Turtle Monitoring at Devilbend Natural Features Reserve

Howard, K., Atkins, Z. and Wegner, H.

December 2022

Arthur Rylah Institute for Environmental Research
Unpublished Client Report

Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

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Citation: Howard, K., Atkins, Z. and Wegner, H. (2022). Turtle Monitoring at Devilbend Natural Features Reserve. Unpublished Client Report for Melbourne Water. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

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Turtle Monitoring at Devilbend Natural Features Reserve

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Arthur Rylah Institute for Environmental Research
Unpublished Client Report for Melbourne Water, Department of Environment, Land, Water and Planning

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Acknowledgements

This project was funded by a Melbourne Water Liveability Grant, and conducted under the Department of Environment, Land, Water and Planning (DELWP) scientific permit number 10010236. Tony O'Connor and Morgan Kurrajong from the volunteer group the 'Citizen Science Crew at Daangean', Manda Henderson and Gemma Hocking from Parks Victoria, and the youth at Bunjilwarra assisted in the field. We further thank this program for the opportunity to engage with Devilbend Ambassadors from Moorooduc Primary School. We thank Louise Durkin and Jenny Nelson for providing feedback on earlier versions of the report.

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Context:

The Devilbend Natural Features Reserve (DNFR) on the Mornington Peninsula is managed by Parks Victoria and is within the natural distribution of the Eastern Long-necked Turtle *Chelodina longicollis.* High numbers of turtle nests at the DNFR have been raided by the introduced Red Fox *Vulpes vulpes.* A local volunteer group, the 'Citizen Science Crew at Daangean', undertake conservation activities to benefit local fauna and flora populations. To mitigate threats to the local turtle population, the Citizen Science Crew at Daangean have implemented various conservation activities including identifying key nesting areas, protecting turtle nests during the nesting seasons, revegetating nesting sites, constructing aquatic artificial basking sites, and increasing aquatic habitat complexity to provide refuge for turtles.

Aims:

This study aimed to gather baseline population data that could be used as a reference point to track changes in turtle population condition over time and assess the effectiveness of current conservation activities. Specifically, the aims of this study were twofold; (1) to undertake trapping to assess the population of turtles at DNFR and provide an overview of population demographics and assemblage, and (2) engage with community groups and provide on-site feedback to the Citizen Science Crew at Daangean on their current turtle protection activities.

Methods:

To assess the local turtle population, three sites within the Devilbend Reservoir were trapped overnight in December 2021, using cathedral and fyke nets. All turtles captured were identified to species, weighed and measured.

Dr Zak Atkins engaged with the local primary school ambassadors, demonstrated how traps are deployed to capture turtles, showed students how to identify the three Victorian turtle species, discussed species-specific behaviours and threats to the local population. The students were then shown local turtle nesting habitat, the nest protection methods used by volunteers, and searched for undisturbed turtle nests. Bunjilwarra Youth, the Citizen Science Crew at Daangean and local Parks Victoria Rangers assisted researchers to deploy and collect the nets and were trained how to identify the three turtle species and process them.

Results:

Twenty-three turtles were captured, including 21 Eastern Long-necked Turtles and one Broad-shelled and Murray River Turtle respectively. The average body condition scores for all three species were 'good'. Within the Eastern Long-necked Turtle population, there was a high proportion of sub-adults captured. There was regular, intermittent recruitment recorded from 1992 to 2013. However, no recruitment has been recorded from 2013 up until trapping in December 2021.

Conclusions and implications:

The Citizen Science Crew at Daangean run an extensive citizen science program at the DNFR. Volunteers have become proficient at identifying turtle nests and the number of nests protected each nesting season is increasing. It is difficult to evaluate the success of the program with one snap-shot study. However, important baseline data has been collected that can be used to compare changes in population demographics over time. The benefits of turtle nest protection on population recruitment can be variable and high mortality rates of sub-adult turtles can negate any increases in nest and hatchling survival. A holistic approach that assesses the impact of threats on the survivorship of both terrestrial and aquatic life-history stages is recommended.

Given the difficulties in determining whether successful nest protection activities have impacted recruitment to date, further monitoring is recommended to track population demographics over time. The development of a metric that describes aquatic habitat cover and diversity would be helpful to map changes in habitat over time. In addition, mark-recapture survey methods could be used to evaluate stage-specific survival and provide insights into the effectiveness of current nest protection methods as well as the survivorship of juvenile turtles once they reach water. The Citizen Science Crew at Daangean have implemented an extensive turtle conservation program that hopes to address the main threat to Victorian turtle recruitment. The program delivers many community benefits and, with the collection of further data, provides a fantastic opportunity to assess the environmental benefits and determine if recruitment can be correlated to conservation actions that could help direct future on-ground management decisions.

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1 Introduction

The Devilbend Natural Features Reserve (DNFR) is located in Moorooduc on the Mornington Peninsula and is managed by Parks Victoria. The reserve covers 1,005 hectares and includes the Devilbend Reservoir. A local volunteer group, the Citizen Science Crew at Daangean (Devilbend), undertake conservation activities that aim to protect and improve the health of local fauna and flora at the reserve. During regular conservation activities, volunteers have observed raided turtle nests along the banks of the Devilbend Reservoir and the nearby drainage channel.

Victoria has three native turtle species, however, only one species occurs naturally in south-eastern Victoria: the Eastern Long-necked Turtle *Chelodina longicollis*. The Broad-shelled Turtle *Chelodina expansa* and the Murray River Turtle *Emydura macquarii* naturally occur throughout northern Victoria, especially along the Murray River and its southern tributaries (Cann and Sadlier 2017). Although these two species have been detected in the Greater Melbourne region (NatureKit 2.0 2022), this is outside their natural range and these individuals are likely to be wild individuals moved by people and released or escapee pets.

The nesting season for Eastern Long-necked Turtles occurs from late September to December (Cann and Sadlier and Sadlier 2017). Individuals typically nest within 30 m of water using an arribada nesting strategy (simultaneous nesting by multiple individuals at the same nesting location). Across south-eastern Australia, Eastern Long-necked Turtle nest survival has been significantly impacted by predation from the introduced Red Fox *Vulpes vulpes* (Thompson 1983). Population declines have been recorded (Chessman 2011) in addition to ageing populations (Thompson 1983). Nest predation by Red Foxes has been identified as a significant driver of turtle extinction (Spencer et al. 2017) and a single fox can destroy > 90 % of nests at a nesting location (Spencer et al. 2016).

Following observations of raided nests at DNFR, the Citizen Science Crew at Daangean initiated a citizen science project in 2018 to identify and undertake conservation activities that would benefit the local turtle population, protect turtle nests, and ensure continued juvenile recruitment. The Daangean Turtle Project specifically aims to investigate Eastern Long-necked Turtle population condition at DNFR, evaluate key threats to the population and implement management actions to mitigate threats and ensure population persistence at the site.

1.1 Conservation activities

The Daangean Turtle Project volunteers, with assistance from Parks Victoria and Melbourne Water, have implemented several conservation activities with the aim of improving turtle recruitment and raising community awareness of the local turtle population. Since 2018, volunteers have been involved in the:

- identification of key turtle nesting areas
- protection of turtle nests
- construction of artificial basking sites
- revegetation of nesting sites and weed control
- improvement of aquatic habitat complexity

Identification of key nesting areas

Surveys have been undertaken annually since 2018 to identify and map key nesting sites around the reservoir. The first year of surveys was extensive, taking months to locate key nesting sites. Only two intact nests were located and 270 raided nests (Table 1). The only identifiable feature of an undisturbed turtle nest is the nest plug (Figure 1) (Cann and Sadlier 2017). Nest plugs, created when the turtle releases fluid from the cloaca which is then mixed with the substrate to seal the nesting chamber (Cann and Sadlier 2017), can be difficult to recognize after the nest plug has dried. The ability of volunteers to identify turtle nests was improved over multiple survey seasons. As a result, the number of intact nests recorded each season has increased annually (Table 1). The number of nests located in 2021 was lower as Covid-19 restrictions impacted the number of nest surveys undertaken.

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Figure 1. Recently laid turtle nest. The nest plug is located in the centre of the fox exclusion wire covering

Table 1. The number of raided, intact and successfully hatched nests recorded each survey year

Survey year	Number of raided nests	Number of intact nests located	Number of nests that successfully hatched
2018	270	2	2
2019	138	43	16
2020	153	51	17
2021	153	17	7

Protection of turtle nests

Marine and freshwater turtle nests can be protected using fox exclusion devices (FEDs), typically constructed using plastic mesh and held in place with metal pegs (O'Connor et al. 2017, Connell 2009). However, with persistence, foxes can chew through the plastic mesh and destroy nests (Connell 2009). The Daangean Turtle Project volunteers initially deployed standard plastic mesh covers to protect turtle nests at the DNFR. Red Foxes removed some of the mesh covers, raiding nests, or damaged nest plugs by digging through the mesh. A new FED was developed and implemented in 2020, constructed with wire with fine mesh over the nest with the cover elevated off the ground by 200 mm (Figure 2). Since deployment, there have been no recorded losses of turtle nests, and no nest plugs have been damaged. In areas of high foot traffic, the unraised nest protectors are still used to minimise trip hazards.

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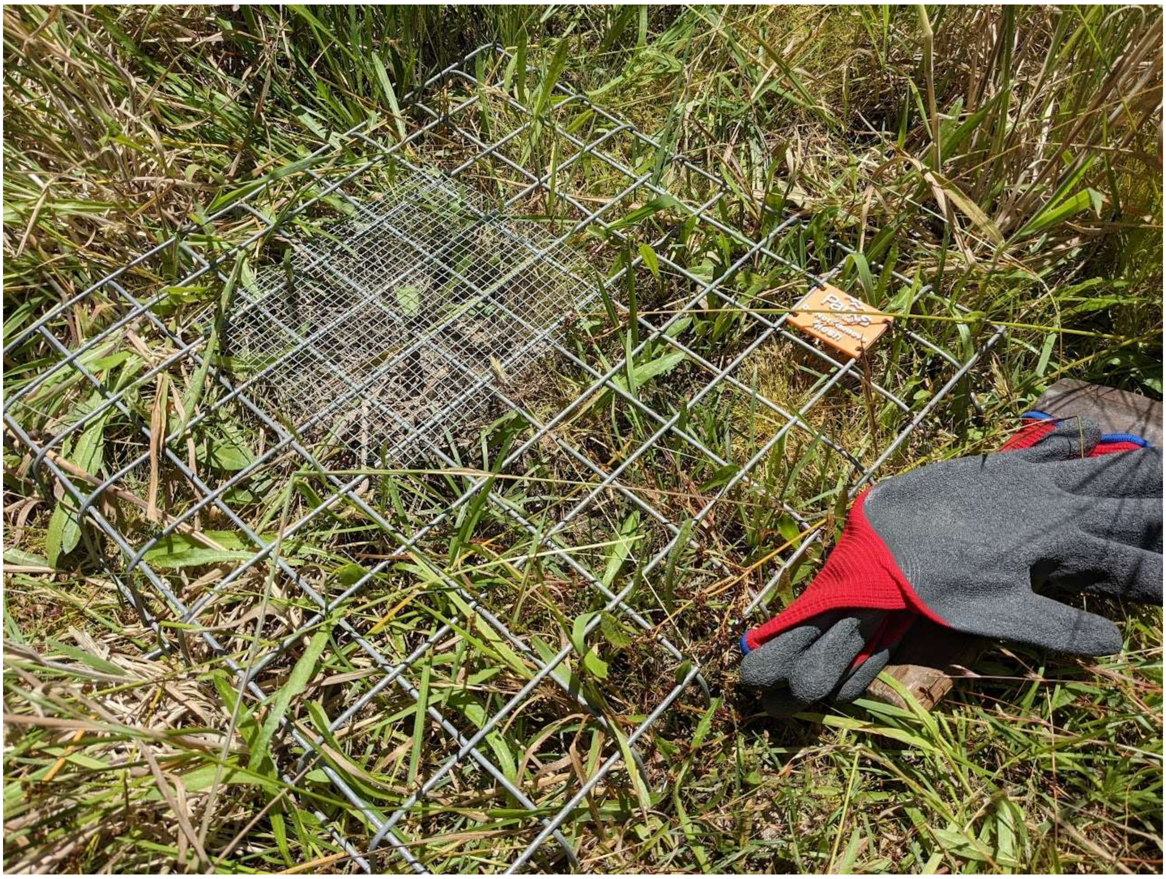

Figure 2. Wire nest guards used to protect turtle nests from Red Fox predation in Devilbend Natural Features Reserve

Increasing aquatic habitat complexity

There is low aquatic habitat complexity at Devilbend Reservoir, with limited large woody debris and aquatic vegetation. Submerged wood provides high value habitat for fauna such as fish (Ayres et al. 2013) and turtles (Santori et al. 2021). Juvenile turtles seek out aquatic vegetation once they emerge from the nest and increasing the extent and diversity of aquatic vegetation may provide refuge from predation by fish, eels and birds. Submerged wood and emergent and submerged macrophytes also provide a substrate on which biofilms can grow. This can increase the diversity and abundance of macroinvertebrates (O'Connor 1991, Papas 2007). The Eastern Long-necked Turtle is an opportunistic carnivore, its diet includes planktonic, nektonic and benthic macro-invertebrates as well as carrion (Parmenter 1976, Chessman 1984, Georges et al. 1986). Improving habitat complexity may increase the availability of macroinvertebrate food sources for Eastern Long-necked Turtles.

To increase aquatic habitat complexity, Daangean volunteers installed six floating islands with substrate that aquatic plants could establish and grow upon. The islands were constructed using a positively buoyant plastic pallet. Straw and coconut fibre were wrapped in shade cloth and bound to the pallet to provide an attachment medium for plants (Figure 3). In addition, eight log piles were constructed, three located on the northern side of the reservoir and five along the south-west shoreline (Figure 4).

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Figure 3. Aquatic habitat islands constructed by Daangean Turtle Project volunteers

Figure 4. Log pile constructed to increase aquatic habitat complexity and provide platforms for turtles to bask upon

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Construction of artificial basking sites

There are limited emergent structures within the Devilbend Reservoir. Eastern Long-necked Turtles thermoregulate using methods such as basking, either aerially on woody debris (snags) or aquatically (Chessman 2019). Thermoregulation benefits for turtles can include an increase in digestive speed with elevated body temperature, vitamin D synthesis, drying of the skin and shell and the removal of leeches, fungi, algae and bacteria (Chessman 2019). The snag piles and floating islands deployed to improve aquatic habitat complexity will also provide basking platforms for turtles. In addition, three floating islands specifically designed for basking were installed in December 2020 in secluded areas to avoid interference from members of the public. The islands were constructed using straw bale wrapped in shade cloth and secured with wire to buoyant pallets. Logs and branches were fixed to the platforms which functioned as ramps for the turtles. Since construction, both Eastern Long-necked Turtles and Murray River Turtles have been observed basking on the islands (Figures 5 and 6).

Figure 5. A Murray River Turtle basking on a straw bale island, on February 11, 2021, six weeks after its installation.

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Figure 6. An Eastern Long-necked turtle basking on a straw bale island at night on February 2, 2021.

Revegetation of nesting sites and weed control

Female Eastern Long-necked Turtles tend to nest on a crest or ridge on top of a slope (Kennett et al. 2009), or, in flatter regions, on raised mounds within 30 m of wetland edges (Howard et al. 2011). Nesting sites are typically located in areas with lower canopy cover and ground cover (Howard unpub. data). At the DNFR, Eastern Long-necked Turtles consistently return to the same nesting areas on the reservoir shoreline and along the adjacent drainage line (Figure 7).

To manage terrestrial habitat at key nesting sites along the reservoir shoreline, volunteers have eradicated noxious weeds and removed and / or controlled impinging vegetation. In particular, the introduced Spanish Heath *Erica lusitanica* has been removed and the spread of native Coastal Wattle *Acacia sophorae* controlled. In some areas, Coastal Wattle has been replaced with native pea species, that allow more light penetration whilst providing cover for nesting turtles. In addition, approximately 4,000 local shoreline and wetland plants have been established to improve native shoreline habitat around the reservoir (Figure 8). Along the drainage line, mowing during the nesting season caused scalping disturbance of turtle nests. To minimise this, the drainage lines are no longer mowed from November onwards. This will reduce disturbance to the nests laid by mid to late season nesting turtles.

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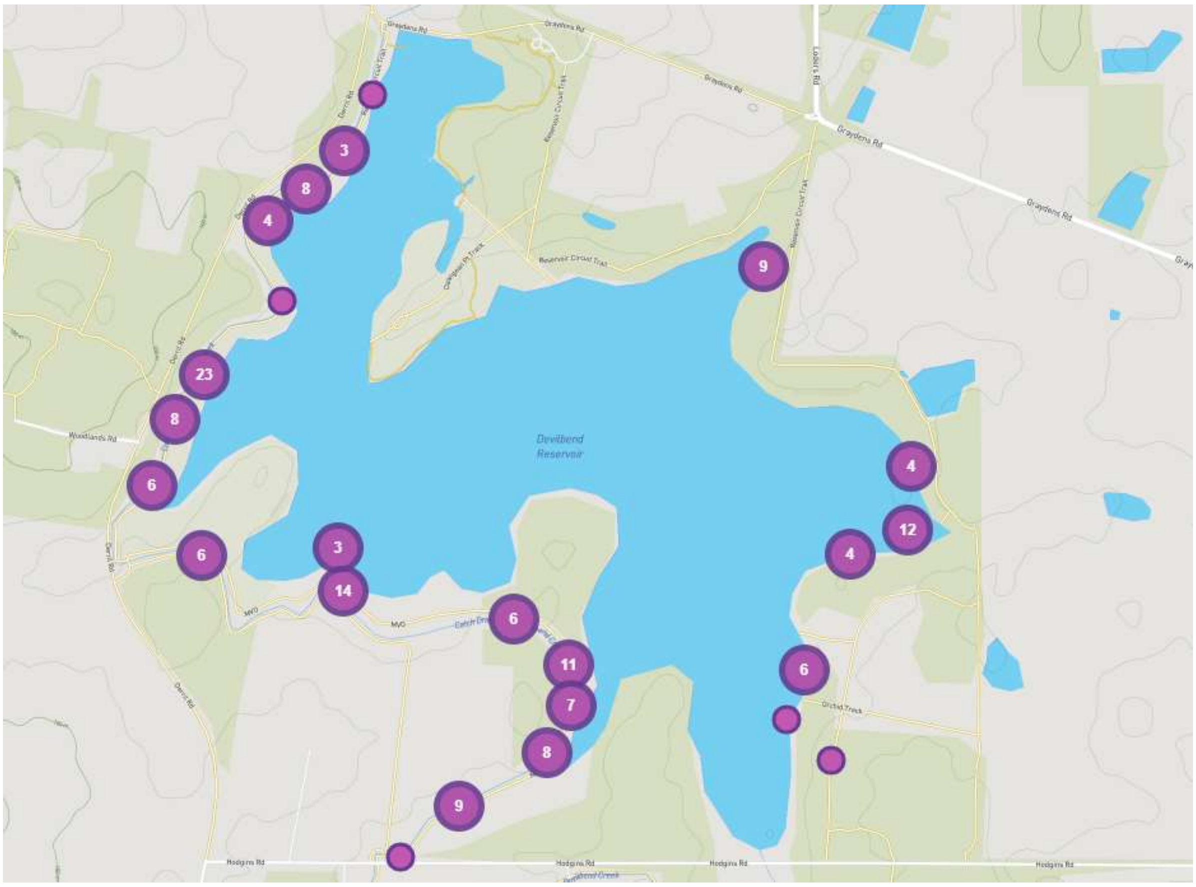

Figure 7. Key nesting areas mapped in the 2022/2023 nesting season. The number of nests located at each nesting site are written within the circles.

Figure 8. One of the turtle nesting beaches where invasive and impinging vegetation has been removed

1.2 Current study aims

The activities initiated by the Daangean Turtle Project at improving turtle population condition at the DNFR cannot be assessed without baseline data. Population surveys provide insights into the current population condition and can be used as a reference point to track the effectiveness of nest protection activities at improving juvenile recruitment. The need for baseline monitoring to assess how effective nest protection is at improving recruitment was identified in Devlin (2019) and led to this study.

Specifically, the aims of this study were to:

- Undertake trapping to assess the population of turtles at Devilbend Natural Features Reserve and provide an overview of population demographics and assemblage;
- Engage with community groups and provide on-site feedback to the Citizen Science Crew at Daangean on their current turtle protection activities.

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2 Methods

2.1 Trapping

Live trapping was undertaken overnight on December 6, 2021 at three sites (Figure 9 and 10). These sites were chosen based on accessibility and habitat suitability (i.e., higher structural complexity such as woody debris and submerged and emergent vegetation). Turtles were captured using cathedral nets and coarse- and fine-meshed fyke nets baited with beef liver (Figure 11 and 12). All turtles caught were identified to species and had their sex determined where possible. Eastern Long-necked Turtles are difficult to sex even as adults and thus were not categorised by sex. The following standard measurements were recorded using Vernier callipers for each turtle: straight carapace length (SCL), straight carapace width (SCW), plastron length (PL) and body depth. Straight carapace length is measured from the middle of the nuchal scute to the middle of the rear marginal scutes. Straight carapace width is measured at the widest point of the carapace, and plastron length is measured from the middle of the anterior and posterior ends of the plastron. Body depth was measured at the widest section between the mid-carapace and mid-plastron. Turtles were weighed to the nearest gram using an 11 kg balance, or 300 g balance for juveniles. Turtles were visually assessed for damage to the shell or limbs.

Turtles were classified as juvenile, sub-adult or adult. Juvenile turtles included all individuals up to three years of age. Size at sexual maturity was used to classify a turtle as sub-adult or adult. The size threshold above which an individual is classed as adult is based on the size at sexual maturity for females, which mature later than males. Although this may mean some males in early adulthood are classified as sub-adults, we take this conservative approach as the size at sexual maturity among females is better understood. Individuals larger than the female size at sexual maturity were classed as adults, and individuals smaller than the female size at sexual maturity were classed as sub-adult (Table 2) (Spencer 2002, Parmenter 1985). Year of hatching / emergence for sub-adult Eastern Long-necked Turtles was predicted using the von Bertalanffy growth model parameters described by Chessman (2018) to create an estimated age / length relationship for sub-adult turtles.

Figure 9. Location of sites trapped in the reservoir at Devilbend Natural Features Reserve

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Figure 10. Example of habitat surveyed for turtles at the reservoir in Devilbend Natural Features Reserve

Figure 11. Coarse-mesh fyke net used for turtle trapping within the reservoir at Devilbend Natural Features Reserve

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Figure 12. (a) Cathedral net out of water and (b) set in a wetland

Table 2. Size at sexual maturity for male and female turtles for all three species found in Victoria. Size is based on straight carapace length (SCL)

Species	Male SCL (cm)	Female SCL (cm)
Broad-shelled Turtle	18	22
Murray River Turtle	15	18
Eastern Long-necked Turtle	15	17

2.2 Community engagement

Before trapping commenced, Dr. Zak Atkins gave a presentation to a group from the Moorooduc Primary School known as the Moorooduc Primary School Ambassadors and discussed the biology of the three Victorian turtle species. Using turtle shells and eggs, Zak discussed turtle morphology, key diagnostic traits between the species, turtle distribution and behaviour, and the key threats to wild populations (Figure 13). Additionally, Zak demonstrated how each survey method was used to capture turtles and the students were given the opportunity to practice setting up each trap on land.

Following the presentation, Hansi Wegner led students through typical Eastern Long-necked Turtle nesting habitats, highlighting the nest protection methods used in the Daangean Turtle Program and describing the activities undertaken by volunteers to protect nests from Red Fox predation, as well as look for new, unidentified nests. Recently raided nests were recorded, providing ambassadors with valuable, firsthand insights on the impacts of Red Foxes on turtle recruitment.

Net deployment was undertaken with assistance from Bunjilwarra Youth (Aboriginal youth participating in the Koori Youth Alcohol and Drug Healing Service) who were briefed on the program's aims, trapping methods and setup protocols. The following morning, Bunjilwarra youth, the Citizen Science Crew at Daangean and Parks Victoria staff assisted with net retrieval and turtle processing. Bunjilwarra youth were actively involved in data recording and measuring and weighing turtles. Attendees were able to observe all three Victorian turtle species and learn their identifying features.

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Figure 13. Dr Zak Atkins and Moorooduc Primary School Ambassadors examining a turtle shell

2.3 Analysis

Relative abundance provides an indication of the size of the population. Catch-per-unit-effort (CPUE) is used to describe relative abundance and is the number of individuals captured per hour of trapping effort.

The year of hatching or nest emergence for Eastern Long-necked Turtles was calculated using the von Bertalanffy growth model parameters described by Chessman (2018). As it is difficult to accurately identify the sex of Eastern Long-necked Turtles externally, the age of individuals is calculated using the average growth rate of both male and female turtles. Adult growth rate can be highly variable over time and age estimations are more accurate for juvenile turtles (Chessman 2018).

Turtle body condition was measured using relative weight (Wr), an index with the formula Wr=(W/Ws) x100 where Ws is a length specific standard weight predicted from a species-specific length-weight relationship from multiple years of trap data collected in the mid-Murray region. Values below 95 indicate poor condition, 95-100 average condition, and >100 indicate good condition.

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3 Results

3.1 Summary of catch

A total of 23 turtles were captured including 21 Eastern Long-necked Turtles, one Broad-shelled Turtle and one Murray River Turtle. The Broad-shelled turtle was an adult male and the Murray River Turtle was an adult female. Eastern Long-necked Turtles accounted for 91 % of the trapped population.

Turtle captures varied considerably per site (Table 3). Both sites one and two recorded Eastern Long-necked Turtles only, with two and six individuals trapped respectively. However, trapping efforts at site three resulted in all three Victorian turtle species: 13 Eastern Long-necked Turtles, one Murray River Turtle, and one Broad-shelled Turtle (Table 3, Figure 14). A total of 10 Short-finned Eels *Anguilla australis* and five European Carp *Cyprinus carpio* were caught as bycatch within both coarse and fine-mesh fyke nets (Figure 15). No bycatch was recorded for the cathedral traps. The largest Eastern Long-necked Turtle captured, weighing just over 1 kg and with a SCL of 20.77 cm, is estimated to be over 50 years old. The smallest Eastern Long-necked Turtle captured weighed 260 g, had a SCL of 13.35 cm and is estimated to be seven years old.

Table 3. Total number of turtles captured per species, per site and the proportion of sub-adult (SA) Eastern Long-necked Turtles captured

	Eastern Long-necked Turtle	Broad-shelled Turtle	Murray River Turtle	SA Eastern Long-necked Turtles
Devilbend Site 1	2	0	0	100%
Devilbend Site 2	6	0	0	38%
Devilbend Site 3	13	1	1	33%

Figure 14. Eastern Long-necked, Murray River, and Broad-shelled Turtles captured at site three in the reservoir at Devilbend Natural Features Reserve

Figure 15. Short-finned Eel by-catch within a coarse-mesh fyke net at Devilbend Natural Features Reserve

3.2 Population demographics

Due to the low number of Broad-shelled Turtles and Murray River Turtles captured, population demographics are presented for the Eastern Long-necked Turtle only. Of the 21 Eastern Long-necked Turtles captured, nine were classified as sub-adults (SCL < 17 cm), accounting for 43 % of the total catch (Figure 16). More than half of these individuals are predicted to have hatched in 2009 (Figure 17). Sub-adult turtles were detected at all three survey sites.

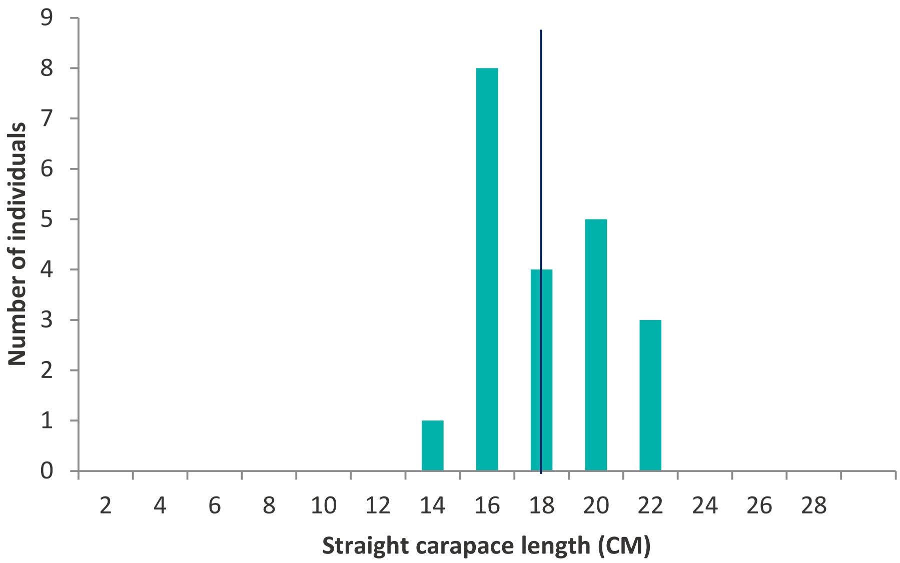

Figure 16. Population size frequency for Eastern Long-necked Turtles. The dark blue line represents size at sexual maturity for female turtles

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3.3 Nest emergence

Predicted growth rates based on Chessman (2018) indicate that many of the large, adult Eastern Long-necked Turtles trapped at DNFR may be over 50 years of age (Figure 17). Of the trapped population, no Eastern Long-necked Turtles emerged between the years of 1970 to 1991. Nest emergence in the last 20 years was highest in 2009, with five individuals estimated to have hatched, accounting for 45 % of the trapped population that emerged over that period. Since 2002, in the sample of captured turtles either one or no turtles were estimated to have hatched in any given year and no recruitment was detected from 2013 to the time of trapping in December 2021.

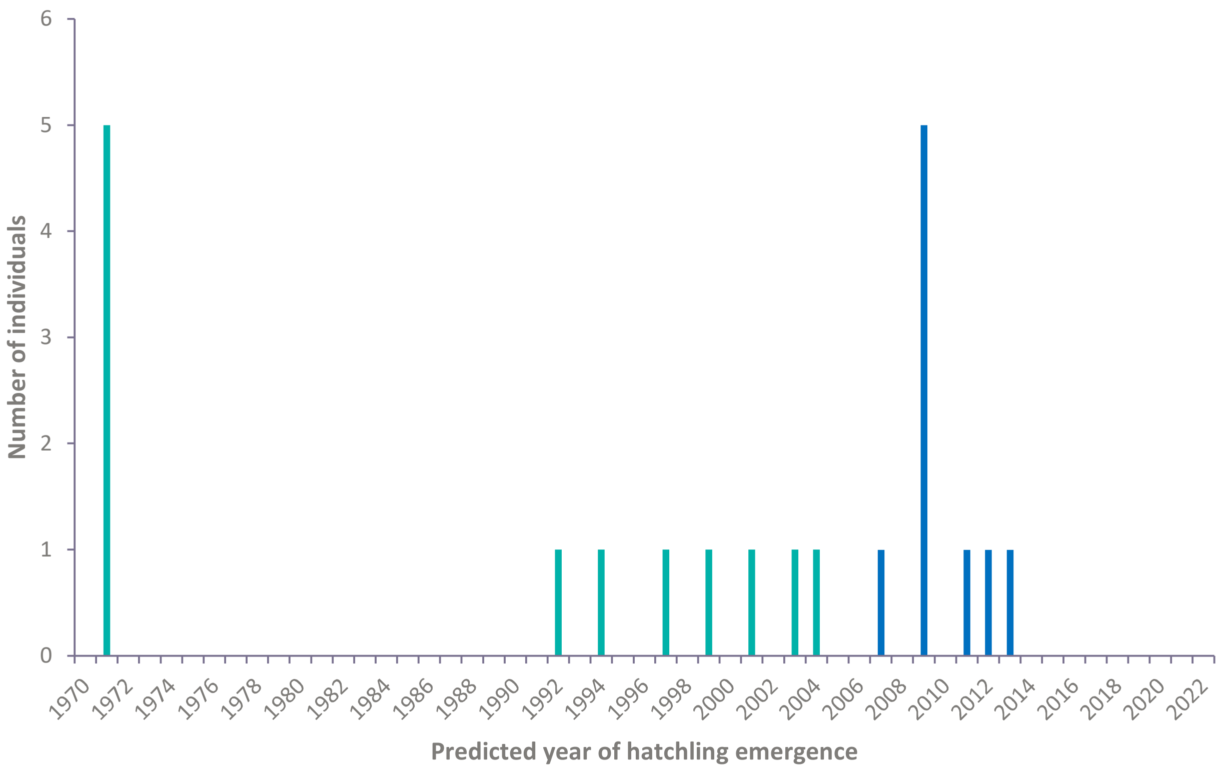

Figure 17. Predicted year of hatchling emergence for Eastern Long-necked Turtles captured at the Devilbend Natural Features Reserve. Green bars = adult turtles and blue bars = sub-adult turtles.

3.4 Relative abundance

Eastern Long-necked Turtle catch-per-unit-effort (CPUE) for the Devilbend Reservoir was 0.067 (SE ± 0.01). CPUE varied between sites (Table 4), with Site 2 recording a CPUE at least double that of both Site 1 and Site 3. Eastern Long-necked Turtle relative abundance also varied between trap type. Fyke nets recorded a CPUE nearly 10 times higher than cathedral traps (0.111 and 0.015 respectively).

The CPUE of both Broad-shelled Turtles and Murray River Turtles at Devilbend Reservoir was low (0.033 respectively), with only one individual captured per species.

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Table 4. Average catch-per unit-effort (CPUE) of Eastern Long-necked Turtles per site, all trap types combined

	Cathedral trap CPUE	Fyke net CPUE	Site CPUE all trap types
Site 1	0.022	0.034	0.027
Site 2	0.022	0.159	0.107
Site 3	0.000	0.089	0.050
Mean	**0.015**	**0.111**	**0.067**

3.5 Turtle condition

Relative weight (Wr) values below 95 indicate poor body condition, 95-100 average body condition, and >100 indicate good body condition. The average body condition score for Eastern Long-necked Turtles was 106.8 $\pm$ 1.6 SE and classified as 'good'. Eastern Long-necked Turtle body condition ranged from 94.7 ('poor' condition) to 118.2 ('good' condition). Only one individual was classified as having 'poor' body condition, five turtles with 'average' body condition, and 15 with 'good' body condition.

The Murray River Turtle and Broad-shelled Turtle had respective body conditions of 102.8 ('good') and 148 ('good'). The Broad-shelled Turtle condition score is one of the highest ever recorded for this species over multiple years of surveys throughout Victoria.

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4 Discussion

Population assessment

This first year of turtle monitoring has provided baseline data on the population demographics, assemblages and relative abundance of turtle species within the DNFR. All three Victorian species were captured at Devilbend Reservoir: the Murray River Turtle, the Broad-shelled Turtle and the Eastern Long-necked Turtle, with the Eastern Long-necked Turtle accounting for 91 % of the trapped population. In comparison, the Murray River Turtle and Broad-shelled Turtle accounted for only 9 % of the trapped population collectively, with one female and one male captured respectively. A female Broad-shelled Turtle was observed nesting in late-November 2019 by Daangean volunteers (Wagner pers. obs.). As well as being unusual behaviour for this species, as they typically nest in March (Booth 1998), this sighting confirms that at least two Broad-shelled Turtles reside within the reservoir and are breeding.

The DNFR is located on the western limit of the south-eastern Victorian distribution for Eastern Long-necked Turtles (Cann and Sadlier 2017). The Eastern Long-necked Turtle is a floodplain specialist that preferentially occupies ephemeral habitats, returning to permanent refuges in dry periods (Kennett and Georges 1990). It can undertake large overland movements to access recently inundated waterbodies that have more food resources and provide a refuge from inter and intra- specific competition. This preferential habitat use results in higher body condition scores and reproductive output when compared to turtles occupying waterbodies with higher turtle abundances (Kennett and Georges 1990).

The natural distributions of the Murray River and Broad-shelled Turtles do not extend into south-eastern Victoria (Cann and Sadlier 2017). The Murray River and Broad-shelled Turtles trapped are likely to have been moved there by people from areas where they naturally occur or may be released or escapee pets and at present, given the low number captured, should not pose a competitive threat to the Eastern Long-necked Turtles. However, as these species are locally introduced, sustaining a population of Murray River and Broad-shelled Turtles through conservation work is not encouraged and it is recommended that conservation efforts focus on Eastern Long-necked Turtles moving forward.

Relative abundance

The CPUE calculated from the first year of trapping will provide an important baseline measurement of relative abundance and allow volunteers to monitor changes over multiple survey seasons. If additional data is collected, other factors that influence Eastern Long-necked Turtle relative abundance can be investigated, including the conservation activities implemented by the Citizen Science Crew at Daangean.

When compared to cathedral nets, fyke nets are a more efficient trap method for capturing Eastern Long-necked Turtles. If future surveys are undertaken, it is recommended that a higher proportion of fyke nets are deployed to maximise survey effort for Eastern Long-necked Turtles.

Population demographics

Within the trapped population of Eastern Long-necked Turtles, a higher proportion of sub-adults were detected at the DNFR (43 %) compared to historical surveys conducted in the 1970's at Yarrawonga (Chessman 2011). In Yarrawonga, sub-adult turtles accounted for 32 % of the trapped population (Chessman 2011), levels that are typically higher than the proportion of sub-adults captured more recently along the Murray River (e.g., Howard et al. 2020). However, the proportion of sub-adult turtles can be highly variable over time (Howard et al. 2020). Eastern Long-necked Turtles are highly mobile (Roe and Georges 2008) and, in small populations, the dispersal of adults into nearby dams may lead to shifts in population demographics and temporary increases in the proportion of sub-adult turtles. Repeating the survey may show if the population demographics are stable or fluctuating.

The predicted dates of hatchling emergence indicate that half of the trapped adult population emerged before, or no later than, 1970. The growth rates of adults are typically slow once sexual maturity is reached but can also be highly irregular and dependent on environmental conditions such as food and water availability (Chessman 2018, Kennett et al. 2009). This is especially evident in adult turtles (Chessman 2018), where large variations in adult growth rates occur both within and between individuals. Therefore, turtle ages calculated using the von Bertalanffy growth model parameters (Chessman 2018) should be considered estimates only, as they can't account for environmental variation.

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Recruitment

Although there was a high proportion of sub-adults within the population, there was little evidence of recent recruitment. Within the trapped population of Eastern Long-necked Turtles, there were consistent, low-level pulses of recruitment every two to three years until 2013. Our survey did not detect any evidence of recruitment from 2013 to the current survey season. However, the absence of juvenile or young sub-adult turtles does not infer that nest protection activities have been unsuccessful. Multiple factors may influence both the survey results and recruitment success. We conducted a snap-shot survey at three discrete locations within the DNFR, with unseasonably cold weather and a minimum air temperature of 11.2° C (Cerberus Station, BOM 2022). In comparison, the average minimum air temperature in January 2022 was 16.5° C (Cerberus Station, BOM 2022). Although Eastern Long-necked Turtles are still active at low water temperatures, their detectability increases once water temperatures exceed 15° C (Chessman 1988). To limit temperature impacts on CPUE and maximise detection probabilities, it is recommended that future trapping be conducted in January or February when mean water temperatures are higher.

The detection probabilities of juvenile turtles are also highly variable and typically low for individuals under four years of age (Howard et al. 2020). The Daangean Turtle Project was initiated in 2018, and the number of nests protected each season has increased annually. Recruitment may not be detected in the trapped population for five years after hatching and, if nest protection measures have been successful, we would expect to see signs of recent recruitment next survey season. However, turtles have both aquatic and terrestrial life-history stages. The unique threats to each life-history stage can influence the perceived success of one conservation activity. For example, conservation activities that mitigate the threat to one life-history stage may not improve recruitment if threats persistently impacting other life-history stages are not mitigated. For example, the terrestrial life-history stage of turtles, including eggs and hatchling turtles, are at risk of predation from both native and introduced fauna (e.g., Thompson 1983). Hatchling turtles utilise complex aquatic habitat as refuge sites to minimise the probability of predation (Santori et al. 2021). Devilbend Reservoir has various aquatic predator species including, but not limited to, Short-finned Eels, Rainbow Trout *Oncorhynchus mykiss* (stocked), Brown Trout *Salmo trutta* (stocked) and birds, including the White-faced Heron *Egretta novaehollandiae* and various cormorant species. The DNFR lacks natural aquatic rock, log and vegetation structure that would otherwise provide important cover for juvenile turtles. Habitat enhancement activities undertaken by the Citizen Science Crew at Daangean volunteers, including constructing log piles and deploying floating habitat islands, are likely to positively impact food resources and refuge site availability.

Overview of conservation activities

Environmental benefits

The Citizen Science Crew at Daangean have implemented several conservation activities that primarily aim to protect and improve the health of local fauna and flora at the DNFR (outlined in the Introduction). For the Eastern Long-necked Turtle specifically, nest protection and habitat supplementation and augmentation activities are used to improve local population condition. Currently, the program is investing heavily in individual nest protection to directly improve turtle recruitment. Volunteers have become increasingly successful at identifying and protecting turtle nests, and the project provides an ideal opportunity to evaluate the efficacy of nest protection methods. Conservation 'wins' in this space could be applied across the natural range of these turtle species to improve conservation outcomes at discrete waterbodies like the DNFR.

Native revegetation exercises, a key component of the citizen science program within the DNFR, will also benefit a suite of native species including birds, mammals, fish and invertebrates. The annual turtle nest surveys conducted by the Citizen Science Crew at Daangean can also identify other threatening processes to resident fauna and flora species. For example, recent changes to the watering regime inundated key turtle nesting areas in 2020/2021 and increased flow rates through Southern Toadlet breeding habitat (Wagner, pers. obs.). Field observations can highlight the impact that environmental or management changes may have over time on local species that are dependent on aquatic environments for recruitment success and population persistence. Recent observations highlight the importance of assessing the requirements and breeding biology of local fauna and incorporating these needs into management actions.

Community benefits

The program provides community benefits by educating volunteers about local fauna and flora. In addition, it fosters broader community interest in understanding and protecting local, natural ecosystems. The project is multi-faceted and volunteers of the Citizen Science Crew at Daangean liaise with expert scientists, engage

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with traditional owners, facilitate community access to environmental initiatives and run school educational programs at the DNFR. This citizen science program facilitates engagement with over 60 volunteers from a range of community groups including primary school students, Bunjilwarra Youth, the Australian Plant Society and Fire Risk Victoria.

The DNFR is open to the community and supports recreational activities such as fishing, birdwatching and the use of non-powered watercraft. Community access to the DNFR, as well as the surrounding private landholders, make traditional landscape-scale fox management methods (i.e., baiting) challenging. The manual nest protection methods employed by the Citizen Science Crew at Daangean, as well as having species-specific environmental outcomes, allow continued access by members of the public to the DNFR and negate any potential impacts of baiting to residential pets.

4.1 Conclusion and recommendations

The benefits of turtle nest protection on recruitment can be variable (Campbell et al. 2020) and impacted by threats to different life-history stages. High mortality rates of sub-adult turtles can negate any increases in nest and hatchling survival (Campbell et al. 2020). Thus far, it is difficult to ascertain whether current nest protection methods alone are sufficient to increase turtle recruitment at the DNFR. This snap-shot survey provides an indication of current population demographics and condition only. It cannot account for low and variable detection probabilities of hatchling and juvenile turtles, nor the extent of predation on or survivorship of other life-history stages. An approach that addresses threats that impact the survivorship of both terrestrial and aquatic life-history stages is recommended.

Further investigations are required to identify potential refugia for juvenile turtles within the DNFR. It is recommended that a metric is developed that can describe changes in the extent and diversity of aquatic habitat. Mapping these changes over time may account for variation in recruitment success and help researchers evaluate both terrestrial and aquatic predation pressure. An additional survey method that could be used to evaluate life-history stage-specific survival is mark-recapture. Mark-recapture projects allow researchers to identify individual turtles over time by uniquely marking captured turtles that can be subsequently re-trapped in future surveys. Mark-recapture would provide insight into the effectiveness of current nest protection methods and the survivorship of juvenile turtles once they reach the water. This method could also provide data on nest site fidelity if volunteers are frequently encountering nesting turtles and are trained in individual identification. This could help land managers identify key areas to target conservation activities.

Given the difficulties in determining whether successful nest protection activities have impacted recruitment to date, it is recommended that further monitoring is undertaken to track population demographics over time. This will help identify trends in population structure and recruitment, dampen any seasonal environmental effects on detectability, e.g., temperature, and account for changes in the detectability of juveniles over time and any long-term changes in habitat complexity. Within this discrete location (the DNFR), population recruitment can be monitored over time and directly correlated to conservation actions if baseline data on nest survivorship, habitat augmentation and population demographics is available. This would provide land managers with conservation outcomes that could direct future on-ground management actions.

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Appendix 1. Trap and turtle data

Where for ‘trap type’ C = cathedral and F = fyke, for ‘species’ ELNT = Eastern Long-necked Turtle, MRT = Murray River Turtle and BST = Broad-shelled Turtle, for ‘class’ SA = sub-adult and AD = adult. SCL = straight carapace length, SCW = straight carapace width, PL = plastron length, PW = plastron width and PC = plastron curvature. All measurements are in cm except for weight (g).

Site	Net #	Trap type	Trap effort (hrs)	Species	Class	Weight	SCL	SCW	PL	PW	PC	Depth
DB1	C8	C	14.50	ELNT	SA	260	13.35	10.76	11.07	6.45	Flat	4.1
DB1	C1	C	14.50	Nil								
DB1	C2	C	14.50	Nil								
DB1	F2	F	14.50	Nil								
DB1	F1	F	14.50	ELNT	SA	344	14.25	11.12	12.15	7.16	Cave	4.6
DB2	C25	C	15.08	ELNT	AD	670	18.5	14.33	15.09	9	VEX	5.73
DB2	C3	C	15.08	Nil								
DB2	C4	C	15.08	Nil								
DB2	F1	F	15.08	ELNT	AD	793	18.88	14.55	15.3	9.73	VEX	6.72
DB2	F1	F	15.08	ELNT	SA	436	15.82	11.49	12.7	7.67	CAVE	5.23
DB2	F2	F	15.08	ELNT	SA	405	15.49	11.57	12.18	7.18	Cave	4.95
DB2	F2	F	15.08	ELNT	SA	442	15.48	11.81	12.77	8.03	Cave	5.01
DB2	F2	F	15.08	ELNT	AD	510	17.08	12.65	13.95	8.54	FLAT	5.68
DB2	F2	F	15.08	ELNT	AD	574	17.4	12.99	14.2	9.05	VEX	5.78
DB2	F3	F	15.08	ELNT	SA	347	14.65	10.91	11.95	7.18	FLAT	4.7
DB2	F3	F	15.08	ELNT	AD	1047	20.77	16	17.1	10.06	VEX	6.94
DB2	F3	F	15.08	ELNT	AD	958	21.33	17.2	16.67	10.21	VEX	6.61
DB2	F4	F	15.08	BST	AD M	3584	28.49	21.8	21	8.96		9.03
DB2	F4	F	15.08	ELNT	AD	777	20.05	14.5	16.15	9.95	VEX	6.69
DB2	F4	F	15.08	ELNT	SA	484	15.89	11.89	13.18	7.48	FLAT	5.45
DB2	F5	F	15.08	MRT	AD F	1140	22.15	17.75	17.31	6.9		7.1
DB2	F5	F	15.08	ELNT	AD	748	19.5	15.76	15.87	9.74	VEX	5.98
DB3	F1	F	16.83	ELNT	AD	715	18.41	13.54	18.48	9.65	VEX	6.44

DB3	F1	F	16.83	ELNT	AD	562	17.8	13.95	14.65	9.11	VEX	5.04
DB3	F1	F	16.83	ELNT	SA	375	15.44	11.49	12.74	7.85	Cave	4.82
DB3	F1	F	16.83	ELNT	SA	592	18.19	13.55	14.41	9.22	Cave	5.54
DB3	F2	F	16.83	ELNT	SA	637	18	13	14.55	9.14	VEX	6.12
DB3	F3	F	16.83	ELNT	SA	414	15.21	11.2	12.24	7.3	Cave	5.19
DB3	C5	C	16.83	Nil								
DB3	C7	C	16.83	Nil								
DB3	C6	C	16.83	Nil								
DB3	F4	F	16.83	Nil								

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