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Movement and habitat use of Australia's largest snake-necked turtle: implications for water management

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Abstract

Hydrological regimes strongly influence ecological processes in river basins. Yet, the impacts of management regimes are unknown for many freshwater taxa in highly regulated rivers. We used radio-telemetry to monitor the movement and activity of broad-shelled river turtles *Chelodina expansa* to infer the impact of current water management practices on turtles in Australia's most regulated river – the Murray River. We radio-tracked *C. expansa* to (1) measure the range span and examine the effect of sex, size and habitat type on turtle movement, and (2) examine habitat use within the river channel and its associated backwaters. *C. expansa* occupied all macro habitats in the river (main channel, backwater, swamp and connecting inlets). Within these habitats, females occupied discrete home ranges, whereas males moved up to 25 km. The extensive movement of male turtles suggests that weirs and other aquatic barriers may interfere with movement and dispersal. Turtles regularly move between backwaters and the main river channel, which highlights the likely disturbance from backwater detachment, a water saving practice in the lower Murray River.

Introduction

Animals have discrete times of the day and year when activity is concentrated (Heatwole & Taylor, 1987), yet movement and activity are not always predictable. Behaviour may be influenced by physical factors, such as climate (Huey & Pianka, 1977; Vogt, 1979), as well as attributes of the landscape, such as topography (Dickson, Jenness & Beier, 2005). Biotic factors also influence movement and activity, including prey availability (Shine, 1979), reproductive condition and experience of individuals (Rose, 1981). Knowledge of such factors is extremely useful to minimize negative interactions between anthropogenic disturbance and wildlife (Dolbeer & Wright, 2009) or to assist wildlife managers in minimizing threats to rare species and those of conservation concern (Brussard, 1991).

Research on conservation in freshwater systems is important because freshwater systems contain disproportionately high biodiversity, yet are the most threatened and the least represented in scientific research (Abell, 2002; Jenkins, 2003). Morphological and hydrological changes to rivers occur through regulations to provide stable water supplies for drinking, irrigation and industry (Maybeck, 2003). Dams, weirs and regulators provide barriers to some species and change the flow and structure of river systems (Walker, 1985). Despite global anthropogenic modifications of river flow and water extraction, how these changes alter freshwater fauna is complex, poorly understood and, for many individual taxa, virtually unknown. This lack of fundamental ecological knowledge hampers conservation efforts (Abell, 2002).

Before regulation, the lower Murray River was a desert river system, alternating between periods of high, heavy flows with extensive floodplain inundation and drought years when the river retracted into shallow pools (Walker, 2006). Between 1920 and 1937, 10 weirs were constructed in the lower Murray for navigation. These dramatically altered the flow and flooding of the river (Walker, 2006) and transformed the river into a series of cascading weir pools (each pool is 29–88 km in length) with tightly controlled water level and flow. This regulation has reduced absolute flow and its variability (Walker, 2001). A period of low rainfall combined with over-extraction of water from the river resulted in water shortages in the lower Murray River (Goss, 2003). The government initiated measures to conserve water by confining water to the main river channel because the channel has lower rates of evaporation than shallow backwaters. Between 2007 and 2009, managers of the lower Murray temporarily drained regulated wetlands and closed the inflows to permanent unregulated wetlands to conserve water in the main river channel. This drainage isolated the previously permanent, interconnected wetlands and prevented entry or exit of aquatic fauna.

Impacts of river regulation may be complex (Bodie, 2001) because freshwater turtles use both aquatic and terrestrial habitats during their life cycle and can be highly vagile in both water and on land (Roe & Georges, 2008; Buhlmann *et al.*, 2009). River turtles can be habitat specialists and maintain discrete home ranges when they rely on some particular features of the habitat, such as riffle zones (Tucker *et al.*, 2001). Other species undergo large migrations to breed or forage (Fachín-Teránet, Vogt & Thorbjarnarson, 2006; Seminoff & Jones, 2006).

To evaluate potential impacts of river regulation on river turtles, we radio-tracked a large carnivorous Australian freshwater turtle *Chelodina expansa*. Horseshoe Lagoon was connected to the main channel during the tracking period. However, movement of *C. expansa* in and around Horseshoe Lagoon is used to infer consequences of disrupting backwater connectivity elsewhere in the river. Specifically, we aimed to (1) compare the effect of sex and size on turtle movement to identify intra-specific differences in the vulnerability of *C. expansa* to river modification and (2) determine habitat use by *C. expansa* to gauge the likely impact of disrupting the interconnection of river channels.

Materials and methods

Study species

The broad-shelled turtle *C. expansa* occurs in eastern and south-eastern Australia. It is distributed from the coastal rivers of Queensland from the Tweed River in the south to the Fitzroy-Dawson drainage in the north. The distribution includes the dune lake systems of Stradbroke, Moreton and Fraser Islands, and the Murray-Darling Basin, which extends across the states of Queensland, New South Wales, Victoria and South Australia. Within the Murray-Darling Basin, *C. expansa* occurs with the Murray River turtle *Emydura macquarii*, the eastern long-necked turtle *Chelodina longicollis* and the western saw-shell turtle *Myuchelys bellii*. *C. expansa* is widespread, but seldom abundant (Georges, 1985; Chessman, 1988; Spencer & Thompson, 2005; De Lathouder, Jones & Balcombe, 2009) and has been declared 'Vulnerable' in South Australia under the National Parks and Wildlife Act (1972) and 'Threatened' in Victoria under the Flora and Fauna Guarantee Act (1988). The species feeds primarily on crustaceans, molluscs, insect larvae and fish (Legler, 1978; Chessman, 1983) but will also consume carrion.

Study area

The lower Murray River and associated catchment begins at the confluence of the Darling and Murray Rivers and terminates at the mouth of the Murray-Darling system, south of Adelaide, in South Australia. This 830-km stretch of river is subject to hot, dry summers and cool winters (annual means: 9.5°C min–24.9°C max; 1995–2009 Australian Bureau of Meteorology). Mean annual rainfall is low, with an annual average of 221 mm (1995–2009), low to moderately variable among years and falls mainly in the winter months.

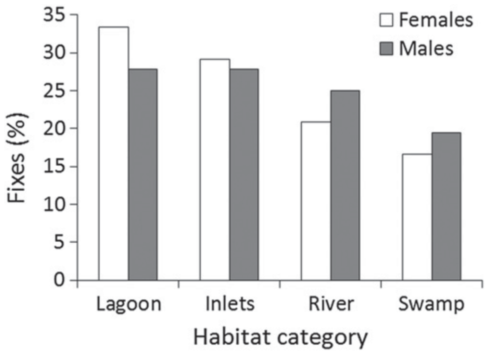

Figure 1 All aquatic habitats were used by radio-tracked *Chelodina expansa* in the lower Murray River, South Australia.

Radio-telemetry was completed between lock five and six and was focused on a permanent backwater called Horseshoe Lagoon (34˚05′S, 140˚47′E; Fig. 1) and an adjacent stretch of main river channel. Horseshoe Lagoon is shallow (depth < 2.5 m), 5 km long by 180–220 m wide, and connected to the river channel by one direct inlet and one inlet leading to a very shallow lagoon (depth < 1 m; hereafter 'swamp') that connects to the river. The lagoon is surrounded by Murtho Forest Reserve, which is not accessible to the public. The fringe of the lagoon is almost entirely surrounded by stands of semi-aquatic vegetation *Typha domingensis* (Typhaceae) and *Phragmites australis* (Poaceae). The adjacent river is of similar width but deeper (maximum 7 m). The river has sporadic stands of *T. domingensis* but most of the edge has a sharp drop in profile, preventing the establishment of semi-aquatic vegetation.

Study method

Between 1 December 2006 and 30 February 2007, 25 turtles were caught in snorkel traps (Legler, 1960) with modifications (Georges, Guarino & White, 2006) in Horseshoe Lagoon and an adjacent 8-km stretch of the main river channel. Traps were baited with pig or cow liver that had been soaked in tuna oil or in unbaited fyke nets (5 ply net; 12 mm mesh size; 20 m arm length with a 2.5 m drop). Each turtle was given an individual identification by a series of unique notches (Cagle, 1939), measured to obtain a straight line carapace length to the 0.01 mm; weighed to the nearest 0.01 g and sexed based on external dimorphic characteristics (Kennett & Georges, 1990). Animal ethics was approved by the South Australian Museum and the University of Canberra. Licences to undertake the research were provided by Primary Industry Research South Australia (PIRSA) and the Department of Environment and Heritage (DEH).

Thirteen female and 12 male *C. expansa* were fitted with transmitters (Holohil Systems, Carp, Ontario, Canada; Doody *et al*., 2009). Turtles were located from a small boat using TR-4 receivers (Telonics Pty Ltd, Mesa, AZ, USA) fitted with Yagi collapsible hand-held antenna (model AY/C; Titley Electronics, Ballina, New South Wales, Australia). Turtle bearing transmitters were reliably detected at distances from 100 to 500 m. Turtles were tracked opportunistically from November 2006 to March 2009; radio-telemetry was frequent in the first 12 months of release (once a week) and less frequent afterwards (once a month). Fixes could not be confirmed visually, as turtles remained submerged within turbid water. A pilot study confining turtles to semi-submerged snorkel traps established our ability to fix locations to within 10 m.

Data analysis

Fixes were determined with a Garmin Map 60 Global Positioning System and analysed in OziExplorer version 3.95.4p (D&L Software Pty Ltd, Brisbane, Queensland, Australia). Distances between fixes (displacement distance) were calculated using the ruler and line function, by measuring the shortest possible distance within the boundaries of the river or wetland. Linear range span was defined as the distance between the farthest locations travelled upstream and downstream in the river or lagoon. This was the most appropriate method to estimate movement extent when turtles confine movements to the river (Plummer, Mills & Allen, 1997).

We tested for a correlation between displacement distance and number of telemetry fixes to determine if mean displacement distance or linear range span was dependent on the number of radio-telemetry fixes. Animals that moved farther were harder to locate and located less often; therefore, animals that were located fewer than 20 times were excluded from analyses of mean displacement distance. Animals that maintain a home range should move within a defined area of river and should not wander randomly from their release site (Slip & Shine, 1988). To test whether individuals maintained a home range, a regression was used to test for an increase in proximity from the release site over a 60-day period after release.

Differences in movements were tested using a *t*-test, with linear range span or displacement distance as the response variable and sex (male and female) and location (river or lagoon) as the explanatory variable (Sokal & Rohlf, 1981).

The proportion of fixes associated with each habitat category was calculated and is reported for each sex, and for the backwaters (Horseshoe Lagoon, connecting inlets and swamp) and river separately. All analyses were conducted in SPSS 17.0 (SPSS Inc., Chicago, IL, USA). In particular, degrees of freedom (d.f.) for *t*-tests were corrected in cases of heteroscedasticity. Where tests to be undertaken were determined *a priori*, they were treated as independent, that is, *P*-values are provided on the basis that they represent the probability of a type I error for each individual test result. Results are accepted as significant when the probability of a type I error in each test was less than 0.05. Results are reported as means ± 95% confidence interval.

Results

Movement patterns

Mean displacement distance correlated only weakly with the number of fixes (Pearson's correlation $r = -0.50$, $n = 25$, $P < 0.002$), and there was no correlation for turtles located 20 or more times ($r = 0.23$, $n = 12$, $P = 0.46$). Movements greater than 15 km from the release site were rare. Distance from the release site could not be predicted from days since initial release (regression $R^2 = 0.008$, $F_{1,323} = 18.96$, $P = 0.11$).

Thirteen females (mean carapace length: 35.63 ± 1.98 cm) and nine males (29.11 ± 0.97 cm) were tracked for 714 ± 388.5 and 582 ± 117.0 days, respectively. Mean linear range span was 11.18 ± 4.10 km for males, which was significantly greater than the 1.43 ± 1.73 km mean female linear home range ($t = 3.96$, *adj. d.f.* = 10.6, $P < 0.002$). This relationship remained significant when the three males that made large movements from the study site (>17 km upstream) were excluded ($t = 3.18$, *adj. d.f.* = 7.2, $P < 0.002$). Mean displacement distance was 1.29 ± 0.10 km for males, which was significantly greater than the mean displacement distance in females, which was only 0.65 ± 0.20 km ($t = 2.69$, *adj. d.f.* = 8.9, $P < 0.05$), although individual movements occupied a similar proportion of total range span in both sexes ($t = 0.82$, *adj. d.f.* = 6.4, $P = 0.44$). Females confined to the lagoon or the river had similar range spans ($t = 0.60$, *adj. d.f.* = 2.3, $P = 0.60$). Linear range span was not significantly correlated with turtle size, for either male (Pearson's correlation $r = 0.30$, $n = 12$, $P = 0.35$) or female ($r = 0.38$, $n = 13$, $P = 0.20$).

All linear range spans overlapped with at least one other individual. Females ($n = 13$) had an average of 14 ± 2.9 other turtles within their range span, whereas male ($n = 12$) linear range span overlapped with 20 ± 2.0 other turtles ($t = 3.01$, *adj. d.f.* = 19.480, $P < 0.010$). Female linear range span overlapped with significantly more male than female turtles ($t = 3.82$, *adj. d.f.* = 23, $P < 0.001$), whereas male turtles had similar numbers of males and females within their range ($t = 0.19$, *adj. d.f.* = 15.4, $P = 0.08$).

Habitat use

All fixes were in water; 42% of males used both the lagoon and the river ($n = 46$), compared with 7% of females ($n = 38$). Females used, on the average, two of four habitat types (most often the lagoon and a connecting inlet), while males used three. Five females used only one type of habitat and no females used all four habitat types – river, connecting inlet, swamp and lagoon (Fig. 1).

Discussion

Movement patterns

C. expansa showed a high degree of fidelity to specific areas of the river but was capable of extensive movement. Females remained sedentary, while males easily navigated large tracks of river. The extensive movements of *C. expansa* are the largest recorded of chelid turtles in Australia and the ability to move such distances may give river turtles an advantage in a historically dynamic river system to access temporary resources such as flooded backwaters. The ability to quickly invade areas may well be beneficial for species in dynamic river systems. Such rapid invasions allow access to resources after dry periods when aquatic species are confined to shallow pools. Long distances moved by other freshwater turtle species have been attributed to migrations for resources (Galois *et al*., 2002).

The spacing of *C. expansa* along the river can be used to infer life history strategies. The ranges of all radio-tracked turtles overlapped with at least one other radio-tracked animal and the trapping data indicate many more individuals were using the area during the study period. Females overlapped more with males perhaps because males had larger range spans. The greater movements by male *C. expansa*, compared with sedentary females, may be a strategy for males to access multiple females. Overlapping range spans and use of large areas of the river by males suggest that males are not territorial. Female turtle range spans were far more discrete and also overlapped. Thus, Horseshoe Lagoon and the associated river were productive enough to support multiple individuals in close proximity.

C. expansa used all habitat types from the backwaters and swamps to the main river channel. Thus, in periods of low water availability, all aquatic habitats are available to turtles. Female turtles from either the lagoon or the river had similar linear range spans, suggesting that the river and the lagoon had no biological differences that affected turtle movements. The use of the entire river system by *C. expansa* in the lower Murray may be facilitated by the weirs, which slow down the flow and enable aquatic macrophytes to establish in the main channel (Walker, 2001).

Implications for management

The large and frequent movements of male turtles in various habitats imply that recent management decisions to block backwaters in similar habitats may have an ecological impact on *C. expansa.* Males regularly revisited the lagoon and river, and both sexes used all the aquatic habitats in the river system. Thus, ecological health of both the main river channel and the backwaters are important to *C. expansa*. The distance that the far-ranging males moved was equal to half the length of the weir pool, which suggests that the frequency of weirs within the river may affect the dispersal and behaviour of males. The large degree of linear range span overlap suggests that localized disturbance to an area is more likely to interfere with multiple individuals because many individuals use resources in any one area.

Conclusion

The persistence of turtles is valuable not just socially and environmentally but also for the services they provide to the river. Carrion eating species such as *C. expansa* in the Murray River may reduce eutrophication (Thompson, 1993). Anthropogenic disturbance to freshwater systems can change ranging behaviour with subsequent alteration of key demographic processes. For example, stress in freshwater turtles suppresses ovulation and egg production (Kuchling & Bradshaw, 1993). To improve conservation of freshwater turtles, we need to understand how turtles respond to anthropogenic activities, including which structures impede turtle movement and how turtles respond to wetland draining.

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