetation zone on which most tracks and nests were located, were determined visually in OziExplorer. Descriptions of the areas containing tracks and/or nests were organized to establish a pattern of nesting habits of females.

The total area of each vegetation type available in Horseshoe Lagoon was calculated in OziExplorer. The length of tracks for *Typha domingensis*, *Phragmites australis*, and *Juncus* spp. was measured and multiplied by an average width relative to the bank. Areas of aquatic macrophytes (*Vallisneria* spp, *Potamogeton crispus*, *Ludwigia pepliodies*, *Potamogeton sulcatus*, and *Arizola* spp.) visible in open water were measured in a similar manner to the reeds. The total number of submerged logs and dead trees along the bank was counted, and each was given a standard area of four square meters in order to estimate the area in the direct vicinity of logs. Open water was considered to be water with no visible vegetation in its direct vicinity and was determined as the remaining area. These habitat types were calculated as proportions of total water area. Areas were calculated to an accuracy of 5 square meters.

The fixes of *C. expansa* individuals were counted and each habitat type was calculated as a proportion of total locations. If, for example, an animal was found in typha reeds near a log, the fix was counted for two locations.

3. RESULTS

3.1 Lake Bonney

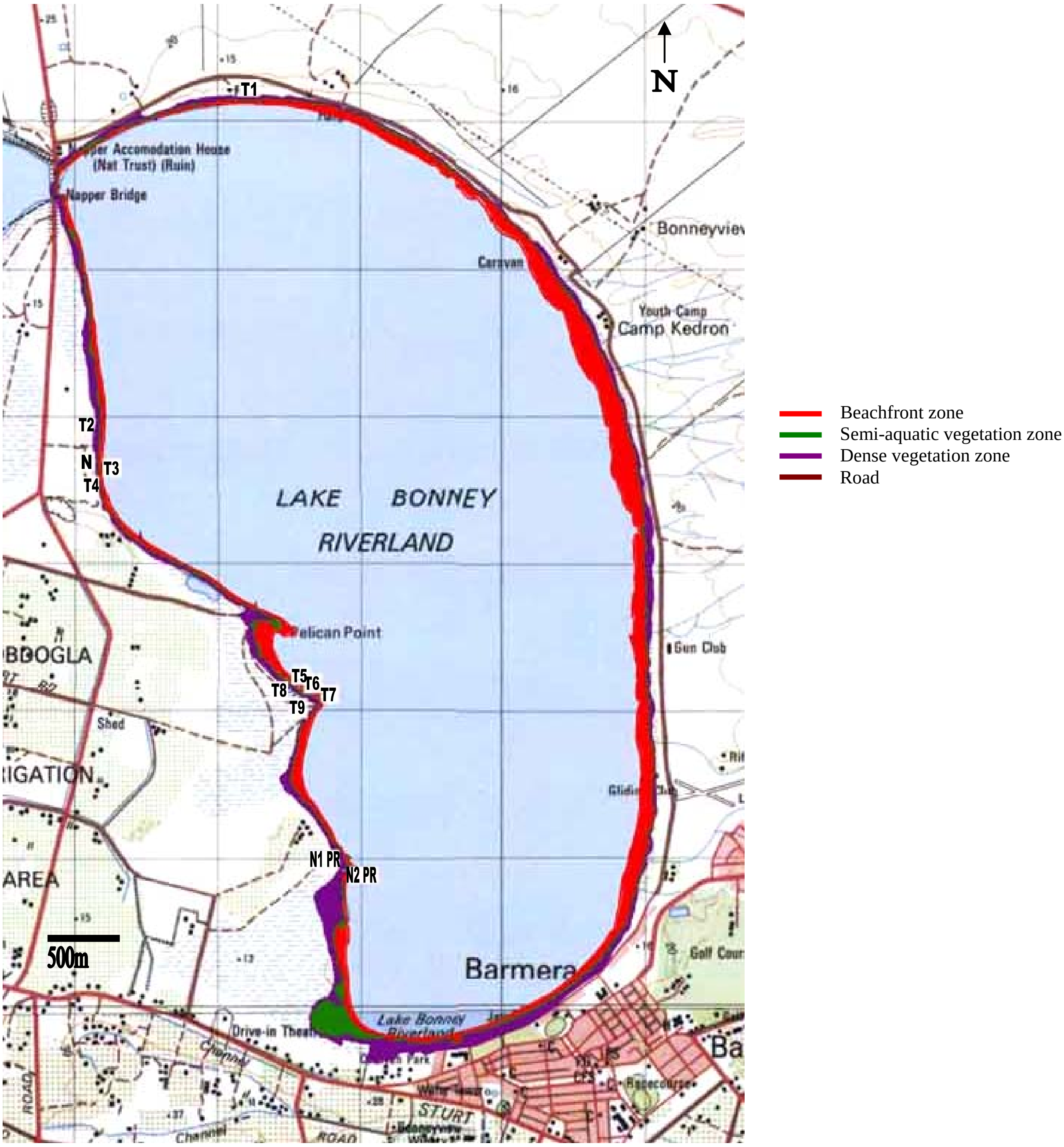

Figure 1. Outline of vegetation zones at Lake Bonney study site. Tracks (T1-9), nests (N), and predated nests (N1-2 PR), from three days in April 2008, are numbered north to south.

A total of 10 tracks were located around Lake Bonney following 2 mL of rainfall in April 2008. Of these tracks, only three had corresponding nests. Two of the three nests found were laid in the sand of the beachfront zone, a few centimeters before the semi-aquatic vegetation. These two nests were predated, in a fashion characteristic of ravens (*Corvus* spp.)

(N1 PR and N2 PR, Figure 1). The third nest (N) was located past the fourth edge, in dense cover of small-fruited samphire (*Halosarcia* spp.), tangled and short sclerolaena (*Sclerolaena dicantha, S. cuneata*), and pigface inland (*Carpobrutus modestus*). With the exception of two return tracks (T4 and T7) within the beach zone itself, all other tracks were observed past the third zone edge. Distance from the semi-aquatic vegetation zone varied from a few centimeters up to ten hundred centimeters. Terrestrial habitat use by females engaging in nesting activities was limited to the west- and north-facing slopes of Lake Bonney. No tracks or other signs of *C. expansa* were observed at the south-east and east edges of the lake (Figure 1).

3.2 Horseshoe Lagoon

The location of *C. expansa* individuals were successfully obtained 113 times. Of 13 individuals, 6 were followed every two hours during the 24-hour tracking session on 24-25 April and we obtained 72 fixes during this period. Both sexes occupied all the five habitat types available to them, with the exception of males which were not found near logs only. Females spent a greater proportion of their time in open water. Each animal was located in typha reeds (*Typha domingensis*) at least once during the tracking period (Figure 2).

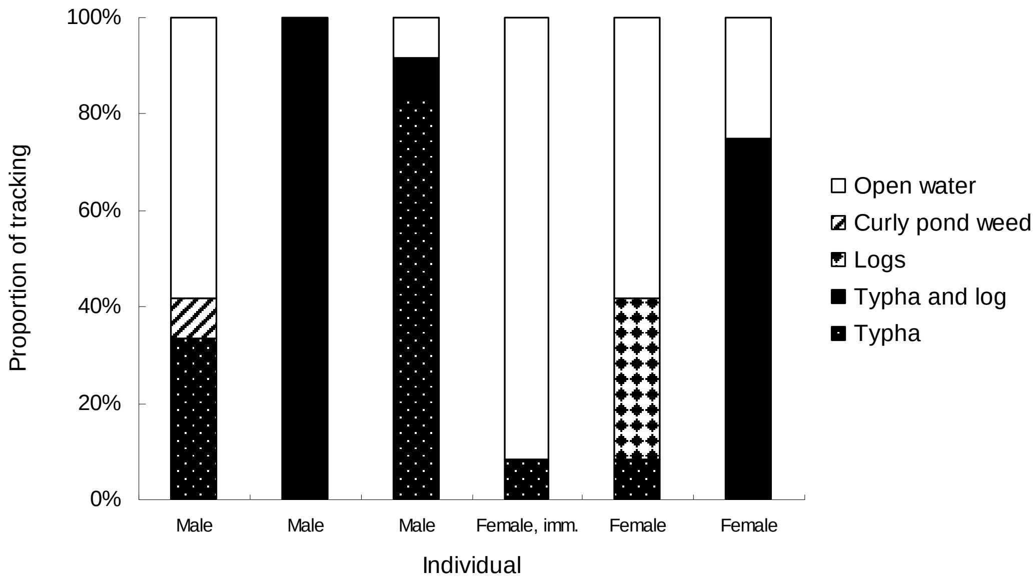

Figure 2. Proportion of time spent in each habitat type over 24 hours by *C. expansa* individuals in Horseshoe Lagoon.

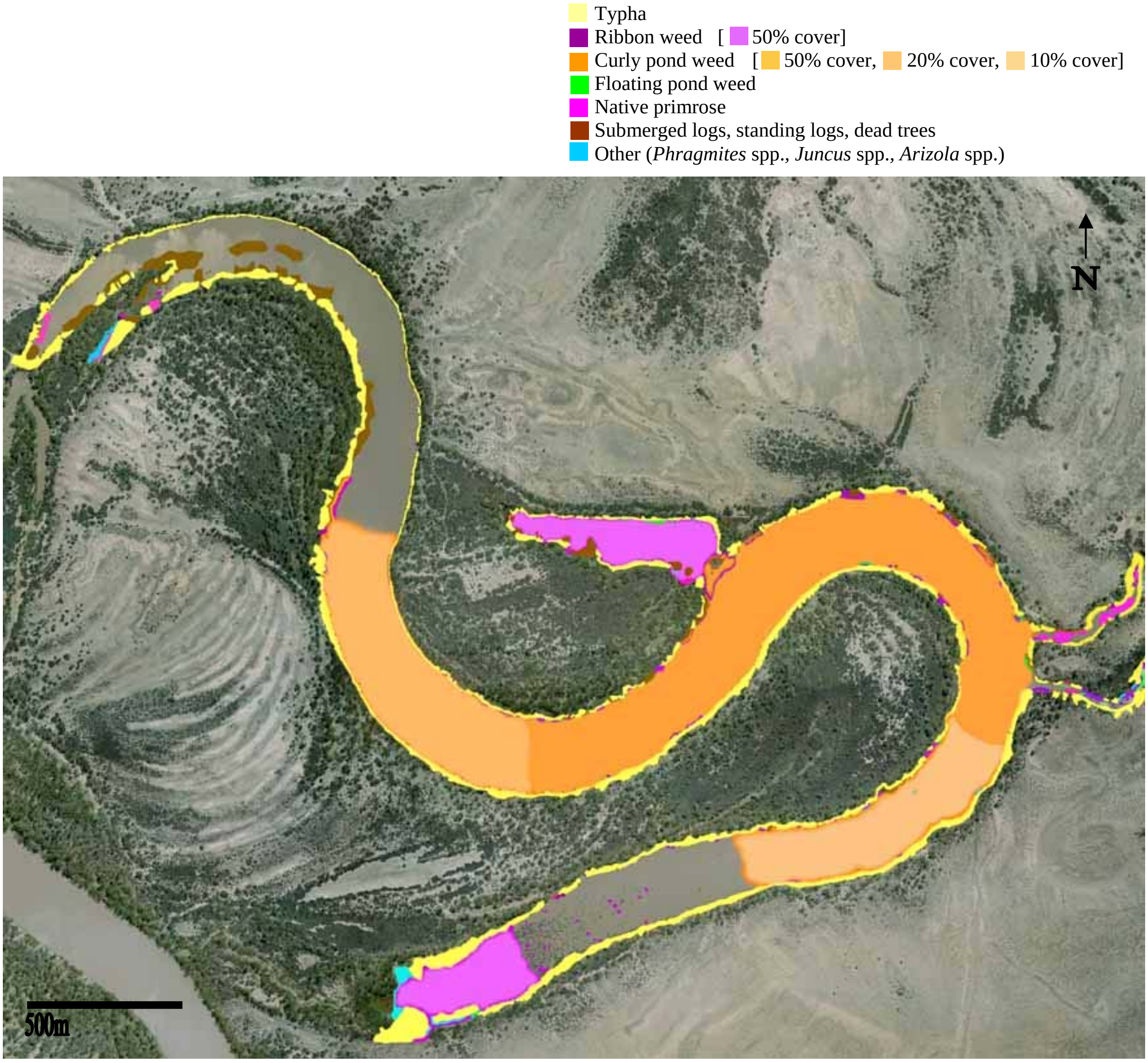

Figure 3. Habitat types available at Horseshoe Lagoon in April-May 2008.

Of the ten different vegetative habitats surveyed in Horseshoe Lagoon, typha reeds (*Typha domingensis*) and curly pond weed (*Potamogeton crispus*) dominated in abundance. Both were evenly distributed throughout the lagoon, typha reeds occurring at almost every point along the river bank, while curly pond weed covered large sections of water area in patches. Submerged logs, standing logs or stumps, and dead trees were very common along the banks of the lagoon; however, these did not occupy an area similar in size to any of the aquatic macrophytes. Ribbon weed (*Vallisneria* spp.) was moderately abundant and distributed, while native primrose (*Ludwigia pepliodies*), floating pond weed (*Potamogeton sulcatus*), *Arizola* spp., phragmites (*Phragmites australis*), and feather reed (*Juncus* spp.)

occurred in sparse and random locations, particularly in inlets and the southern end of the lagoon (Figure 3, Figure 4).

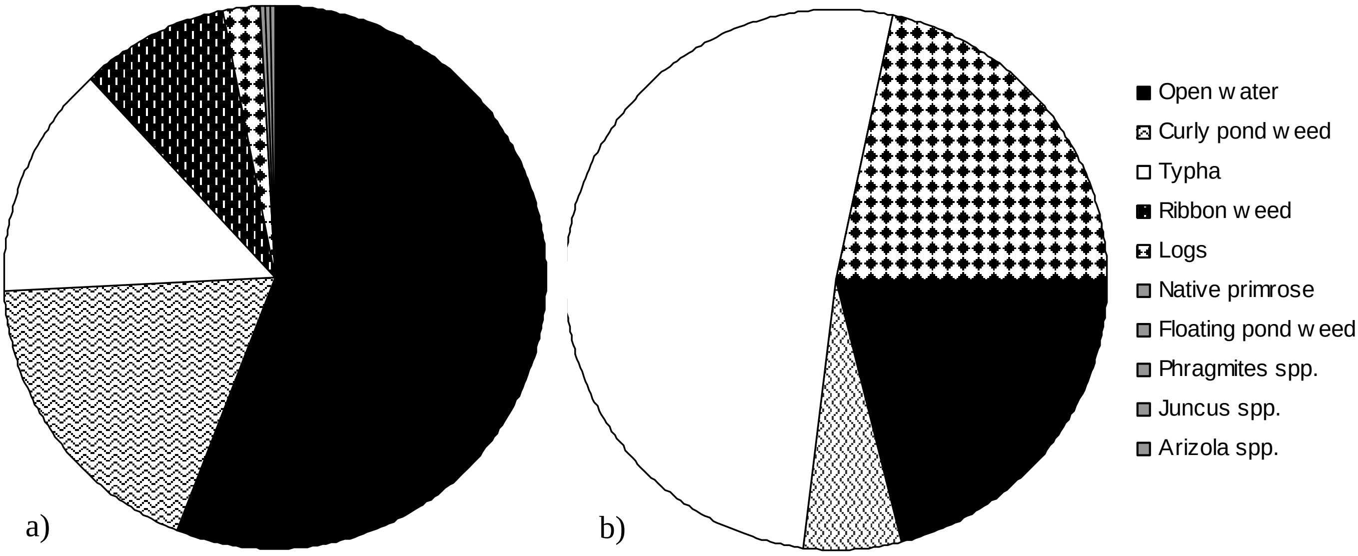

Figure 4. a) Proportion of the total availability of each habitat type at Horseshoe Lagoon in April-May 2008; b) Proportion of total fixes associated with each habitat type from radiotelemetry locations of C. expansa at Horseshoe Lagoon.

The distribution of turtles among habitat types varied in relation to the total availability of each habitat type (Figure 4). Most fixes were located in typha reeds (*Typha domingensis*) and in close proximity to submerged logs, standing logs or stumps and dead trees relative to the total abundance of each in the lagoon. The area cover of typha reeds was more than five times greater than that of logs, while the proportion of locations in typha reeds was only about twice the amount of those in or around the various log forms. Fixes were lower for curly pond weed (*Potamogeton crispus*) and in open water locations than their abundance in the lagoon, and both turtle location and total availability appears insignificant for other vegetation types (Figure 5).

The 12 individuals located during this study were found throughout the lagoon, representing areas of both shallow (<1 m) and deep (>2 m) water, and in all three inlets or channels. A preference in water depth was not evident, apart from areas of typha reeds, in which the water level rarely exceeded 1 m. Additionally, individuals did not move long distances; females moved the maximum of only 500 m within twenty four hours. There did not appear to be a difference in movements or distances traveled between male and female animals during this study period.

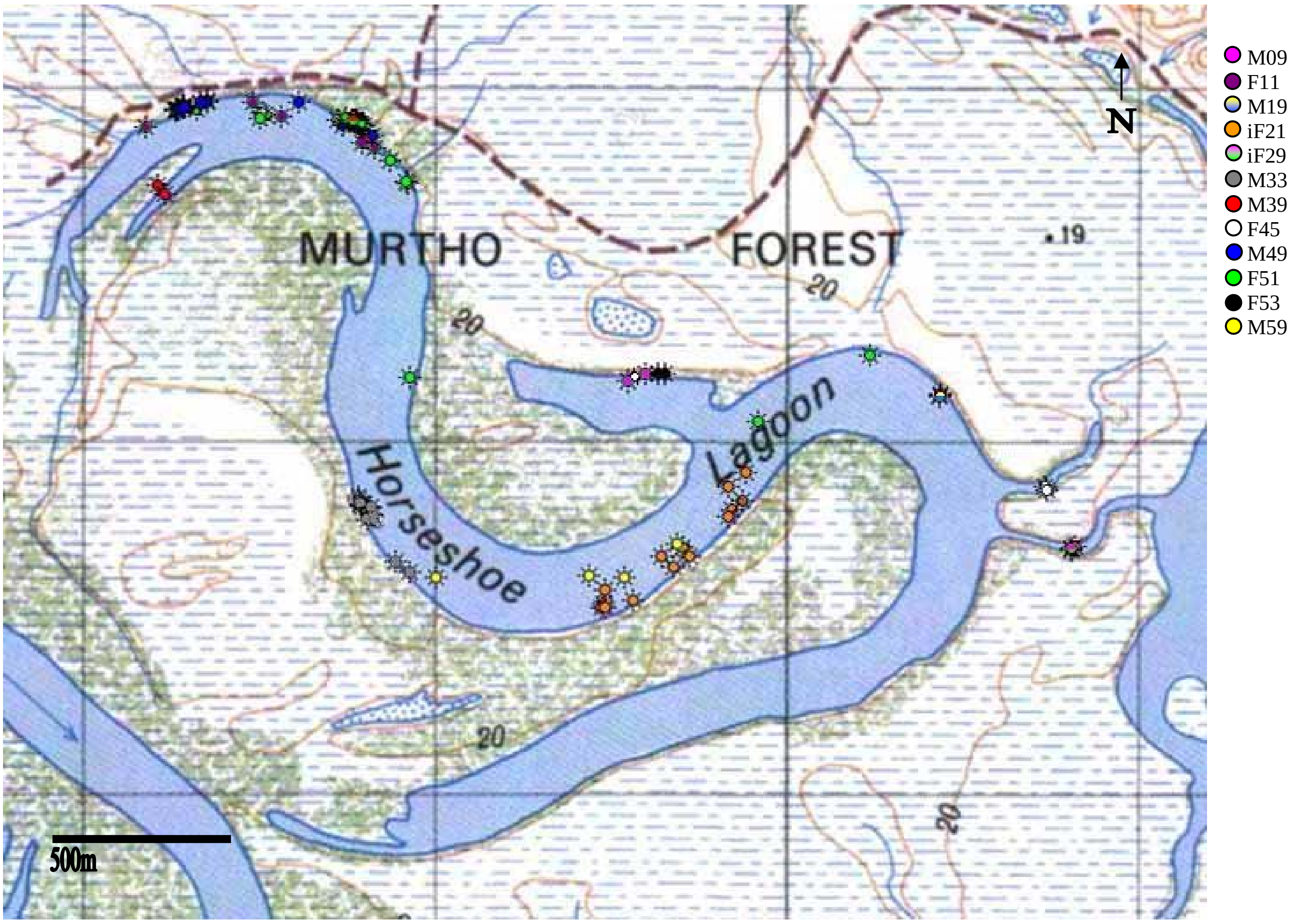

Figure 5. Combined locations of all fixes of *C. expansa* individuals over four days and a 24-hour period at Horseshoe Lagoon.

4. DISCUSSION

4.1 Patterns of habitat use

4.1.1 Terrestrial

Tracks and nests observed at Lake Bonney indicated that female *C. expansa* select to nest in dryland habitats lacking disturbance, with moderate to dense vegetation cover. The north and west sides of the lake were significantly less developed, or disturbed, than the south and east sides. Non-native grass (*Pennisetum clandestinum*) on the south side was not used by the turtles, and suggests a possible avoidance of these monotonous habitats. The east side of Lake Bonney was dominated by thicker vegetation cover in most areas, notable by the presence of more trees, taller bushes, and softer sand; however, the close proximity of a paved road on the east side of the lake may explain the lack of *C. expansa* tracks, which tended to be in less disturbed areas.

Females of this species attempt to nest close to vegetation (Spencer and Thompson, 2005; Georges, 1984), and thus select for an area of accessibly adequate cover. The dried semi-aquatic vegetation, *Cynodon dactylon* and *Typha domingensis*, may create a physical barrier for females, as the vegetation layers have become impassable with the receding water level of Lake Bonney. This prevented access to the outer vegetation zones with denser cover. This is a new challenge faced by *C. expansa*, in response to the management decisions to close water access to the lake. We saw two predated nests in areas on the beach zone on the southwestern side of the lake, further suggesting that barriers may decrease nesting success.

Females emerging from the water to nest may return without depositing eggs if soil conditions are unsuitable because of the difficulty of constructing a nest in dry conditions (Goode and Russell, 1968). As the water level of Lake Bonney continues to recede and no water is returned, both the vegetation and soils that were in close proximity to the water will become drier and more inappropriate for *C. expansa* to utilize.

Changes to the thermal and moisture conditions of a developing reptile nest are unpredictable and mothers may select conditions in response to the requirements for their nests (Warner and Andrews, 2002). The use of the north and western aspects of the lake may correlate to the heat requirements of the nests laid by *C. expansa*. Nests are excavated in autumn, and are subject to extreme temperature drops over winter. The duration of time that direct sunlight contacts the nests may be greatest at the west and north angles. Development of the embryos of ectothermic animals is faster at warmer temperatures, giving offspring a selective advantage because they develop faster, hatch earlier and utilize available resources before other competing offspring (Goode and Russell, 1968).

Although nests were not discovered for all tracks observed, it is clear that the ultimate destination of nesting females was past the fourth edge and into denser vegetation cover. Whether a nest was laid or not may depend on other factors, such as soil moisture or recent rainfall, recognition of a predator, or other disturbance, such as human interruption (Georges, 1984; Legler, 1978; Spencer and Thompson, 2005; Bowen *et al.*, 2005). Terrestrial habitat use of *C. expansa*, as observed in this study, suggests an importance of aspect and a lack of disturbance for the selection of an adequate nesting site.

4.1.2 Aquatic

More than three quarters of the fixes collected from animals in Horseshoe Lagoon were associated with a complex habitat structure. Movement of individuals between components of their home ranges and available habitat may explain the animals located in open water. It is also possible that the few animals found in these areas were utilizing vegetation that was not visible to the human eye due to water turbidity. The lack of fixes in ribbon weed (*Vallisneria* spp.), with respect to its relative abundance and distribution throughout the lagoon, may indicate that this sparse thin reed does not provide the structure required in a micro-habitat for *C. expansa*.

The structured habitats selected by *C. expansa* may provide an advantage for resting or feeding within their home range. Complex habitat types provide shelter and camouflage from possible disturbances, and increased food resources. Past studies have found that most biological diversity occurs in the littoral zone, especially in the vicinity of tree snags (submerged logs and root systems), and in the cover of water plants (macrophytes) (Walker, 1992, Walker *et al.*, 1992). In the Riverland of South Australia, the littoral zone of the Murray River and its backwaters is dominated by emergent plants (*Typha domingensis* and *Phragmites australis*), which provide a refuge for many terrestrial and aquatic animals. Snags present similarly complex refuge; allow development of plant communities; and are desired sites for fish spawning events and feeding grounds. Algae in the littoral zone is, in turn, food source for prawns and shrimps (Walker, 1992).

The interactions among organisms and vegetation present in the littoral zone supplies large predators, such as *C. expansa*, with abundant food resources. The carnivorous diet of *C. expansa* will be available in the diverse communities of macroinvertebrates and fish, which live in typha reeds. In addition, *C. expansa* is primarily a sit-and-wait predator, attacking only as prey pass, and may use the surrounding vegetation as support against the strong force of its strike (Legler, 1978). The vegetation of the littoral zone, as well as some areas of open water in which the macrophyte curly pond weed was present, maintain resources important to the fitness of *C. expansa* in the Murray River, and can indicate a strong preference of the animal for selection of an appropriate habitat type.

The observation that most animals tracked were not moving great distances, especially males, may be influenced by the time of year, as metabolism is slowing for the colder months ahead and females are not receptive to mating. It is also important to note however, that animals will not always move large distances. Females will retain a home range of one up to a few kilometers, while males can move up to 20km in some instances (Deb

Bower, unpublished data). The time gap we allowed between locating individual turtles (two hours minimum) was sufficient to allow for movement, because these are large animals that can move long distances quickly in water, and was therefore not relevant to the lack of movement observed.

This species is not known to occur in high densities in Horseshoe Lagoon (Deb Bower, unpublished data; Chessman, 1988), or to utilize terrestrial habitat for activities other than nesting (Greer, 2006). However, their distribution spatially throughout the lagoon showed that the selection of a habitat, or home range, is in close proximity to one another. In one instance, two turtles were located within centimeters of each other for over one third of the 24 hour tracking period. The efficiency of these turtles to avoid stress from possible overlap may be due to an abundant food supply and different metabolic demands between sexes (Tucker *et al.*, 2001). More importantly, their close proximity and preference to certain areas show that the structured habitats of typha reeds (*Typha domingensis*), curly pond weed (*Potamogeton crispus*), and submerged logs or dead trees in the lagoon are highly preferred by *C. expansa*, and results in usage of restricted, and often overlapping, areas.

4.2 Conservation and management implications

Monitoring the threats faced by a species within its habitat will provide a basis for conservation, restoration, and management practices; especially in highly regulated systems such as the Murray-Darling Basin. Habitat loss, human disturbance, and invasive species may be the greatest threats facing *C. expansa*. Terrestrial habitats are used primarily by females during autumn (March - May). Beyond nesting activities, this species is not known to move overland. As females may travel up to one kilometer from the water's edge to excavate a nest, it seems impractical to restore and conserve large terrestrial areas for use by a small portion of the turtle population during a short time period. However, without nesting success to facilitate recruitment, the populations of *C. expansa* may suffer in generations to come

(Spencer and Thompson, 2005). The preference of females for undisturbed nesting habitats indicates that it is very important to retain, at least some, undisturbed areas for the path of females searching to nest (i.e. a road or areas of development). It would be preferable to assess the nest-site selection in a region before prioritizing areas for management, as nesting at Lake Bonney suggested species may also select nest sites based on thermal advantages.

Chelodina expansa is subject to disturbances and interruptions throughout daily activities from interactions with biotic factors. There is not much known about the sustainability of a *C. expansa* population relative to human disturbance, except that an increasing presence of vehicles on nearby roads and recreational fishing or boating is harming adult individuals on land and in the water. Past studies have described impacts of other predators, such as the introduced red fox (*Vulpes vulpes*), on these turtle populations. Whilst predation on recruitment may greatly affect the persistence of *C. expansa* populations, the survival of adult animals is likely to be essential to this long-lived, low density predator (Spencer and Thompson, 2005). A female *C. expansa* may have the ability to locate areas of vegetation of lesser disturbance, just as she may use olfactory cues to recognize the presence of a predator as discovered in the close relative, *Emydura macquarii* (Spencer, 2002).

Habitat structure is clearly important to *Chelodina expansa,* which show a distinct preference to live and nest in areas with complex vegetation. Without structured aquatic habitats, such as emergent reeds, aquatic macrophytes, and submerged snags or root systems, the food resources that *C. expansa* rely on may decrease. A decline in crustaceans, small fish and vertebrates, which feed on macroinvertebrates and other small organisms, may occur in response to the loss of habitat on which they depend. In turn, this will affect turtles, as well as other carnivores in the system, such as fish and birds. Efforts to reduce the amount of de-snagging operations and to make recreational users of river waters aware of the importance of these structures for habitat will support the restoration of habitat availability for *C. expansa*, and others, of the Murray-Darling Basin (Walker *et al.*, 1992). In addition, as future efforts develop in an attempt to repair river hydrology, flow and flooding cycles, the modified habitats that have resulted from human modification should not be ignored. The dense vegetation cover in the littoral zone by emergent plants and macrophytes has expanded over the years, and loss of this can hinder habitat suitability for *C. expansa* (Walker *et al*., 1992; Walker, 1992). Invasive species will also interact with native carnivores, such as *C. expansa*, and increase competition for resources, including food and space.

4.4 Conclusion

The findings of this study suggest that the habitat selection of *C. expansa* in the Riverland region of the Murray-Darling Basin was limited to areas containing complex, structured vegetation cover. Terrestrially, females will travel to ovipost in areas lacking disturbance with a west or north aspect and moderate to dense vegetation cover dominated by short shrubs and sandy soils. In aquatic habitats, these animals were located most commonly among emergent reeds, aquatic macrophytes, submerged logs, dead trees, and tree root systems, which are closely associated with feeding preferences and shelter.

4.4.1 Sources of error

There are two main sources of error in this study. First, female *C. expansa* were never observed on land during the walking surveys of Lake Bonney, and it was therefore very difficult to locate nests. Exactly what the turtle did in her terrestrial expedition would have confirmed habitat usage as tracks were often lost or hard to follow because of dry, compacted soils. If the animals were not laying nests, observing a probable reason for this would have been more possible (e.g. dry soils preventing digging, interruptions from the presence of a human or other animal). Secondly, the mapping of vegetation with a GPS at Horseshoe

Lagoon was limited by mobility in the motor boat, and further calculation of areas in OziExplorer was limited by the accuracy of the tools used to trace the designated area.

4.4.2 Future research

This study was restricted in length to one month, and therefore does not consider spatial movement for *C. expansa* temporally. It is unknown how movement patterns of these turtles vary throughout the year; however, changes in habitat types based on seasonal variations and altered yearly flow regimes could impact on the proportion of usage to habitat availability and should be assessed in the future. This is imperative for further understanding of the complete habitat use of *C. expansa*, in order to direct appropriate management of water and land resources.

Obtaining more detailed information on the activity and habitat use of nesting turtles is necessary in order to understand the parameters required for successful nesting (or the emergence and return without laying). Further investigation of terrestrial habitat usage is important for the development of conservation efforts, to direct efforts for management; especially as human development appears to be a major disturbance influencing these turtles.

Finally, the impact of rising salinity levels and decreasing water levels in the backwaters, and main river channel, of the Murray River on habitat availability should be investigated. Abiotic factors such as these may directly affect physiological processes, and in turn, habitat selection by *C. expansa* turtles.

5. REFERENCES

Arthur, S.M., Manly, B.F.J., McDonald, L.L., and Garnger, G.W. 1996. Assessing Habitat Selection when Availability Changes. *Ecology* 77: 215-27

Bodie, J.R. and Semlitsch, R.D. 2000. Spatial and temporal use of floodplain habitats by lentic and lotic species of aquatic turtles. *Oecologia* 122: 138-46.

Bowen, K.D., Spencer, R.J. and Janzen, F.J. 2005. A comparative study of environmental factors that affect nesting in Australian and North American freshwater turtles. *J. Zool., Lond*. 267: 397–404.

Bower, Deborah. 2006-08. Broad-shelled turtles in the Riverland: rare and endangered or common and cryptic?, unpublished data. PhD Candidate, Institue for Applied Ecology, University of Canberra.

Cann, J. 1998. Australian Freshwater Turtles. Beaumont Publishing, Singapore.

Chessman, B. 1988. Habitat preferences of freshwater turtles in the Murray Valley, Victoria and New South Wales. *Aust. Wildl. Res.* 15: 485-91.

Georges, A. 1984. Observations on the nesting and natural incubation of the long-necked tortoise *Chelodina expansa* in south-east Queensland. *Herpetofauna* 15: 27-31.

Goode, J. and Russell, J. 1968. Incubation of eggs of three species of chelid tortoises, and notes on their embryological development. *Aust. J. Zool*. 16: 749-61.

Greer, A.E. 2006. Encyclopedia of Australian Reptiles. Australian Museum Online http://www.amonline.net.au/herpetology/research/encyclopedia.pdf Version date: 7 August 2006.

Johnson, D.H. 1980. The Comparison of Usage and Availability Measurements for Evaluating Resource Preference. *Ecology* 61: 65-71.

Legler, J.M. 1978. Observations on behaviour and ecology in an Australian turtle, *Chelodina expansa*, (Testudines: Chelidae). *Can. J. Zool*. 56: 2449-53.

Mysterud, A. and Ims, R.A. 1998. Functional Responses in Habitat Use: Availability Influences Relative Use in Trade-Off Situations. *Ecology* 79: 1435-41.

Phillott, A.D. and Parmenter, C.J. 2000. Spotted barramundi predation upon *Emydura krefftii* and *Chelodina expansa* hatchlings in central Queensland. *Herpetofauna* 30: 22-5.

Spencer, R.J. 2002. Experimentally Testing Nest Site Selection: Fitness Trade-Offs and Predation Risk in Turtles. *Ecology* 83: 2136-44.

Spencer, R.J. and Thompson, M.B. 2005. Experimental Analysis of the Impact of Foxes on Freshwater Turtle Populations. *Cons. Biol.* 19: 845-54.

Storch, D. and Frynta, D. 1999. Evolution of habitat selection: stochastic acquisition of cognitive clues? *Evol. Ecol*. 13: 591-600.

Reese, D.A. and Welsch, H.H. 1998. Habitat use by western pond turtles in the Trinity River, California. *J. Wildl. Manag*. 63: 842-53.

Regan, H.M., Hierl, L.A., Franklin, J., Deutschman, D.H., Schmalbach, H.L., Winchell, C.S., and Johnson, B.S. 2008. Species prioritization for monitoring and management in regional multiple species conservation plans. *Diversity Distrib*. 14: 462-71.

Rosenzweig, M.L. 1981. A Theory of Habitat Selection. *Ecology* 62: 327-35.

Tucker, A.D., Limpus, C.J., Priest, T.E., Cay, J., Glen, C., and Guarino, E. 2001. Home ranges of Fitzroy River turtles (*Rheodytes leukops*) overlap riffle zones: potential concerns related to river regulation. *Biol. Cons.* 102: 171-81.

Walker, K.F. 2006. Serial weirs, cumulative effects: the Lower River Murray, Australia. In *Ecology of Desert Rivers*, ed. R.T. Kingsford, pp 248-79. Cambridge University Press.

Walker, K.F. 1992. The River Murray, Australia: a semiarid lowland river. In *The Rivers Handbook*, ed. P.A. Calow and G.E. Petts, 1: pp 472-92. Oxford: Blackwell Scientific.

Walker, K.F., Thoms, M.C., and Sheldon, F. 1992. Effect of weirs on the littoral environment of the River Murray, South Australia. In *River Conservation and Management*, ed. P.J. Boon, P.A. Calow, and G.E. Petts, pp 270-93. Chichester: Wiley.

Warner, D.A. and Andrews, R.M. 2002. Nest-Site Selection in Relation to Temperature and Moisture by the Lizard *Sceloporus undulatus*. *Herpetologica* 58: 399-407.