Journal of Biological Research-Thessaloniki **8**: 119 – 127, 2007
J. Biol. Res.-Thessalon. is available online at http://www.jbr.gr
Indexed in: WoS (Web of Science, ISI Thomson), CAS (Chemical Abstracts Service) and DOAJ (Directory of Open Access Journals)

Gone walkabout? Movement of the eastern long-necked turtle *Chelodina longicollis* from farm dams in northwest peri-urban Sydney (Australia)

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Received: 4 August 2007 Accepted after revision: 27 November 2007

Many freshwater turtle species maintain site fidelity. Short term studies (1-4 years) of the eastern long-necked turtle *Chelodina longicollis* have shown that turtles moved among water bodies, but some were later recaptured at the dam of initial capture. No long-term studies have been undertaken to determine if site fidelity is maintained. In this paper we re-visited farm dams, initially surveyed a decade previously, and sampled turtles to determine the extent to which *C. longicollis* maintained site fidelity. Only 11.9% (n = 572) of turtles were recaptured. We then expanded the search (from 1 km to 2 km radius of core of original survey site) for marked individuals, and found one marked individual among 179 additional captures. Overall < 10% of turtles netted in 2006 were captured in 1995-1996. The sex ratio of recaptured animals after one decade did not differ significantly (1:1 sex ratio). Based on the growth of carapace length, annual growth rate varied between 0-0.84 cm year^{-1}. Population structure in 1995-1996 and 2006 was similar, which indicated that the change was not due to loss of aged individuals and recruitment of young, but to an overall turnover of individuals. We concluded that *C. longicollis* turtles do not maintain site fidelity over extended periods. Although shown to navigate accurately during fine weather, *C. longicollis* turtles frequently move during inclement weather and we suggest that they become disoriented due to a lack of environmental queues, and thus take up residence in 'new' wetlands.

Key words: freshwater turtles, home range, population turnover, migration, recruitment.

INTRODUCTION

The most widespread freshwater turtle in Australia, the eastern long-necked turtle *Chelodina longicollis*, inhabits a broad range of aquatic habitats from Rockhampton in the north, south into southern Victoria, and west across the Murray-Darling basin (Cann, 1998). It is found in sympatry with other endemic turtle species [e.g. *Emydura macquarii* and *Chelodina expansa* in Murray-Darling Basin (Chessman, 1988; Thompson, 1993; Cann, 1998), *Elseya latisternum*, *Chelodina expansa* in Brisbane River (Cann, 1998; Judge, 2001) and, with the introduced *Trachemys scripta elegans* in south-eastern Queensland (O'Keeffe, 2005) and Sydney (Burgin 2006, 2007)]. Population density varies, but based on a complete census of a farm dam in western Sydney, Burgin *et al*. (1999) determined that the resident population at the time of draining the dam equated to 370 ha^{-1}. Estimates from elsewhere have ranged from between 236 ha^{-1} (Chessman, 1978) and 400 ha^{-1} (Parmenter, 1976).

Chessman (1978) netted *C. longicollis* turtles in every sampled water body, from ponds and small billabongs to rivers. Turtles inhabit deep flowing, permanent waterways (Chessman, 1984; Kennett & Georges, 1990), and are also widespread in shallow or ephemeral water bodies (Chessman, 1988) and farm dams (Wong & Burgin, 1997; Burgin *et al*., 1999).

When habitat becomes unsuitable (e.g. reduced water levels), *C. longicollis* turtles may migrate. It has been suggested that they move to limit competition

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with fish and other turtles. Kennett & Georges (1990) observed this phenomenon. They found that when water levels in relatively small water bodies dropped during drought, the density of turtles increased in an adjacent permanent water body, and subsequently, food became limited, and this led to a decline in the growth rate of resident turtles, and reproduction ceased. When it rained, some turtles left the permanent water, and moved to the newly replenished swamps, where it was expected to exist a greater food abundance, and less competition from fish and other turtles. Movement into an ephemeral swamp from permanent water occurred within four days of rain.

Because *C. longicollis* turtles have a much lower rate of evaporative water loss than other Australian freshwater turtles (Chessman, 1984, 1988), they are able to move substantial distances overland between aquatic destinations. Stott (1987) found that they moved predominantly at night, and during periods of rain. However, they may also move under other conditions (Graham *et al*., 1996; Dalem, 1998). Although Graham *et al*. (1996) observed that when they moved under overcast conditions, orientation was random, others (*cf.* Stott, 1987; Dalem, 1998) have observed that their movement is essentially non-random, indicated by their movement in effectively a straight line over substantial distances. There was no evidence of a search pattern. Based on such observations, it has been concluded, that *C. longicollis* turtles move through their home range using compass orientation references in the environment (Stott, 1987; Graham *et al*., 1996; Dalem, 1998). This would include the sun by day, and potentially, the moon at night. At other times movement may be less directed.

Dalem (1998) sampled seven dams within a 1 km radius, in farmland in north-western peri-urban Sydney, and observed that 10% of the *C. longicollis* turtles moved among dams over a 12 month period in 1995-1996. Movement occurred along drainage lines and over land. However, these turtles frequently returned to their initial place of capture. This pattern of movement among dams has also been observed by other researchers (Parmenter, 1976; Stott, 1987).

Past observations have, therefore, indicated that *C. longicollis* navigate through their environment, and at least some tracked animals that move away from the impoundment of the initial point of capture, return, on occasions some months later (Dalem, 1998). Based on these observations, we hypothesised that, despite their propensity for overland movement, *C. longicollis* turtles maintain a home range that may include a number of water bodies that they move among. Although arguably they are the most studied Australian freshwater turtles, and have a lifespan > 36 years (Parmenter, 1976), no long-term data have been collected to investigate their movement over a period greater than four years (Parmenter, 1976). We re-visited farm dams that were initially studied a decade previously and sampled *C. longicollis* turtles to determine to what extent they maintained site fidelity over this period of time.

MATERIALS AND METHODS

Site description

This survey of turtles was undertaken in March and April 2006, on the University of Western Sydney's Hawkesbury campus (150°75′ E, 33°62′ S) in peri-urban north western Sydney (Australia). The climate of the area is temperate, and during the study period the mean monthly daily temperature varied between 23.9°C and 27.1°C. Most rainfall occurs in summer. Influenced by drought conditions, there was only 26 mm of precipitation across the sampling period, which is within the lowest 30% of historical totals (Bureau of Meteorology, http://bom.gov.au/dwo/IDCJDW2119.latest.shtml, accessed in September 2006).

The dams sampled were within the farmland of the University. While the intensity of farming has varied over time, the area has been used for agricultural teaching, since an agricultural college was established on the site in the late 1800s. Cattle grazing, and dryland and irrigated cropping occurs in the area (White & Burgin, 2004). The dams sampled were within the farmland areas, or abutted remnant woodlands at the interface between farmland and woodlands. The sources of water for the dams varied across the campus, and natural rainfall, runoff and groundwater seepage, were supplemented in some dams by dairy waste, treated effluent or bore water.

Dam selection

Seven dams on the core of the University's Hawkesbury campus had been sampled in 1995-1996 (Dalem, 1998; Burgin, unpublished data). Surveys of the dams showed that the water in four of these dams was insufficient to set traps and, therefore, were not included in the survey. To compensate, the closest dam to each of those with insufficient water to set nets, was sampled. These were all within the original spatial area

TABLE 1. Brief description of dams sampled for *Chelodina longicollis* turtles on the Hawkesbury campus of the University of Western Sydney, March and April 2006 [all dams in the area were numbered arbitrarily by Dalem (1998), and dams for sampling selected at random]

Dam number	Description
4	Interface between farmland and open woodlands. Some emergent vegetation around dam perimeter. Water source rainwater, and overflow from Dam 7 via drainage line.
5	Open farmland with scattered remnant vegetation. Receives recycled effluent. Steep sloping banks, small amount of emergent vegetation.
7	Open farmland, occasionally grazed by cattle. Water level maintained by dairy wastewater. No emergent vegetation.
10	Interface between grazing fields and open woodland. Modified wetland that receives rainwater. Emergent vegetation in the middle of the dam.
13	Grazed field (horses). Levels maintained by bore water. Substantial emergent vegetation and weed.
14	Grazed field (cattle). Receives rainwater. Limited emergent vegetation. Bare banks with steep slope.
20	Open field, not grazed by stock. Sandy banks. Level maintained with treated effluent from Richmond Sewage Treatment Plant. No emergent vegetation.
21	Open field, ungrazed. Grass to the water's edge. Emergent vegetation at one end of dam. Water levels maintained with bore water. Very turbid.
28	Open field, bordering roadway. Ungrazed, 1.8 m fence surrounds paddock. Emergent vegetation surrounds perimeter. Water supplemented by treated effluent.
29	Middle open, flat field, close to bushland. Rainwater supplemented with groundwater. No emergent vegetation.

sampled by Dalem (1998). The three dams originally sampled, that contained sufficient water to set nets, were surveyed for turtles. In addition, sampling effort was expanded to encompass representative dams in a wider band around the original site (i.e. the search was expanded from a 1 to 2 km radius). A brief description of each dam is presented in Table 1.

Turtle sampling

During March and April 2006, each dam was sampled over four consecutive days. Two dams (arbitrary paired) were sampled over a four-day period. After this period, two new dams were sampled for four sequential days. This staggered approach to sampling ensured that turtles could be processed efficiently in the early morning before heat stress potentially became an issue.

The use of fyke nets to capture *C. longicollis* turtles is an effective method to determine the size and structure of populations within a dam (Burgin *et al*., 1999). Four fyke nets were used to sample each dam. Their placement was determined by first measuring the perimeter of the dam, and dividing it into four segments. Within each of these segments a net was randomly placed. Fyke nets were set in the late afternoon, and cleared daily over the next four days. The nets were subsequently removed on the final day after early morning checking.

Retrieved turtles were placed in baskets to await processing. This included a check for previous markings and injuries, measurement of the curved carapace length (± 0.1 mm) with a measuring tape, and body weight (± 0.1 g), measured using a portable field balance (Sartorius Portable PT1200 scales) for turtles up to 999 g, and Salter Super Samson Balance (10 g to 2 kg) for turtles over 999 g.

Turtles with carapace length under 11.0 cm were classed as juveniles (*cf*. Dalem, 1998, after Parmenter, 1976). Sex of individuals over 11.0 cm carapace length, was determined using a metal ruler at the girth of the plastron to determine if the plastron was convex (female) or concave (male) (*cf*. Chessman, 1978; Thompson, 1983a; Kennett & Georges, 1990; Dalem, 1998).

To uniquely identify individuals, each *C. longicollis* turtle had two numbered shellfish tags (Hallprint type FPN flexible polyethylene 8×4 mm glue-on shellfish tags, Hallprint Pty Ltd, Victor Harbor) glued (Selleys 'Quick Fix' liquid superglue) to the shell: one was placed on the marginal scutes, and the other on the plastron on the side of the shell, between the front and back legs. After processing was completed, each turtle was released at the point of capture. When all turtles had been released, nets were reset each day of sampling, or removed at the end of the sampling period.

Data analysis

Initially, the numbers of all *C. longicollis* turtles captured were graphed (males, females and juveniles), and a growth curve based on carapace length *versus* weight was developed using the correlation statistic. The sex ratio of the sample was determined using Chi square analysis. To investigate the differences in the size structure of males and females, ANOVA (one way analysis of variance) was undertaken on the carapace length of each sex. This was then repeated using the ratio of weight to length.

To determine whether there had been a change in the population size structure over the decade, the carapace length at last capture in Burgin's 1995-1996 survey (unpublished data), was compared with the 2006 data using one-way ANOVA. To compare the condition of animals between the two surveys, the weight was standardised by dividing the turtle weight by the carapace length in 1995-1996. A random subset of the 2006 sample was then taken because of the great discrepancy in the two sample sizes, while the same ratio of males to females was sampled to ensure that there was no bias due to differences between the sexes. One-way ANOVA was used to compare the two samples, and this was repeated three times with different randomly determined subsets of the 2006 data to ensure that the sample for 2006 was representative of the population structure. Mean annual growth of recaptured turtles was also calculated.

To determine whether water characteristics influenced distribution of turtles, the dam water source (no supplementation, or supplemented with dairy waste, treated effluent, or groundwater) was compared with the density of turtles found in the different dams. This was achieved with the application of one-way ANOVA.

RESULTS

Population structure

A total of 751 *Chelodina longicollis* (892 captures) were netted during this study: 28 juveniles (3.7% of total population), 308 (41%) adult males, and 415 (55.3%) adult females. The sex ratio was significantly skewed towards females ($\chi^2_{1,\ 0.0001} = 15.78$) but, overall, there was no significant difference in the carapace length between males and females.

Carapace length varied between 3.2 and 24.1 cm (mean = 16.8 cm, s.e. = 0.104). The weight of these animals varied between 5.7 g and 1090.0 g (mean = 434.4 g, s.e. = 6.643). Carapace length was strongly correlated to a curved linear relationship ($R^2 = 0.978$).

There were 3.9% of turtles that had been injured, and there was no significant difference in the injuries sustained between males and females. Three animals had a deformed limb, and one had a 'blister' on the side of the head. However, most injuries resulted in broken or disfigured shells consistent with vehicle injury, while puncture marks (presumably made by a predator) were less common.

The source of supplementary water (natural fill, groundwater, dairy effluent, treated effluent) and the density of turtles were not significantly different among treatments ($p > 0.05$).

Changes in turtle populations over time

Of the turtles captured a decade previously, 9.2% (n = 751) were recaptured in the current survey. In the area originally sampled (Dalem, 1998; Burgin, unpublished data), 11.9% (n = 572) of *C. longicollis* netted in this survey were also captured in 1995-1996. When the study site was expanded to search for marked individuals, only one of 179 (0.6%) turtles netted was marked. The sex ratio of the recaptured animals did not differ significantly (1:1 sex ratio).

The carapace length of recaptured turtles ranged from 16.3 to 23.0 cm (mean = 19.31 cm, s.e. = 0.197). The weight of these animals varied between 247.9 g and 1025 g (mean = 611 g, s.e. = 20.4). There was no significant difference in the size structure of the population surveyed in 1995-1996 and 2006.

Only one turtle did not increase in carapace length over the decade between 1995-1996 and 2006. Mean annual carapace growth in the other 17 turtles that Burgin had first sampled in 1995-1996, varied between 0.15 and 0. 84 cm and only one individual grew more than an average of 0.45 cm year^{-1} (range 0-0.84 cm year^{-1}). There was a strong relationship between the initial carapace length, and the turtle growth over the decade ($R^2 = 0.6124$, Fig. 1), and a weaker relationship between the initial size and the growth ($R^2 = 0.3704$, Fig. 2). Of the four turtles that lost weight (range = 21-189.3 g), three weighed more than 600 g in 1996. The weight gained amongst the remainder of

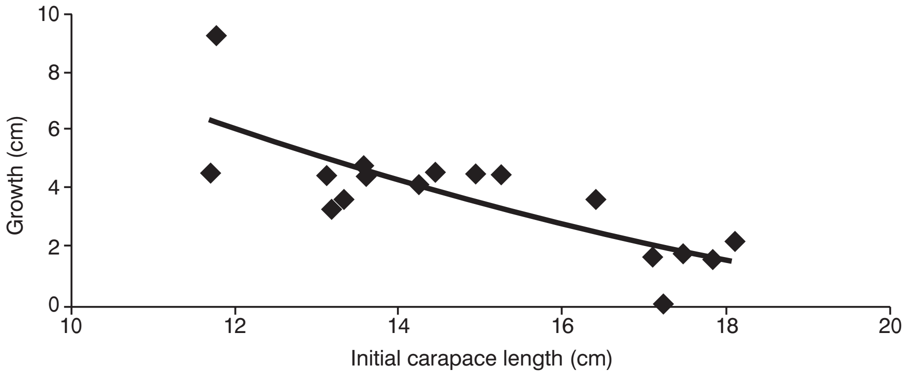

FIG. 1. Carapace length (cm) of *Chelodina longicollis* at initial capture (1995-1996) and the growth (cm) when recaptured in 2006 ($R^2 = 0.6124$).

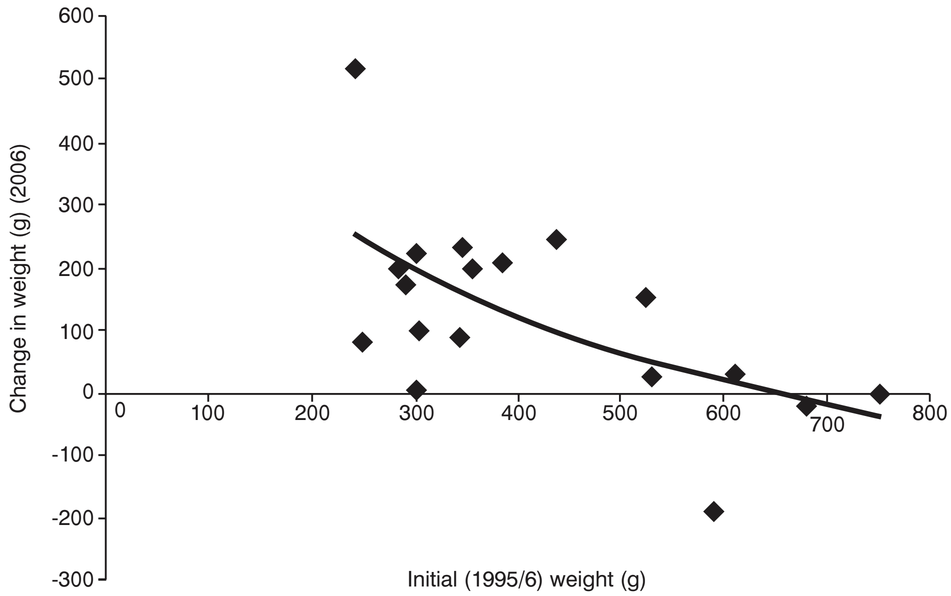

FIG. 2. Weight of *Chelodina longicollis* turtles at initial capture (1995-1996), and the change in weight over the decade to 2006 ($R^2 = 0.3704$).

the sample, varied between 24.7 and 517.8 g. There was no significant difference in condition (ratio of carapace length to weight) between the pre-drought sample (1995-1996), and the drought sample (2006).

DISCUSSION

Overall, less than 10% of the *C. longicollis* turtles netted in this survey were also captured in the area in 1995-1996 (Dalem, 1998; Burgin, unpublished data). Although there are no published data available on long term site fidelity for any Australian freshwater turtle, these results were unexpected. Dalem (1998) found that over the 12 months of his study, approximately 10% of the turtle population moved from one dam to another, and frequently these animals were later recaptured in their first dam of capture. In other studies of *C. longicollis* (Parmenter, 1976; Stott, 1987), it was also observed that turtles did move from one water body to another, but frequently returned to their original place of capture. Other Australian freshwater species, for example, the Fitzroy river turtle *Rheodytes leukops*, have been shown to maintain a 2.4 ha home range within a river (Cay *et al*., 2001).

It has also long been accepted that turtles have visual and auditory acuity, and this provides them with the ability to navigate non-randomly within their environment (Casteel, 1911; Tinklepaugh, 1932; Kuroda, 1933; Dudziak, 1955; Boycott & Guillery, 1962; Lenhardt, 1981; López *et al*., 2004). These abilities have been demonstrated in aquatic and terrestrial environments (Dudziak, 1955). For example, López *et al*. (2004) showed that in the terrestrial environment, *Pseudemys scripta* (*Trachemys scripta elegans*) turtles trained in place, cue, and control open-field procedures, were able to navigate accurately to their goal, even from different start locations. Authors concluded that turtles use spatial strategies similar to those described in mammals and birds to navigate through their environment. Tinklepaugh (1932) considered that *P. scripta* had the ability to learn to negotiate a maze as efficiently as rats placed under the same conditions. Based on this information we assumed that, even though *C. longicollis* turtles have a propensity for overland movement, they would maintain a home range, and hence fidelity that included a group of water bodies.

If *C. longicollis* moved longer distances than other turtles, they may be 'accidentally' displaced from their habitat. In Greece, the land tortoise, *Testudo hermanni boettgeri* attains a marginally longer carapace length (26.4 cm; Highfield, 1988) than *C. longicollis* (25.4 cm; Goode, 1967). It travels up to 450 m a day within a home range of 1.8 ha (Hailey, 1989). This distance is similar in area to our study site. When migrating between water bodies, *C. longicollis* has been recorded to move broadly similar distances, up to 556 m per day (Stott, 1987). The North American wood turtle *Clemmys insculpta*, is more similar in habit to *C. longicollis* than *T. h. boettgeri*, since it moves between aquatic (e.g. streams, creeks, rivers) and terrestrial habitats, and it grows to a similar size (25 cm carapace length; Harding, 2002). *Clemmys insculpta* turtles have been shown to maintain a home range that was sustained over a 20 year study period (Burger & Garber, 1995). However, when Carroll & Ehrenfeld (1978) artificially displaced *C. insculpta* more than 2 km overland from their home range, only 17% were able to return, although 84% of those artificially displaced less than 2 km returned. In contrast, Harding & Bloomer (1979) observed that when they displaced an animal 8 km upstream along a river from its home territory, it returned 2 months later. Based on these data, it is reasonable to assume that such displacement would result in at least some *C. longicollis* not returning.

Eastern Australia has experienced drought for much of the decade between 1996 and 2006. In the area of our survey, the water level in some dams has dropped dramatically, and all ephemeral water bodies have been dry for much of that time (personal observation). Under similar circumstances, Kennett & Georges (1990) found that a segment of the *C. longicollis* population they studied in the coastal wetlands of the Australian Capital Territory, migrated to nearby permanent water during drought, and food became limiting and reproduction was inhibited. After rain, the density in the lake decreased, and several *C. longicollis* turtles were found in a newly filled ephemeral swamp within four days. Due to long term drought conditions, the turtles that occupied the dams in 1995-1996 could have moved to larger, more permanent waters, such as the Hawkesbury-Nepean river which is within 5 km of the study site. However, such a conclusion is logically inconsistent with the observation that the dams sampled had turtles in a size range equivalent to that of the previous inhabitants that had emigrated.

It is unlikely that *C. longicollis* turtles moved from the area because of poor quality habitat. There were more turtles captured in 2006 (751) than in 1995-1996 (679; Dalem, 1998), and this equated to a sampling effort of 20 turtles/net/day in 2006 compared to 13.81 turtles/net/day in 1995-1996. This indicated that despite drought conditions, the habitat remaining was capable of absorbing even higher numbers of healthy turtles during prevailing drought conditions, compared to the non-drought conditions of the previous decade.

Several of the dams were maintained at non-drought levels with supplementary water, and some also abut, or are within, farmland that is irrigated to maintain pastures. Apart from a number of dams that did have very low water levels, there have been no major changes in the landscape. For example, farming practices have remained unchanged, and there have been no additional water bodies created or in-filled. There was, therefore, no apparent reason for approximately 90% of the resident turtles to migrate due to physical changes in the landscape, and for this population to be replaced by a similar population, in terms of size structure.

The pattern of growth varies with age and climatic conditions (presumable indirect measure of food availability). Hatchlings typically grow rapidly in the first year (e.g. 3.5 cm, Chessman, 1978; Dalem & Burgin, 1996), and then growth plateaus (Armstrong, 1980), thereafter it tends to be dependent on rainfall. In the Australian Capital Territory, Kennett & Georges (1990) observed that the annual growth of adults can average 0.62 cm during periods of high rainfall, while in lower rainfall periods no animals grew more than 0.05 cm. Chessman (1978) found that annual growth was between 0.1 and 0.25 cm in Gippsland, while in the study area, Dalem (1998) found that annual growth averaged 0.055 cm. Wong & Burgin (1997) observed that in a previous drought period, adult males of *C. longicollis* turtles from small farm dams in the same region that the current surveys were undertaken, weighed only 55 and 75%, and females weighted between 67 and 105% of their predicted weight at maturity. While only one of the 18 animals we had growth data for was above the average highest growth rate by Kennett & Georges (1990), only one did not achieve the growth that Dalem (1998) recorded in a non-drought period in our study area. In addition, in 2006, the condition of turtles was equivalent in dams with nutrient enrichment and visually eutrophic (e.g. supplemented with dairy waste or treated effluent), and those that were not enriched. There was, therefore, no evidence to suggest that the turtles immigrated due to competition for food.

There was also no evidence that the loss of animals from the population was due to death in an ageing population, and subsequent recruitment of hatchlings to the population. Indeed, the percentage of hatchlings captured in the current survey (3.7%) was lower than Dalem (1998) recorded (10.3%) for the same time of the year. The only other comparable study (i.e. using the same definition of juvenile), was that by Parmenter (1976) who collected 24.6% juveniles across four years of sampling. While the lack of recruitment may be a result of depressed reproduction due to drought (Kennett & Georges 1990), predation cannot be discounted as a factor in the low level of recruitment to the population. Thompson (1983b) found that over 96% of turtle nests were taken by predators in the Murray river (south eastern Australia). Exotic predators (e.g. foxes) accounted for over 90% of the predation. Burgin (2006) confirmed that foxes predated on turtle nests in the Sydney area, and although not quantified, the evidence indicated that this occurred in our study area. For example, one dam was fenced which should have inhibited some predators. Seventeen juveniles were trapped in that dam compared to zero to five in the unfenced dams.

The population structure was broadly similar across both the 1995-1996 and the 2006 turtle surveys. Based on the observation that recaptures were across a range of sizes, including *C. longicollis* that had been small and large in the 1995-1996 survey, there is no support for the suggestion that the turnover in population was due to natural birth and death regimes. Recruitment to the population was lower than previously recorded (Parmenter, 1976, 1985; Thompson, 1983b; Dalem, 1998), and could not explain why there was a turnover in the population of over 90% in the decade.

One factor that could be responsible for the lack of marked recaptured *C. longicollis* turtles is the loss of marks. The recaptured turtles that had been marked in 1995-1996 had obvious marks in their marginal scutes. Dalem (1998) used a modified form of the marking system used by Cagle (1939), whereby the marginal scutes of the turtle were filed in a specific configuration. There is no evidence from this study, or from the literature, that marks 'grow out' of the scutes. The potential for turtles to have lost their unique marking is, therefore, not considered feasible unless the rate of injury to the marginal scutes resulted in their loss.

Chessman (1978) found that in the Murray river area, 7% of the *C. longicollis* turtles netted had an injury to their body or shell. In the 1995-1996 survey, 8.8% of the turtles had some injury to their shell or body, with approximately half of these injuries being to the carapace (Dalem, 1998). In the 2006 survey, most injuries damaged the shell, however, the number of animals that carried evidence of injury was low (3.9%), and less than half of these resulted in damage or loss of the marginal scutes. Based on a lack of change in land use (e.g. expansion of roadways, agriculture, urbanisation), there was also no reason to believe that during migration mortality rates would have increased substantially over the decade. There is also no apparent reason for an increased or more efficient predation to have occurred in 2006, compared to 1995-1996. There is, therefore, no evidence that marks were lost.

CONCLUSION

Chelodina longicollis turtles are long-lived, slow growing animals (e.g. Thompson, 1993; Dalem, 1998). Adult mortality, at least in one rural area, was calculated to be less than 2% annually, and apparently independent of age (Parmenter, 1985). If the resident population had moved because of drought, it would be expected that there would have been a lack of turtles in the dams we surveyed. This was not the situation. We also did not identify any other reason for a lack of recaptures (e.g. loss of marks, enhanced predation) that could provide an alternative explanation for the low level of recaptured animals, other than their migration. All indications are that *C. longicollis* turtles do not have strong site fidelity.

The animals that have emigrated, have apparently moved beyond the immediate area, since although we expanded the area of survey from approximately a 1 km radius to a 2 km radius, only one turtle was captured that had been previously marked. If the explanation for our results was that *C. longicollis* turtles had a larger home range than we envisaged, we would have expected to have netted a larger percentage of marked animals in the area surrounding the original study area.

The observation by Graham *et al*. (1996) that, under overcast conditions *C. longicollis* orientation may be considered as random, and that turtles frequently undertake migration during periods when orientation references in the environment are limited (e.g. during rain and overcast conditions), their ability to navigate under such conditions may become impaired and hence they become 'lost' and have to seek new habitat.

ACKNOWLEDGEMENTS

David Hall from Hallprint Pty Ltd donated the shellfish tags that were used to mark animals. Judy and Geoff Ryan also provided invaluable assistance during the field work. The research was carried out under the approval of the University's Animal Care and Ethics Committee.

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