# Residency of white sharks, *Carcharodon carcharias*, at the Neptune Islands Group Marine Park (2020–21)

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Photo: Andrew Fox

SOUTHERN SHARK ECOLOGY GROUP

Marine & Coastal Research Consortium

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# 5. EXECUTIVE SUMMARY

- This report provides updated estimates of residency of tagged white sharks (*Carcharodon carcharias*) and a summary of electronic logbook data describing cage-diving activities at the Neptune Islands Group (Ron and Valerie Taylor) Marine Park between 1 July 2020 and 30 June 2021.

- Fifteen sharks ranging 2.8–3.9 m total length (TL) were tagged at the Neptune Islands Group Marine Park (N = 10), Dangerous Reef (N = 1), and the Pages Islands (N = 4) between 1 July 2020 and 30 June 2021, ten of which were detected within the array. In addition, 17 individuals tagged in previous years, including four sharks tagged in the 2018–19 and 13 from the 2019–20 financial year, were also detected.

- Grand mean residency from the 27 sharks detected within the 2020–21 monitoring period at the North and South Neptune Islands was 6.30 ± 5.08 days (median = 6.05) and 6.41 ± 12.00 days (median = 2.00), respectively. The $\log_{10}$ of the grand mean residency at North Neptune Islands was 0.62 ± 0.44 and is within the Target range (≤ 0.7).

- E-logbook recorded 446 entries between 1 July 2020 and 30 June 2021 for 239 days of operations at the Neptune Islands Group. Reported daily sightings ranged 0–9 white sharks (mean ± standard error = 1.4 ± 0.1), while no white sharks were sighted on 102 days (42.7% of the days at the Neptune Islands). This represents a considerable increase in the number of days when no white sharks were sighted compared to the 2019–20 period (26.5%).

# 6. INTRODUCTION

The white shark (*Carcharodon carcharias*) occurs world-wide in coastal temperate and subtropical regions (Klimley and Ainley 1996, Domeier 2012). White sharks are long-lived, relatively slow growing, late in maturing, and low in reproductive potential (Cailliet et al. 1985, Wintner and Cliff 1999). This combination of life history traits, and world-wide concerns regarding their population status, has prompted their protection across a number of jurisdictions. This includes listings under the International Union for the Conservation of Nature (IUCN – 'Vulnerable'), the Convention on International Trade in Endangered Species (CITES – Appendix I + II), and the Convention on Migratory Species (CMS – Appendix I + II), of which Australia is a signatory country. White sharks are listed as 'Vulnerable' under the Australian Commonwealth Government's *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and are protected in all Australian and Commonwealth waters. However, as identified by the *National Recovery Plan for White Sharks*, the Australian white shark population is still threatened by interactions with commercial and recreational fishing, shark control activities, illegal trade in body parts, and the potential impacts of ecotourism and cage-diving operations (DEWHA 2010). Sites where white sharks aggregate can be targeted by wildlife tourism operators where industries have developed around cage-diving activities. These sites are also areas where white sharks can be exposed to a large amount of interactions and interference from human activities.

In Australia, the white-shark cage-diving industry began in the late 1970s in waters off the Eyre Peninsula in South Australia. The industry is now restricted in operations to the Neptune Islands Marine Park located 60–70 km south of Port Lincoln (Fig. 1), with most cage-diving activities focussed at the North Neptune Islands group. The locality is the only place where cage-diving with white sharks is permitted in Australia. After 2007, the industry expanded from two to three operators and the mean annual number of days when tours operated rose from 124 (2000–2006) to 265 (2008–2011) (Bruce and Bradford 2013). Studies showed that the residency of white sharks at the Neptune Islands changed between these periods and that the spatio-temporal distribution of white sharks is affected by the cage-diving industry (Bruce and Bradford 2013, Huveneers et al. 2013). As a result, DEW developed and implemented a new policy to improve management of white shark tourism at the site. The policy limits the number of commercial tour operator licences (currently three), number of days of operation (currently 12 per fortnight), and the amount of food-based attractant that can be used (currently 100 kg $day^{-1}$). The policy also sets a framework for the adaptive management of the cage-diving industry and decision ranges when changes in licensing arrangements should be considered. Since 2013–14, the effects of the cage-diving industry on white sharks has been monitored annually using estimates of residency as

defined in Bruce and Bradford (2013) and compared to the decision ranges set in Annexure A to the South Australian White Shark Tour Licensing Policy.

The aim of this report is to provide residency estimates of white sharks at the Neptune Islands (Ron and Valerie Taylor) Marine Park for 2019–20 and compare them to previous years and to decision ranges set in Annexure A to the South Australian White Shark Tour Licensing Policy. This report also summarises cage-diving activities and number of sharks sighted reported via a daily electronic logbook to put residency estimates in context of cage-diving activities.

# 7. METHODS

## 7.1 Geographical area

The Neptune Islands Group (Ron and Valerie Taylor) Marine Park (referred to as the Neptune Islands hereafter) is located near the approach to Spencer Gulf, ~30 nautical miles from Port Lincoln, South Australia and 14 nautical miles from the southern Australian mainland. This offshore island complex of limestone-capped granite mounds comprises the North and South Island groups, which are ~12 km apart (Figure 1). The Neptune Islands comprise a Sanctuary Zone (North Neptune Islands), Habitat Protection Zone (South Neptune Islands), and Restricted Access Zones (North and South Neptune Islands) (http://www.environment.sa.gov.au/marineparks/find-a-park/eyre-peninsula/neptune-islands). At the North Neptune Islands, cage-diving operators mostly anchor in the bay on the southeast side of the largest islands and on the northern side of the two islands. At the South Neptune Islands, operators mostly anchor on the eastern side of the northern island.

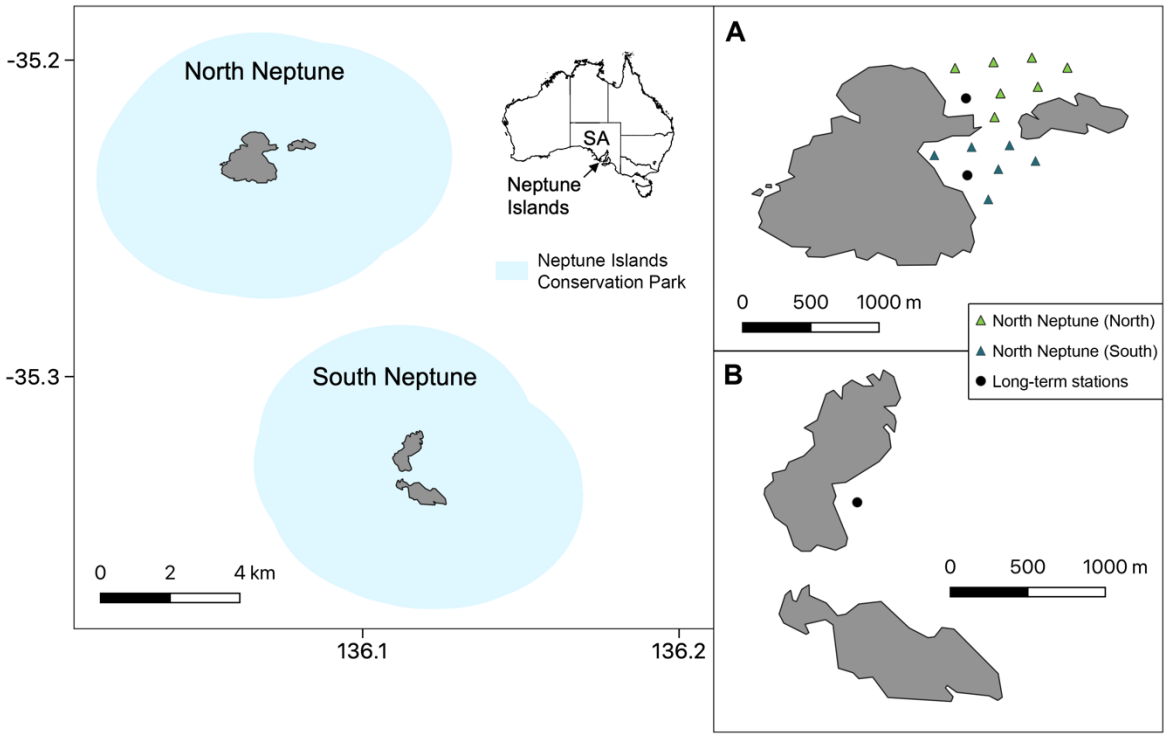


**Figure 1.** Map of the Neptune Islands Group (Ron and Valerie Taylor) Conservation Park with deployment locations of acoustic receiver stations within (A) the North Neptune Islands and (B) the South Neptune Islands. Stations with a black point represent long-term stations that have been present since the start of the monitoring in 2013, with coloured positions denoting the fine-scale positioning system deployed in 2018.

## 7.2 Acoustic telemetry

### *7.2.1. Receiver deployments*

Three VR2AR acoustic receivers (Vemco Ltd., Halifax, Canada) were deployed within the Neptune Islands using a low-profile sub-surface mooring system that reduces interactions with operators' anchors and chains, and white sharks. One VR2AR was deployed at each of the main berleying sites at the North Neptune Islands group and one at the South Neptune Islands group and have been maintained at those locations since 2013 (Figure 1; black points). In 2018, a fine-scale positioning system (VPS Vemco Positioning System, Vemco Ltd., Halifax, Canada) consisting of an additional array of 13 VR2AR receivers were deployed and expanded the acoustic coverage at the North Neptune Island (Figure 1; coloured points). The deployment of these receivers will provide opportunities to investigate the positioning of sharks at the Neptune Islands in relation to cage-diving vessels, e.g. are white sharks mostly using Action Bay or the Main Bay; does white shark preferred location vary in relation to cage-diving vessels?

### *7.2.2. Tag deployments*

Fifteen white sharks were tagged in the 2020–21 financial year with V16-6H acoustic transmitters, adding to the 128 sharks tagged during the previous six years of monitoring periods (2013–2020). In addition to the sharks tagged within the Neptune Islands, detections from three additional white sharks tagged in Western Australia were detected in the array, one of which (ID 104) was tagged in the 2019–20 financial year. Acoustic transmitters programmed to send signals at random interval of 70–150 seconds (VEMCO Ltd., Halifax, Canada). Tags were tethered to a Domeier umbrella dart-tag head using a 10- to 15-cm-long stainless wire trace (1.6 mm diameter). Tags were implanted in the dorsal musculature of sharks using a modified spear-gun applicator. Biases in residency estimates can be introduced by targeting specific sharks (e.g., sharks likely to remain in the Neptune Islands) or due to temporal variations in residency (e.g., sharks are more likely to remain within Neptune Islands during weaning of New Zealand fur seals). To minimise the potential impacts of these biases, tags were opportunistically deployed throughout the monitoring period.

### *7.2.3. Detection summary and residency periods*

Daily detection summaries were plotted to examine the pattern of overall presence of tagged sharks during the study period. For each tagged white shark, the number of consecutive days that individuals were present was calculated each time they entered the study area. A residency period was defined as the number of days between the first and last detection of a tagged shark, without any gaps in consecutive days of detection exceeding 5 days. A five-

day period was selected on the basis of estimated transit times between the North and South Neptune Islands (Bruce and Bradford 2013). Where sharks were not detected over periods of >5 consecutive days, individuals were assumed to have left the Neptune Islands and any subsequent return was considered to represent a new residency period. Residency period was estimated for each tagged shark and for each North and South Neptune Island Groups.

The residency of white sharks is reported for the period between 1st July 2020 and 30th June 2021.

## 7.3 Electronic logbooks

Since 01/03/2020, operators used a new custom-designed application developed to record operator activity (i.e. time of arrival at and departure from the Neptune Islands Group, quantity or type of attractant used, anchoring location), number of passengers, and number of shark sighted (with sex and estimated total length when known). The new application does not change the metrics collected by operators but provides a more streamlined and efficient way to record and report information. Data collected by operators since the new update is compatible with the older version. The e-logbook was used to collect data on daily activities and sighting frequency of white sharks between 1 July 2020 and 30 June 2021.

# 8. RESULTS

We tagged 15 white sharks ranging 2.8–3.9 m total length (TL) between 17 July 2020 and 13 May 2021 (North Neptune Island: N = 3; South Neptune Island: N = 7; Dangerous Reef: N = 1; Pages Islands: N = 4), 10 of which were detected at the Neptune Islands (Table 1). Table 1 provides a detection summary for the 27 white sharks that were detected at the Neptune Islands during the 2020–21 monitoring period. Seventeen sharks (62.9%) detected within the Neptune Islands in the 2020–21 monitoring period were tagged in previous years; four of which (14.8%) were tagged in the 2018–19 period, and thirteen sharks (48.1%) from 2019–20 (Figure 2). A total of 68,622 acoustic detections was recorded from 27 sharks in the 2020–21 monitoring period (mean ± standard error = 334 ± 3,518 per shark). Tagged white sharks were detected for periods ranging between 1 and 66 days (mean = 18 days) (Table 1).

**Table 1.** Detection summary of white sharks (n=27) between July 2020 and June 2021 acoustically tagged at the Neptune Islands Marine Park, Dangerous Reef, and the Pages Islands. TL = total length (m). NNI = North Neptune Islands; SNI = South Neptune Islands; DR = Dangerous Reef; PI = Pages Islands

| Shark | TL | Sex | Date tagged | Location tagged | North Neptune | | South Neptune | |
|---|---|---|---|---|---|---|---|---|
| | | | | | N detections | N days detected | N detections | N days detected |
| **76** | 3.4 | Male | 08/01/2018 | NNI | 1281 | 21 | 65 | 8 |
| **89** | 3.7 | Male | 19/12/2018 | NNI | 3358 | 14 | - | - |
| **91** | 3.8 | Male | 07/04/2019 | NNI | 1016 | 21 | 1137 | 35 |
| **94** | 2.8 | Male | 16/05/2019 | NNI | 9 | 1 | 5 | 1 |
| **97** | 2.9 | - | 14/08/2019 | NNI | 7885 | 19 | - | - |
| **102** | 3.2 | - | 28/10/2019 | NNI | 2586 | 12 | - | - |
| **104** | 3.2 | Male | 30/10/2019 | NNI | 405 | 8 | - | - |
| **105** | 2.8 | Male | 30/10/2019 | NNI | 20887 | 41 | - | - |
| **110** | 2.9 | Female | 12/02/2020 | NNI | 2974 | 49 | 213 | 18 |
| **111** | 3.0 | Male | 12/02/2020 | NNI | 1316 | 7 | - | - |
| **112** | 2.8 | Male | 12/02/2020 | NNI | 1288 | 20 | 138 | 10 |
| **116** | 2.7 | Female | 11/04/2020 | NNI | 3 | 1 | - | - |
| **117** | 4.5 | Male | 12/04/2020 | NNI | 6 | 1 | 7 | 3 |
| **118** | 2.8 | Female | 18/05/2020 | NNI | 4400 | 24 | 161 | 5 |
| **120** | 2.6 | Male | 21/05/2020 | SNI | 719 | 4 | - | - |
| **121** | 2.8 | Female | 21/05/2020 | SNI | 443 | 5 | 48 | 4 |
| **123** | 3.8 | Female | 22/05/2020 | SNI | 1202 | 10 | - | - |
| **124** | 3.6 | Male | 17/07/2020 | PI | - | - | 47 | 6 |
| **125** | 3.1 | Male | 03/12/2020 | SNI | 3339 | 22 | 1159 | 20 |
| **126** | 3.5 | - | 03/12/2020 | SNI | 2040 | 13 | 141 | 6 |
| **127** | 2.8 | Male | 03/12/2020 | SNI | 1642 | 16 | 641 | 18 |
| **128** | 3.6 | Male | 21/12/2020 | SNI | 4212 | 19 | 187 | 5 |
| **129** | 3.1 | Male | 01/01/2021 | SNI | 448 | 14 | 5 | 2 |
| **130** | 3.9 | Male | 08/01/2021 | NNI | 2899 | 15 | - | - |
| **131** | 3.0 | - | 08/01/2021 | NNI | 203 | 1 | - | - |
| **132** | 3.2 | - | 08/01/2021 | NNI | 51 | 1 | - | - |
| **133** | 3.5 | Female | 13/05/2021 | DR | 56 | 1 | - | - |

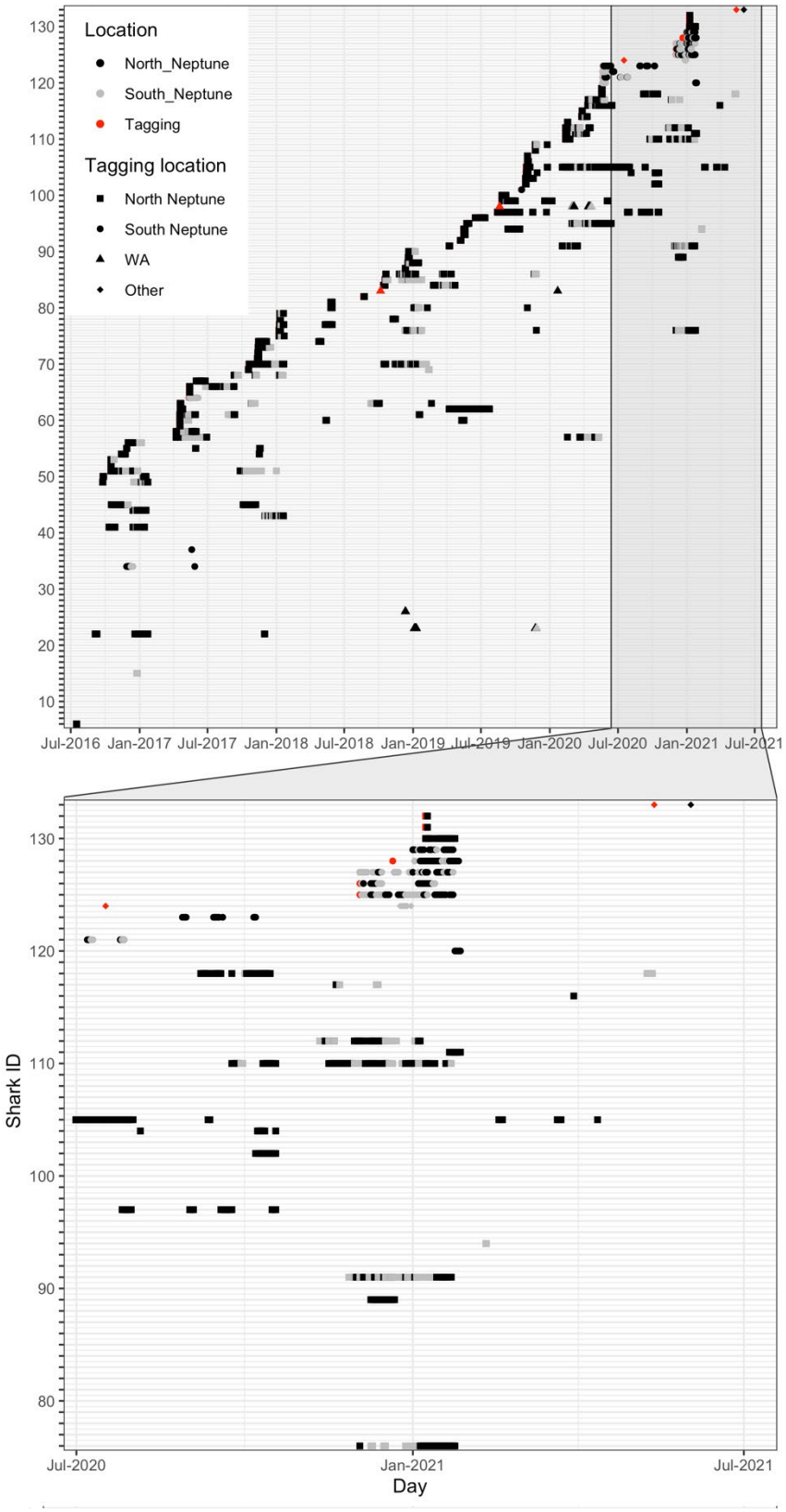


**Figure 2. top panel:** Daily detections for white sharks between 1 July 2016 – 30 June 2021 (n = 80) at the North (black symbols) and South (grey symbols) Neptune Islands. Red symbols represent dates when each shark was tagged. **Bottom panel:** Detection plot for white sharks detected at the Neptune Islands during the 2020–2021 financial year (n = 27).

## 8.1 Residency

Residency periods exhibited by white sharks at the North and South Neptune Islands combined ranged from 1 to 31 days (Table 2). Sharks had similar or longer residency at the North Neptune Islands than the South Neptune Islands (Table 2). Across all sharks detected in 2020–21, maximum residency at South Neptune Islands was higher (47 days) than at North Neptune Islands (31 days) (Table 2). Most shark detections (94.2%) occurred at North Neptune Islands, where the grand mean residency was 6.30 ± 5.08 days (grand median = 6.05). Most white sharks had a mean residency <10 days (84.6%), with one individual resident at North Neptune Islands for >20 days and another shark resident at South Neptune Islands for >40 days (Table 2). Of the 26 sharks detected at North Neptune Islands, 13 were also detected at South Neptune Islands, with one only detected there (Shark 124). Residency periods of most these sharks were substantially lower at South Neptune Islands, except for shark 91, 125, and 127. The grand mean residency at South Neptune Islands was 6.41 ± 12.00 days (grand median = 2.00).

Long-term detection patterns across the eight monitoring periods (2013–2021) show sharks had elevated rates of detection at North Neptune Islands between the October to February period and also in May, with low detection rates in March–April and between June and September (Figure 3). At the South Neptune Islands, however, detection patterns indicated an elevated visitation of sharks in May, July–August, and November–January, with comparatively lower detection rates in February and September–October (Figure 3).

**Table 2.** Summary statistics showing residency estimates (mean; N = number of visits) for white sharks (n = 27) at the Neptune Islands Group between 1 July 2020 and 30 June 2021. SD = standard deviation. Summary statistics were not provided when a shark only had a single residency period.

| ID | Sex | North Neptune Island | | | | | | South Neptune Island | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | Mean | $Log_{10}$ (mean) | SD | Min | Max | N | Mean | $Log_{10}$ (mean) | SD | Min | Max |
| **76** | Male | 2 | 9.66 | 0.98 | 13.65 | 0.01 | 19.32 | 3 | 2.76 | 0.44 | 3.68 | 0.12 | 6.98 |
| **89** | Male | | 13.44 | 1.12 | - | - | - | - | - | - | - | - | - |
| **91** | Male | 4 | 7.73 | 0.88 | 1.92 | 5.51 | 9.91 | 1 | 46.82 | 1.67 | - | - | - |
| **94** | Male | 1 | 1.00* | 0.00 | - | - | - | 1 | 1.00* | 0.00 | - | - | - |
| **97** | - | 4 | 3.80 | 0.58 | 2.34 | 1.50 | 6.14 | - | - | - | - | - | - |
| **102** | - | 1 | 10.75 | 1.03 | - | - | - | - | - | - | - | - | - |
| **104** | Male | 2 | 1.57 | 0.19 | 2.30 | | 4.21 | - | - | - | - | - | - |
| **105** | Male | 5 | 7.24 | 0.86 | 13.53 | 0.01 | 31.39 | - | - | - | - | - | - |
| **110** | Female | 6 | 8.68 | 0.94 | 5.63 | 1.55 | 16.17 | 6 | 2.18 | 0.33 | 2.03 | 0.01 | 5.39 |
| **111** | Male | 1 | 5.47 | 0.73 | - | - | - | - | - | - | - | - | - |
| **112** | Male | 3 | 7.56 | 0.88 | 8.48 | 0.35 | 16.91 | 3 | 4.95 | 0.69 | 3.54 | 0.92 | 7.62 |
| **116** | Female | 1 | 1.00* | 0.00 | - | - | - | - | - | - | - | - | - |
| **117** | Male | 1 | 1.00* | 0.00 | - | - | - | 2 | 1.00* | 0.00 | - | - | - |
| **118** | Female | 3 | 8.27 | 0.92 | 6.94 | 0.29 | 13.01 | 2 | 1.49 | 0.17 | 2.06 | 0.03 | 2.95 |
| **120** | Male | 1 | 3.40 | 0.53 | - | - | - | - | - | - | - | - | - |
| **121** | Female | 2 | 1.21 | 0.08 | 0.31 | 0.99 | 1.43 | 2 | 1.00* | 0.00 | 0.14 | 0.47 | 0.47 |
| **123** | Female | 3 | 2.52 | 0.40 | 2.93 | 0.06 | 5.77 | - | - | - | - | - | - |
| **124** | Male | - | - | - | - | - | - | 1 | 6.25 | 0.79 | - | - | - |
| **125** | Male | 3 | 9.49 | 0.98 | 7.65 | 1.23 | 16.34 | 2 | 11.96 | 1.07 | 0.24 | 11.79 | 12.14 |
| **126** | - | 2 | 6.63 | 0.82 | 0.34 | 6.39 | 6.87 | 3 | 1.19 | 0.07 | 0.63 | 0.59 | 1.85 |
| **127** | Male | 4 | 3.61 | 0.56 | 3.76 | 0.05 | 7.39 | 4 | 6.33 | 0.80 | 4.04 | 2.06 | 11.25 |
| **128** | Male | 1 | 20.44 | 1.31 | - | - | - | 2 | 1.82 | 0.26 | 2.03 | 0.39 | 3.26 |
| **129** | Male | 2 | 8.78 | 0.94 | 5.78 | 4.69 | 12.87 | 2 | 1.00* | 0.00 | 0.02 | 0.00 | 0.03 |
| **130** | Male | 1 | 15.26 | 1.18 | - | - | - | - | - | - | - | - | - |
| **131** | - | 1 | 1.00* | 0.00 | - | - | - | - | - | - | - | - | - |
| **132** | - | 1 | 1.00* | 0.00 | - | - | - | - | - | - | - | - | - |
| **133** | Female | 1 | 1.00* | 0.00 | - | - | - | - | - | - | - | - | - |
| **Grand Mean** | | | **6.30** | **0.62** | | | | | **6.41** | **0.45** | | | |
| **Grand Median** | | | **6.05** | **0.78** | | | | | **2.00** | **0.30** | | | |
| **Grand SD** | | | **5.08** | **0.44** | | | | | **12.0** | **0.50** | | | |

(*) Sharks with a single visit of less than 24-hours residency were rounded up to 1 day.

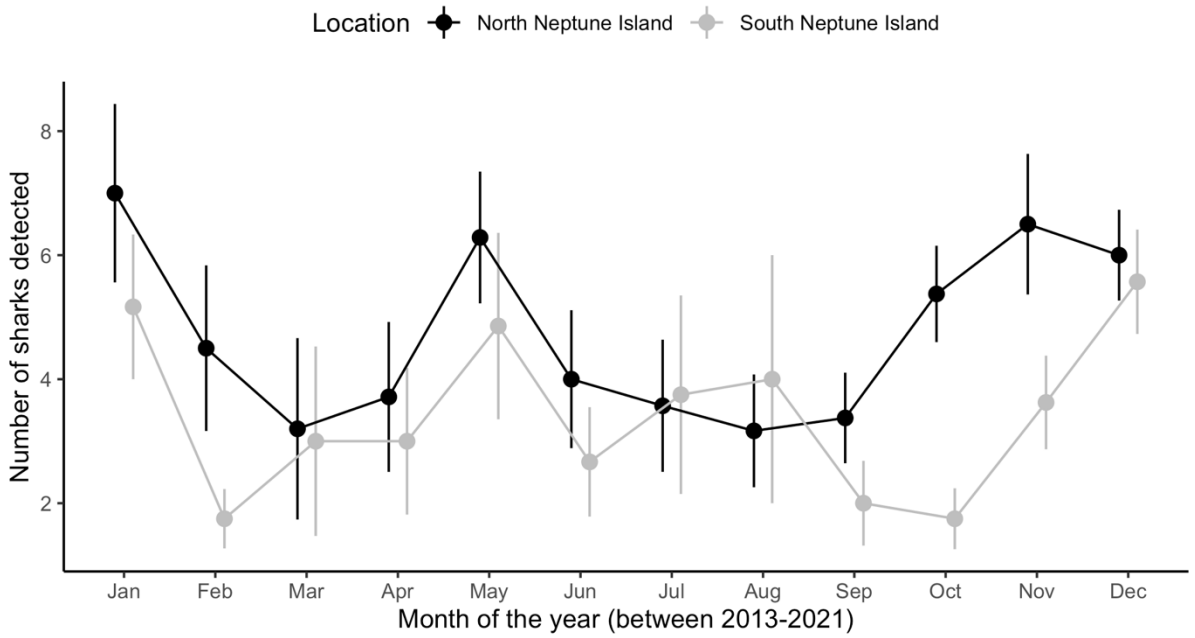


**Figure 3.** Seasonal pattern in shark detections between North and South Neptune Islands across the full monitoring period between July 2013 and June 2021. Points represent mean numbers of sharks detected per calendar month at North (black) and South Neptune Islands (grey), with bars representing standard error of the mean across seven financial years.

## 8.2 Electronic logbook

*Number of sharks sighted*

E-logbook describing cage-diving industry activities comprised records for 239 days out of the 364 days (65%) between 4 July 2020 to 30 June 2021. Reported daily sightings ranged 0–9 white sharks (mean ± standard error = 1.4 ± 0.1; Figure 4). No or only one white shark was sighted on 102 and 40 days respectively (42.7 and 16.7% of the days at the Neptune Islands respectively). The number of sharks sighted peaked between December–January, with low numbers sighted in August, October, and February–April. Similar numbers of male and female sharks were sighted throughout the year, with males being less and more frequent than females in August and December–January, respectively.

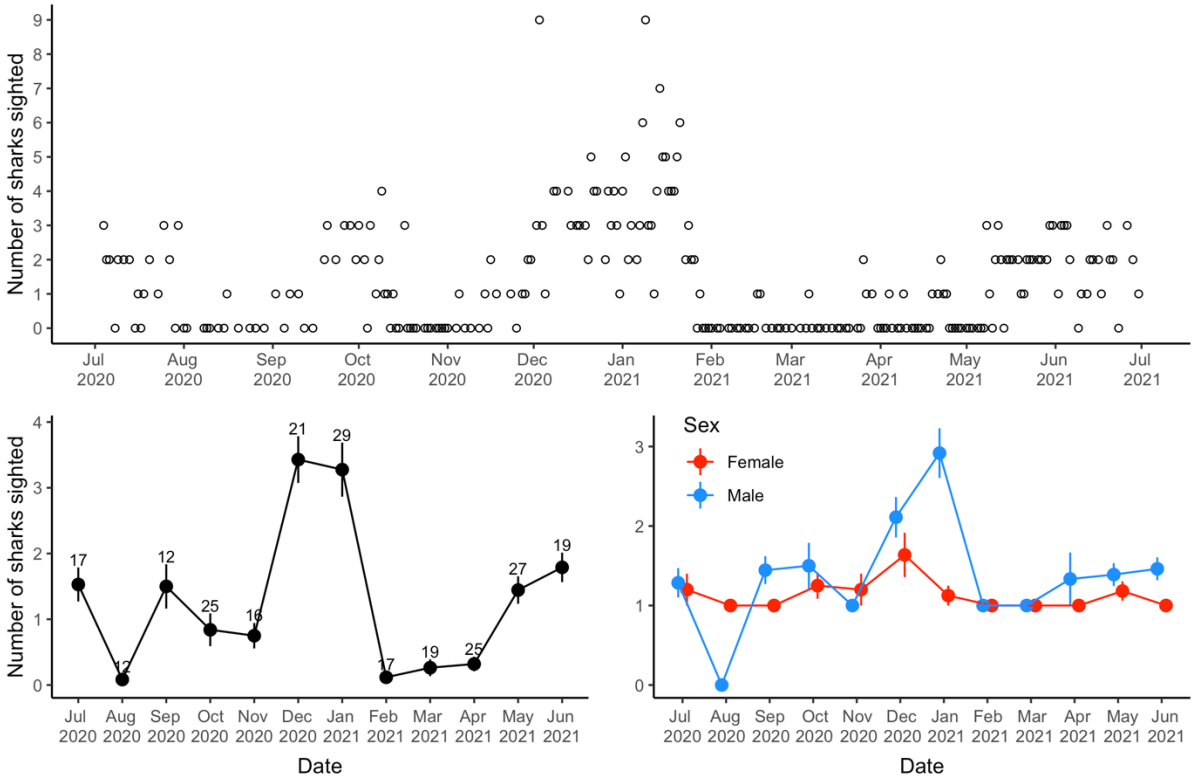


**Figure 4. (a)** Number of sharks sighted reported by the cage-diving operators through the e-logbook in the 2020–21 financial year. **(b)** Mean daily number of sharks sighted each month and **(c)** separated by sex for the 2020–21 financial year. Error bars represents standard error of the mean values. Number above to each point in plot b shows the number of days operators conducted diving activities at the Neptune Islands each month.

# 9. DISCUSSION

## 9.1 Residency

In 2001–02, prior to the cage-diving industry expanding, the grand mean residency of white sharks at North Neptune Islands was 9.7 ± 13.7 days (Bruce et al. 2005; Fig 5). Based on this study, Annexure A to the South Australian White Shark Tour Licensing Policy was developed which includes decision ranges for the cage-diving industry:

- Target range: ≤ 0.70 $\log^{10}$ days
- Caution range: 0.70 – 1.20 $\log^{10}$ days
- Response range: ≥ 1.20 $\log^{10}$ days

Prior to the new policy and limits on number of days operators allowed at the Neptune Islands (2009–2011), residency and $\log_{10}$ increased to well-above the target range and within the response range. In the first year of the monitoring period (2013–14), residency and $\log_{10}$ decreased but was still within the caution range. Since then, residency and $\log_{10}$ has decreased further and has remained within the Target range (Fig. 5; Table 3). Long-term trends since the 2015–16 financial year until present highlight a stabilisation of residency and $\log_{10}$ values to below 2001–02 baseline levels and within the Target range (Fig. 5).

***In 2020–21, the grand mean residency of white sharks at North Neptune Islands was 6.30 days ($log_{10}$ = 0.62) and is within the Target range.***

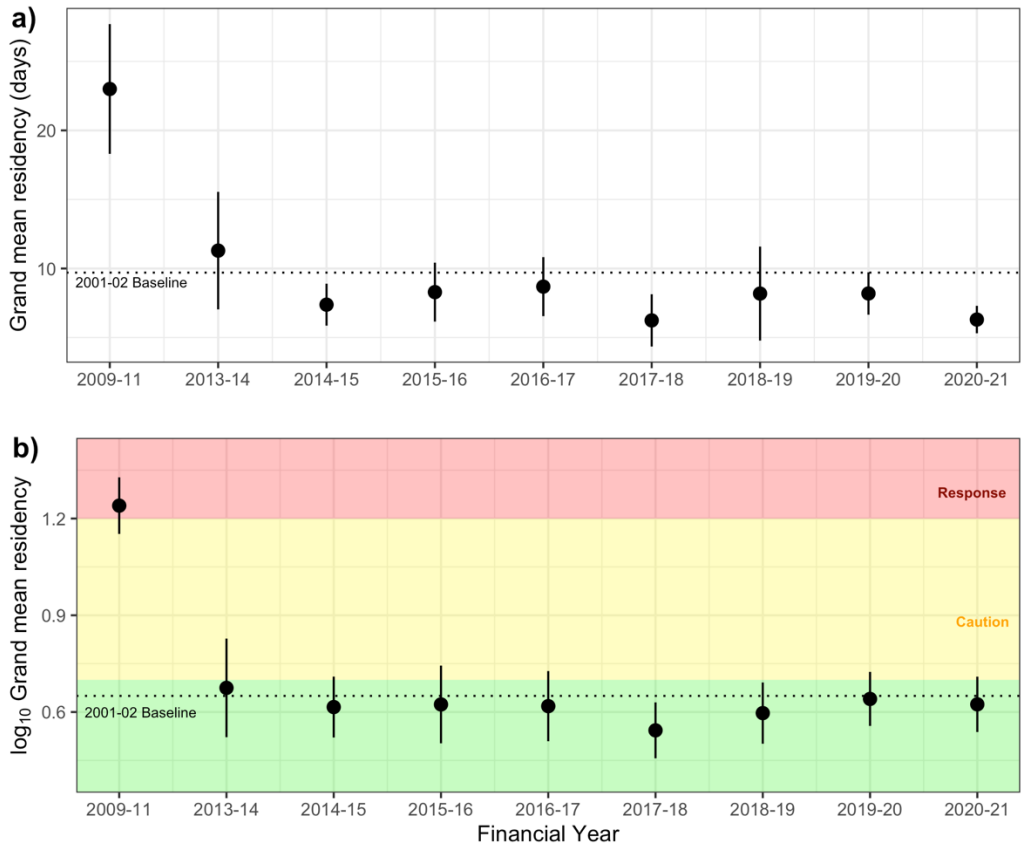


**Figure 5.** Change in **(a)** grand mean residency, and **(b)** $\log_{10}$ of grand mean residency of acoustically monitored white sharks at North Neptune Islands, across the nine monitoring periods. Error bars represent standard error. Horizontal broken lines in plots represent the baseline values of grand mean residency and $\log_{10}$ transformed value calculated by Bruce et al. (2005) in 2001–2002. Shaded areas in panel **(b)** represent decision ranges developed for the cage-diving industry and described in Annexure A to the South Australian White Shark Tour Licensing Policy. Discrepancies with previous reports are due to annual reassessment of potentially shed tag and refinement of the methods with residencies less than one day now rounded up to one day.

**Table 3**. Estimates of overall mean $log_{10}$ residency of white sharks detected at North Neptune Islands between 2001 and 2021. Discrepancies with previous reports are due to annual reassessment of potentially shed tag and refinement of the methods with residencies less than one day now rounded up to one day.

| Period | Grand mean residency (days) | SD | $Log_{10}$ of residency | SD |
|---|---|---|---|---|
| 2001–02 (baseline) | 9.7 | 13.7 | 0.65 | 0.56 |
| 2009–2011 | 23.0 | 18.2 | 1.24 | 0.34 |
| 2013–2014 | 11.3 | 16.5 | 0.67 | 0.59 |
| 2014–2015 | 7.4 | 8.0 | 0.61 | 0.50 |
| 2015–2016 | 8.3 | 9.5 | 0.62 | 0.54 |
| 2016–2017 | 8.7 | 10.9 | 0.61 | 0.55 |
| 2017–2018 | 6.2 | 9.3 | 0.54 | 0.42 |
| 2018–2019 | 8.2 | 16.7 | 0.59 | 0.46 |
| 2019–2020 | 8.2 | 9.3 | 0.64 | 0.51 |
| 2020–2021 | 6.3 | 5.1 | 0.62 | 0.44 |

## 9.2 Cage-diving activities

The e-logbook is an important tool to record cage-diving activities and the number of white sharks frequenting the Neptune Islands Group. The e-logbook revealed that the proportion of days without any shark sighted increased during this monitoring period compared to the previous 2019–20 period (26.5 *vs.* 42.7%). Low abundance or lack of sharks occurred in different months across the monitoring periods, i.e. July–August (2019–20) vs. February–April (2020–21), while peak in shark sighting in 2020–21 occurred in December and January which was the period with lowest number of shark sighted in 2019–20. The increased number of days where sharks were not sighted led to a considerable decrease in the average number of sharks sighted per day from 2.2 in 2019–20 to 1.4 in 2020-21 (Fig. 6).

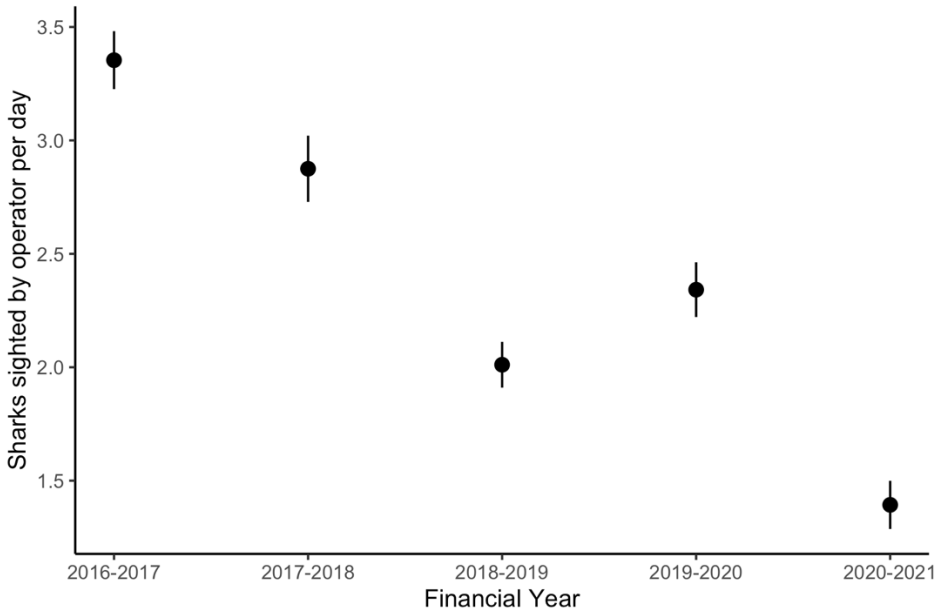


**Figure 6.** Trend in annual sighting rate recorded by operators using the e-logbook tool over the last four financial years (2016–2021). Error bars represent standard error.

## 10. CONCLUSION

The 2020–21 residency of white sharks at North Neptune Islands ($log^{10}$ residence of 0.62) continues to be within the Target range for the eight consecutive year. Individual variation, however, remains high with shark residency ranging from less than a day to 47 days. Residency estimates should, therefore, be interpreted with caution, especially when originating from a low number of individuals.

Number of sharks sighted were reported by cage-diving operators throughout the monitoring period and showed periods of consistently low shark abundance since 2014 (i.e. February–April). However, a large number of white sharks were previously sighted during some of these months, e.g., February 2013. Last year's period of lowest shark abundance was also this year's period of highest shark abundance. The inter-annual variability in shark abundance highlights the complexity of understanding what drives white sharks to visit and reside at the Neptune Islands Group. With the number of sharks sighted having been recorded on each operator days since 1999, we now have > 21 years of daily shark sightings to assess the factors that might influence shark abundance at the Neptune Islands Group Marine Park. Such analysis will enable to better understand the processes affecting shark numbers at the Neptune Islands Group and will help predicting shark abundance, allowing cage-diving operators to plan their activities accordingly.

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