# Population status of the Oblong turtle in Lake Claremont

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TOWN OF CLAREMONT
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## Disclaimer

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# Executive Summary

*Chelodina oblonga* populations appear to be in decline throughout the Swan Coastal Plain, making monitoring and targeted management strategies of high importance if this trend is to be reversed. This is the fourth population survey of the Lake Claremont *Chelodina oblonga* population, with previous surveys in 2005, 2016, and 2017. Higher Catch Per Unit Effort suggests that the Lake Claremont *C. oblonga* population is denser than that of many other Swan Coastal Plain wetlands. Males dominated adult captures suggesting high adult female mortality, a common occurrence in urban populations. There was a lack of small individuals in the system, indicating a lack of recent recruitment to the system as found in most other urban populations of the species. The population also lacked larger individuals which may be contributing to the recruitment issues in the system. If the reason for low variability in sizes and ages of *C. oblonga* in the Lake Claremont population can be properly identified, alongside restoration of recruitment, the population may be encouraged towards representing one of a more diverse, healthy system.

## Background

The oblong turtle (*Chelodina oblonga*) is an iconic, keystone species that inhabits aquatic systems within south-western Western Australia. *Chelodina oblonga* is endemic, with a range that extends along the coast from the Hill River (inland from Jurien Bay), south-east to the Fitzgerald National Park (Cann 1998). Within this range, *C. oblonga* inhabits a variety of permanent and semi-permanent wetlands that include natural and constructed lakes, swamps, rivers and creeks (Burbidge 1967, Santoro et al. 2020a). It is the only native freshwater turtle species found throughout the Perth metropolitan region, following the reduction in range of the western swamp tortoise (*Pseudemydura umbrina*).

The species is the underwater apex predator within its range and is a generalist feeder and an opportunistic carnivore (Woldring 2001). As an apex predator, *C. oblonga* plays a crucial role in aquatic ecosystems and is valuable to humans through helping to control insect populations. Furthermore, as it is a large-bodied species and visible in wetlands, it has an important role in community education on the value of maintaining biodiversity in wetlands; most of which have been severely altered or degraded on the Swan Coastal Plain since European settlement.

*Chelodina oblonga* is currently listed as 'near threatened' by the IUCN (Tortoise & Freshwater Turtle Specialist Group 1996), although its status has not been assessed for 25 years. The most comprehensive study on the species was recently conducted by our research team (Santoro et al. 2020a), and involved surveying 33 Perth wetlands to explicitly determine the factors influencing the status and viability of the remnant populations. The study revealed abundances of *C. oblonga* in Perth wetlands are alarmingly low. There were less than 25 turtles captured at ~60% of wetlands, and no juvenile turtles in ~40% of wetlands surveyed (Santoro et al. 2020a). Therefore, conserving and managing remaining populations in both natural and artificial waterbodies is required to help to halt the decline in abundances.

Further research into *C. oblonga* populations at wetlands within the Beeliar Regional Park by the authors in Perth has revealed that *C. oblonga* populations face significant threats from terrestrial predation of nesting females, eggs, and hatchlings by introduced species (such as foxes) and mortality from road strikes. This supports the findings of (Santoro et al. 2020a) who revealed that the amount of adequate surrounding terrestrial nesting habitat availability (that presumably reduces the risk of those factors listed above) was the key predictor of relative abundances within wetlands.

Lake Claremont (Fig. 1) is a wetland located within the Town of Claremont that harbours a population of *C. oblonga*. The lake is fed by groundwater and exhibits a seasonal hydro regime that is highly ephemeral. Lake Claremont is a registered as a site of significance to the traditional owners and traditional custodians. Lake Claremont is a conservation category wetland and the site of a major revegetation project. Thus, it has been identified as culturally and environmentally significant for both its conservation and recreation values. The Town of Claremont have identified a need to better understand the *C. oblonga* population within Lake Claremont in order to preserve and enhance the lakes biodiversity values for present and future generations.


**Figure 1**. *Lake Claremont*

## Objectives

The current report details the condition of the *C. oblonga* population in Lake Claremont. This includes:

- Characterising the *C. oblonga* population status and viability within Lake Claremont.
- Providing an assessment of potential nesting habitat.
- Providing an assessment of the intensity of nest predation at Lake Claremont.
- Providing a review of turtle carapaces collected around the lake over the last few years.
- Providing management recommendations to help ensure the long-term viability of this important species within Lake Claremont
- Identifying ongoing monitoring and research that may be required to fully increase the understanding of the *C. oblonga* population within Lake Claremont and detect changes in the population over time.

# Methods

## Study Site

Lake Claremont is an extensive (~16.5 ha aquatic surface area), freshwater wetland located within the Town of Claremont, Perth, Western Australia. It is a natural, seasonally inundated lake, where the extent of drying varies annually with rainfall. The terrestrial habitat surrounding the wetland is highly urbanised, with the exception of a bushland area (~10 ha) along the north-western edge. Several roads, residential areas, a shopping centre, schools with extensive ovals, a golf course, and an aquatic centre all fall within a 500 m perimeter of the lakes aquatic zone (Fig. 2).


**Figure 2.** Aerial image of Lake Claremont showing highly urbanised terrestrial zone within 500 m perimeter (red line).

## Trapping regime

Trapping for *C. oblonga* occurred within Lake Claremont between the 15th and 18th of November and the 13th and 16th of December 2021 for a total of six trapping nights. A combination of modified funnel traps (Kuchling 2003) and fyke nets were used (Fig. 3). These two trap designs are proven to efficiently capture the species unharmed when deployed by experienced personnel. All traps and nets are set in the afternoon, left overnight, and checked the following morning. The traps and nets were baited with tinned sardines. Individual *C. oblonga* were prevented from eating the bait by only partially opening the tins, ensuring the bait remained active through to trap retrieval. Floats were placed in all traps to ensure access to the surface for any air-breathing species captured. Six modified funnel traps and six fyke nets were deployed on each trapping night. Trap and net locations varied each night to ensure as much as possible of the aquatic zone of the wetland was surveyed.

## Turtle processing and identification

Upon retrieval of each trap, each turtle was placed into a clean calico bag to reduce stress while awaiting processing. Prior to release, turtles were weighed to the nearest 5 g using hanging scales (Kern HDB 5K5N Digital Hanging Scale 5 kg), and carapace and extended tail length (from the base of the plastron to the tip of the tail) measured to the nearest 1 mm using 300 mm Vernier callipers. The sex of each turtle was identified in the field based on tail length (Burbidge 1967). Straight carapace length was used to classify individuals as juvenile (male, <129 mm; female, <149 mm) or adult (male, >130 mm; female, >150 mm) (Kuchling 1988, Kuchling 1989, Santoro 2020). Each turtle was scanned for presence of a Passive Integrated Transponder (PIT) tag and assessed for marginal scute notches to identify recaptures. To allow future identification of recaptured turtles, turtles without PIT tags had a PIT tag (HPT 8 mm) (that remain active for >20 years to enable long-term monitoring of individuals) injected into the body cavity in accordance with Department of Biodiversity, Conservation and Attractions Standard Operating Procedure (Department of Biodiversity Conservation and Attractions 2017) and approved under Murdoch University Animal Ethics Committee.

**Figure 3.** Modified funnel trap (top) and fyke net (bottom).

## Data analysis

Relative abundance was estimated based on the catch per unit effort (CPUE). CPUE was calculated with the formula CPUE = T / Tn / TH, where T = total number of *C. oblonga* captured, Tn = number of traps, and TH = trap hours. This equation standardised turtle captures to relative abundance to allow comparison among studies where differing numbers of traps and trap hours have been used. A Welch's two sample t-test was used to assess differences between Fyke net and modified funnel trap CPUE. Population estimates were calculated using the Jolly-Seber open population estimator that has been corrected for bias (Population estimate = ((n+1)*M) / (m+1), where n = the number of individuals captured, M = number of marked individuals in the population, and m = the number of recaptures). A Chi-squared test of homogeneity was used to analyse whether the sex ratio of the *C. oblonga* population was biased. Sex ratio (male: female) was compared against a 1:1 ratio. Turtle condition was assessed using linear models of the ratio of carapace length to body mass. Sex was added as a factor to the model to test for differences between male and female weights at identical carapace lengths. All analysis was performed in R (Studio version 1.4.1106, 2020; R Development Core Team, 2013).

## Turtle carapace review

To gain an understanding of the minimum impact predation has had on the Lake Claremont turtle population in recent history, we provide an overview of the turtle cadavers collected around Lake Claremont since 2015. Each turtle cadaver had its straight carapace length measured (where possible) using 300 mm vernier callipers. The sex of each turtle cadaver was identified using external morphometrics such as tail length and plastron curvature where possible. Each turtle cadaver was scanned for presence of a Passive Integrated Transponder (PIT) tag and checked for shell notching. A cause of death was assessed where possible. Cadavers with obvious signs of chewing on the shell, head or limbs, broken necks, missing heads or limbs were assigned to the fox predation category. Cadavers without these indicators or where the cadaver was just a shell were assigned to the unknown category.

## Nesting habitat assessment

An assessment of availability of potential nesting habitat within 500 m of Lake Claremont's water's perimeter was conducted using Google Earth Pro software. The identified areas were ground-truthed during the turtle survey. The area of available habitat was calculated and categorised into three categories of accessibility: directly connected to water perimeter, not directly connected and road crossing not required, or not directly connected and road crossing required.

## Nest predation assessment

Nest predation rates were assessed on the 13th December 2021, by transects around the entire perimeter of Lake Claremont within a 50 m zone extending out from the water's edge. This zone is where most *Chelodina oblonga* nests occur (Santoro 2020). Additional transects were performed throughout areas identified as suitable nesting habitat (Santoro 2020). Four researchers spaced ~10 m apart walked the transects at approximately 100 m every 5 minutes.

# Results

## Total capture, relative abundance and population estimates

A total of 389 turtles were captured over the six trapping nights. Two hundred and thirty-two turtles were captured between the 15th and 18th November 2021, including 32 recaptures. One hundred and fifty-seven turtles were captured between the 14th and 16th December 2021, including 20 recaptures.

One individual that was initially captured and then recaptured during the November 2021 session was also recaptured during the December 2021 session, while another individual initially captured during the November 2021 session was recaptured twice more during the December 2021 session. Two individuals initially captured during the 2017 survey (Natural Area 2018), were recaptured once in each of the November and December 2021 sessions, while another initially captured in the 2017 survey (Natural Area 2018), was recaptured twice during the November 2021 session.

The CPUE of the entire survey was 0.300 ± 0.029 (Mean ± SE) turtles per trap per hour (Table 1). CPUE was generally higher in the November trapping session compared to the December trapping session (Table 1). CPUE of Fyke nets was significantly higher than that of modified funnel traps (Table 1, $t = -7.0164$, $p = <0.00$).

Population estimates were calculated for each session during the current survey and were based only on turtles captured during the current survey. Inclusion of the 2017 trapping events would require a significantly more complex population model that is beyond the scope of this project. The number of recaptures was relatively consistent for each trapping session despite more marked turtles being available for capture (Table 2). Population estimates had an average of 1747 ± 266 and ranged from 814 to 2365 (Table 2). Population estimates increased each session, with the exception of the final session (Table 2). There is a considerable difference between the total marked population and the population estimates (Table 2). Assuming that none of the marked turtles from the 2017 survey have died or emigrated since that survey (very unlikely), there would be a minimum of 478 individuals in the *C. oblonga* Lake Claremont population.

**Table 1.** Catch Per Unit Effort (Turtles/Trap/Hour) of *Chelodina oblonga* in Lake Claremont between the 15th November and 16th December 2021.

| Date | Modified Funnel Traps | Fyke Nets | Total |
|---|---|---|---|
| 15/11/21 – 16/11/21 | 0.046 | 0.639 | 0.343 |
| 16/11/21 – 17/11/21 | 0.102 | 0.704 | 0.403 |
| 17/11/21 – 18/11/21 | 0.167 | 0.491 | 0.329 |
| 13/12/21 – 14/12/21 | 0.083 | 0.324 | 0.204 |
| 14/12/21 – 15/12/21 | 0.093 | 0.407 | 0.250 |
| 15/12/21 – 16/12/21 | 0.028 | 0.519 | 0.273 |
| All (Mean ± SE) | 0.086 ± 0.020 | 0.514 ± 0.058 | 0.300 ± 0.029 |

**Table 2.** Population estimates after each trapping session. The marked population included only turtles captured during the current survey.

| Date | Captured | Recaptures | | Re-recaptures | | Marked Population | Population Estimate |
|---|---|---|---|---|---|---|---|
| | | Current | 2017 | Current | 2017 | | |
| 16/11 | 74 | NA | 6 | NA | NA | NA | NA |
| 17/11 | 87 | 7 | 6 | NA | 0 | 74 | 814 |
| 18/11 | 70 | 5 | 7 | 0 | 1 | 154 | 1562 |
| 14/12 | 44 | 3 | 2 | 0 | 1 | 218 | 1962 |
| 15/12 | 54 | 5 | 3 | 2 | 0 | 258 | 2365 |
| 16/12 | 52 | 6 | 1 | 0 | 1 | 307 | 2034 |
| Mean | 64 | 5 | 4 | 1 | 1 | 202 | 1747 |
| SE | 7 | 1 | 1 | 1 | 0 | 41 | 266 |

## Population structure and turtle condition

Carapace lengths ranged from 53 mm to 208 mm, with an average size of 155 mm (Fig. 4). Female carapace lengths ranged from 84 mm to 208 mm, while males ranged from 108 mm to 178 mm (Figs 4, 5). One individual with a carapace length of 53 mm was unable to be sexed (Fig. 4). Three individuals with carapace lengths <100 mm were captured (Fig 4). Eighty-eight percent of the captured population were adults, with 42 (12%) juveniles captured (Fig 6). Seventy-one percent of the captured turtles were male; a sex-ratio of 2.02M:1F (Fig. 7). The sex ratio was significantly different from 1:1 ($X^2$ = 41.116, p-value = <0.000). Female turtles were slightly heavier than male turtles of the same size (Fig. 8, p = <0.00). Both the male and female linear models were significant, however, the model for females had higher predictive power than the model for males (Female: R2 = 0.900, p-value = <0.00, Male: R2 = 0.632, p-value = <0.00) (Table 3).

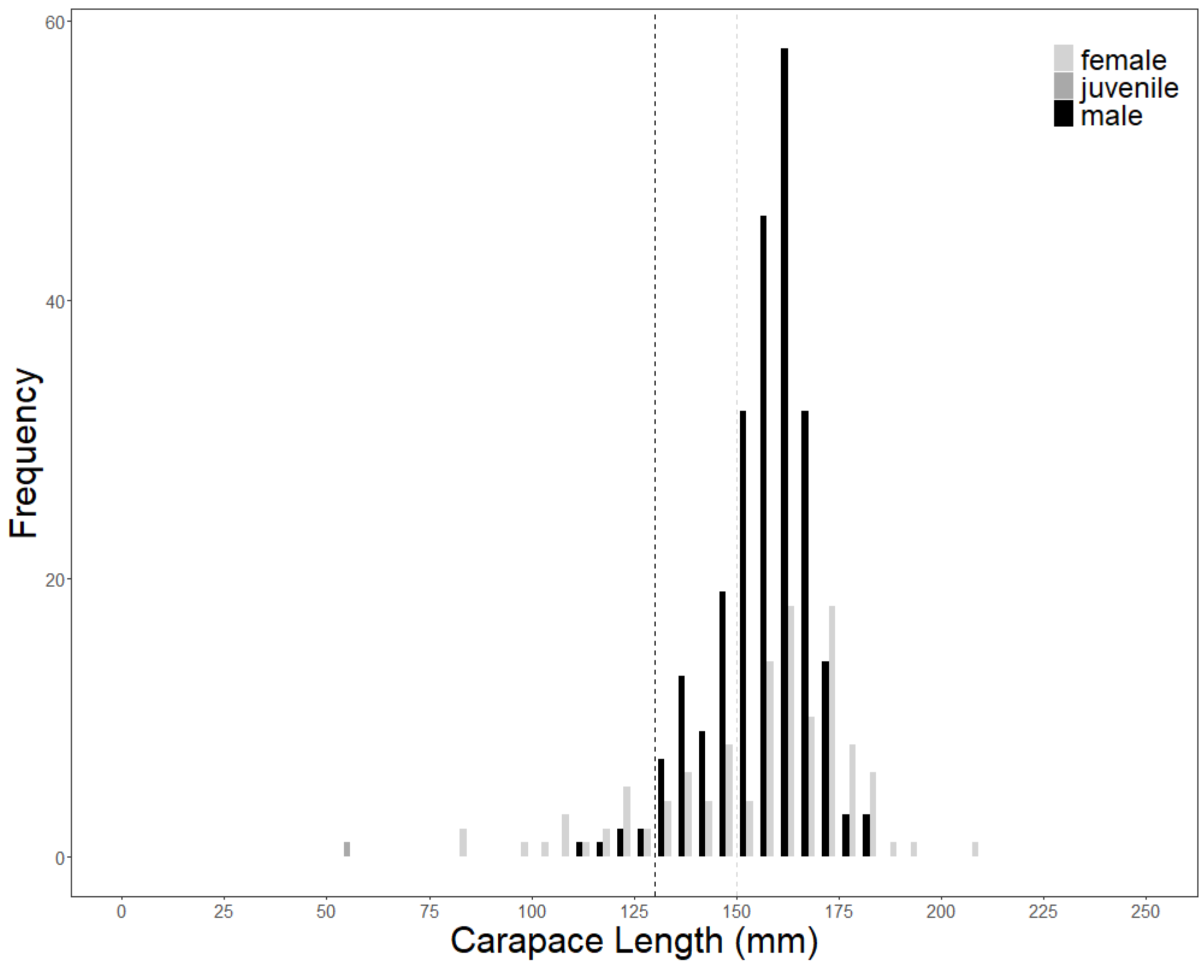


**Figure 4.** Carapace length distribution of *Chelodina oblonga* captured within Lake Claremont between the 15th November and 16th December 2021. Dashed lines indicate sexual maturity for males (130 mm) and females (150 mm).

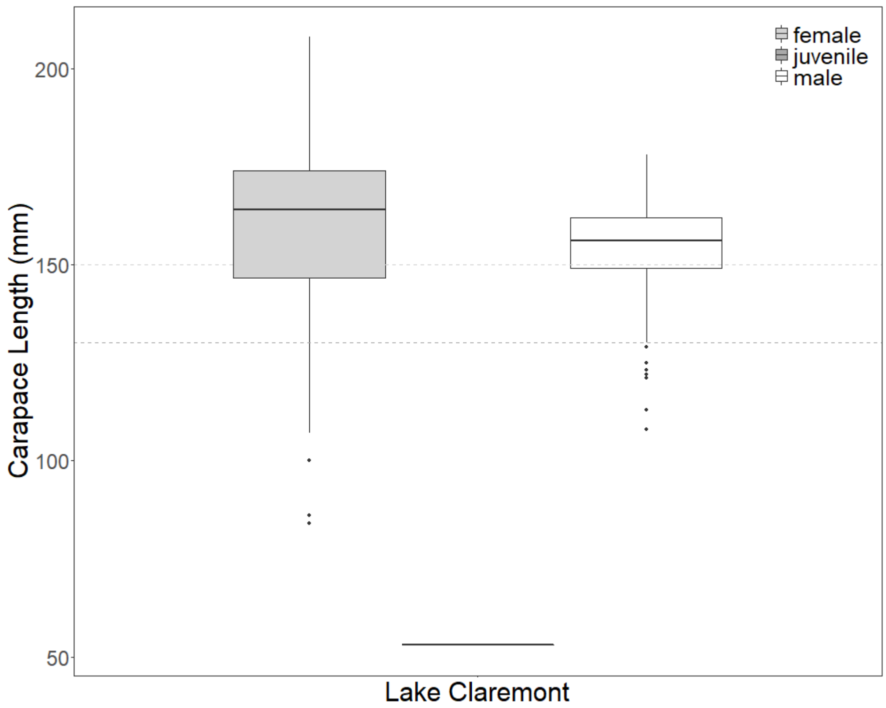


**Figure 5.** Distribution of carapace length by gender of *Chelodina oblonga* captured within Lake Claremont between the 15th November and 16th December 2021. Dashed lines indicate size at sexual maturity for males (130 mm) and females (150 mm).

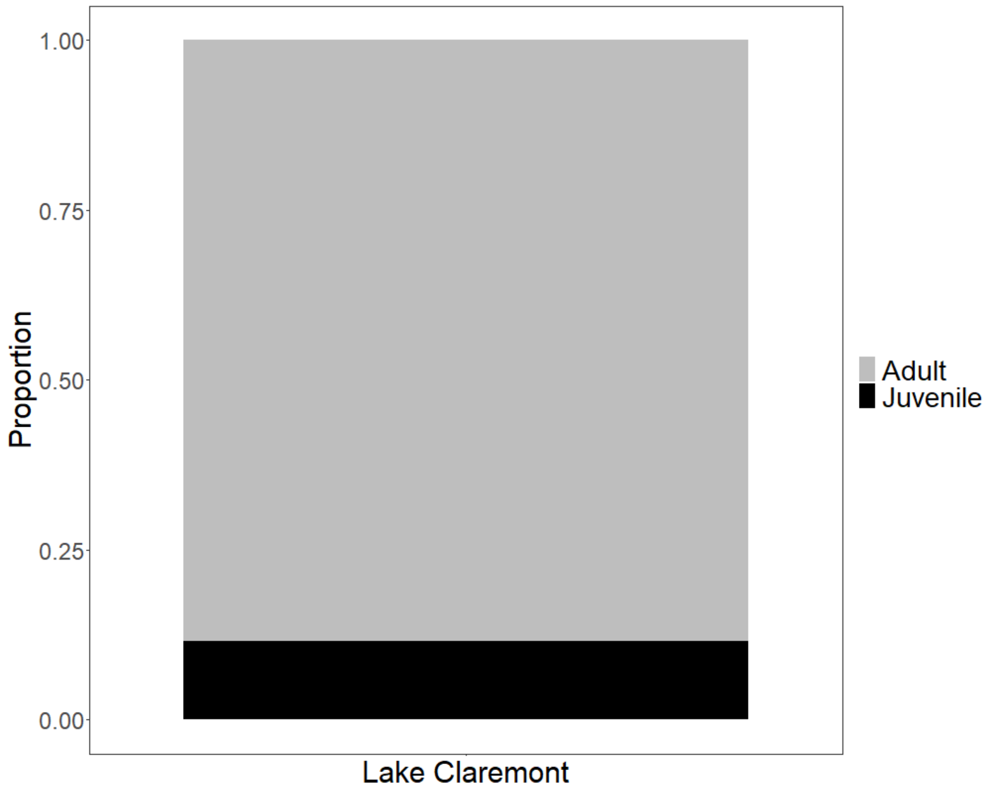


**Figure 6.** Proportion of each age class of *Chelodina oblonga* captured within Lake Claremont between the 15th November and 16th December 2021.

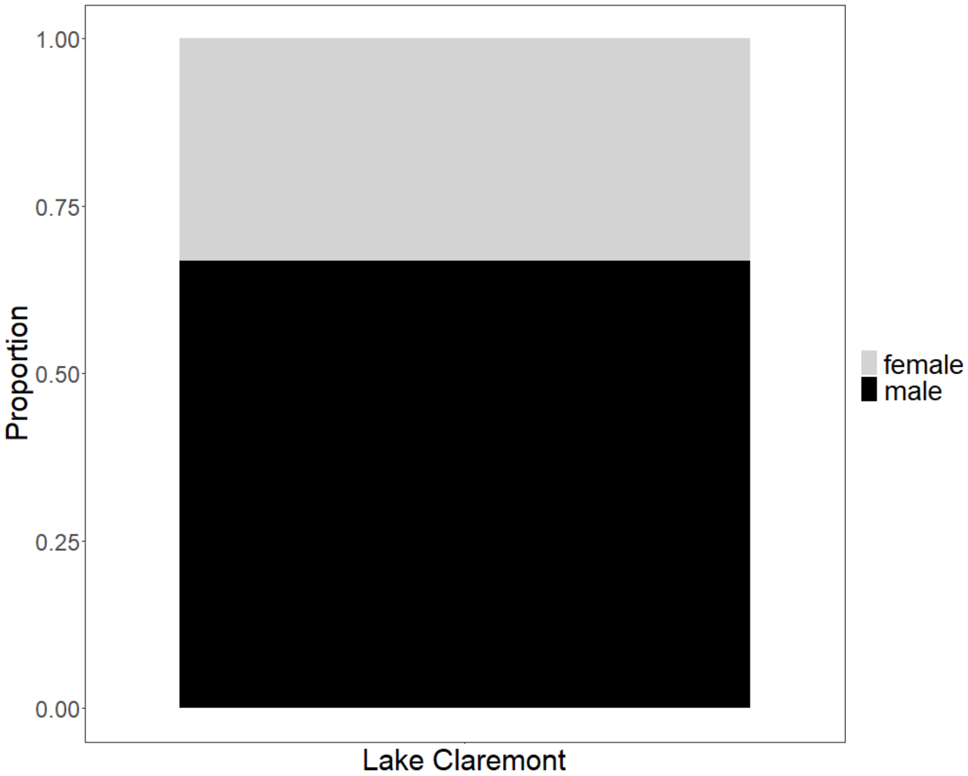


**Figure 7.** Proportion of each sex of *Chelodina oblonga* captured within Lake Claremont between the 15th November and 16th December 2021.

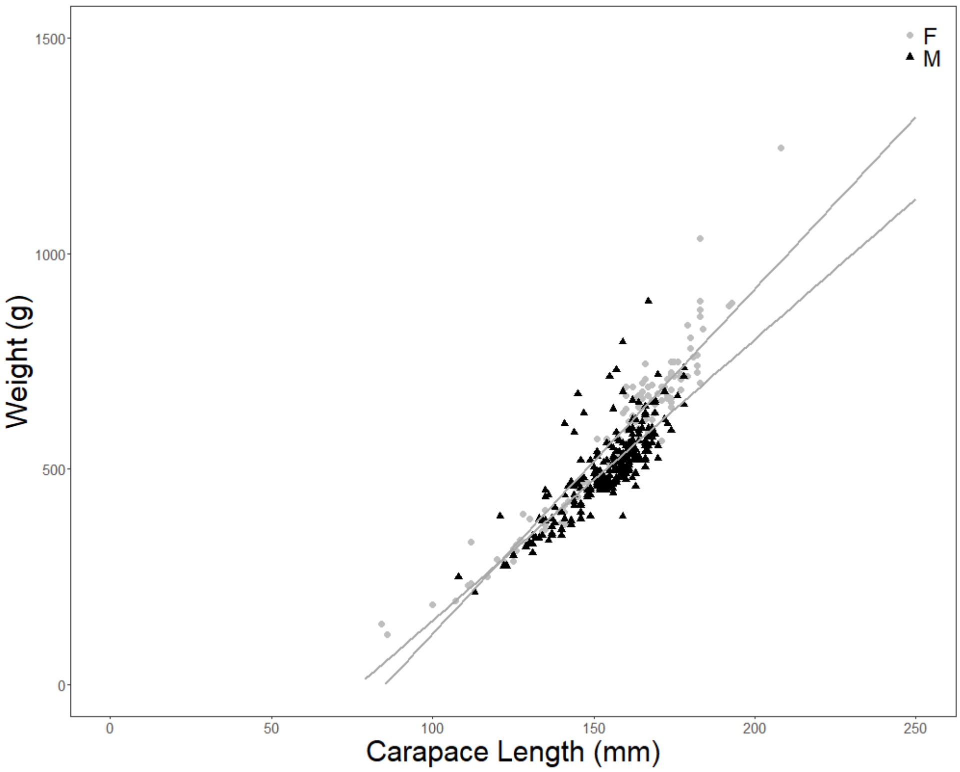


**Figure 8.** Scatterplot of carapace length and weight of male and female *Chelodina oblonga* captured within Lake Claremont between the 15th November and 16th December 2021.

**Table 3**. Linear model summary for condition index of male and female *Chelodina oblonga* captured within Lake Claremont between the 15th November and 16th December 2021.

| Model | Formula | R2 | p-value |
|---|---|---|---|
| Male | Weight = 6.53 Carapace – 504.29 | 0.632 | <0.00 |
| Female | Weight = 8.00 Carapace – 682.12 | 0.900 | <0.00 |

## Growth rates

Twenty-three turtles were recaptures from previous surveys; one from Anthony Santoro's Honours research (Santoro et al. 2020a) and 22 from the 2017 survey conducted by Natural Area Consulting Management Services (Natural Area 2018). Turtles were captured between 1456 (4.0 years) and 1783 (4.9 years) days after initial capture. Straight carapace lengths had an average increase of 6.5 ± 0.8 mm (range 2–21 mm) between captures, or a growth rate of 1.5 ± 0.2 mm per year.

## Turtle cadavers

One hundred and seventy-six turtle cadavers were assessed. Fifty-seven were identified as females, and 16 as males, while 103 were unable to be sexed (Table 4). Straight carapace lengths had an average length of 151.9 ±1.2 mm and ranged from 90–194 mm (Fig. 9). Cadavers identified as female had an average carapace length of 158.1 ±1.6 mm and ranged from 136–194 mm (Fig. 9). Those identified as males had a range of 137–170 mm and an average of 150.4 ±2.2 mm (Fig. 9). Cadavers unable to be sexed had an average carapace length of 148.8 ±1.7 mm, and a range of 90–190 mm (Fig. 9).

One-hundred turtle cadavers showed evidence of fox predation such as missing or chewed heads and/or limbs, broken necks and/or chewed shells. It was not possible to identify a cause of death for 76 cadavers, 37 of which only a shell was present (Table 4). Presumed fox predation accounted for most (84%) female deaths, while fox predation and unknown causes were relatively even for males and un-sexed cadavers (Table 4).

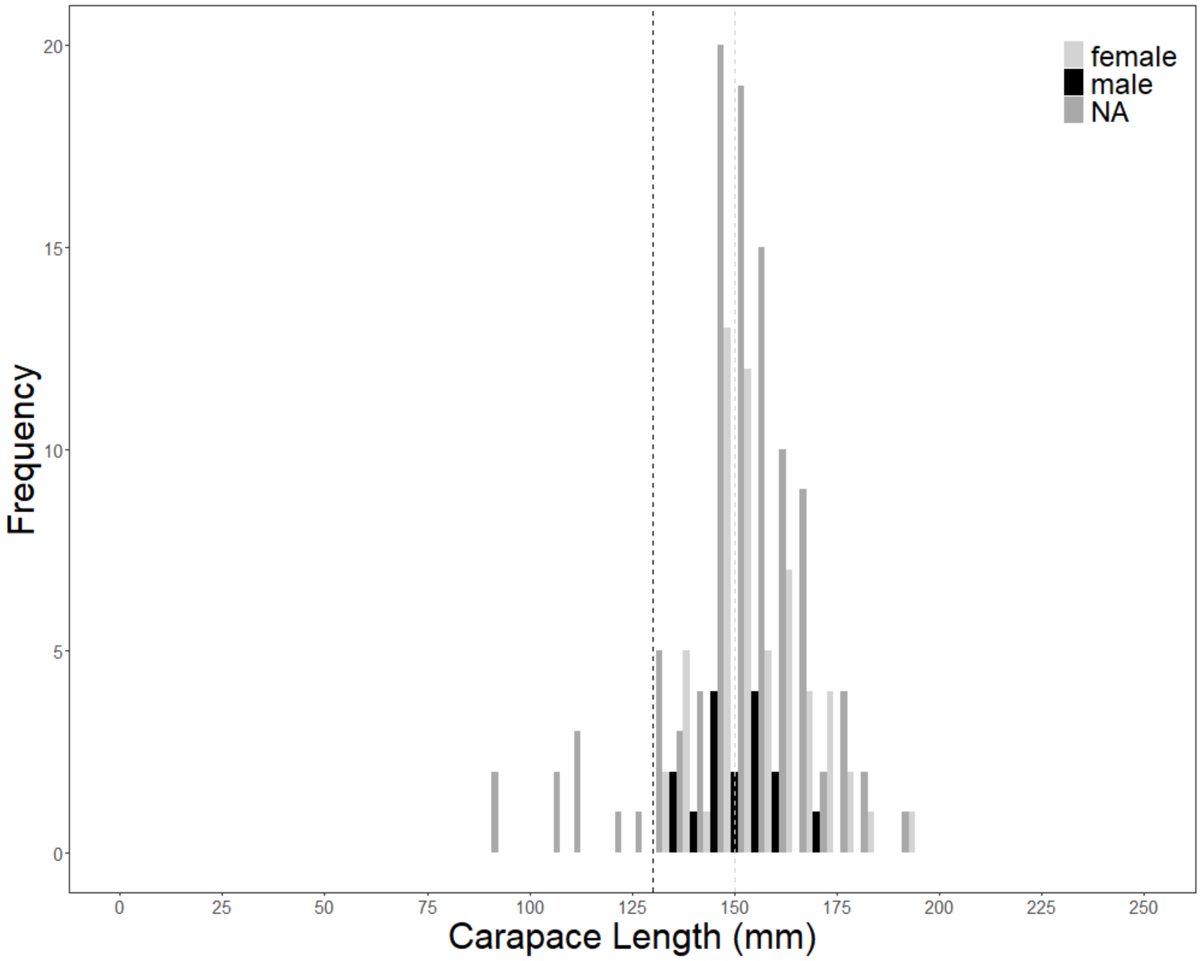


**Figure 9.** Carapace length distribution of deceased *Chelodina oblonga* collected around Lake Claremont between the 2015 and 2020. Dashed lines indicate sexual maturity for males (130 mm) and females (150 mm).

**Table 4.** Frequency of turtle cadavers identified as male, female or unknown and suggested causes of death.

| Sex | Frequency | Cause of death | |
|---|---|---|---|
| Male | 16 | Fox: 9 | Unknown: 7 |
| Female | 57 | Fox: 48 | Unknown: 9 |
| Unknown | 103 | Fox: 43 | Unknown: 60 |

## Nesting habitat

A total of six areas were identified as potential nesting habitat for *C. oblonga* within a 500 m perimeter of the water's edge of Lake Claremont (Fig. 10). Two of these areas, one being an island, were directly connected to the water's edge and covered a total area of 13.0 ha (Table 5). Four were not directly connected to the water's edge, one of which required crossing a road to access (Fig. 10). While a road crossing was not required for three of these four areas, navigating a golf course and/or dog off-leash areas is necessary. The three areas that did not require a road crossing covered a total area of 1.0 ha, while the area that required crossing a road covered 2.5 ha (Table 5). The area requiring a road crossing is not located within the Town of Claremont's jurisdiction.

**Table 5.** Area of habitat available for *Chelodina oblonga* nesting within a 500 m zone from the water's edge of Lake Claremont.

| Habitat type | Size (ha) |
|---|---|
| 500m perimeter | 178.0 |
| Directly connected to water perimeter | 13.0 |
| Not directly connected and road crossing not required | 1.0 |
| Not directly connected and road crossing required. | 2.5 |

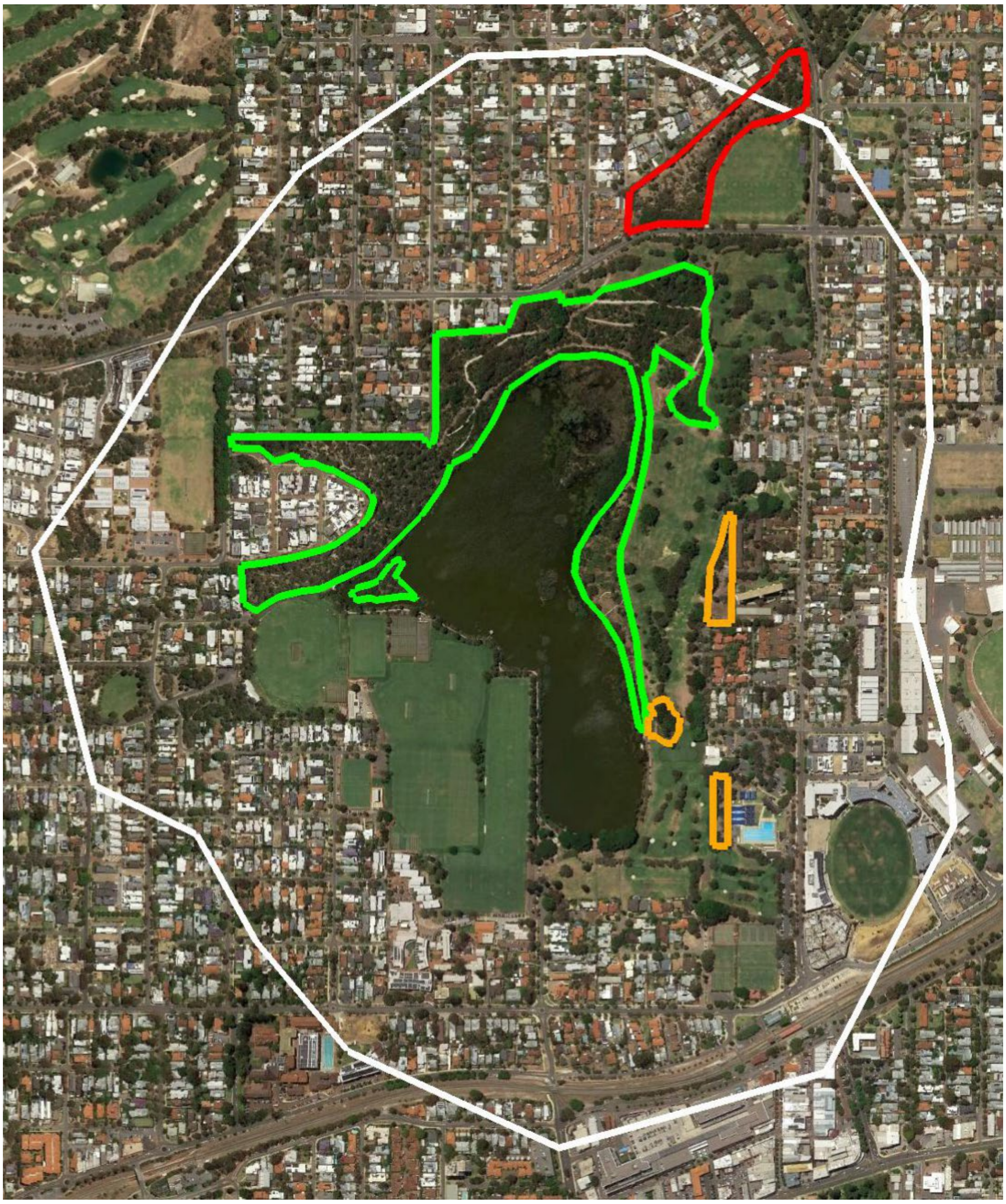

**Figure 10.** Aerial imagery highlighting the 500 m terrestrial zone (white), and areas identified as suitable nesting habitat for *Chelodina oblonga*. Green represents areas directly connected to the water's edge, orange represents areas not directly connected to the water's edge and not requiring a road crossing, and red represents areas not directly connected to the water's edge and requiring a road crossing.

## Nest predation

No predated nests were observed. However, several diggings were observed. Additionally, one dead turtle was found at the northern end of the lake (Fig. 11).

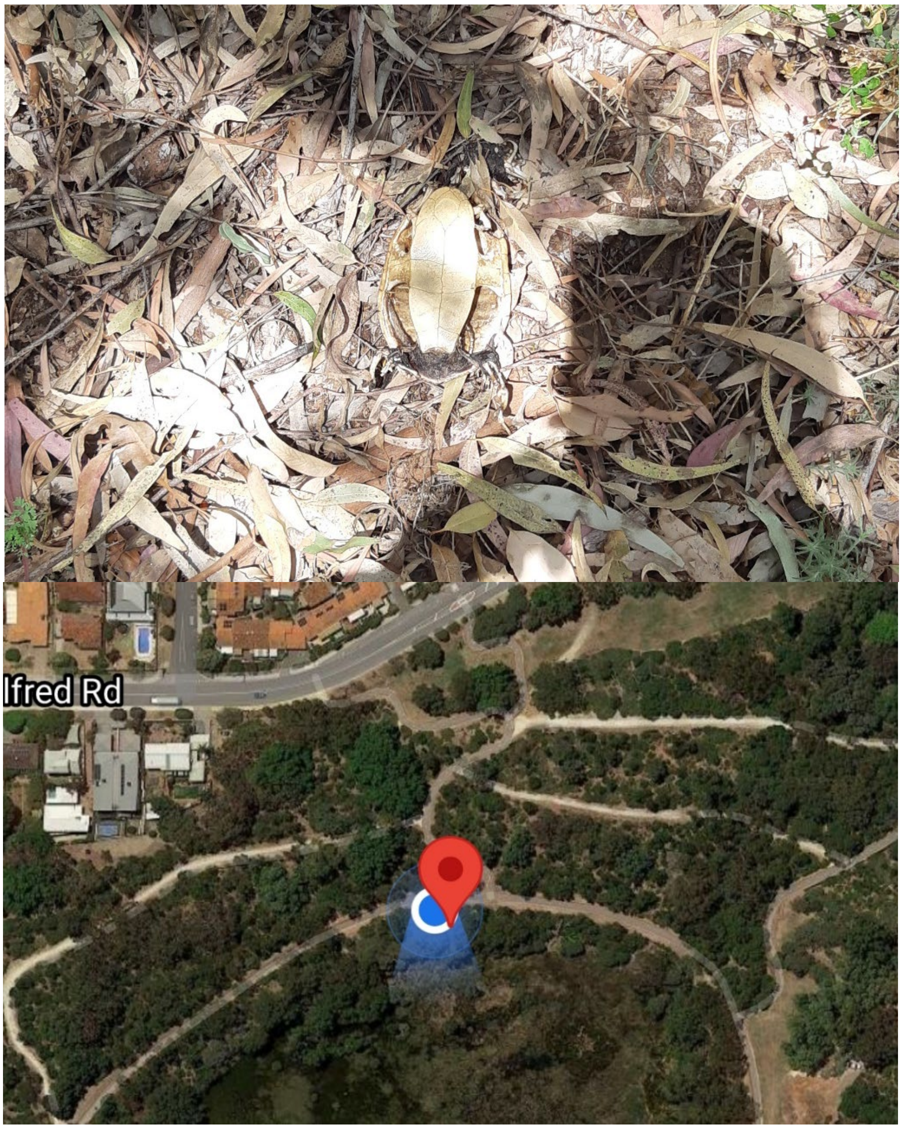


**Figure 11.** Dead turtle (top) found while performing predated nest transects, and approximate location (bottom).

## Other species captured

Bycatch mainly consisted of tadpoles (91), however included two frogs, two water beetles, 11 dragonfly larvae, and one damselfly larvae.

# Discussion

The 2021 survey of the Lake Claremont *C. oblonga* population exhibited a higher CPUE than 97% of previous wetlands surveyed (including Lake Claremont) by Santoro et al. (2020a), and higher CPUE than all wetlands surveyed throughout the SCP recently by Murdoch University (Santoro et al. 2020c, Santoro et al. 2020d, Santoro and Beatty 2021a, Santoro and Beatty 2021b). Higher CPUE at Lake Claremont compared to other wetlands suggests that the current *C. oblonga* population is larger and/or more dense than other wetlands. This may be due to a combination of productivity and habitat diversity within Lake Claremont. In particular, Lake Claremont has a large variety and density of aquatic flora present compared to other wetlands where greater proportions of open water dominate the aquatic zone. The floral diversity at Lake Claremont may support a larger population of macroinvertebrates (see: Engel 1987, Thorp et al. 1997, Schad et al. 2020), which form a large portion of *C. oblonga*'s diet (Tysoe 2005). However, due to a higher ratio of fyke nets to modified funnels in the current study, the CPUE may be slightly inflated in comparison to previous surveys where the trap ratio favoured modified funnel traps which returned lower CPUE than fyke nets. Higher CPUE in November compared to December during the current survey is likely a result of turtles developing 'trap shyness' (Reed et al. 2011, Willson et al. 2011) and a reduction in turtles remaining in the population that have not been previously captured.

Assumptions of the open-population calculation include equal catchability of all individuals. As *C. oblonga* appears to exhibit considerable trap shyness (i.e., those previously captured are less likely to be recaptured) causing substantial over-estimations of population size (Santoro et al. 2020a). To overcome this limitation in calculation of population estimates, a more complex population model would be required that incorporate assumptions of addition and loss of individuals in the population over time and is beyond the scope of this project. However, a relatively high recapture rate (14.7%) at Lake Claremont when compared to other shorter-term studies on the species may indicate that trap shyness reduces overtime (i.e., four years between 2017 Natural Areas and 2021 Santoro study). Given the combined total of 478 tagged individuals now in the Lake Claremont population (assuming no death or emigration), and potential for reduced trap shyness over time, future population surveys may consider implementing more stringent population size modelling into the project design.

The majority of turtles captured were adults, a result similar to that of previous surveys of *C. oblonga* at Lake Claremont (Tysoe 2005, Santoro 2017, Natural Area 2018), and throughout the Swan Coastal Plain (Santoro et al. 2020a, Santoro et al. 2020b, Santoro et al. 2020c, Santoro et al. 2020d, Santoro and Beatty 2021a, Santoro and Beatty 2021b). While hatchlings are expected to be absent from captures due to differences in diet and habitat usage compared to adults (Pike and Reeder 2006, Santori et al. 2021), juvenile sized turtles are generally captured when they are present as evidenced in other *C. oblonga* population assessments (Giles et al. 2008, Bartholomaeus 2016, Santoro et al. 2020a, Santoro et al. 2020b, Santoro and Beatty 2021a). This suggests that the captured population is likely an accurate assessment of the true population.

Though juveniles made up 12% of captures, very few (0.8%) turtles were <100 mm. Turtles with carapace lengths <100 mm represent individuals within an approximate maximum age <~5 years (Spencer 2002) and an absence of such individuals indicates a lack of recent recruitment into the population. Viable freshwater turtle population structure would be expected to have a far greater proportion of juveniles and subadults (i.e., non-reproductive individuals) than adults (i.e., reproductive individuals) (Congdon et al. 1993, Congdon et al. 1994, Gibbs and Amato 2000). For example, a juvenile to adult ratio of 18:1 was observed in a population of the common snapping turtle (*Chelydra serpentina*) (Congdon et al. 1994). While the turtle population in Lake Claremont may currently be dense it appears to be lacking the population structure characteristic to that of a healthy population. Therefore, declines may be observed over time if recruitment of juveniles does not occur.

Despite adult turtles representing the majority of the captured population, there was a distinct lack of turtles over ~200 mm carapace length. This is similar to results found by (Natural Area 2018), (Santoro et al. 2020a), and (Tysoe 2005), a study conducted 17 years ago. The lack of individuals over 200 mm carapace length may be a result of Lake Claremont being an ephemeral wetland system, completely drying up some/most years (Simpson and Newsome 2017). During dry conditions, *C. oblonga* are required to either migrate to nearby wetlands or aestivate; a hibernation-like response to hot, dry conditions (Roe et al. 2008). The dominant response observed for *C. oblonga* during drying at North Lake was aestivation, despite the nearby, more permanent Bibra Lake wetland (Santoro 2020). It is likely that *C. oblonga* is prioritising aestivation during dry periods at Lake Claremont too. Very few or no turtles larger than 200 mm were captured in wetlands that seasonally dry out in previous surveys, including North Lake (Santoro 2017, Santoro et al. 2020a). Thus, aestivation may be slowing growth rates of *C. oblonga* in these wetlands, including Lake Claremont. The projected continued reduction of rainfall in southwestern Western Australia will extend dry periods (Silberstein et al. 2012), placing additional pressure on *C. oblonga*, including potentially reducing survival. Artificially maintaining the historic water regime of Lake Claremont may be required to ensure a thriving *C. oblonga* population.

Alternatively, larger individuals may be dying during overland migration. A lack of nearby wetlands to Lake Claremont means that any turtles attempting to migrate during dry conditions are at a greater risk of mortality through causes such as wildlife vehicle incidents (Giles 2001, Gibbs and Shriver 2002, Santoro 2020), predation (Boarman 2003, Fordham et al. 2006, Dawson et al. 2016, Santoro 2020), and desiccation or dehydration (Finkler 2001). However, there was also a distinct lack of turtles over 200 mm in the cadaver collection, indicating that this hypothesis is unlikely. Larger adult turtles, especially females, are advantageous for the population as they are likely to have higher fecundity than smaller counterparts (Congdon and Gibbons 1985). As a consequence, it is important to understand why these individuals are not present in the population.

Twice as many males as females were captured in the current survey. Previous studies observed sex ratios of 1M:1.4F (Tysoe 2005), 1M:0.9F (Santoro 2017), and 1M:0.3F (Natural Area 2018), indicating a transition from a slightly female dominated population to a heavily male dominated population. We observed a slightly less male dominated ratio than Natural Area (2018). However, Natural Area (2018) did not measure tails nor state how turtles were sexed, and one individual observed to be female in the current study was previously recorded as male by Natural Area (2018). Thus, it is possible that the sex ratio reported by Natural Area (2018) is unreliable as some additional females may have been recorded as males.

Nevertheless, the Lake Claremont turtle population appears to be male dominated based on captures. Additional support for the male bias in the current adult population comes from the dominance of females in the turtle cadavers. This is expected as female *C. oblonga* face a higher risk of mortality during overland nesting movements, both from wildlife-vehicle collisions (Steen and Gibbs 2004, Aresco 2005, Andrews et al. 2008, Santoro 2020) and predation by native (i.e., raven) (Boarman 2003) and invasive (i.e., fox) species (Dawson et al. 2016, Santoro 2020). Our assessment suggested that fox predation appears to be the dominant cause of turtle mortality around Lake Claremont, however Nick Cook (the collector of the carapaces) suggests that Raven predation accounted for the majority as they were found "on their back with wounds where the leg skin joins the shell and internal organs missing". Raven predation has been observed at other wetlands throughout the Swan Coastal Plain (Santoro

2020). It is likely that both fox and raven predation contribute to the mortality observed around Lake Claremont and that both species interact with the cadavers prior to collection. The use of wildlife cameras would provide further insight into the cause of predation occurring around Lake Claremont.

An ongoing reduction in the proportion of females presents a risk to the population in the long-term as females are required for successful breeding and thus recruitment. Therefore, reducing or preferably preventing continued mortality of adult/nesting females is essential if the population is to prosper into the future. Increasing the abundance of understorey vegetation would likely aid in reducing avian predation as the species has been observed using available vegetation for cover during nesting migrations (Clay 1981). If foxes are present, control and removal is recommended, preferable just before and during the peak nesting season (September to November).

The bushland to the north-northwest region of Lake Claremont appears to be suitable nesting habitat, however suitable nesting habitat appears to be lacking elsewhere. *Chelodina oblonga* demonstrate preference for nest-sites within naturally vegetated areas, characterised by bare sandy ground, relatively sparse native grasses dominating the ground level and approximately 40% canopy cover (Santoro 2020). These characteristics are likely selected to achieve ideal incubation conditions for their eggs (Wilson 1998, Kolbe and Janzen 2002). Of the limited available nesting habitat, much of the area is largely shaded, potentially posing an issue for egg incubation which can result in reduced post-hatch body size, growth, and locomotor performance of hatchlings (Booth et al. 2004, Mitchell et al. 2013, Riley et al. 2014). Thus, a lack of suitable nesting habitat may be exacerbating poor recruitment into the system.

Four other areas were identified as potential nesting habitat. However, turtles would need to navigate dog off-lead areas and/or a golf course to access two and three of these areas, respectively. The Town of Claremont could consider enforcing these areas as on-leash during peak nesting season and enclosing the potential nesting areas with turtle friendly fencing (~20 cm gap at the bottom). As mentioned, *C. oblonga* utilises available vegetative cover, so increasing the vegetative cover between the lake and these areas may increase both female survival and successful nesting. The potential nesting area requiring a road crossing is located within the City of Nedlands, which may present some management issues. If turtles are commonly seen migrating to the area to nest (recorded through the TurtleSAT application), the Town of Claremont and City of Nedlands may consider a joint project to install a turtle tunnel/wildlife corridor. However, in both cases, creation of suitable nesting habitat closer to the lake in locations identified through the TurtleSAT application would likely be a superior option.

A predated nest sweep found no predated nests. The large degree of leaf litter and detritus within the suitable nesting habitat may have limited the possibility for predated nests to be observed. However, it may have also limited the ability of predators to find nests. Alternatively, it is also possible that few nests are being laid. The latter two possibilities may be the most likely given the apparent low recruitment into the system. It is advised that future surveys employ the use of ultrasound equipment to assess the proportion of the mature, female population that is gravid. This will help to identify if a lack of breeding is a contributing factor to the suggested minimal recruitment. Furthermore, it is recommended that the local community is encouraged to use the TurtleSAT App to log sightings of turtles (both alive and dead) and nests (both being laid and predated). This will assist in the identification of turtle hotspots and facilitate the protection of current nesting locations as well as creation of additional nesting habitat if required. Additionally, installation of nesting refuges in identified nesting hotspots may aid in reducing both female and nest predation, and thus aid recruitment of juveniles into the population.

This study has provided an assessment of the Lake Claremont *C. oblonga* population. The current population appears to be relatively abundant, however its structure suggests it is not characteristic of a healthy turtle population. In particular, both juveniles and older individuals were absent from captures, and males were over-represented. Lake Claremont is situated in a heavily urbanised area of Perth and this anthropogenic influence is likely impacting the population through reduced suitable nesting habitat and altered predator presence and abundance. The ephemeral nature of Lake Claremont means that the projected continued drying of southwestern WA through climate change represents an additional threat to the population's survival. In the short-term, reducing female mortality and increasing recruitment are essential to increase population viability. Recommendations to help achieve this include identification of predators through wildlife cameras and subsequent controls (increased understorey vegetation or predator removal), protection and creation of suitable nesting habitat, preferably adjacent to the wetland or connected via vegetated corridors, installation of nesting refuges in identified nesting hotspots, development of a 'Turtle Trackers' team, encouraging the wider community to use TurtleSAT, and assessment of the populations reproductive potential using ultrasound in future studies. In the long-term, continued monitoring of the Lake Claremont *C.*

*oblonga* population is recommended to assess if efforts to reduce female mortality and enhance recruitment are successful. Due to the life history of the species, changes in populations occur slowly, thus, monitoring is recommended to occur every third year. This will also help combat against the apparent trap shyness of the species.

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# Appendix 1. Trap Locations

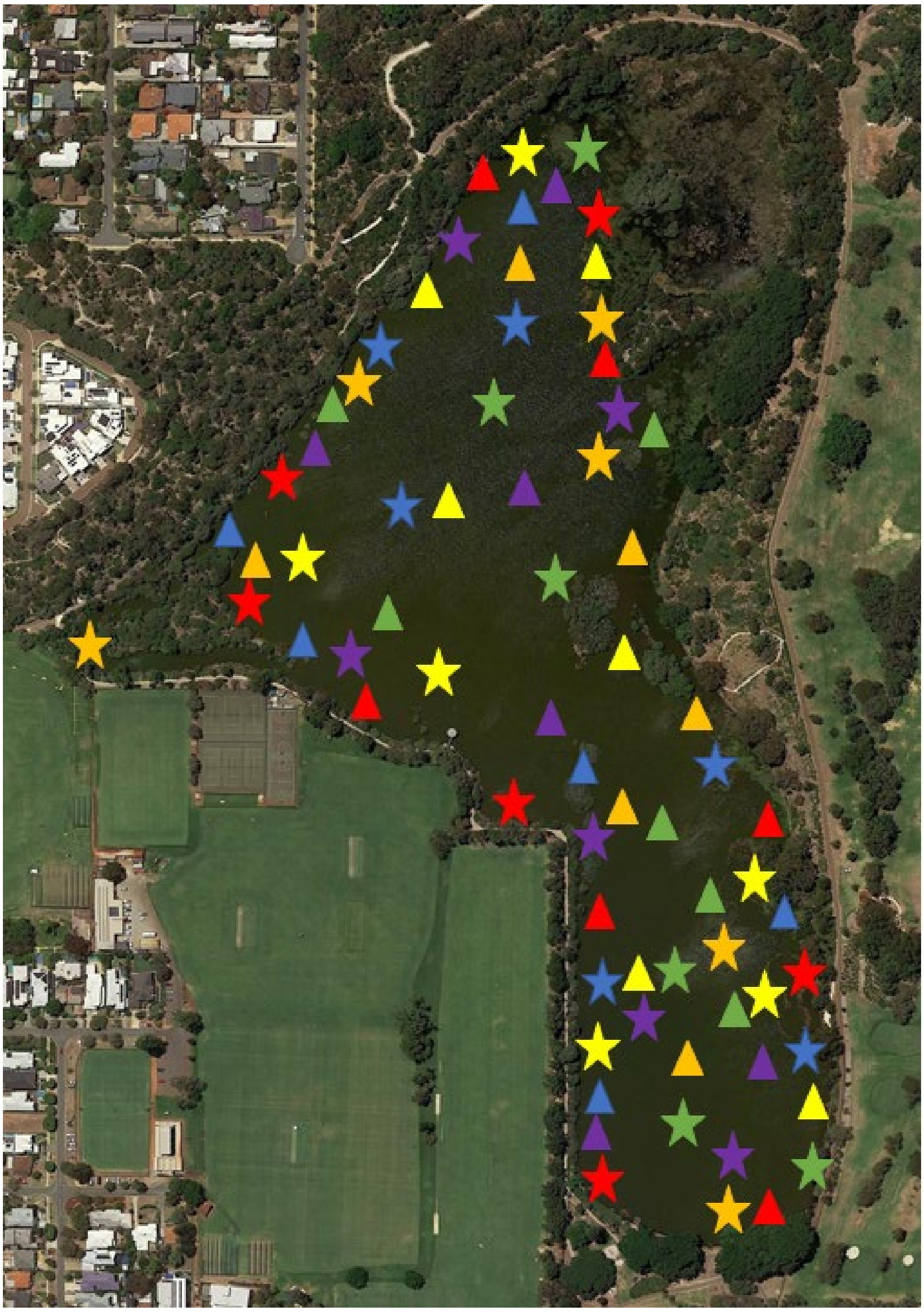

**Figure A1.1.** Aerial Image of Lake Claremont, Claremont. Dates of trapping are indicated by colour (Blue = 15/11/21, Red = 16/11/21, Orange = 17/11/21, Purple = 13/12/21, Yellow = 14/12/21, Green = 15/12/21). Shapes indicate trap locations (Star = modified funnel trap, Triangle = fyke net).