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FINAL REPORT

Project 4.15

Grey nurse shark aggregations

[1]Russell W Bradford, [2]David Harasti, [2]Brett Louden, [1]Emma L Westlake, [1]Sarah Stephenson, [3]Carley Kilpatrick, [4]Ross Dwyer, [4]Jarrod Cameron, [5]Harley Wanganeen, [6]C Samantha Sherman, [6]Daniel Ierodiaconou, [7]Mike Travers, [7]Matias Braccini, [8]Joel Williams, [7]Stephen J Newman

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Please address inquiries to: David Harasti, david.harasti@dpi.nsw.gov.au

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[1] Commonwealth Scientific and Industrial Research Organisation, Environment. GPO Box 1538, Hobart, Tasmania, 7001

[2] New South Wales Department of Primary Industries and Regional Development, Fisheries Research. Taylors Beach, New South Wales, 2316

[3] Queensland Department of Environment, Tourism, Science and Innovation. Great Barrier Reef & Marine Parks Region, QPWS.

[4] University of Sunshine Coast. School of Science, Technology and Engineering. Sippy Downs, Queensland, 4556.

[5] Gunaikurnai Lands and Water Aboriginal Corporation (GLaWAC). Forestec, Kalimna West, Victoria, 3909.

[6] Deakin University, School of Life and Environmental Sciences.

[7] Western Australia Department of Primary Industries and Regional Development.

[8] Institute of Marine and Antarctic Studies, University of Tasmania.

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1. Acknowledgments

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2. Executive summary

The primary aim of this project was to synthesise existing data on grey nurse shark (GNS) distribution and known aggregation sites to inform a revised definition for a GNS aggregation to be used for future conservation efforts. Concurrently, the project expanded research into several potential (but currently unrecognised) aggregation sites in Commonwealth waters off Queensland and New South Wales. Further, this project supported training opportunities for Indigenous Rangers in Victoria from the Gunikurnai Lands and Water Aboriginal Corporation, Eastern Maar Aboriginal Corporation, and the Bunurong Land Council Aboriginal Corporation.

A GNS aggregation has been defined as a site where five or more grey nurse sharks can be observed. Although this definition served well during the initial stages of conservation actions in the early 2000s, a review of the definition is required to support future conservation efforts.

This project has proposed that a GNS aggregation be redefined as a discrete area where multiple GNS (two or more) can be observed on a predictable basis (e.g., annually, seasonally) and includes one or more behavioural driver consistent with the Biologically Important Areas (BIAs) and Important Shark and Ray Areas (ISRA) frameworks.

Field activities have been carried out in Queensland, New South Wales, and Victoria aimed at increasing our understanding of GNS presence and behaviour to better inform the derivation of a definition for a GNS aggregation.

In Queensland, additional acoustic receiver coverage has been installed at Barwon Banks within Commonwealth waters.

In New South Wales, presence of GNS at the Outer Gibber Reef in the Commonwealth Hunter Marine Park has been further documented to provide baseline data on the importance of the site to GNS.

In Victoria, surveys of potential GNS habitat in western Gippsland were undertaken using baited remote underwater video systems (BRUVS), remote operated vehicles (ROV), and environmental DNA (eDNA). No GNS were detected. Activities in Victoria included members from the Gunaikurnai Lands and Water Aboriginal Corporation, Eastern Maar Aboriginal Corporation, and the Bunurong Land Council Aboriginal Corporation. The primary aim of the study in Victoria was to transfer skills in the use of these survey tools to the Rangers.

This study recommended that potential GNS aggregation sites be assessed with the BIA and ISRA frameworks in mind. Determining the temporal pattern of use and driver(s) behind aggregating behaviour are likely to require multiple site surveys over at least one year. To assist with documenting site use, Appendix F provides a standard suite of data aligned to the BIA and ISRA frameworks to collect for each site survey.

3. Introduction

Carcharias taurus (grey nurse shark, GNS) is distributed throughout warm-temperate and tropical coastal waters of the Atlantic, Mediterranean Sea, and Indo-West Pacific Ocean (Compagno 2001). In Australia, GNS have been observed in all Australian coastal waters, except Tasmania (Last & Stevens 2009). However, they are rarely observed in South Australia, Northern Territory, and Victoria (where they are considered functionally extinct). Although GNS inhabit waters to at least 190 m depth, they are most commonly observed in shallow waters where they aggregate in gutters and caves (Pollard et al. 1996, Otway & Burke 2004).

Global declines in GNS abundance led to the listing of GNS as Endangered in 1996 by the International Union for Conservation of Nature (IUCN); then in 2000 reassessed to Vulnerable on the IUCN Red List of Threatened Animals. Further assessment of GNS population numbers led to the eastern Australian and the southwest Atlantic GNS populations being upgraded to Critically Endangered in 2003 and 2007, respectively.

Protection in Australia was first afforded in 1984 to the eastern GNS population in New South Wales under the Fisheries and Oyster Farms Act (1935). By 1998, all Australian states had legislation in place under which protection for GNS was implemented (see Table 2, DoE 2014b). The Commonwealth of Australia enacted national protection in 1997 under the [1]Endangered Species Protection Act (1992); then in 2000 under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). For a detailed description of protection measures, please refer to the Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (DoE 2014a) and associated Issues Paper for the Grey Nurse Shark (*Carcharias taurus*) (DoE 2014b), available at https://www.dcceew.gov.au/environment/biodiversity/threatened/recovery-plans/recovery-plan-grey-nurse-shark-carcharias-taurus-2014.

In Australia, GNS is listed as two separate populations under the *Environment Protection and Biodiversity Conservation* (EPBC) Act (1999) (Stow et al. 2006). One population extending along the western seaboard from Exmouth Gulf in the north to Cocklebiddy in the Great Australian Bight, and the other extending along the eastern seaboard from central Queensland to at least Narooma, NSW (DoE 2014b). The western population is listed as Vulnerable under the EPBC Act, while the eastern population is listed as Critically Endangered.

GNS is a migratory species that undertakes predictable and cyclical migrations on a seasonal and reproductive basis (UNEP/CMS/ScC-SC6/Inf.13.4, 2023). As such, it was added to Appendix I and II of the Convention on the Conservation of Migratory Species (CMS) in 2024 and added to the [2]EPBC Act list of migratory species in 2024.The eastern Australian GNS is known to undertake extensive migrations along the eastern seaboard, with a general northern movement over the Austral autumn/winter period, and a southerly movement over the Austral spring/summer period (Otway & Burke 2004, Bansemer 2009, Otway et al. 2009, Otway & Ellis 2011). However, movements are individualistic and appear to be linked with maturity status (Otway & Burke 2004, Bansemer 2009, Otway & Ellis 2011), as well as reproductive state

[1] https://www.legislation.gov.au/C2004A04485/latest/text
[2] https://www.legislation.gov.au/F2024L01190/asmade/text

(Bansemer & Bennett 2009). Although less well studied, there is evidence of extensive migratory behaviour within the western Australian GNS population (Jakobs & Braccini 2019, Hoschke et al. 2023). Migrations within both populations are punctuated with periods of residency at sites where multiple GNS can be observed in close proximity to each other; these have been loosely termed aggregation sites.

Fouche et al. (2019) defined an aggregation as both the process of grouping and the resulting spatial grouping of animals. Further, aggregations can involve physical contact, close proximity, persist over time, involve a stable composition of individuals or turnover of individuals, and consist of a few individuals to several millions (Fouche et al. 2019).

There are very few examples of animals that rarely aggregate (e.g., polar bears: McGlynn 2010), which has resulted in a large body of literature on aggregations. For most animals, aggregations form important functional roles such as for reproduction, predator avoidance, or improved feeding success, amongst other functions (Sadovy de Mitcheson et al. 2008, Fouche et al. 2019, Winnicki et al. 2020). Although aggregative behaviour is largely considered to be beneficial to the aggregating animals, aggregating animals are also susceptible to a variety of natural and anthropogenic pressures that may ultimately result in population declines (Shizuka & Johnson 2020, Papastamatiou et al. 2022, López et al. 2023, McInturf et al. 2023).

Throughout their global distribution, GNS are known to form aggregations (Pollard et al. 1996, Smale 2002, Teter et al. 2015). Aggregations have also been identified within both Australian populations. To date, five possible aggregation sites have been identified for the western Australian population (Hoschke & Whisson 2016, Hoschke et al. 2023). There are 19 listed key aggregation sites for the eastern GNS (see Table 1, DoE 2014b): four in Queensland waters, 13 in NSW waters, and a further two in Commonwealth waters.

A GNS aggregation has previously been defined as a collection of five or more individuals present at a site (Otway et al. 2003). Although reference to consistency of site usage was provided (i.e., the number of times GNS were observed at a site across 10 surveys), it was not used to define an aggregation site. Hoschke & Whisson (2016) added to the basic definition to include “gather on a recurrent basis each year”. Thus, the current definition of a GNS aggregation can be defined as a site where five or more GNS are present either continuously or on a predictable cycle. Whilst this definition has been applied, the aggregation definition is considered inadequate and precludes an objective assessment of potential sites that may benefit from the implementation of protective measures.

The primary aims of this study were to:

1. Compile the evidence by which a new definition for a grey nurse shark aggregation could be defined (Chapter 2).
2. Expand acoustic monitoring in southern Queensland to investigate a possible grey nurse shark aggregation at Barwon Banks (Chapter 3.1).
3. Complete towed video and BRUVS surveys of Outer Gibber Reef within the Commonwealth Hunter Marine Park, NSW to identify GNS presence (Chapter 3.2).

4. Extend field studies into Victorian waters to investigate potential recolonisation/range expansion, with a focus on engaging Indigenous organisations to build skills within their ranger programmes (Chapter 3.3).
5. Review existing literature on aggregation sites in WA (Chapter 3.4).

4. Defining a grey nurse shark aggregation

The term "aggregation" has been widely and variably used to describe co-occurrence across elasmobranch species, but its defining criteria remain vague and indeterminate (McInturf et al. 2023). This statement is highly germane to the discussion surrounding what constitutes a GNS aggregation. In this section, we propose a refined more specific definition for a GNS aggregation that will better serve conservation efforts, along with providing recommendations towards a structured pathway for the identification of new aggregation sites.

In the context of GNS, a definition for an aggregation should include reference to temporal occupancy (accounting for their migratory nature) and function of the site (the underlying driver for occupying a site). The definition must also give due consideration to the differences between east and west coast populations and inter alia the associated marine environments that they occupy and utilise. We have summarised available information for listed GNS aggregation sites (Appendix A) and compiled the available data on acoustically-tagged GNS from key aggregation sites in NSW (Appendix B) to identify commonalities and assist with developing a framework for a definition on what constitutes a GNS aggregation. The definition draws upon the approach for BIAs under the EPBC Act, and for the IUCN ISRA (Hyde et al. 2022, Palacios et al. 2023) framework as well as the work of McInturf et al. (2023) to establish a unified definition for an elasmobranch aggregation.

Identifying Key Aggregation Sites.

There are currently 19 listed key aggregation sites for the eastern GNS (see Table 1 in DoE 2014a & b), each of which has been afforded some level of protection. However, the migratory routes between these sites have not received specific protection, nor have additional sites where GNS have been observed to aggregate outside of the 19 listed sites. Identification of the listed key aggregation sites was based on the Otway et al. (2003) observations of locations where five or more GNS are regularly found throughout the year. This approach served well for the purpose of immediate protection and initial population rebuilding efforts. However, the rationale used for the number of GNS (5) was ambiguous and was not suited to assessing new potential aggregation sites. Hoschke and Whisson (2016) later defined an aggregation as a location where five or more GNS gather on a recurrent basis each year, allowing for the inclusion of seasonal aggregations where animals occur regularly and predictably, but not necessarily throughout the year. Despite this refinement, there is now a need to update the definition of an aggregation to align with the BIA and ISRA frameworks in order to further progress conservation efforts for GNS. This new definition should have a clear set of criteria, including the drivers behind aggregations, and consider temporal patterns of occupancy.

Recently, a more structured approach to identify areas of importance for marine species protected under the EPBC Act has been established. Biologically Important Areas ([3]BIAs) are spatially and temporally defined marine areas used by protected marine species for critical life functions (feeding, reproduction, resting or migration). BIAs are designated by the Australian government when an area is known or likely to be regularly or repeatedly used by individuals or

[3] Biologically Important Areas for protected marine species (BIAs) – DCCEEW: https://www.dcceew.gov.au/environment/marine/bias

aggregations of a single species. The Australian BIA framework is closely aligned with the IUCN ISRA framework (Hyde et al. 2022, Palacios et al. 2023), but in addition, allows for cultural values to be considered.

Despite preceding the BIA (2010) and ISRA (2022) frameworks, there is some alignment between the designation of existing key GNS aggregation sites and these delineation processes.

Following the BIA and ISRA frameworks, this study proposes that:

A GNS aggregation site is defined as a discrete area where multiple GNS (two or more) can be observed on a regular and predictable basis (e.g., annually, seasonally) and includes one or more of the behavioural drivers (reproductive, feeding, resting, migration or [1] undefined).

Where the behaviour driving the aggregation is not immediately obvious, an unidentified category can be assigned until further site surveys can be undertaken.

[1] See Table 1 for definition of undefined.

Our refined definition aligns with both BIA and ISRA frameworks by incorporating temporal occupancy and functional use of aggregation sites. Using this approach, the driver(s) for the aggregative behaviour (Table 1) may inform the level of protection that should be afforded to the area. If the driver(s) cannot be identified (Appendix C: ISRA sub-criterion C5 – Undefined Aggregation), a basic level of protection should be afforded simply because of the potential for external forces to impact multiple individuals of a small population.

Table 1. Descriptions of behaviours identified under the Biologically Important Areas (BIAs) framework.

Behaviour	BIA description
Reproduction	Areas (and times) known or likely to be regularly or repeatedly used by individuals or aggregations of a species for reproduction (including courtship, mating, nesting, egg laying, inter-nesting, hatching, pupping, birthing, nursing or accompanied by dependent young), or to provide refuge, or other advantage to young.
Feeding	Areas (and times) known or likely to be regularly or repeatedly used by individuals or aggregations of a species for feeding, foraging (searching for food including for provisioning of young) or otherwise obtaining nutrition. May be persistent in space and time or associated with ephemeral features that are less predictable but are located within an area that can be delineated.
Migration	Areas (and times) known or likely to be regularly or repeatedly used by individuals or aggregations of a species for undertaking seasonal or other temporal movements (such as dispersal by marine turtle hatchlings) which contribute to connectivity with other functionally important areas.
Resting	Areas (and times) known or likely to be regularly or repeatedly used by individuals or aggregations of a species for metabolic or physiological advantage (such as resting, recovery, conserving energy, thermoregulation, osmoregulation, or other unknown reason such as basking by marine turtles) or for seeking refuge from predators or con specifics.
Undefined	Areas where an aggregation regularly and repeatedly occurs, but the function of the assemblage is currently unknown.

5. Field activities

5.1 Queensland – Barwon Banks (Commonwealth waters)

5.1.1 Introduction

GNS are afforded some level of protection in east Australia at most of the 19 listed key aggregation sites through restrictions to fishing activities. However, significant knowledge gaps persist regarding site use outside the current protection network (Dwyer et al. 2023). This includes GNS usage of areas in the southern part of the Fraser Shelf, located north of Moreton and south of K'gari (formally Fraser Island). This region is known to hold large numbers of adult grey nurse sharks as they migrate north to breed and gestate at Wolf Rock, located ~2 nm east of Double Island Point.

Marine resource users have observed GNS in high numbers at the Barwon Bank and the Hards, areas of submerged structure located approximately 22 nm and 31 nm east of Mudjimba, Qld. The Barwon Bank is an elongate, roughly ellipsoidal shoal, approximately 80 km long and 15 km wide that rises about 30 m above the surrounding seafloor to a depth of 60 m (Passos et al. 2019). The Hards, like Barwon Bank, is also a northly trending linear feature and lies to the northeast of Barwon Bank with water depths ranging up to 100 m.

Our understanding of when GNS utilise these sites and how long they spend there is limited due to the remoteness of these sites, which limits access by researchers and commercial dive operators.

5.1.2 Methods

Presence, residency and movements of GNS in the vicinity of Barwon Bank and the Hards were monitored using passive acoustic telemetry between 2023 – 2025. Acoustic telemetry is the preferred method to track GNS due to this species strong association with areas of structure close to the coastline (where the national acoustic receiver array is placed).

Acoustic tags (Innovasea: www.innovasea.com) transmit a series of 'pings', encoding a unique identification number, at 69 kHz typically once every 1-2 minutes. When a tag transmits and is within the acoustic listening envelope (typically 300-500 m) of a moored acoustic receiver, the receiver will record the coded ID, date and time. These data are downloaded from the acoustic receiver on recovery and stored in a central database.

A VR2-AR acoustic release receiver (Innovasea: www.innovasea.com) was deployed on 03/04/2024 in 110 m depth at Hards slimie bump (Table 2). The VR2-AR was secured to the seafloor using a sand anchor (14 lb) and approx. 30 kg of 16 mm chain. A 300 mm pressure float above the VR2-AR maintained the receiver in an upright position approx. 2 m above the seafloor. The site was re-visited on 15/03/2025 when a replacement receiver was deployed at Hards Slimie bump and another VR2-AR unit was deployed 14 nm to the southwest at Barwon Bank Central in 42 m depth (2 m above the sea floor) using the same mooring setup as before.

To gain further insights into the use of the area by tagged GNS, we reached out to other researchers tracking animals in the region using passive acoustic telemetry. The Department of Primary Industries (Qld) installs Fish Aggregation Devices (FADs) off the Queensland coast as part of the FADs program (https://www.qld.gov.au/recreation/activities/boating-fishing/rec-fishing/fish-aggregating-devices). These consist of a 800 mm cone-shaped yellow special marker buoy, a 2 nm range marine lantern, an Innovasea© 69 kHz VR2-W acoustic receiver (positioned 20 m below the surface buoy with the hydrophone facing down), a GPS tracker (in case the FAD becomes dislodged from the mooring), and rope and chain going down to a 80 lb plough anchor on the sea floor. The closest receivers to Barwon Bank were FAD 8 (deployed 3 nm southeast of Barwon Banks Central in 101 m depth) and FAD 19 (4 nm southwest of Barwon Bank Central in 55 m depth). FAD 8 and FAD 19 were both deployed in August 2023 and downloaded in December 2024. FAD 8 was also downloaded a second time in March 2025.

5.1.3 Results

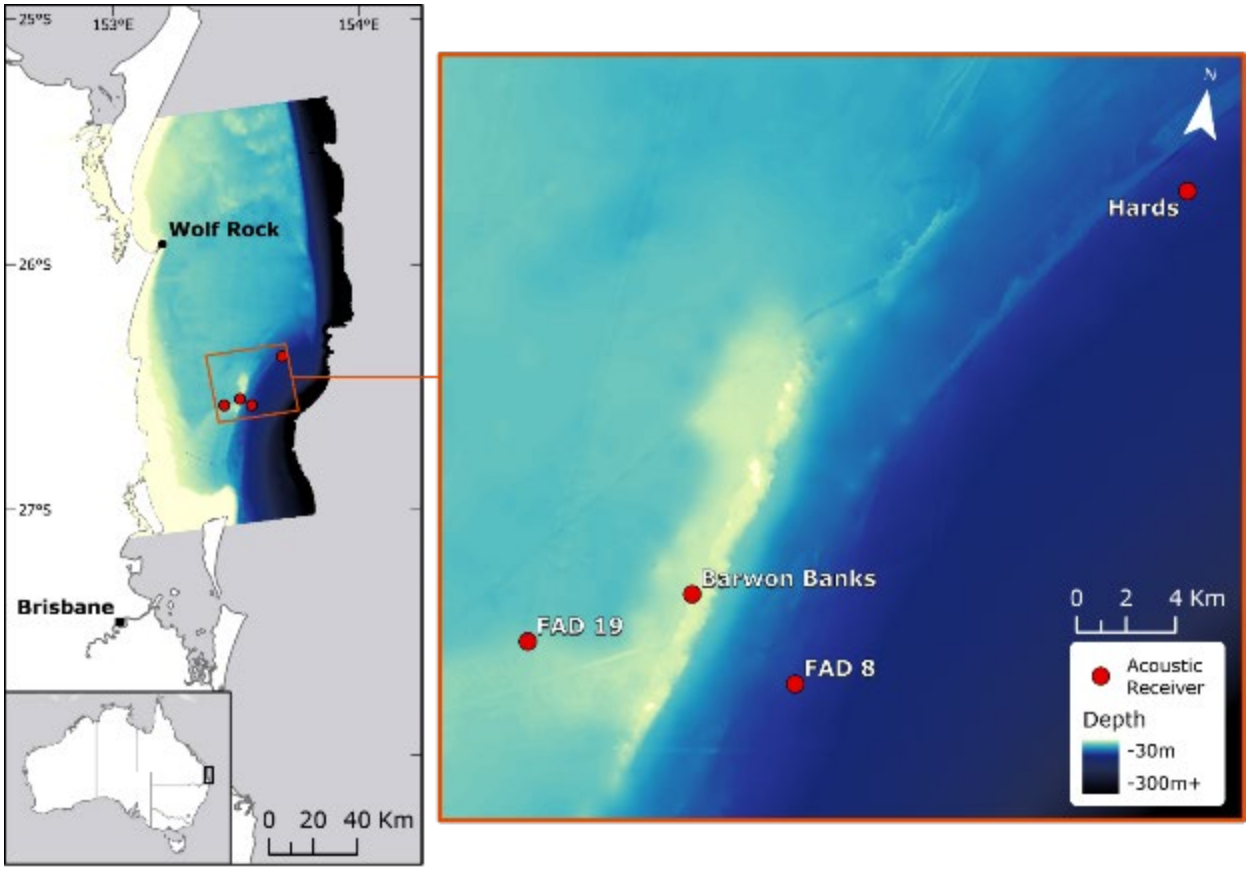
Significant challenges during the initial stages of this project led to delays in purchasing equipment for field work. To minimise impact, the University of the Sunshine Coast (UniSC) appropriated several receivers from other projects to ensure coverage of Barwon Bank.

Receivers were deployed on two Fish Aggregating Devices (FADs) serviced by Queensland Fisheries, and a further two on sites serviced by UniSC (Figure 1). Water depths ranged from 42 to 112 m.

Table 2. Acoustic receiver deployment metadata for Barwon Heads, Queensland.

Site	Receiver Type	Receiver ID	Deployment Date	Latitude (S)	Longitude (E)	Recovery Date
FAD 8	VR2W	104401	21/08/2023	26.5743	153.5645	31/08/2024
FAD 8	VR2Tx	491824	16/12/2024	26.5743	153.5645	25/03/2025
FAD 8	VR2Tx	491824	25/03/2025	26.5743	153.5645	* late 2025
FAD 19	VR2W	113950	21/08/2023	26.5754	153.4536	12/10/2024
FAD 19	VR2Tx	482874	17/12/2024	26.5754	153.4536	
Hards Slimie Bump	VR2AR	546492	03/04/2024	26.3759	153.6886	Lost – failed to release
Hards Slimie Bump	VR2AR	552970	25/03/2025	26.3759	153.6886	* late 2025
Barwon Central	VR2AR	552969	25/03/2025	26.5486	153.5166	* late 2025

* Scheduled recovery – receiver currently deployed.



Bathymetry data from Flukes, E., (2024). Multi-resolution bathymetry composite surface for Australian waters (EEZ). Institute for Marine and Antarctic Studies (IMAS). Data accessed from https://metadata.imas.utas.edu.au/geonetwork/srv/eng/catalog.search#/metadata/69e9ac91-babe-47ed-8c37-0ef08f29338a on [2025-06-23].

Figure 1. Location of acoustic receivers deployed in Queensland for this project. Bathymetry consists of a multi-resolution composite surface with inset showing locations of the four receivers (red dots) in the Barwon Banks and Hards complex. Bathymetry has been cropped and coloured ranging from -30 m to -300 m. The composite bathymetry is arranged in a tiered display of mosaics, each gridded at a resolution guided by the Australian Multibeam Guidelines (2020), with finer detail in shallower waters transitioning to coarser resolution at depth.

A search on the IMOS Animal Tracking Facility acoustic telemetry database (https://animaltracking.aodn.org.au) indicates that 60 grey nurse sharks have been tagged in east Australia with acoustic telemetry transmitters since 2015. Of these, 32 individuals have been detected within the last three years.

One tagged grey nurse shark (A69-9001-57804) was detected at FAD 8 to the east of Barwon Bank in October 2023. This 2.6 m male shark was originally tagged on 12/09/2022 at Flat Rock and had been detected 20 times over a six-day period at FAD 8 from 24-29/10/2023.

No grey nurse sharks were detected at FAD 19 to the west of Barwon Banks between 21/08/2023 and 11/10/2024. The receiver initially deployed at Hards Slimie Bump failed to release and is considered “lost”. A replacement receiver was deployed 25/03/2025 and remains in place.

The next recovery of acoustic receivers for all sites will be in late 2025.

All detection data will be analysed by J. Cameron as part of his PhD candidacy being undertaken at UniSC. The focus of the PhD is on understanding the role of habitat in central and south Queensland for multiple critically endangered marine megafauna, including GNS. The acoustic detection data collected as part of this program will be used to inform a chapter investigating and comparing residency of acoustic tagged GNS at sites in Queensland. This will involve comparing Barwon Bank and the Hards against listed key GNS aggregation sites (i.e., Wolf Rock, Flat Rock, Cherubs Cave, Henderson Rock) and other sites which have been identified as harbouring aggregating GNS (e.g., Gneerings/Wobby/Nurse Rock, China Wall, Flinders Reef and others).

5.2 New South Wales – Outer Gibber, Hunter Marine Park (Commonwealth)

5.2.1 Background/Introduction

The Outer Gibber is a small high relief reef system located in the Special Purpose Zone of the Commonwealth's Hunter Marine Park (Figure 2). The position of the reef system is 32° 33' 10.72" S by 152° 26' 06.25" E.

The reef varies between 30 and 50 m depth and is known for its high species diversity (Monk et al. 2017, Williams et al. 2020, Williams et al. 2019). This, coupled with its relatively close proximity to Port Stephens, makes the Outer Gibber reef a target of the commercial and recreational fishing sector. Grey nurse sharks are known to occupy the site (Monk et al. 2017, Williams et al. 2020), however, the degree (number of GNS and temporal distribution) to which this site is occupied by GNS is unknown.

The Outer Gibber reef system has been monitored on several occasions by the NSW Department of Primary Industries over the past 15 years using Baited Remote Underwater Video Systems (BRUVS) as part of the NSW state-wide reef fish monitoring program. It was first surveyed using single-BRUVs in 2010 as it was used as a control site for the Port Stephens-Great Lakes Marine Park rocky reef fish monitoring program. Stereo-BRUVs that allow precise measurement of fish were used from 2012 onwards. The BRUVS program has previously detected a single grey nurse shark occurring at the site. However, the BRUVS sampling has only ever been undertaken in August-September which is outside the key period of January-June when GNS are considered to be most abundant in Seal Rocks-Port Stephens region based on acoustic telemetry data (Otway & Louden, 2025).

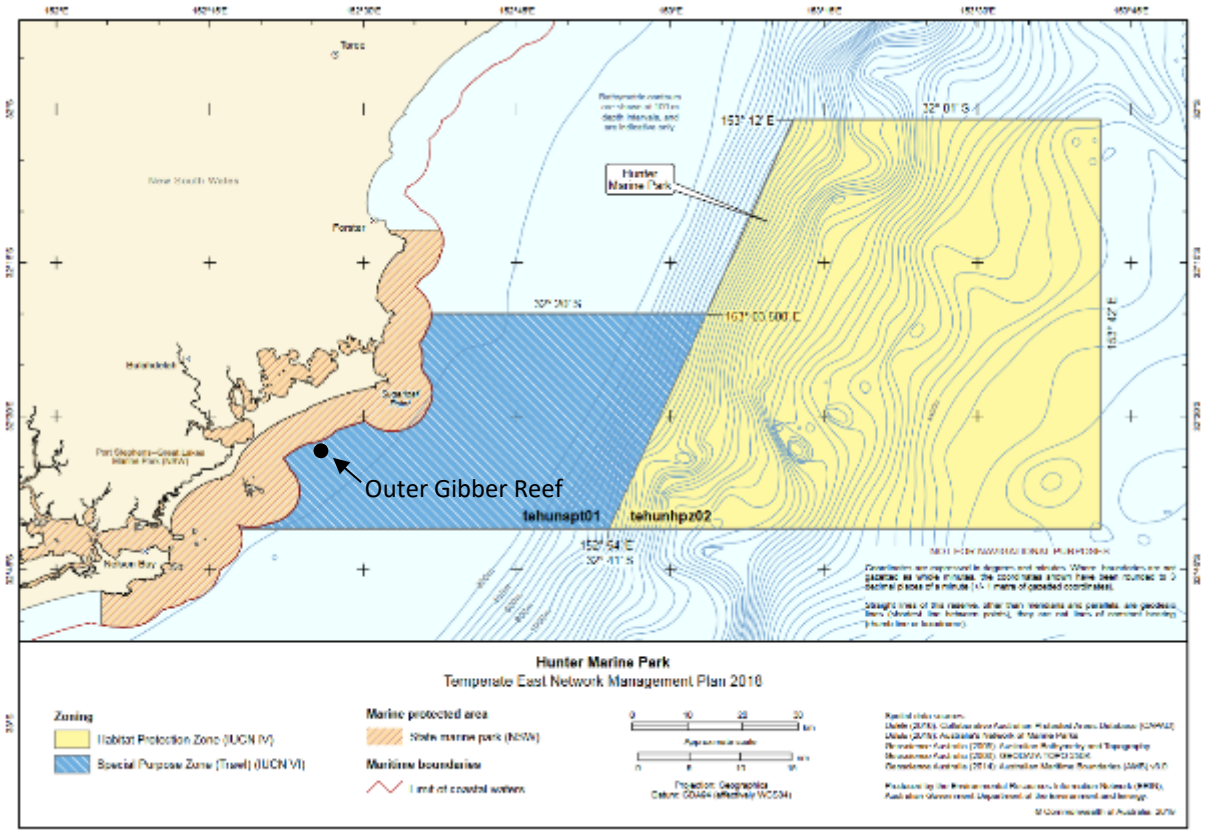


Figure 2. Hunter Marine Park (https://australianmarineparks.gov.au/static/de7ea457d6ebecc5d355e01205b249ae/amp-document-fnl-mp-2018-te-map-hunter-mp.pdf).

5.2.2 Methods

Stereo Baited Remote Underwater Video Systems (BRUVS)

Stereo BRUVS are a recognized standard method for sampling fish assemblages on rocky reefs around Australia (Langlois et al. 2020). In NSW, there have been numerous studies using BRUVS to assess the effects of marine protected area zoning, impacts of illegal fishing and assessing abundance of threatened and protected species (Knott et al. 2021, 2025, Harasti et al. 2019, Harasti & Malcolm 2013). Whilst there have been no specific projects using BRUVS to assess the occurrence of GNS, they have been used in the region to assess the occurrence of other shark species such as white sharks (*Carcharodon carcharias*) (Harasti et al. 2016).

To assess the occurrence and abundance of GNS on the rocky reefs of Outer Gibber, stereo-BRUVS were deployed in February, March and April 2025. To assess if GNS were occurring in the area at the time of deployment, BRUVS were also deployed at four other locations where GNS are known to occur (Figure 3). These sites were Big Seal Rock, Little Seal Rock, Outer Edith Breaker and Inner Edith Breaker; all four sites are known to have aggregations of GNS from February – May (NSW DPI unpublished data). The purpose of sampling these additional four sites was to confirm the presence of GNS in the region at the time sampling was undertaken at Outer Gibber.

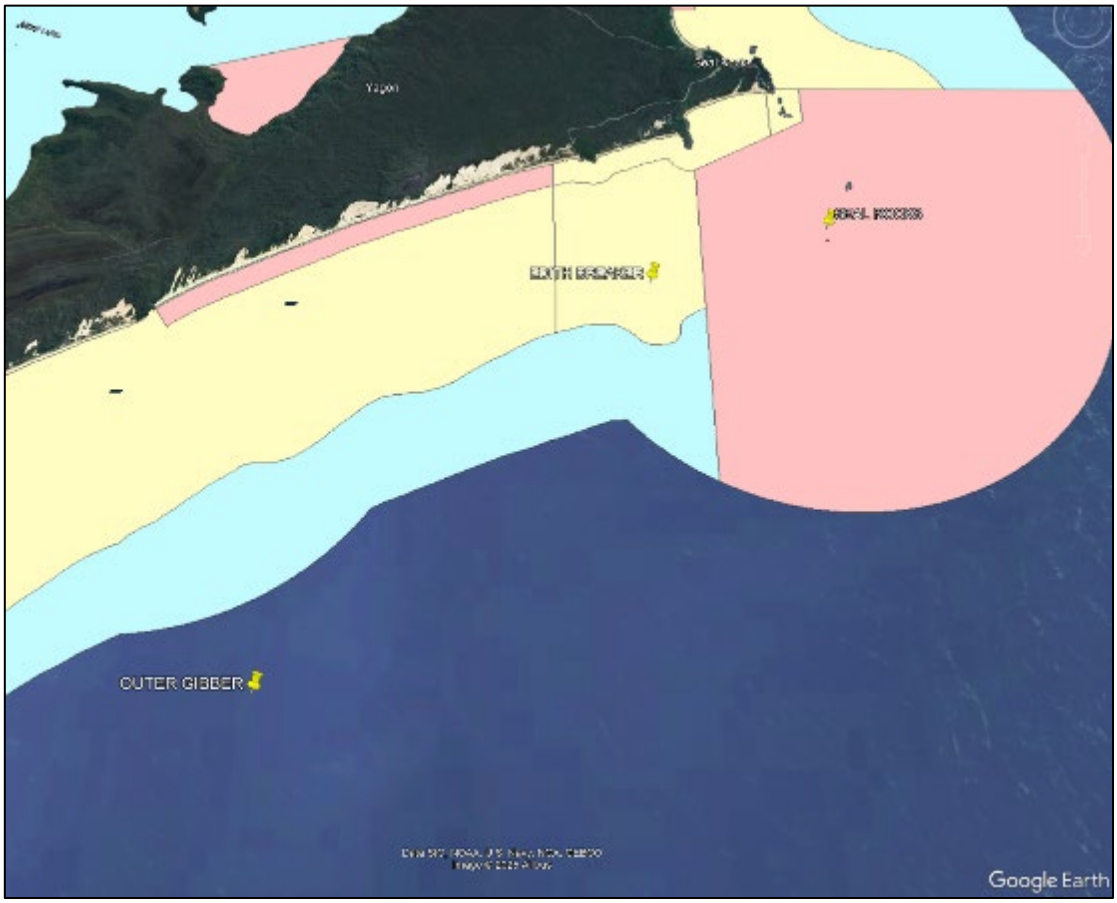


Figure 3. Location of the BRUVs sampling site for Outer Gibber, Edith Breaker and Seal Rocks. Pink = Port Stephens-Great Lakes Marine Park 'Sanctuary Zone, yellow = 'Habitat protection zone' and light blue = General use zone.

BRUVS consisted of a SEAGIS stereo-camera system within a metal frame, with a bait placed at 1.5 m from the cameras. BRUVS were baited with approximately 500 g of crushed pilchards (*Sardinops sagax*), plus the bait bag included a small cloth (approx. 15 x 15 cm) soaked in tuna oil. BRUVS were set for a period of 60 mins, as a 60 min set time is considered a standard deployment time in Commonwealth Marine Reserves (Langlois et al. 2020, Brown et al. 2022). At each location, four BRUVs were deployed which were separated by at least 200 m.

Video analysis consisted of a user watching the video in Eventmeasure v.6.47 (www.seagis.com.au) and recording the presence of any GNS observed. The time, depth and location were recorded for any GNS observed, and where feasible, a stereo length estimate was provided.

Towed video

A towed video system was used during the same period that the BRUVS were deployed at the Outer Gibber site. Towed video was undertaken at Outer Gibber in February, March and April 2025. The towed video system consisted of a SPOT X video camera (https://www.spotx.com.au/) on an 80 m cable projecting a live video stream to a monitor

onboard the vessel. As part of the towed camera system, a GoPro Hero 13 (https://gopro.com) was used to record all the underwater footage from the tow.

The concept of the towed camera system was to cover as much of the Outer Gibber reef system as possible, however, this was constrained by sea conditions, particularly current and wind (Figure 4). Generally, for each towed video sampling period, approx. 30 to 60 mins of towed footage was recorded. Video analysis involved a user watching all the recorded towed video footage and recording the presence of any grey nurse sharks, with an estimate of depth and location provided.

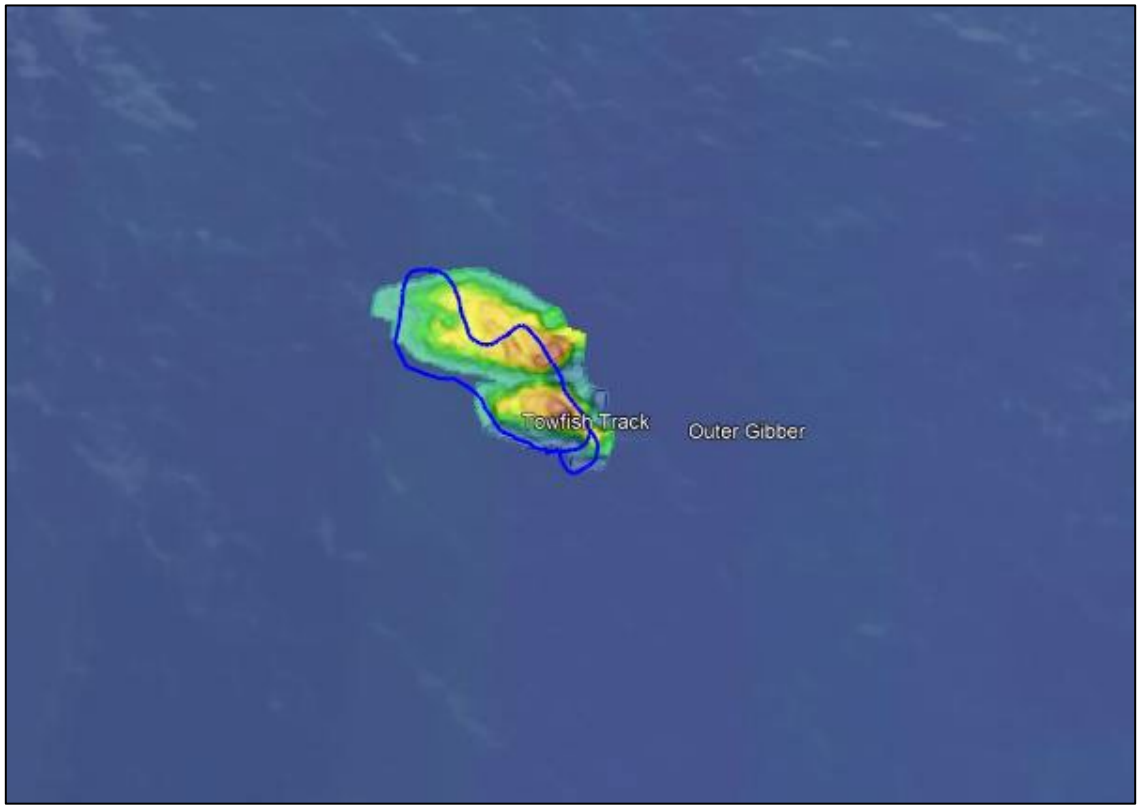


Figure 4. Towed video track on the Outer Gibber reef system in March 2025.

5.2.3 Results

Grey nurse sharks were recorded at the Outer Gibber site on both the BRUVS and Towed video camera system (Table 3). The highest number of sharks recorded in a sampling event was the occurrence of five sharks that were observed on a BRUV occurring over a large bommie in approximately 30-35 m on the south-east corner of the Outer Gibber reef system (Figure 5). The towed video system also detected four grey nurse sharks on this bommie on the same day (Figure 6).

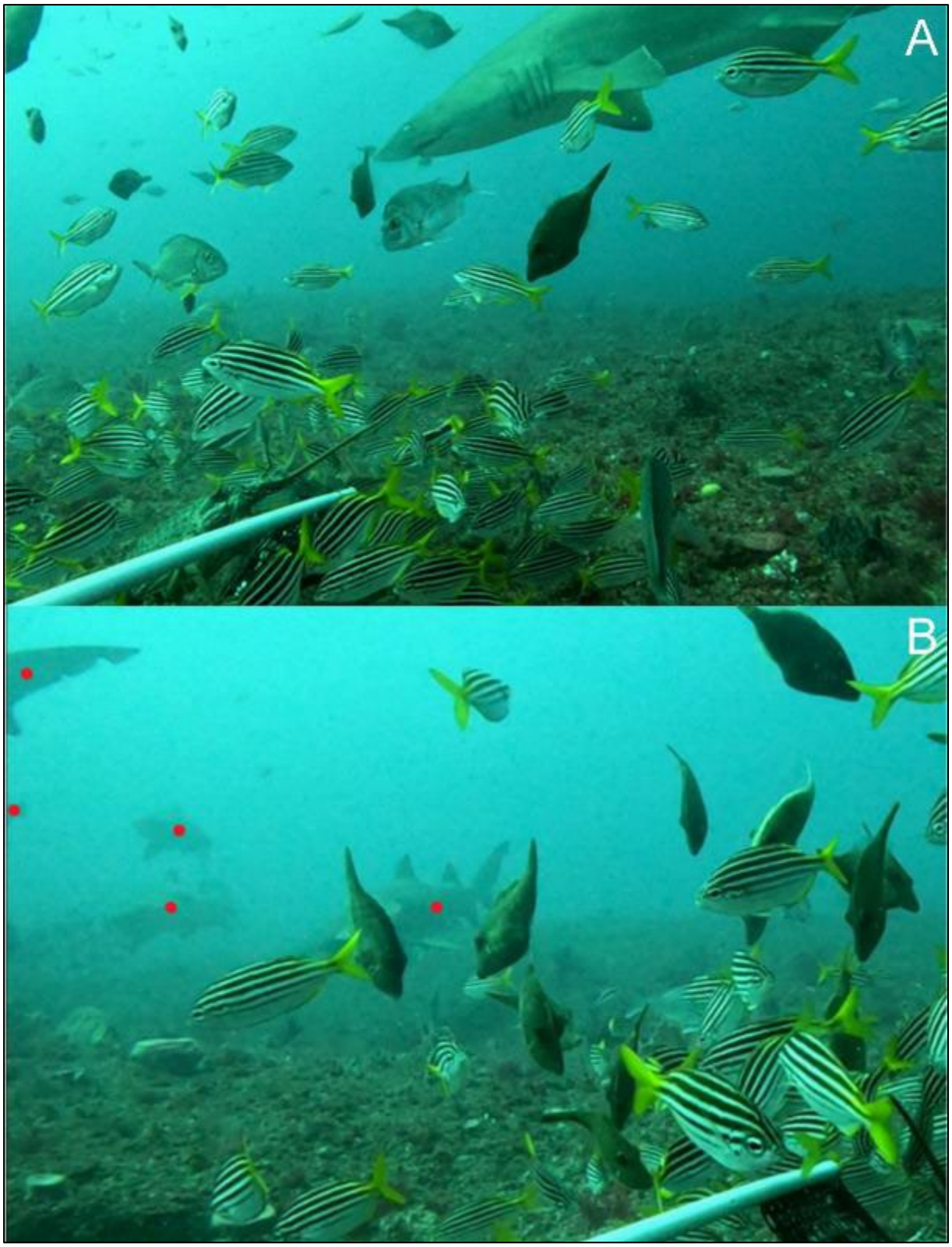


Figure 5. A: Single GNS recorded near the southern Bommie from BRUVs at Outer Gibber in February 2025. B: MaxN of five GNS recorded near the southern Bommie from BRUVs at Outer Gibber in February 2025. Red spots indicate each individual GNS.

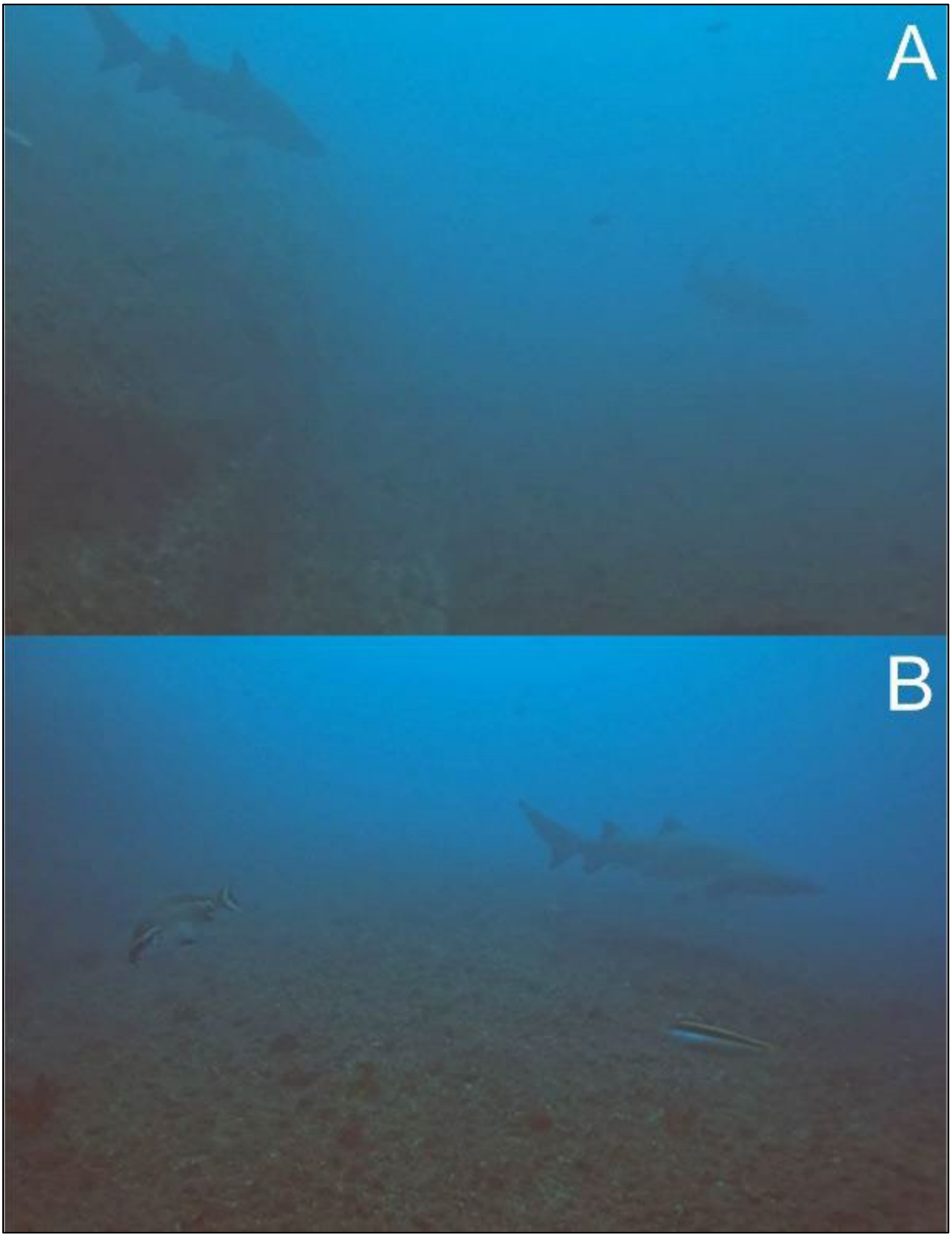


Figure 6. A: Two GNS recorded on southern Bommie from towed video camera at Outer Gibber in February 2025. B: Single GNS recorded on southern Bommie from towed video camera at Outer Gibber in February 2025.

Of the five sharks observed on the stereo-BRUV at Outer Gibber, three of the sharks were able to be measured. A male GNS measured 2.67 m and two individuals considered female (no obvious claspers) measured 2.75 m and 2.85 m (Figure 7).

Figure 7. A: Stereo length measurement of male GNS at Outer Gibber. This male measured 2.67 m. B: Stereo length measurement of two female GNS at Outer Gibber measuring 2.75 m and 2.85 m.

In March 2025, a single individual was captured on the towed video camera at a depth of approximately 42 m on a sand gutter on the south-east corner of the reef system.

Table 3. Occurrence of GNS at Outer Gibber as observed via BRUVs or towed video system.

Date sampled	BRUVs	Towed Video
February	5	4
March	0	1
April	0	0

One important observation made whilst sampling in February was the large number of recreational fishing vessels on the Outer Gibber site. Between 9 and 11 am on 25/02/2025, a total of 21 vessels were observed fishing around the site, which all appeared to be targeting marlin.

At the control sites at Seal Rocks and Edith Breaker, three GNS were observed on a single BRUV at Inner Edith in March 2025.

5.2.4 Discussion

The surveys at the Outer Gibber site in the Commonwealth Hunter Marine Park confirmed the occurrence of GNS at this locality in the months of February and March. The highest number of GNS in a single sample period was five sharks which were recorded on a single BRUV in February 2025. The most recorded on the towed video camera was also on the same day, with four GNS recorded. Sighting of GNS on the Outer Gibber reef system detected from BRUVS and towed video always occurred on the south-eastern section of the reef system in depths of 33 – 45 m.

The sharks observed at Outer Gibber are all considered to be mature adults as they were measured to be larger than 2.6 m in total length. Large adult sharks are present at both Seal Rocks and Edith Breaker during this time of year, so their occurrence at Outer Gibber is not unusual.

As this is the first survey for the occurrence of GNS on the Outer Gibber reef system, it is not possible to make any assumptions regarding the species temporal or seasonal occurrences at this site. To determine if this site could be classified as a GNS aggregation site in the future, more monitoring would need to be undertaken in different seasons, and in subsequent years, to determine if their occurrence in 2025 was a one off, or whether this location could be considered an aggregation area.

One important consideration for conducting GNS surveys at the Outer Gibber site is that GNS have been detected at depths greater than 30 m. This poses a challenge for scuba diving operations, as the AS/NZS 2299.1:2007 standard for occupational diving, under which NSW DPIRD operates, does not permit dives beyond 30 m. Although dives to depths of up to 40 m are allowed under the Scientific Diving Code, special permission must first be obtained from the NSW DPIRD Occupational Diving Officer for any dive exceeding 30 m. Additionally, specific equipment requirements apply for these deeper dives, including the mandatory use of a fully redundant ‘bail-out’ air supply.

5.3 Victoria – Gippsland

5.3.1 Introduction

Over the past 10 years there have been several sightings and interactions with GNS in the Gippsland region (e.g., Whitmarsh et al. 2023), particularly in the vicinity of Corner Inlet. These interactions provide support for GNS reestablishing in Victorian waters, most likely on a seasonal basis. In partnership with the Gunaikurnai Land and Water Aboriginal Corporation (GLaWAC), surveys of several promising sites were to be undertaken. These surveys were to primarily provide training opportunities for joint management rangers from GLaWAC in the use of baited remote underwater video systems (BRUVS), Remote Operated Vehicle (ROV), and the collection of environmental DNA (eDNA) enabling future research capability.

Ongoing discussions with other Indigenous groups in Victoria highlighted an interest in similar training opportunities. Discussions with GLaWAC management resulting in informal arrangements for members from the Bunurong Land Council Aboriginal Corporation (BLCAC) and the Eastern Maar Aboriginal Corporation (EMAC) to participate.

Discussions with the Gunditj Mirring Traditional Owners Aboriginal Corporation are ongoing, however, no staff were available for field trips nor for on-Country training.

5.3.2 Methods

The focus region for this project included the Cliffy Islands group and Rabbit Island (Figure 8). Surface features of the islands in this region (large cracks, gutters) and seafloor mapping showing extension of these features (Kennedy et al. 2014) suggested possible GNS habitat below. However, to efficiently use the available time and resources, preliminary subsurface surveys using the ROV were undertaken with an aim to identify the most promising subsurface features.

The team also distributed a flyer (Appendix D), requesting information on sightings of GNS, to recreational fishing groups, Fisheries officers and the general public in the Gippsland region.

Remotely Operated Vehicle (ROV)

A BlueRobotics Remotely Operated Vehicle (ROV: https://bluerobotics.com) was used to conduct underwater visual surveys of the rocky reefs around the Rabbit and Cliffy Island group. The BlueRobotics ROV is a small, battery powered, ROV with a DJI Osmo action camera attached to the front. The ROV was hand deployed at the start of each transect and piloted to approximately 1 m above the seafloor at the interface of soft sediment and rocky reef. The ROV was then flown at speed of 0.5 $m \cdot s^{-1}$ following the line of reef around the island in a near direct line. When a gutter, crack or indentation in the reef was observed the ROV was flown in and out of the feature at the same speed. At Rabbit Island the transects were broken into 200 m sections circumnavigating the island. Transects in the Cliffy Island group were haphazard selecting locations with favourable above water habitat. Where possible island circumnavigation was attempted but not achieved when strong (>20 kn) westerly winds made conditions unworkable. GPS tracks were recorded using a Garmin GPS onboard the vessel.

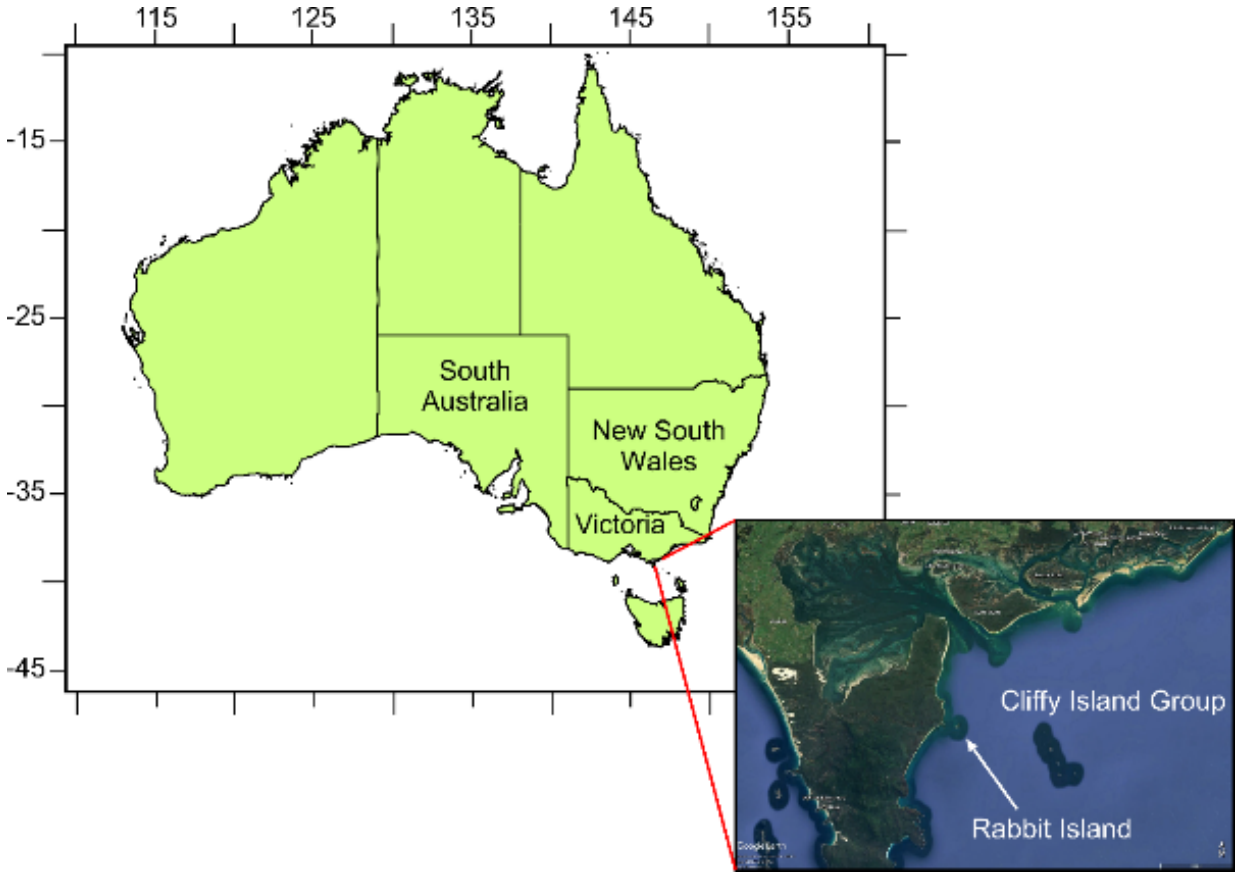


Figure 8. Location of Rabbit Island and the Cliffy Island Group, Gippsland Victoria, where field surveys with Indigenous rangers were conducted aimed at detecting the presence of grey nurse shark (*Carcharias taurus*).

Stereo Baited Remote Underwater Video Systems (BRUVS)

Stereo Baited Remote Underwater Video Systems (Stereo-BRUVS) were deployed in December 2024 out of Port Albert, Victoria at the Rabbit and Cliffy Island group. Two GoPro Hero 7s were used for each stereo BRUVS with cameras set 0.8 m apart. A bait arm with a mesh bag containing ~ 1 kg of crushed pilchards (*Sardinops sagax*) was placed 1.2 m in front of the cameras. BRUVS were deployed in the morning hours in depths between 6 and 25 m. BRUVS were manually lowered to the seabed with rope and a surface buoy.

BRUVS were annotated by two independent readers using EventMeasure (www.seagis.com v.6.46). Annotators marked the arrival time and presence of each species that entered the field of view throughout the video. The maximum number of individuals of the same species in each frame (MaxN) was noted.

Environmental DNA (eDNA)

Sampling for eDNA took place over three days (3-5 December 2024) across three sites: Rabbit Island, and Seal Island and Notch Island (within the Cliffy Island group), Victoria (Figure 8). Sampling was conducted concurrent with BRUVS sampling, with specific sites at both Seal and Notch Island being sampled at two time points; Rabbit Island was sampled once.

Environmental DNA (eDNA) samples were collected using a Smith-Root eDNA backpack filtration system using 3 µM MCE filter papers, aiming for 5 L of sea water sampled per replicate. All eDNA sampling equipment was cleaned with 10% bleach prior to each day of sampling. Five replicate filter paper samples were collected at each site which took around one hour of sampling time per site. A blank filter paper control sample was collected at each site and sample occurrence to detect any background field DNA around the small boat. Filter papers were preserved in Longmire's preservative (Longmire 1992) and stored at ambient temperature for transport to Hobart.

Samples were processed within 30 days of sample collection and DNA was extracted following the Edmund and Burrows (2020), "Preserve, Precipitate, Lyse, Precipitate, Purify" (PPLPP) workflow. DNA was eluted in 100 µl of 1x TE buffer. The PPLPP DNA extracts were cleaned up with an extra Qiagen DNeasy PowerClean Pro kit protocol to remove any PCR inhibitors prior to amplification. DNA concentrations were checked using a qubit fluorometer and DNA yield ranged between 70 ng/µl to 200 ng/µl in 100 µl. Laboratory blank controls were included in the DNA extract process to detect any laboratory contamination through the sample processing. All laboratory blanks were too low to detect DNA using the qubit process.

A metabarcoding approach was taken for the initial eDNA scoping study allowing for broad taxa community analysis in the absence of a single-species qPCR assay. The ability to detect a species without the risk of amplifying a related species is optimised with a species-specific qPCR assay. Unfortunately, at the planning stages, this approach was not available for GNS and due to project time constraints was not feasible to develop and validate. Metabarcoding involves amplifying a fragment of DNA gene region informative of a whole taxonomic group. For a metabarcoding approach, the DNA is sequenced across a sequencing platform such as the Illumina NextSeq High throughput sequencer. Metabarcoding will detect a broad range of species, including GNS, by matching eDNA sequence data to publicly available taxonomy sequences. Grey nurse shark sequences for mitochondrial 12S (mt12S) and mitochondrial 16S (mt16S) were present in the National Centre for Biotechnology Information (NCBI) Genbank online databases (https://www.ncbi.nlm.nih.gov/).

Two PCR assays were selected for amplifying the collected eDNA and detecting coastal shark and fish species from the sampling sites. The eDNA assays selected were mt12S Elas 02 (Taberlet 2018) for detecting broad elasmobranch species and mt16S (Berry et al. 2017) for sequencing broad fish taxa. Sequencing was undertaken by eDNA Frontiers at Curtin University, WA.

Sequenced data were processed using a custom pipeline (Greenfield Hybrid Amplicon Pipeline (GHAP) (Greenfield, 2017), which applies USEARCH bioinformatics tools V11 (Edgar, 2010, 2013). The eDNA Amplicon Sequence Variant (ASV) data was summarised into an ASV table for downstream analysis. The data were transformed to eDNA occurrence, and the taxonomic matches were screened against the reference databases from Genbank to confirm taxonomic assignments. The acceptable pairwise identity match to assign ASVs from the 12S libraries to the taxonomic level was: Species: >98% match; Genus:<98%->95%; and Family: >86.5% and was applied based on acceptable criteria applied by Wang et al. (2023). The taxonomic matches were also checked against the Fishes of Australia geographical ranges and were reality checked by the project team (R. Bradford, S. Sherman and S. Stephenson).

5.3.3 Results

Training

Project planning meetings with GLaWAC were conducted both on-Country and via video. Training sessions involved land-based orientation sessions with the equipment to be used for the field surveys. The first of these was in June 2024 with an office-based demonstration of BRUVS and eDNA technology, followed by hands-on use of the equipment at Lake Tyers (Figures 9 & 10). These technologies were to be the primary means of surveying for GNS in late spring/early summer when GNS are more likely to be present.

Figure 9. Orientation with Baited Remote Underwater Video Systems (BRUVS) operations at Lake Tyers with collaborators from Gunaikurnai Land and Water Aboriginal Corporation.

Figure 10. Orientation with environmental DNA (eDNA) operations at Lake Tyers with collaborators from Gunaikurnai Land and Water Aboriginal Corporation.

Training in the use of the ROV as well as the survey were completed in August 2024. Joint Management Rangers from GLaWAC and rangers from EMAC participated (Figure 11).

Fieldwork

Remote Operated Vehicle (ROV)

A total of 13 ROV transects (Table 4) were completed in the Rabbit Island and Cliffy Island group to survey reef structure and habitat for suitability for GNS aggregation sites (see Appendix E for ROV transect pathways).

Table 4. Remotely Operated Vehicle metadata for deployments at Notch, Seal, Rag, and Rabbit Island off Corner Inlet, Victoria with transect start and end coordinates.

Location	Date	Latitude (S) start	Longitude (E) start	Latitude (S) end	Longitude (E) End
Rabbit Island-1	08/08/2024	38.907769	146.512609	38.909332	146.514546
Rabbit Island-2	08/08/2024	38.909293	146.514165	38.910958	146.514069
Rabbit Island-3	08/08/2024	38.911031	146.514070	38.911863	146.514602
Rabbit Island-4	08/08/2024	38.911882	146.514822	38.913292	146.513433
Rabbit Island-5	08/08/2024	38.913414	146.513604	38.914130	146.510934
Rabbit Island-6	08/08/2024	38.914168	146.510443	38.914758	146.507885
Rabbit Island-7	08/08/2024	38.914653	146.507525	38.912996	146.505868
Cliffy Island	09/08/2024	38.948818	146.706789	38.951373	146.707030
Cliffy Island	09/08/2024	38.951695	146.707561	38.952090	146.705317
Rag Island	09/08/2024	38.953796	146.683752	38.955156	146.683213
Rag Island	09/08/2024	38.955510	146.682652	38.955694	146.681871
Notch Island	09/08/2024	38.941150	146.677842	38.943619	146.677399
Seal Island	09/08/2024	38.927237	146.660676	38.927364	146.658870

In summary the majority of seabed surrounding these island groups is shallow, low relief, sloping reef dominated by kelp and algae. The most notable reef that appeared most similar in structure to GNS habitat found in NSW was recorded on the eastern side of Notch Island and the southwest corner of Seal Island. These reef features included gutters or walls to a depth of approx. 8 m.

Figure 11. Indigenous rangers operating the ROV at sites around Rabbit Island, Victoria.

Rabbit Island

The Rabbit Island coast was surveyed from the north-east corner, along the southern edge to the southwest corner, travelling in a southerly or westerly direction. The reef was mostly mid to low relief and gentle sloping reef dominated by kelp and algae. The maximum depth reached was 12 m with the average depth of reef approx. 5 m. The two obvious large indents or gutters seen from land were very shallow and narrow underwater. Large numbers of ornate cowfish (*Aracana ornata*) and herring cale (*Olisthops cyanomelas*) were observed. Other species included leatherjackets (Monocanthids), dusky morwong (*Dactylophora nigricans*), and old wives (*Enoplosus armatus*). There were no obvious gutters or reef formations that replicate those found at NSW GNS aggregation sites. The northwest side of the island is mainly shallow sand.

Cliffy Island

Despite Cliffy Island having dramatic and high cliffs, the underwater reef system consisted of shallow and gentle sloping reef. The maximum depth was 13 m with an average of approx. 5 m. The reef was also dominated by kelp and algae. There were no notable gutters or walls. The western side of the island could not be sampled due to the unfavourable westerly winds.

Rag Island

The Rag Island ROV transects started on the northern side investigating a large indentation in the island. The reefs around this indentation were more high relief with large boulders and narrows cracks or gutters. A large seal colony inhabits these reefs and were recorded on the ROV. The eastern tip of the island is low sloping relief reef. The second transect at Rag Island investigated the large gap that splits the island in two. The western side of the gap consists of a high relief wall to approx. 5 m depth. The eastern side of the reef was more gentle sloping reef.

Notch Island

One ROV transect was completed around the southeast corner of Notch Island. The first half of the transect followed a high relief reef drop off from the island. Approximately 200 m into the transect there was a large, submerged reef that formed a long gutter between the reef and island with a maximum depth of 8 m. This reef was considered most similar to GNS habitat encountered at aggregation sites in NSW. The second half of the transect followed low relief sloping reef dominated by kelp and algae. The western side of the island could not be sampled due to unfavourable wind conditions.

Seal Island

The southwest corner of Seal Island was surveyed with the ROV. There were a number of large gutters north to south with high relief walls of reef. This transect showed the most likely habitat within the region that is similar to the NSW GNS aggregation sites.

Baited Remote Underwater Video Systems

Field surveys using the BRUVS and eDNA sampling equipment were scheduled for December 2024 when it was hypothesised that GNS were more likely to be in the region. Three days of surveying (3-5 Dec 2024) were conducted at a variety of sites around Rabbit Island and the Cliffy Islands group (Table 5).

Table 5. Metadata for BRUVS deployments at Notch, Seal, Rag, and Rabbit Island off Corner Inlet, Victoria. Five replicate eDNA samples were collected at each BRUVS deployment.

Location	Date	BRUVS ID	Depth (m) (BRUVS)	Time In (BRUVS)	Latitude (S)	Longitude (E)
Seal Island (1)	03/12/24	GNS-001	10.0	7:58	38.92741	146.66049
Notch Island (1)	03/12/24	GNS-002	9.4	8:42	38.94094	146.67471
Rag Island (1)	03/12/24	GNS-003	18.0	9:11	38.95553	146.68250
Rag Island (2)	03/12/24	GNS-004	11.0	9:31	38.95509	146.68359
Seal Island (2)	04/12/24	GNS-005	17.3	8:29	38.92081	146.66171
Notch Island (2)	04/12/24	GNS-006	17.8	9:02	38.94035	146.67885
Rag Island (3)	04/12/24	GNS-007	25.0	9:19	38.95266	146.68233
Rag Island (4)	04/12/24	GNS-008	17.9	9:31	38.95332	146.68425
Rabbit Island (1)	05/12/24	GNS-009	10.2	8:16	38.91100	146.51428
Rabbit Island (2)	05/12/24	GNS-010	6.0	8:31	38.91420	146.51006
Rabbit Island (3)	05/12/24	GNS-011	7.0	8:45	38.91267	146.50406
Rabbit Island (4)	05/12/24	GNS-012	10.0	9:00	38.90823	146.51367

Twelve BRUVS were deployed across the four islands. One BRUVS landed facing the surface and was not used for annotation but still captured imagery of fish assemblages. The footage included 499 unique fish identified from 59 species, 52 genera, and 40 families. Seven different shark and ray species were observed, though no GNS were observed (Table 6). Sharks and/or rays were observed on nine of the eleven BRUVS. Multiple species were in view at the same time with four shark and ray species observed in the same frame in GNS_011 (Port Jackson Shark, Gummy Shark, Southern Eagle Ray, and Fiddler Ray).

As expected, the most abundant species were not sharks or rays, but teleost fish. Cumulatively across all BRUVS deployments, there were four species with total counts of more than 20 individuals. These included, 39 Blue-throated Wrasse (*Notolabrus tetricus*), 25 Barber Perch (*Caesioperca rasor*), 23 Sea Sweep (*Scorpis aequipinnis*), and 23 Silver Sweep (*Scorpis lineolata*).

Table 6. Shark and ray species observed on the BRUVS deployments at Notch, Seal, Rag, and Rabbit Island off Corner Inlet, Victoria.

Species	Latin Name	Number of BRUVS Present	Total Individuals (Sum of MaxN)
Short-tail Stingray	*Bathytoshia brevicaudata*	3	3
Australian Swellshark	*Cephaloscyllium laticeps*	3	3
Port Jackson Shark	*Heterodontus portusjacksoni*	4	6
Gummy Shark	*Mustelus antarcticus*	2	2
Southern Eagle Ray	*Myliobatis tenuicaudatus*	3	7
Fiddler Ray	*Trygonorrhina spp.*	2	4
Unknown Skate	*Rajidae*	1	1

Environmental DNA (eDNA)

From the mitochondrial 12S and 16S eDNA metabarcoding results, no DNA sequences for GNS were detected at any of the sites during the sampling period in December 2024 using this method.

Krona plots (Ondov et al. 2011) are used to display and compare the taxonomy identified at each site in the eDNA metabarcoding results (Figure 12). The Krona plot is a hybrid of traditional pie charts and taxonomic tree maps and illustrate all taxonomic levels based on the NCBI taxonomy.

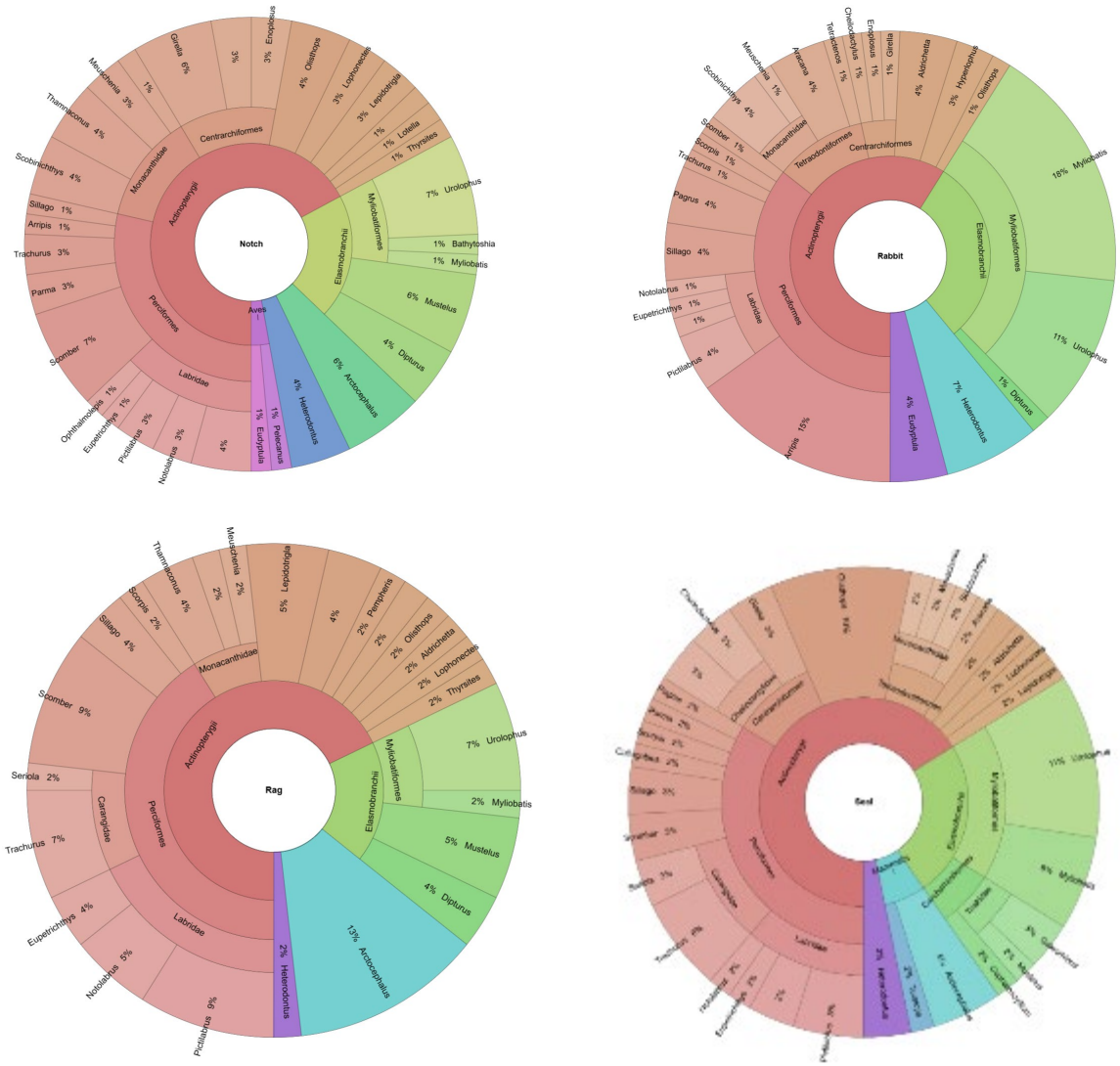


Figure 12. Krona plots of taxonomy identified in eDNA samples from the four sites off Corner Inlet, Victoria.

A wide range of taxa including fish, shark/rays, and mammals were detected at the sampled sites (Figure 13). The sites with greatest taxonomic richness (S) from the eDNA analysis included Notch (S = 30) and Seal Islands (S = 32) while the Rabbit site (S = 24) showed lowest taxonomic richness of all sites (Figure 14). Elasmobranch taxa which were detected and confidently assigned to species (>98% sequence match) included *Mustelus antarcticus* (gummy Shark), *Galeorhinus galeus* (school shark), *Heterodontus spp.* (likely Port Jackson Shark), *Cephaloscyllium laticeps* (Draughtboard Shark), *Bathytoshia brevicaudata*. The Elasmobranch taxa detected from the eDNA sequence data that were assigned to Genus level included *Myliobatis*, *Urolophus* and *Dipturus*. The most common Elasmobranchs across the sites were *Urolophus*, *Myliobatis* and *Heterodontus*. DNA from these taxa were detected at all the sites sampled in December 2024.

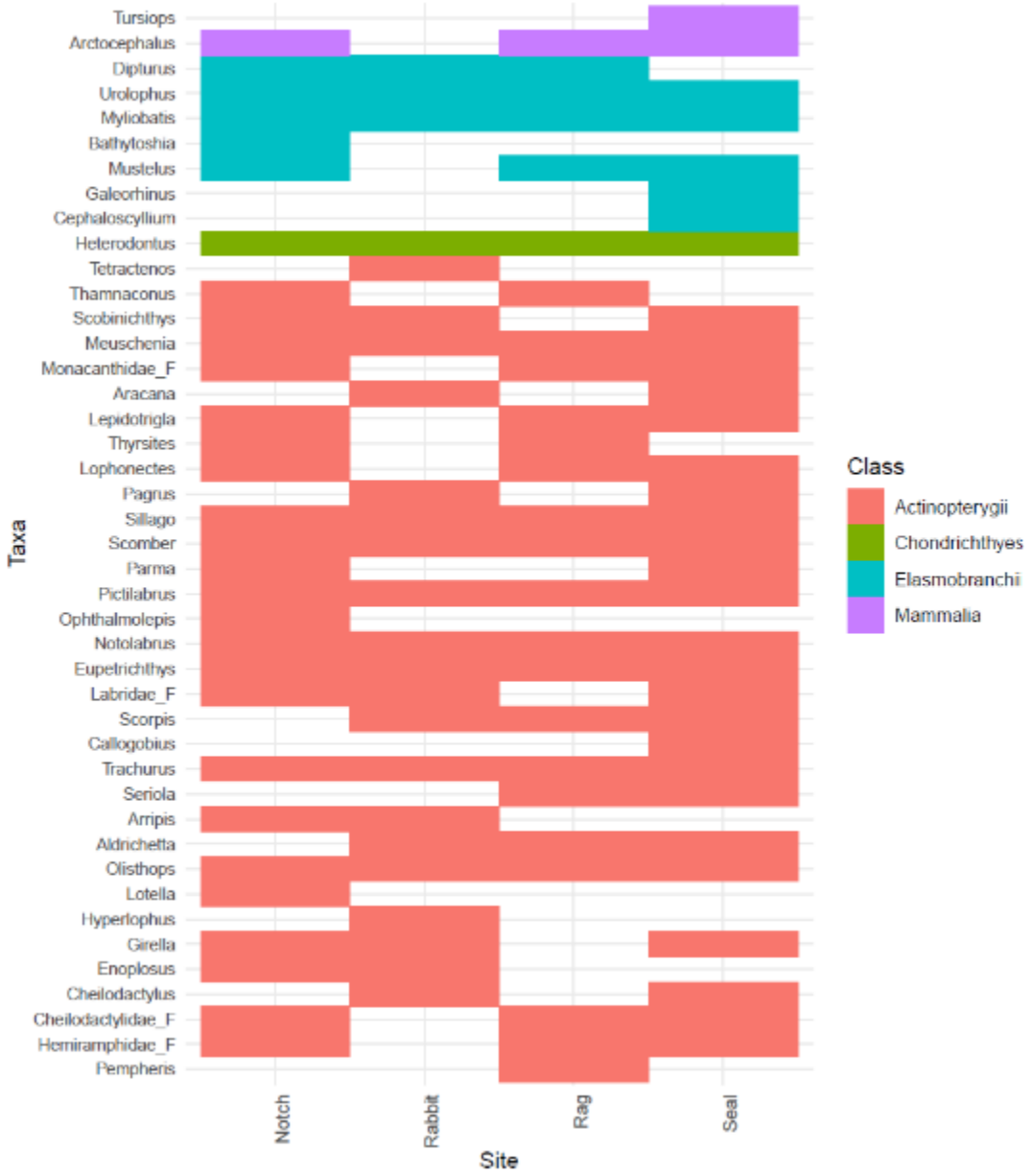


Figure 13. Taxonomic range detected in eDNA samples from Notch Island, Rabbit Island, Rag Island, and Seal Island off Corner Inlet, Victoria.

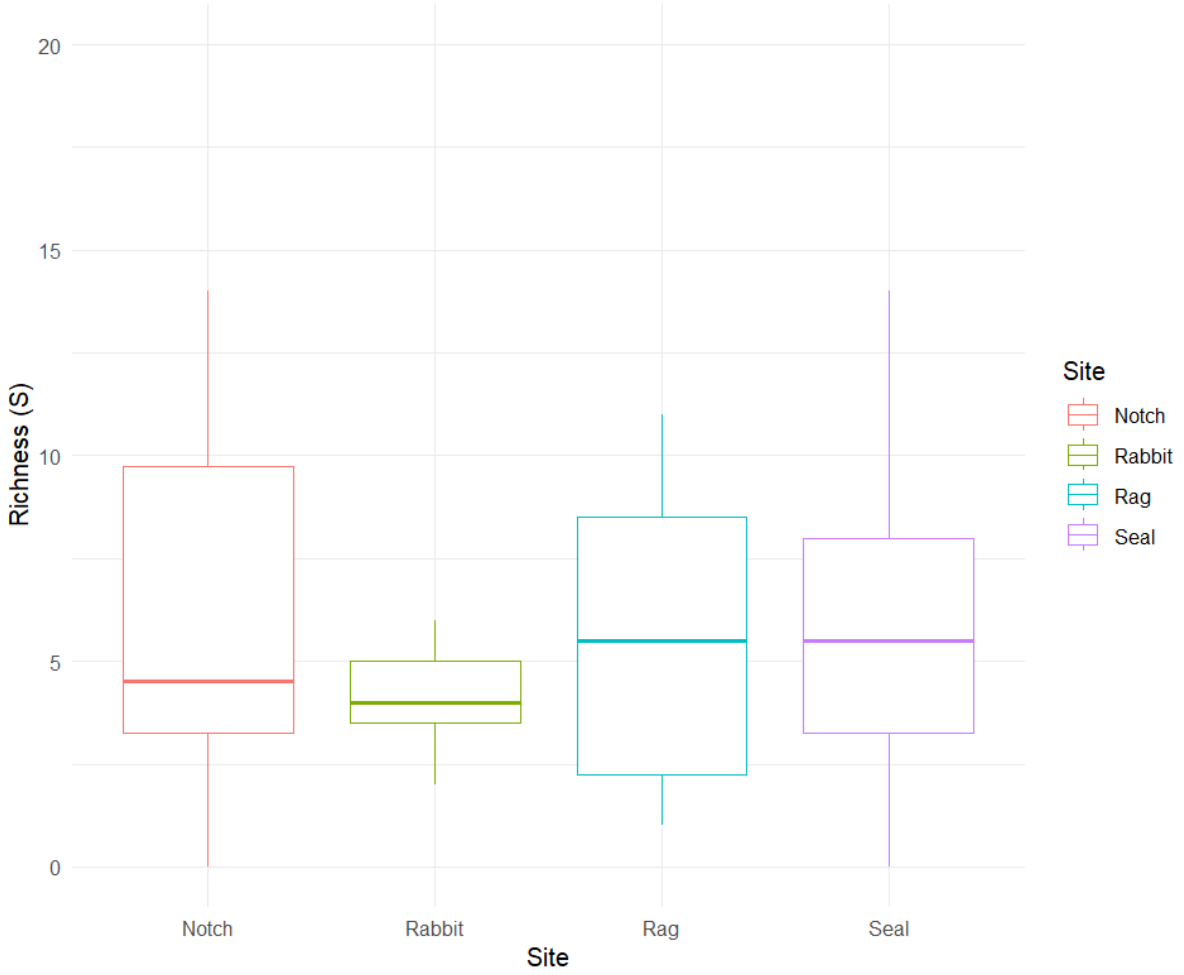


Figure 14. Taxa richness (S) detected in eDNA samples from Notch Island, Rabbit Island, Rag Island, and Seal Island off Corner Inlet, Victoria. The boxplots show median and quantiles of richness data for the survey sites, including the range of data from the sampling replicates and sampling time points.

5.3.4 Discussion

Training

Surveys of the islands off Gippsland allowed the opportunity to provide hands-on training to Indigenous rangers in the use of a variety of survey tools. Initially, training was only to be provided to rangers from GLaWAC. However, discussions with two other Indigenous organisations in Victoria, and through agreement with GLaWAC, resulted in extending the training to rangers from the Bunurong Land Council Aboriginal Corporation (Figure 15) and the Eastern Maar Aboriginal Corporation (Figure 16). Discussions with the Gunditj Mirring Traditional Owners Aboriginal Corporation are ongoing. In order to accommodate and take advantage of the higher-than-expected number of people, we undertook additional field trips to provide on land and on water training.

Figure 15. Members from Bunurong Land Council Aboriginal Corporation.

Figure 16. Members from Eastern Maar Aboriginal Corporation.

Site Surveys (ROV, BRUVS, eDNA)

All three survey approaches failed to identify GNS during surveys of Rabbit Island and the Cliffy Island group. Although disappointing, it was not entirely unexpected due to the limited amount of survey time and infrequent reports of GNS in Victorian waters. The limited search effort was insufficient to conclude GNS are not present in the region. The ROV surveys did identify several regions of habitat similar to aggregation sites in NSW that warranted further investigation (southeast corner of Rag Island and southwest corner of Notch Island). Neither eDNA sampling nor BRUVS identified GNS at these sites. Previous catch records indicate the

region between Rabbit Island and the mainland may also provide habitat for GNS; however, the topography of this region is unlike that of the aggregation sites found off NSW. Reports are more frequent from eastern Victoria between Lakes Entrance and Mallacoota. Although logistically more challenging, access to some reefs may be conducted out of Marlo or Mallacoota.

Even though no GNS were observed on the BRUVS deployed, this study shows the suitability of this method to observe shark and ray species in the Gippsland region. A shark or ray was observed on almost all BRUVS deployed and multiple species were observed on five of the eleven BRUVS showing the effectiveness for a variety of species. As all species observed were mesopredators, it is not surprising to see multiple species co-occurring and not exhibiting any negative reactions to the other sharks and rays present. Had there been larger potential predators present (but unobserved) in the area while the BRUVS were deployed, it is likely we would have observed fewer smaller sharks and rays (Sherman et al. 2020).

Despite not detecting GNS using eDNA, this study has provided preliminary data of shark communities at the four sites sampled. This is a positive start towards characterising the communities of these habitats using eDNA. Environmental DNA surveys rely upon isolating small fragments of DNA, with primer sets designed to target gene regions with maximum discriminatory power. That said, detections may be missed owing to primer biases and incomplete reference databases (Clark et al. 2024, Stepien et al. 2023). While GNS reference sequences were confirmed to be present in the reference databases for the genes amplified, DNA sequences for GNS were not detected at the sample sites. The DNA collected for this study can be used for downstream analysis with future eDNA qPCR assays once they have been developed and validated.

One of the aims of this component of the larger project was to provide training to Indigenous Rangers in multiple methods of marine monitoring. Training was highly successful and with the knowledge gained, Indigenous Rangers could extend future surveys across a broader spatial and temporal scale more typical of a scientific study (minimum recommended 20-50 replicates; MacNeil et al. 2020, Weerarathne et al. 2021).

The future ability to reliably detect GNS in eDNA samples from Victorian coastal waters, where expected prevalence is low, would be enhanced using GNS-specific primers. This process requires identification of a conserved area for within-species variability and a variable region for the off-target species sequences.

The first stage of the process to design a GNS-specific qPCR and primer development, the consolidation of NCBI Genbank sequences, screening, and alignment (using Geneious: ver. 2024.05, Biomatters, Auckland, New Zealand), has been completed. The next stage, which is currently underway, is to design suitable primers based on the consensus GNS sequences. In silico and laboratory-based tests are then undertaken to validate the primer candidates before applying the results to the stored eDNA samples.

5.4 Western Australia

5.4.1 Discussion

The Western Australia (WA) subpopulation of GNS, unlike the eastern subpopulation, has never been subject to targeted fishing. Catch and catch rate data from the demersal gillnet fishery that operates between Steep Point and the South Australian border provides the best available information on the potential location of aggregation sites in WA and status of the WA GNS population. These data indicate that GNS were relatively abundant in temperate WA waters in the mid-late 1990s and that the population was stable (Cavanagh et al. 2003). While stable catch rates in WA commercial fisheries were reported prior to its listing as a protected species throughout Australian waters (Cavanagh et al. 2003, Pollard et al. 2003), there is no new information on population trends. Fishing effort, however, has substantially dropped since the historic peaks in the 1980/90s and numerous protected areas have since been implemented in coastal and offshore waters.

Commercial catch records include incidental captures from Shark Bay south and across to the border with South Australia. Recreational fisher, diver and research records extend GNS distribution across the WA continental shelf including offshore and inshore waters from Shark Bay north through to Broome and offshore islands off the northern-most tip of Western Australia (Momigliano & Jaiteh 2015, Hoshke et al. 2023). Genetic analysis of tissue samples (Krause & Stow 2025, Bradford et al. 2025) has confirmed an extension of western Australian GNS distribution into the Timor Sea.

Identification of GNS aggregation sites in Western Australia has been undertaken through analysis of commercial catch information, collation of existing research data including shark tagging, underwater surveys (diver and ROV) and community-based diver surveys (Chidlow et al. 2005, Hoschke et al. 2023). A summary of potential WA GNS aggregation sites from those studies is provided below.

Using both commercial and fishery-independent sources of information, Chidlow et al. (2005) identified a total of 25 potential GNS aggregation sites, with 16 of those sites considered suitable for diver survey (Table 7) and nine for ROV survey (Table 8). Following a dedicated field program to record sharks at these sites the authors identified and ranked those potential aggregation sites in water depths between 2 and 200 m (see Tables 7 and 8).

In summary, Chidlow et al. (2005) concluded that GNS in Western Australia may not:

- aggregate to the same degree as in eastern Australia,
- aggregate in depths or areas suitable for recreational SCUBA diving,
- aggregate with sufficient regularity in locations frequented by recreational divers.

In support of western Australian GNS potentially aggregating in deeper regions, Langlois et al. (2021) observed a group of five GNS at a depth of approx. 140 m within the South-West Corner Marine Park. Further exploration of this region would be required to determine if the site is used on a recurrent basis.

Table 7. Potential grey nurse aggregation sites identified in Chidlow et al. (2005) as suitable for surveys using SCUBA. Ranking 1 = Low, 2 = Medium, 3 = High. [reproduced from Chidlow et al. 2005]

Site	Location	Depth (m)	Source	Comments	Ranking
1	28 06 36 S 113 28 12 E (NW of North Island, Houtman Abrolhos)	11-30	Research capture data	Three GNS caught 14/11/1995. One caught 27/08/2003	3
2	30 54 00 S 115 00 36 E (southwest of Wedge Island)	29	Research capture data	Four GNS caught on four different occasions close to this location	3
3	30 55 48 S 115 00 36 E (southwest of Wedge Island)	23-30	Research capture data	(see site 2 above)	3
4	34 18 17.4 S 115 01 22.2 E (Mimms Ledge, south of Cape Hamelin)	5-15	Fisher reports	Site identified by two demersal gillnet fishers where GNS are occasionally caught	2
5	34 13 06.6 S 114 59 27 E (west of Hamelin Bay)	2-15	Fisher reports	(see site 4 above)	2
6	34 19 17.4 S 114 59 38.4 E (Geographe Reef, southwest of Cape Hamelin)	2-15	Fisher reports	(see site 4 above)	2
7	31 41 24 S 115 37 48 E (Staggie Reef, west of Quinns Rock)	27	Research capture data and fisher reports	One GNS caught on 11/7/1996, and one fisher capture	2
8	31 44 42 S 115 38 24 E (northwest of Three Mile Reef)	27	Research capture data	Two GNS caught on 10/07/1996, and one caught on 25/02/1997	3
9	31 39 42 S 115 28 12 E (west of Quinns Rock)	29	Research capture data and fisher reports	One GNS caught on 13/06/1996 and one fisher capture	2
10	32 05 24 S 115 27 36 E (south of Rottnest Island)	26	Research capture data	One GNS caught on 22/03/1995, and two nearby on 13/05/1996 and 15/02/2003	2
11	32 01 48 S 115 25 48 E (West Patch, west of Rottnest Island)	20-30	Research capture data and diver reports	One GNS caught on 16/09/1994 and three separate reports of sightings from divers	3
12	32 25 12 S 115 19 48 E (west of Singleton Beach)	27-30	Research capture data	One GNS caught on 09/03/1995 and one nearby on 04/03/2002	2
13	21 41 24 S 114 17 24 E (south of Muiron Island)	8-15	Diver reports	GNS sighted occasionally by two dive companies operating in this area	2
14	25 29 24 S 112 57 00 E (north of Dirk Hartog Island, St Madelina wreck)	22	Diver reports	GNS regularly sighted by dive operator	3
15	31 10 1.2 S 115 11 24 E (southwest of Ledge Point)	30	Research capture data	Four GNS caught on 04/04/2002	3
16	31 09 00 S 115 16 12 E (southwest of Ledge Point)	30	Research capture data	Two GNS caught on 16/06/2003	2

The Exmouth Navy Pier on WA's North West Cape was the first confirmed GNS aggregation site in WA (Hoschke & Whisson 2016). Compilation of further available information on GNS in WA by Hoschke et al. (2023) provided an assessment of additional potential aggregation sites including indicators of seasonal occurrence. The following is a summary of the information provided in that study which utilised community monitoring data from recreational divers and bycatch data for GNS caught as bycatch in the Temperate Demersal Gillnet and Demersal Longline Fishery (TDGDLF) for the period 2006 to 2017.

Community monitoring data compiled in Hoschke et al. (2023) resulted in four potentially new GNS aggregation sites (Table 9) being identified between Rottnest and Lancelin on the south-west coast of Western Australia. These are the 'Shark Cave' located in the West End Demersal Sanctuary Zone of the Rottnest Island Marine Park; 'Opera House' located 5 km northeast of Rottnest Island; 'Direction Bank', which is a series of caves approximately 30 km west-south-west of Two Rocks; and 'Key Biscayne', a jack-up oil rig platform that sank in 1983 20 km southwest of Lancelin.

Table 8. Potential grey nurse aggregation sites identified in Chidlow et al. (2005) as suitable for surveys using ROV. Ranking 1 = Low, 2 = Medium, 3 = High. [reproduced from Chidlow et al. 2005]

Site	Location	Depth (m)	Source	Comments	Ranking
1	32 03 23.7 S 115 22 47.3 E (wreck southwest of Rottnest Island)	80-90	Research capture data and diver reports	Occasional sightings of GNS by divers and capture of GNS nearby	2
2	31 53 24 S 115 19 48 E (northwest of Rottnest Island)	80-100	Research capture data	One GNS caught on 15/11/2000, one on 10/12/2002, and one nearby on 12/12/2002	2
3	30 39 00 S 115 00 00 E 30 43 12 S 115 01 48 E (west of Green Island)	38	Research capture data	Three GNS caught in this area on 10/04/2001, and two caught on 30/04/2001	3
4	31 36 36 S 115 24 00 E (southwest of Two Rocks)	37	Research capture data	Two GNS caught on 02/05/1996, and two nearby on 20/03/1997	2
5	33 01 11.4 S 114 56 11.4 E (northwest of Naturaliste Reef)	44-50	Research capture data and fisher reports	One GNS caught on 22/03/1997, and one fisher capture in this area	2
6	30 20 13.8 S 114 54 19.2 E (west of Jurien Bay)	40-45	Fisher reports	Fourteen GNS caught in one day in this area by fisher	3
7	21 36 07.2 S 114 14 33 E (northwest of South Muiron Island)	50-100	Research capture data and fisher reports	Two GNS caught on 07/11/2001, one on 12/12/2002, and occasional captures by fishers in this area	3
8	21 43 27.6 S 114 01 28.2 E (west of North West Cape)	100	Research capture data	One GNS caught on 13/11/2001, also noted to be suitable GNS habitat	1
9	21 45 19.8 S 113 53 35.4 E (west of North West Cape)	200	Research capture data	One GNS caught on 09/06/2002, also noted to be suitable GNS habitat	1

Table 9. Four potentially new grey nurse shark aggregation sites as identified in Hoschke et al. (2023). [Reproduced from Hoschke et al. (2023)].

Site	Location	Depth (m)	Status
Shark Cave, Rottnest Island	Southwestern Australia	20-25	Closed to recreational fishing (within a demersal fishing closure). Closed to commercial fishing (within closed waters of the West Coast Demersal Gillnet and Demersal Longline Fishery).
Opera House, Rottnest Island	Southwestern Australia	25-30	Open to recreational fishing. Closed to commercial fishing (within closed waters of the West Coast Demersal Gillnet and Demersal Longline Fishery).
Direction Bank, off Two Rocks	Southwestern Australia	30-40	Open to recreational fishing. Closed to commercial fishing (within closed waters of the West Coast Demersal Gillnet and Demersal Longline Fishery).
Key Biscayne Wreck, off Lancelin	Southwestern Australia	25-40	Open to recreational fishing. Closed to commercial fishing (within closed waters of the West Coast Demersal Gillnet and Demersal Longline Fishery).

6. References

Bansemer, C. S. (2009). Population biology, distribution, movement patterns and conservation requirements of the grey nurse shark (*Carcharias taurus*: Rafinesque 1810) along the east coast of Australia. University of Queensland. St Lucia, Queensland, Australia. 143 pp. [espace.library.uq.edu.au/view/UQ:184453]

Bansemer, C. S., Bennett, M. B. (2009). Reproductive periodicity, localised movements and behavioural segregation of pregnant *Carcharias taurus* at Wolf Rock, southeast Queensland, Australia. *Marine Ecology Progress Series* **374**: 215-227. DOI: 10.3354/MEPS07741

Berry, T. E., Osterrieder, S. K., Murray, D. C., Coghlan, M. L., Richardson, A. J., Grealy, A. K., Stat, M., Bejder, L., Bunce, M. (2017). DNA metabarcoding for diet analysis and biodiversity: A case study using the endangered Australian sea lion (*Neophoca cinerea*). Ecology and Evolution **7**(14): 5435-5453. DOI: 10.1002/ece3.3123

Bradford, R.W., Harasti, D., Westlake, E. L., Thomson, R., Feutry, Baylis, S., P., Mayne, B., Anderson, C., Hillary, R., Gunasekera, R., Butcher, P., Louden, B., Gallen, C., Patterson, T.A. (2025). NESP2 MaC Hub Project 3.13: Eastern grey nurse shark, *Carcharias taurus*, population abundance and trend. Report to the National Environmental Science Program. CSIRO Environment, Hobart, Tasmania

Brown, K., Monk, J., Williams, J., Carroll, A., Harasti, D., & Barrett, N. (2022). Depth and benthic habitat influence shallow and mesophotic predatory fishes on a remote, high-latitude coral reef. *PLOS one* **17**(3): e0265067

Chidlow, J., Gaughan, D. and McAuley, R. 2005. Identification of Western Australian Grey Nurse Shark aggregation sites, Final Report to the Australian Government, Department of the Environment and Heritage. ISBN: 0642551952

Chidlow, J., Gaughan, D. and McAuley, R. 2006. Identification of Western Australian Grey Nurse Shark aggregation sites, Final Report to the Australian Government, Department of the Environment and Heritage, Fisheries Research Report No. 155, Department of Fisheries, Western Australia, 48p

Clark, A. J., Atkinson, S. R., Scarponi, V., Cane, T., Geraldi, N. R., Hendy, I. W., Shipway, J. R., Peck, M. (2024). Cost-effort analysis of Baited Remote Underwater Video (BRUV) and environmental DNA (eDNA) in monitoring marine ecological communities. *PeerJ* **12**: e17091. DOI: 10.7717/peerj.17091

ConocoPhillips (2018). Barossa Area Development Offshore Project Proposal. ConocoPhillips document number: BAA-00-EN-RPT-00001 Revision 5, March 2018 [https://www.nopsema.gov.au/sites/default/files/documents/2021-03/A598152.pdf, accessed 13/06/2025]

Compagno, L. J. V. (2001). Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Volume 2. Bullhead, mackerel and carpet sharks

(Heterodontiformes, Lamniformes and Orectolobiformes). FAO Species Catalogue for Fishery Purposes. No. 1, Vol. 2. Rome, FAO. 2001. 269pp

DoE (2014a). Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*). Australian Government Department of the Environment, Canberra. 48 pp [environment.gov.au/resource/recovery-plan-grey-nurse-shark-carcharias-taurus]

DoE (2014b). Issues Paper for the Grey Nurse Shark (*Carcharias taurus*). Australian Government Department of the Environment, Canberra. 48 pp [environment.gov.au/resource/recovery-plan-grey-nurse-shark-carcharias-taurus]

Dwyer, R. G., Rathbone, M., Foote, D. L., Bennett, M., Butcher, P. A., Otway, N. M., Louden, B. M., Jaine, F. R., Franklin, C. E., Kilpatrick, C. (2023). Marine reserve use by a migratory coastal shark, *Carcharias taurus*. *Biological Conservation* **283**: 110099. DOI: 10.1016/j.biocon.2023.110099

Edgar, R. C. (2010). Search and clustering orders of magnitude faster than BLAST. Bioinformatics, 26(19), 2460-2461. https://doi.org/10.1093/bioinformatics/btq461

Edgar, R. C. (2013). UPARSE: highly accurate OTU sequences from microbial amplicon reads. Nature Methods, 10(10), 996-998. https://doi.org/10.1038/nmeth.2604

Edmunds, R. C. and D. Burrows (2020). Got Glycogen?: Development and Multispecies Validation of the Novel Preserve, Precipitate, Lyse, Precipitate, Purify (PPLPP) Workflow for Environmental DNA Extraction from Longmire's Preserved Water Samples. *Journal of Biomolecular Technology* **31**(4): 125-150. DOI: 10.7171/jbt.20-3104-003

Flukes, E., (2024). Multi-resolution bathymetry composite surface for Australian waters (EEZ). Institute for Marine and Antarctic Studies (IMAS). [https://metadata.imas.utas.edu.au/geonetwork/srv/eng/catalog.search#/metadata/69e9ac91-babe-47ed-8c37-0ef08f29338a, accessed 23/06/2025]

Fouche, Q., Charabidze, D., Lihoreau, M. (2019). Aggregation. In: Vonk, J., Shackelford, T. (eds) Encyclopedia of Animal Cognition and Behavior. Springer, Cham. DOI: 10.1007/978-3-319-47829-6_681-1

Greenfield, P. (2017). Greenfield Hybrid Analysis Pipeline (GHAP). In (Version v1) Commonwealth Scientific and Industrial Research Organisation. https://doi.org/10.4225/08/59f98560eba25, https://researchdata.edu.au/greenfield-hybrid-analysis-pipeline-ghap

Harasti, D. & Malcolm, H. (2013). Distribution, relative abundance and size composition of the threatened serranid *Epinephelus daemelii* in New South Wales, Australia. *Journal of Fish Biology* **83**: 378-395

Harasti, D., Davis, T., Jordan, A., Moltschaniwskyj, N. and Erskine, L. (2019) Illegal recreational fishing causes a decline in a fishery targeted species (Snapper: *Chrysophrys auratus*)

within a remote no-take marine protected area. *PLOS One* **14**(1): e0209926. DOI: 10.1371/journal.pone.0209926

Harasti, D., Lee, KA., Laird, R., Bradford, R. and Bruce., B. (2016). Use of baited remote underwater video systems (BRUVs) to estimate relative abundance and size of juvenile white sharks *Carcharodon carcharias*. *Marine and Freshwater Research* **68**(7): 1391-1396. DOI: 10.1071/MF16184

Heupel, M. R., Carlson, J. K., Simpfendorfer, C. A. (2007). Shark nursery areas: concepts, definition, characterization, and assumptions. *Marine Ecology Progress Series* **337**: 287-297. DOI: 10.3354/meps337287

Hoschke, A. M., Whisson, G. J. (2016). First aggregation of grey nurse sharks (*Carcharias taurus*) confirmed in Western Australia. *Marine Biodiversity Records* **9**: 17. DOI: 10.1186/s41200-016-0012-y.

Hoschke, A. M., Whisson, G. J., Haulsee, D. (2023). Population distribution, aggregation sites and seasonal occurrence of Australia's western population of the grey nurse shark *Carcharias taurus*. *Endangered Species Research* **50**: 107-123. DOI: 10.3354/esr01225

Hyde, C. A., Notarbartolo di Sciara, G., Sorrentino, …, Jabado, R. W. (2022). Putting sharks on the map: a global standard for improving shark area-based conservation. *Frontiers in Marine Science* **9**: 968853. DOI: 10.3389/fmars.2022.968853

Jacobs, S., Braccini, M. (2019). Acoustic and conventional tagging support the growth patterns of grey nurse sharks and reveal their large-scale displacements in the west coast of Australia. *Marine Biology* **166**, 150. DOI: 10.1007/s00227-019-3594-1

Kennedy, D. M., Ierodiaconou, D., Schimel, A. (2014). Granitic coastal geomorphology: applying integrated terrestrial and bathymetric LiDAR with multibeam sonar to examine coastal landscape evolution. *Earth Surface Processes and Landforms* **39**: 1663-1674. DOI: 10.1002/esp.3615

Knott, N. A., Rees, M. J., Davis, T. R., Harasti, D., Malcom, H. A., Taylor, M. D., Curley, B., Barrett, N. S., Stuart-Smith, R. D., Edgar, G. J., and Przeslawski, R. (2025). Trends in Eastern Blue Groper (*Achoerodus viridis*) abundance along south-eastern Australia (New South Wales): the influence of latitude, climate change and potential depth refuges. *Marine and Freshwater Research* **76**: MF24130. DOI: 10.1071/MF24130

Knott, N. A., Williams, J., Harasti, D., Malcolm, H. A., Coleman, M. A., Kelaher, B. P., Rees, M. J., Schultz, A., Jordan, A. (2021). A coherent, representative, and bioregional marine reserve network shows consistent change in rocky reef fish assemblages. *Ecosphere* **12**(4): e03447

Krause, S., Stow, A. (2025). A grey nurse shark from the Northern Territory of Australia shares a mitochondrial haplotype only recorded from the western Australian population. *Marine and Freshwater Research* **76**, MF24162. DOI: 10.1071/MF241

Langlois, T., Goetze, J., Bond, T., …, Harvey, E. S. (2020). A field and video annotation guide for baited remote underwater stereo-video surveys of demersal fish assemblages. *Methods in Ecology and Evolution* **11**: 1401-1409

Langlois, T., Monk, J., Giraldo, A., Gibbons, B., Adams, K., Barrett, N., Sims, H., Leplastrier, H., Boyd, M., Siwabessy, J., Nichol, S. (2021). South-West Corner Marine Park Post Survey Report. Report to the National Environmental Science Program, Marine Biodiversity Hub. The University of Western Australia. [https://figshare.utas.edu.au/articles/report/South-West_Corner_Marine_Park_Post_Survey_Report/23199935/2/files/40896131.pdf]

Last, P. R., Stevens, J. D. (2009). Sharks and Rays of Australia. Second Edition. CSIRO Division of Fisheries, Hobart. 644 pp. ISBN 978-0-674-03411-2

Longmire, J. L., Gee, G. F., Hardekopf, C. L., Mark, G. A. (1992). Establishing paternity in whooping cranes (*Grus americana*) by DNA Analysis. *The Auk* **109**: 522–529. DOI: 10.1093/auk/109.3.522

López, N. A., McAuley, R. B., van Elden, S., Meeuwig, J. J. (2023). Spatial and temporal characterization of a recurrent scalloped hammerhead shark *Sphyrna lewini* aggregation using drones. *ICES Journal of Marine Science* **80**: 2356-2367. DOI: 10.1093/icesjms/fsad153

MacNeil, M. A., Chapman, D. D., Heupel, M., Simpfendorfer, C. A., Heithaus, M., Meekan, M., ... Cinner, J. E. (2020). Global status and conservation potential of reef sharks. *Nature* **583**(7818): 801-806. DOI: 10.1038/s41586-020-2519-y

Martins, A. P. B., Heupel, M. R., Chin, A., Simpfendorfer, C. A. (2018). Batoid nurseries: definition, use and importance. *Marine Ecology Progress Series* **595**: 253-267. DOI: 10.3354/meps12545

McAuley, R. and Simpfendorfer C. 2003. Catch composition of the Western Australian temperate demersal gillnet and demersal longline fisheries, 1994 to 1999, Fisheries Research Report No. 146, Department of Fisheries, Western Australia, 78 pp

McGlynn, T. P. (2010). How does social behaviour evolve? *Nature Education Knowledge*, **3(10)**:69. [https://www.nature.com/scitable/knowledge/library/how-does-social-behavior-evolve-13260245/, accessed 13/12/2023].

McInturf, A. G., Bowman, J., Schulte, J. M., Newton, K. C., Vigil, B., Honig, M., Pelletier, S., Cox, N., Lester, O., Cantor, M., Chapple, T. K. (2023). A unified paradigm for defining elasmobranch aggregations. *ICES Journal of Marine Science* **80**: 1551-1566. DOI: 10.1093/icesjms/fsad099

Momigliano, P. and Jaiteh, V.F. (2015) First records of the grey nurse shark *Carcharias taurus* (Lamniformes: Odontaspididae) from oceanic coral reefs in the Timor Sea. Marine Biodiversity Records, 8. DOI: 10.1017/S1755267215000354

Monk, J., Williams, J., Barrett, N., Jordan, A., Lucieer, V., Althaus, F., Nichol, S. (2017). Biological and habitat feature descriptions for the continental shelves of Australia's temperate-water marine parks- including collation of existing mapping in all AMPs. Report to the National Environmental Science Programme, Marine Biodiversity Hub. Institute of Marine and Antarctic Studies, University of Tasmania.

Ondov, B. D., Bergman, N. H., Phillippy, A. M. (2011). Interactive metagenomic visualization in a web browser. *BMC Bioinformatics* **12**: 385. [http://www.Biomedcentral.com/1471-2105/12/385, accessed 26/05/2025]

Otway, N. M., Burke, A. L. (2004). Mark-recapture population estimate and movements of grey nurse sharks. New South Wales Fisheries Final Report Series No.63. NSW Fisheries Office of Conservation, Nelson Bay, NSW. 63 pp.

Otway, N. M., Burke, A. L., Morrison, N. S., Parker, P. C. (2003). Monitoring and identification of New South Wales critical habitat sites for conservation of grey nurse sharks. New South Wales Fisheries Final Report Series No. 47. New South Wales Fisheries Office of Conservation, Nelson Bay, New South Wales, 62 pp.

Otway, N. M., Ellis, M. T. (2011). Pop-up archival satellite tagging of *Carcharias taurus*: movements and depth/temperature-related use of SE Australian waters. *Marine and Freshwater Research* **62(6)**: 607-620

Otway, N.M. and Louden, B.M. (2025). Occupation of aggregation sites and migratory movements of the Grey Nurse Shark (Carcharias taurus) off eastern Australia. NSW Department of Primary Industries and Regional Development. Port Stephens Fisheries Institute. September 2025.

Otway, N. M., Storrie, M. T., Louden, B. M., Gilligan, J. J. (2009). Documentation of depth-related migratory movements, localised movements at critical habitat sites and the effects of scuba diving for the east coast grey nurse shark population. Department of Environment, Water, Heritage and the Arts, Canberra. 88 pp. [webarchive.nla.gov.au/awa/20191112000359/https://www.environment.gov.au/resource/documentation-depth-related-migratory-movements-localised-movements-critical-habitat-sites]

Palacios, M. D., Stewart, J. D., Croll, D. A., Cronin, M. R., Trejo-Ramírez, A., Stevens, G. M. W., Lezama-Ochoa, N., Zilliacus, K. M., González−Armas, R., Notarbartolo di Sciara, G., Galván−Magaña, F. (2023). Manta and devil ray aggregations: conservation challenges and developments in the field. *Frontiers in Marine Science* **10**: 1148234. DOI: 10.3389/fmars.2023.1148234

Papastamatiou, Y. P., Mourier, J., Pouca, V. C. Guttridge, T. L., Jacoby, D. M. P. (2022). Shark and ray social lives: form, function, and ecological significance of associations and grouping. In *Biology of Sharks and Their Relatives*, 3rd edn. Ed. by J. C. Carrier, C. A. Simpfendorfer, M. R. Heithaus, and K. E Yopak. CRC Press, Boca Raton, FL. ISBN 9780367861179.

Pollard, D.A., Lincoln Smith, M. P., Smith, A. K. (1996). The biology and conservation status of the grey nurse shark (*Carcharias taurus* Rafinesque 1810) in New South Wales, Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems* **6**: 1-20

Pollard,D., Smith A. (2009) *Carcharias taurus*. The IUCN Red List of Threatened Species. Version 2014.2. [www.iucnredlist.org]

Roelfsema, C., Bansemer, C., McMahon, K., Joyce, K. (2020): 2003 Habitat Maps derived from Grey Nurse Shark (GNS) Project of Wolf Rock, Double Island Point, Queensland, Australia. [Dataset: https://metadata.imas.utas.edu.au/geonetwork/srv/eng/catalog.search#/metadata/7f6db557-c947-4080-a10d-fa4b3ff0e41e]

Sadovy de Mitcheson, Y., Cornish, A., Domeier, M., Colin, P. L., Russell, M., Lindeman, K. C. (2008). A Global Baseline for Spawning Aggregations of Reef Fishes. *Conservation Biology*, **22**(5): 1233-1244. [https://www.jstor.org/stable/20183518]

Sherman, C. S., Heupel, M. R., Moore, S. K., Chin, A., Simpfendorfer, C. A. (2020). When sharks are away, rays will play: effects of top predator removal in coral reef ecosystems. *Marine Ecology Progress Series* **641**: 145-157. DOI: 10.3354/meps13307.

Shizuka, D., Johnson, A. E. (2020). How demographic processes shape animal social networks. *Behavioural Ecology* **31**: 1-11

Smale, M. J. (2002). Occurrence of *Carcharias taurus* in nursery areas of the Eastern and Western Cape, South Africa. *Marine and Freshwater Research* **53**: 551-556

Stepien, C. A., Schultz, H. K., McAllister, S. M., Norton, E. L., Keister, J. E. (2024). Evaluating metabarcoding markers for identifying zooplankton and ichthyoplankton communities to species in the Salish Sea: morphological comparisons and rare, threatened or invasive species. *DNA* **4**: 1-33. DOI: 10.3390/dna4010001

Stow A., Zenger K., Briscoe D., Gillings M., Peddemors V., Otway N., Harcourt R. (2006). Isolation and genetic diversity of endangered grey nurse shark (*Carcharias taurus*) populations. *Biology Letters* **2**: 308-311. DOI: 10.1098/rsbl.2006.0441

Taberlet, P., Bonin, A., Zinger, L., Coissac, E. (2018). Environmental DNA: For Biodiversity Research and Monitoring (online edn, Oxford Academic, 22 Mar. 2018)., DOI: 10.1093/oso/9780198767220.001.0001

Teter, S. M., Wetherbee, B. M., Fox, D. A., Lam, C. H., Kiefer, D. A., Shivji, M. (2015). Migratory patterns and habitat use of the sand tiger shark (*Carcharias taurus*) in the western North Atlantic. *Marine and Freshwater Research* **66**: 158-169

UNEP/CMS/ScC-SC6/Inf.13.4. (2023). Memorandum of Understanding on the Conservation of Migratory Sharks: Analysis of proposals for inclusion of shark and ray species in the appendices of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) at the 14th meeting of the conference the parties (CMS COP14).

[https://www.cms.int/sites/default/files/document/cms_scc-sc6_inf.13.4_Sharks%20AC%20analysis%20of%20listing%20proposals_e.pdf, accessed 27/06/2025]

Wang, Z., Liu, X., Liang, D., Wang, Q., Zhang, L., & Zhang, P. (2023). VertU: universal multilocus primer sets for eDNA metabarcoding of vertebrate diversity, evaluated by both artificial and natural cases [Original Research]. Frontiers in Ecology and Evolution, Volume 11 - 2023. https://doi.org/10.3389/fevo.2023.1164206

Weerarathne, I. A., Monk, J., Barrett. N. (2021). Sample-size requirements for accurate length-frequency distributions of mesophotic reef fishes from baited remote underwater stereo video. *Ecological Indicators* **122**: 107262.

Whitmarsh, S. K, Porskamp, P., Tinkler, P., Gray, S., Howe, S., Ierodiaconou, D., Sams, M. A., Young, M. A. (2023). An integrated monitoring program for Cape Howe Marine National Park, Parks Victoria Technical Series No 119, Parks Victoria, Melbourne. ISSN: 1448-4935 [https://www.parks.vic.gov.au/-/media/project/pv/main/parks/documents/get-into-nature/conservation-and-science/technical-series/pvts-119-an-integrated-monitoring-program-for-cape-howe-marine-national-park.pdf?rev=4784dc294d01483ab28053680a329f9f]

Williams, J., Jordan, A., Harasti, D., Davies, P., Ingleton, T. (2019). Taking a deeper look: Quantifying the differences in fish assemblages between shallow and mesophotic temperate rocky reefs. *PLoS ONE* **14**(3): e0206778. DOI: 10.1371/journal.pone.0206778

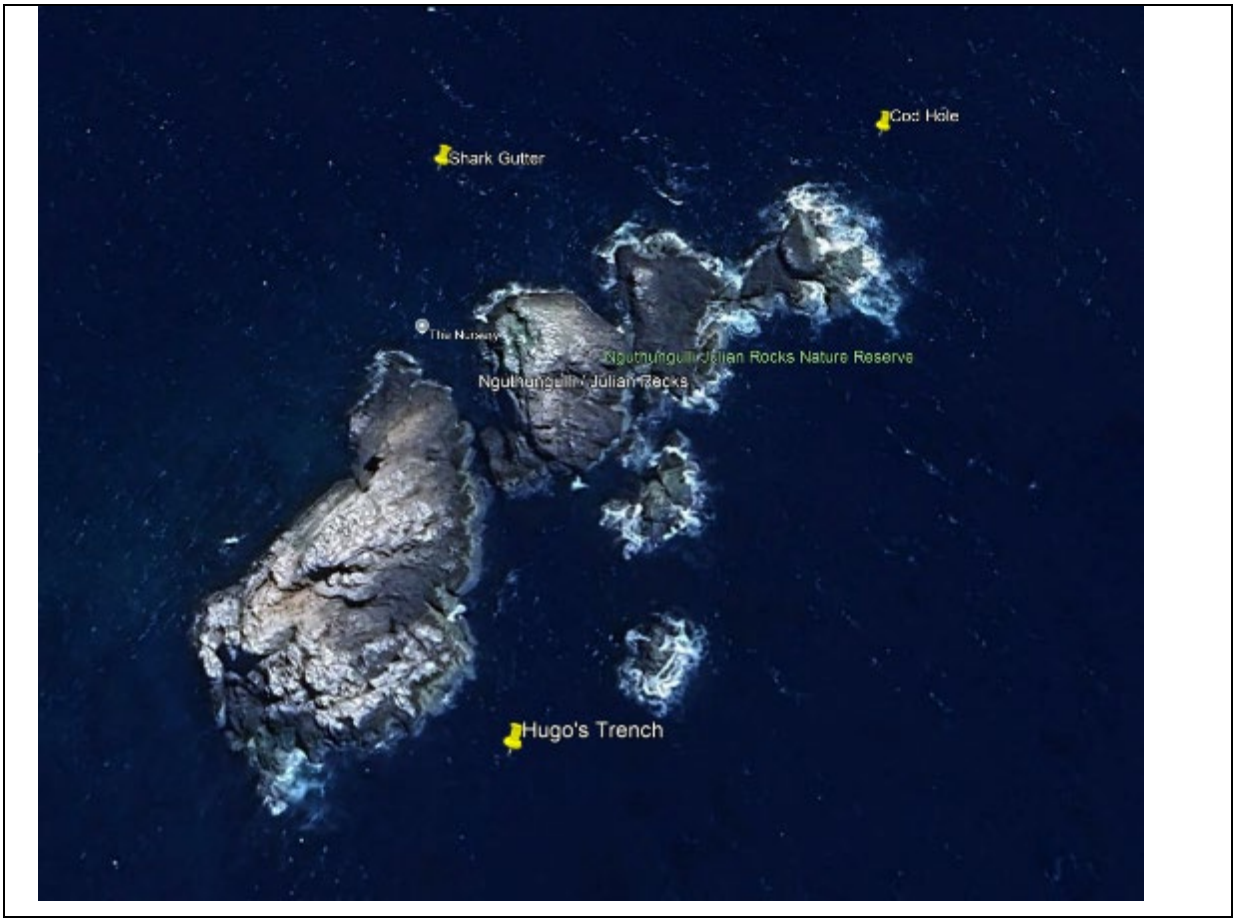
Williams, J., Ingleton, T., Sutherland, M., Davies, P., Monk, J., Barrett, N., Jordan, A. (2020). Mapping and characterising reef habitat and fish assemblages of the Hunter Marine Park. Report to the National Environmental Science Program, Marine Biodiversity Hub. NSW Government

Winnicki, S. K., Mungula, S. M., Williams, E. J., Boyle, W. A. (2020). Social interactions do not drive territory aggregation in a grassland songbird. *Ecology* **101(2)**: e02927.10.1002/ecy.2927

7. Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.

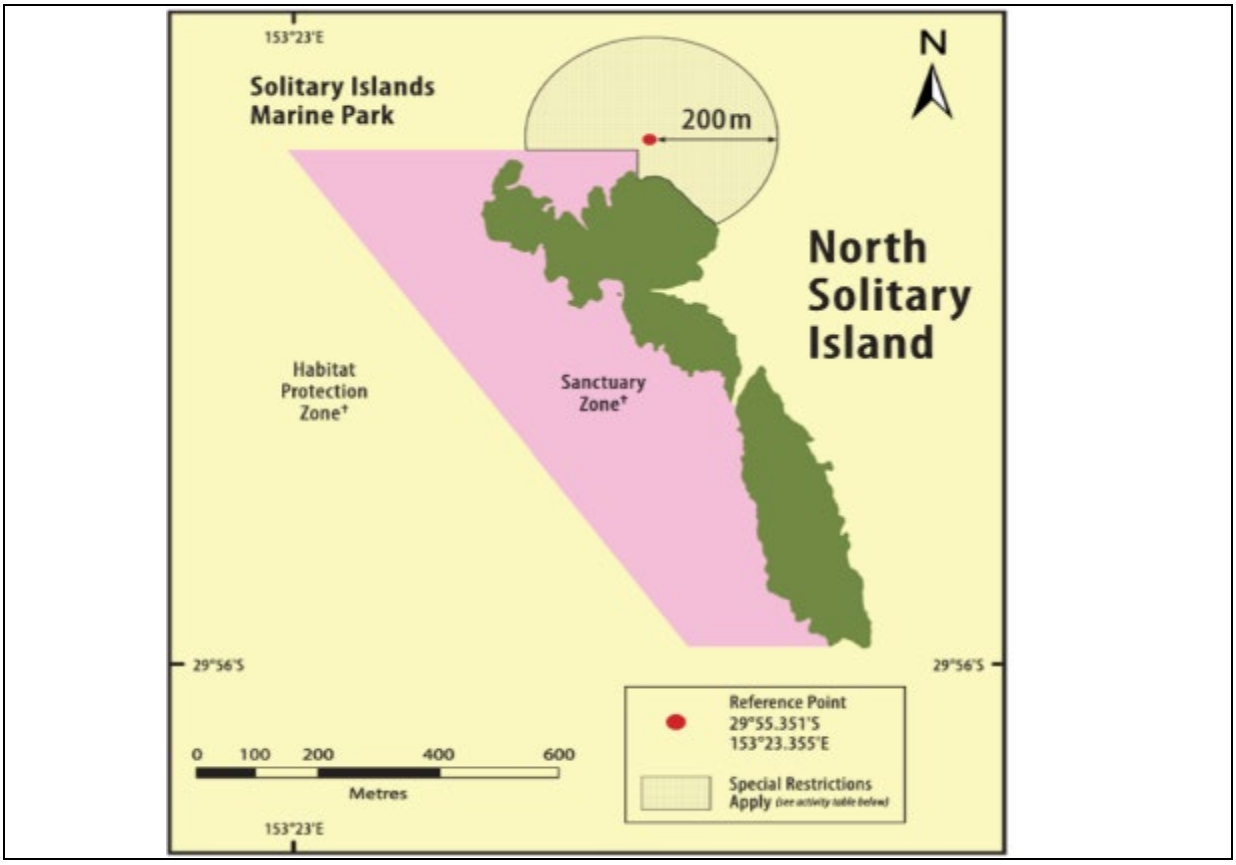
Location	**Julian Rocks, NSW**
GPS Coordinates	Cod Hole: 28° 36' 38.37" S 153° 37' 47.32" E Shark Gutters: 28° 36' 38.83" S 153° 37' 42.97" E Hugo's Trench: 28° 36' 44.05" S 153° 37' 44.09" E
Legislative status	Critical Habitat (FM Act) Marine Park sanctuary zone (no fishing) - CBMP
Size	24.2 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at Julian Rocks in Winter/Spring months. Relative abundance, gender, and size-composition varied both within and among years. Adult males were present in Winter coinciding with the annual northerly migration to Queensland waters; then again in Spring coinciding with the annual southerly migration to NSW aggregation sites. Female GNS were most prevalent in July. Observed residence periods lasted up to nine days. At Julian Rocks, GNS occupied gutters close to the seabed at a mean depth of 16.4 m (range: 12.7-26.4 m). GNS exhibited a diurnal usage pattern at Julian Rocks, spending more time at the site during the day.
Cyclicity	Annual migration stop
Present (months)	Typically, June - December
Sex	Male and Female
Shark Age	All ages
Number of sharks (acoustic tagged)	17 tagged individuals detected (7,401 detections)
Number of sharks (observational)	Up to 40 grey nurse sharks have been recorded on a single dive (B. Louden, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.



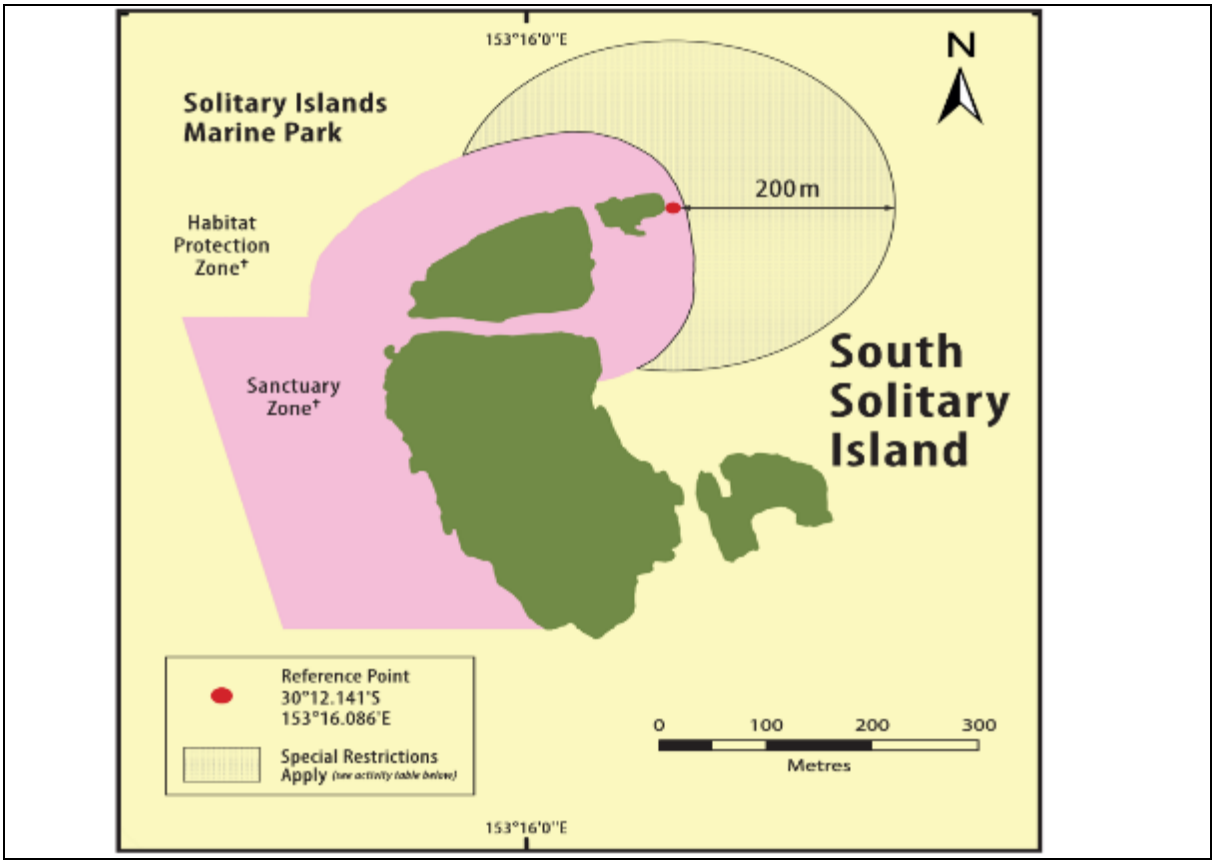
Location	**North Solitary Island, NSW**
GPS Coordinates	29° 55' 21.06" S 153° 23' 21.30" E
Legislative status	Habitat Protection Zone - SIMP Section 8 closure (FM Act) - Line fishing using bait is prohibited*. Wire traces are permitted for trolling purposes only within 500 m of North Solitary Island, but only whilst a vessel is underway.
Size	9.3 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at North Solitary Island from Winter to Summer. Relative abundance, gender, and size-composition varied both within and among years. Adult males were most prevalent in Winter coinciding with the annual northerly migration to Queensland waters; then in Summer coinciding with the southerly migration to mate. Female GNS were prevalent over Winter/Spring and comprised individuals migrating north to mate, and pregnant individuals migrating south to pup. Observed residence periods lasted up to 37 days. At North Solitary Island, GNS were observed swimming close to the seabed at a mean depth of 22.0 m (range: 6.4-37.3 m) and occasionally at mid-water depths. GNS exhibited a diurnal usage pattern at North Solitary Island, spending more time at the site during the day.
Cyclicity	Annual migration stop
Present (months)	Typically, June - December
Sex	Male and Female; but generally favoured by males
Shark Age	All ages
Number of sharks (acoustic tagged)	15 tagged individuals detected (59,200 detections)
Number of sharks (observational)	Up to 25 grey nurse sharks have been recorded on a single dive (B. Louden, pers obs.)
Other Comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.



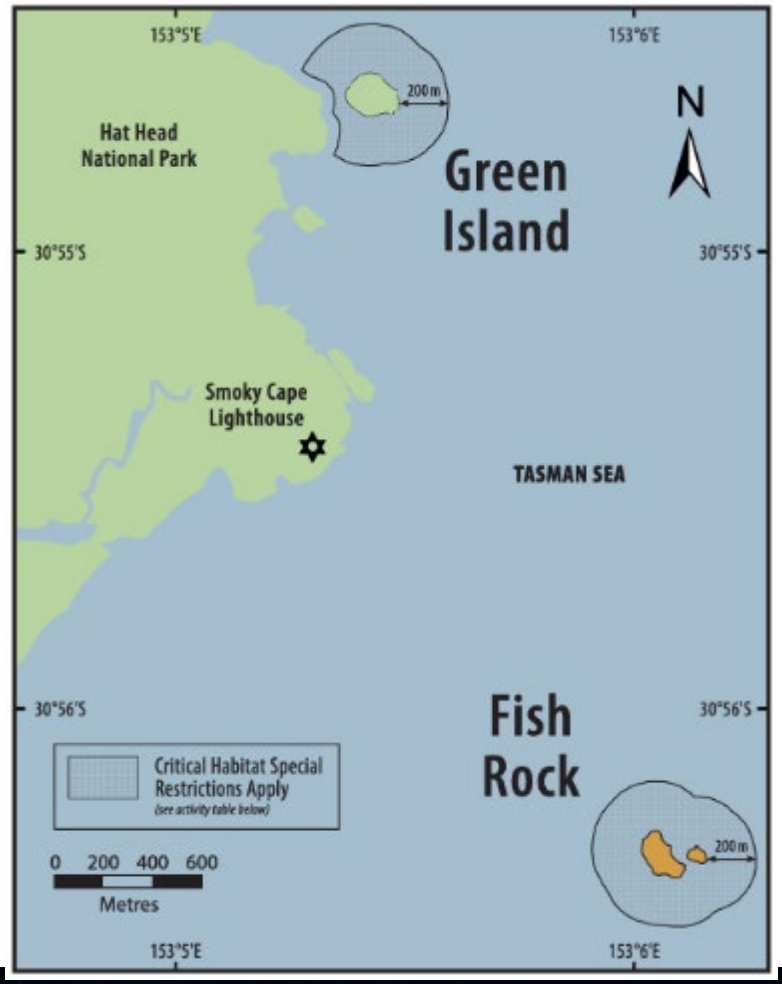
Location	**South Solitary Island, NSW**
GPS Coordinates	30° 12' 08.46" S 153° 16' 05.16" E
Legislative status	Section 8 closure (FM Act) - Line fishing using bait is prohibited*. Wire traces are permitted for trolling purposes only within 500 m of South Solitary Island, but only whilst a vessel is underway.
Size	7.7 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at South Solitary Island throughout the year. Relative abundance, gender, and size-composition varied both within and among years. Adult males were most prevalent in Autumn/Winter coinciding with the annual northerly migration to Queensland waters; then in Spring/Summer coinciding with the southerly migration to mate. Pregnant GNS were present in Autumn/Winter and either pupped at the site in late Winter or migrated further south to pup. Observed residence periods lasted up to 74 days. At South Solitary Island, GNS were observed swimming close to the seabed at a mean depth of 25.1 m (range: 2.7-41.8 m) and occasionally at mid-water depths. GNS exhibited a diurnal usage pattern at North Solitary Island, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	Typically June - December
Sex	Male and Female
Shark Age	All ages
Number of sharks (acoustic tagged)	17 tagged individuals detected (163,736 detections)
Number of sharks (observational)	Up to 40 grey nurse sharks have been recorded on a single dive (B. Louden, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.



Location	**Fish Rock, NSW**
GPS Coordinates	30° 56' 22.78" S 153° 06' 4.53" E
Legislative status	Critical Habitat (FM Act) Section 8 closure (FM Act) - Line fishing using bait is prohibited. The taking of fish by spear or speargun is prohibited within 200m of Fish Rock other than: Australian Salmon; Mahi Mahi; Tailor; Cobia; Marlins and Sailfish (all species in the family Istiophoridae); Mackerels and Tunas (all species in the family Scombridae); Wahoo; Trevallies, Yellowtail Kingfish and Rainbow Runner (all species in the family Carangidae)
Size	21.5 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at Fish Rock throughout the year. Relative abundance, gender, and size-composition varied both within and among years. Adult males were most prevalent in Autumn/Winter coinciding with the annual northerly migration to Queensland waters. Juvenile and resting-phase females were prevalent over Autumn/Spring prior migrating north to mate. Pregnant GNS occupied the site in Autumn/Winter for further gestation over 4-5 months before migrating south in late Winter to pup. Observed residence periods lasted up to 304 days. At Fish Rock, GNS were observed swimming close to the seabed at a mean depth of 25.1 m (range: 2.7-41.8 m) and occasionally at mid-water depths, especially during Summer/Autumn. GNS exhibited a diurnal usage pattern at Fish Rock, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	All year
Sex	Male and Female
Shark Age	All ages
Number of sharks (acoustic tagged)	33 tagged individuals detected (622,871 detections)
Number of sharks (observational)	During winter months, up to 100 grey nurse sharks have been observed (D. Harasti & B. Louden, pers obs.). They are primarily seen in the shark gutter on the southern side of the rock, however, can be seen occurring all around the site.
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

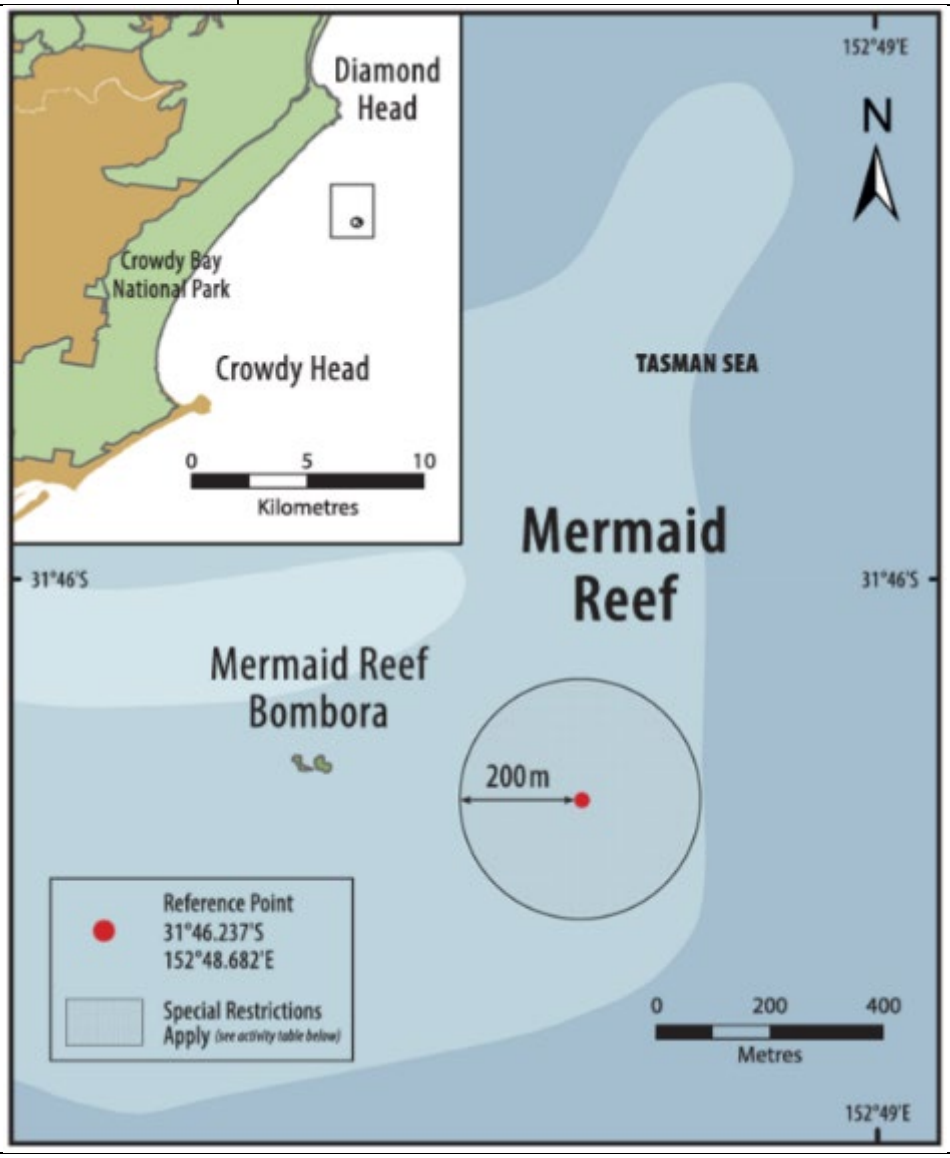
Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.



Location	**Green Island, NSW**
GPS Coordinates	30° 54' 37.50" S 153° 05' 30.55" E
Legislative status	Critical Habitat (FM Act) Section 8 closure (FM Act) - Line fishing using bait is prohibited*.
Size	18.1 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at Green Island from Autumn through to Summer. Relative abundance, gender, and size-composition varied both within and among years. Adult males were most prevalent in Winter/Spring but absent in November while mating further north. Juvenile and resting-phase females were prevalent in Autumn and Summer. Reproductively active individuals migrated north in October/November to mate. Pregnant GNS occupied the site in Autumn/Winter for further gestation before migrating south in late Winter to pup. Observed residence periods lasted up to 7 days. At Green Island, GNS were observed swimming close to the seabed at a mean depth of 15.5 m (range: 1.8-20.9 m) and occasionally at mid-water depths. GNS exhibited a diurnal usage pattern at Green Island, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	Typically June - December
Sex	Male and Female
Shark Age	All ages
Number of sharks (tagged)	22 tagged individuals detected (5,056 detections)
Number of sharks (observational)	Up to 20 grey nurse sharks have been recorded on a single dive (D. Harasti, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

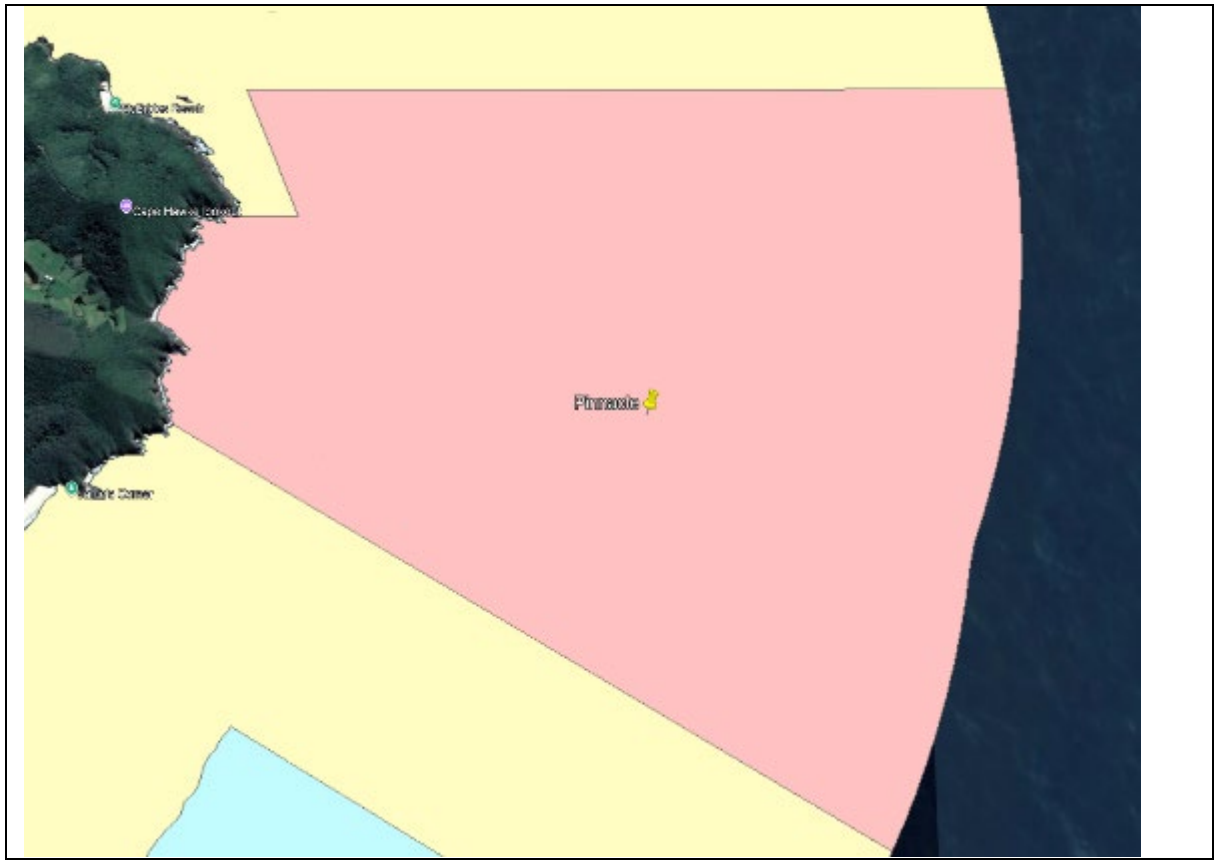
Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.

Location	**Mermaid Reef, NSW**
GPS Coordinates	31° 46' 14.22" S 152° 48' 40.92" E
Legislative status	Section 8 closure (FM Act) - Line fishing using bait is prohibited*.
Size	12.5 hectares
Cyclicity	Not determined – Insufficient observations at this site.
Present (months)	Not determined – Insufficient observations at this site.
Sex	Male and Female
Shark Age	All ages (based on NSW DPIRD observations)
Number of sharks (acoustic tagged)	There was no acoustic listening station deployed at Mermaid Reef.
Number of sharks (observational)	During NSW DPI GNS surveys, a maximum of eight sharks (M&F) were observed (D. Harasti & B. Louden, pers obs.)
Other Comments	



Location	**Pinnacle – Forster, NSW**
GPS Coordinates	32° 13' 42.45" S 152° 36' 05.80" E
Legislative status	Critical Habitat (FM Act); Marine Park sanctuary zone (no fishing) – PSGLMP.
Size	78.5 hectares, 500 m radius around Pinnacle site (2,064 hectares for full SZ).
Occurrence (from Otway and Louden, 2025)	GNS were observed at Pinnacle (Forster) throughout the year. Relative abundance, gender, and size-composition varied both within and among years. Adult males were most prevalent in Autumn/Winter coinciding with the annual northerly migration to Queensland waters. Males were absent during late Spring having migrated north to mate. Juvenile and resting-phase females were prevalent in Autumn and Summer. Reproductively active individuals migrated north in late Spring to mate. Pregnant GNS occupied the site in Autumn/Winter prior to migrating south in late Winter to pup. Observed residence periods lasted up to 12 days. At Pinnacle (Forster), GNS were observed swimming close to the seabed at a mean depth of 28.7 m (range: 13.6-46.4 m). GNS exhibited a diurnal usage pattern at Green Island, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	All year but typically December - May
Sex	Male and Female
Shark Age	All ages
Number of sharks (acoustic tagged)	18 tagged individuals detected (27,215 detections)
Number of sharks (observational)	Up to 20 grey nurse sharks have been recorded on a single dive (B. Louden, pers obs.)
Other Comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.

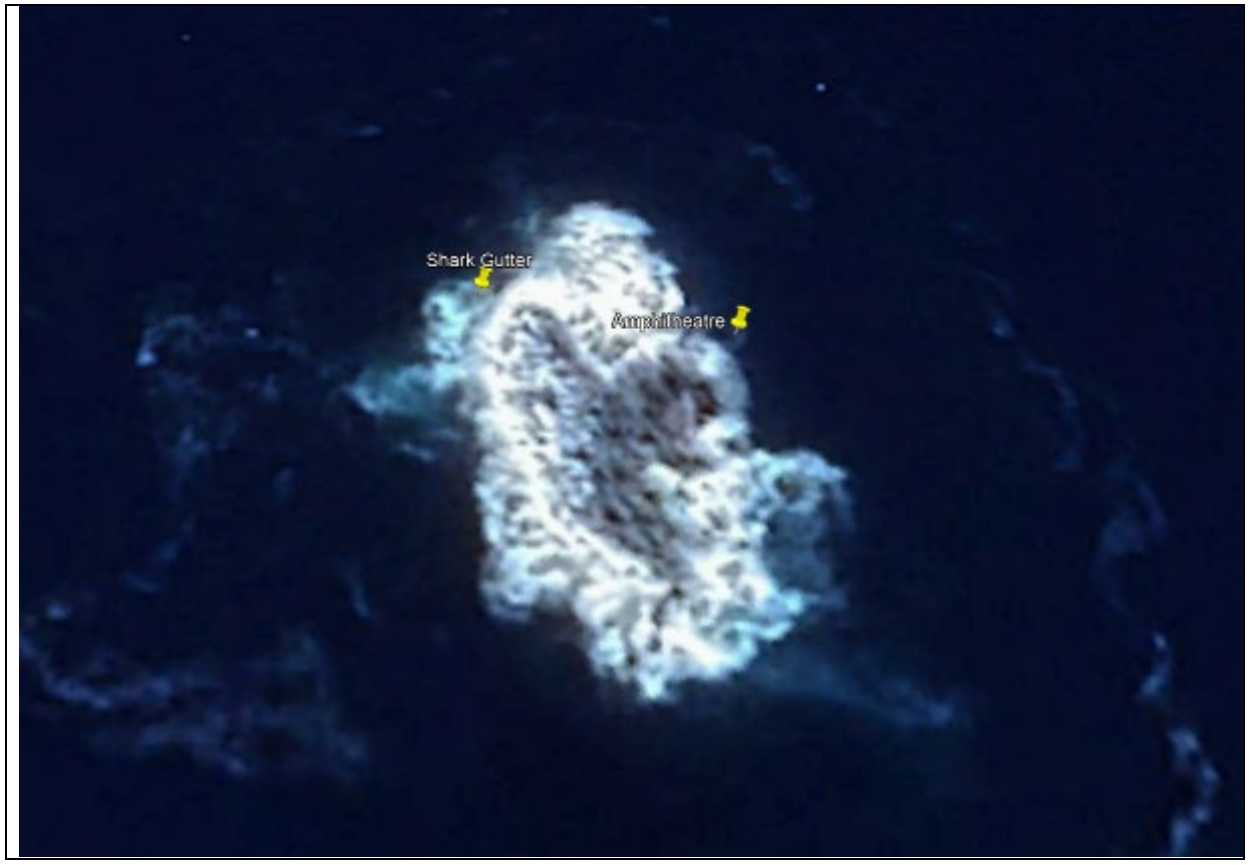


Location	Big Seal Rock, NSW
GPS Coordinates	Drop off (24 m): 32° 27' 41.87" S 152° 33' 10.69" E Juvenile Cave: 32° 27' 43.99" S 152° 33' 10.12" E Western Gutter (15 m): 32° 27' 46.22" S 152° 33' 08.17" E Eastern Ridge (18 m): 32° 27' 46.08" S 152° 33' 12.49" E Grotto (15-25 m): 32° 27' 49.14" S 152° 33' 09.83" E
Legislative status	Critical Habitat (FM Act); Marine Park sanctuary zone (no fishing) – PSGLMP.
Size	82.3 hectares (combined with Little Seal Rock)
Occurrence (from Otway and Louden, 2025)	GNS were observed at Big Seal Rock throughout the year. Aggregations, often large, were observed all around the site. Relative abundance, gender, and size-composition varied both within and among years. Adult males were most prevalent in Autumn/Winter coinciding with the annual northly migration to Queensland waters. Males were absent during late Spring having migrated north to mate. Juvenile and resting-phase females were prevalent in Autumn and Summer. Reproductively active individuals migrated north in late Spring to mate. Pregnant GNS occupied the site in Autumn/Winter and likely pupped in the local vicinity. Observed residence periods lasted up to 22 days. At Big Seal Rock, GNS were observed swimming close to the seabed at a mean depth of 21.6 m (range: 7.3-36.4 m) and occasionally in mid-water depths. GNS exhibited a diurnal usage pattern at Big Seal Rock, spending more time at the site during the day.
Cyclicity	Yes, every year
Present (months)	All months of the year (from acoustic tags). Peak is January - June
Sex	Male and Female
Shark Age	YOY, juveniles and adults. Predominantly adults
Number of sharks (tagged)	24 tagged individuals detected (200,788 detections)
Number of sharks (observational)	200+ observed in Feb 2023, and numerous sightings of over 100 GNS on a dive (D. Harasti & B. Louden, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.

Location	**Little Seal Rock, NSW**
GPS Coordinates	Amphitheatre: 32° 28' 26.80" S 152° 32' 49.81" E Shark Gutter: 32° 28' 26.58" S 152° 32' 48.41" E
Legislative status	Critical Habitat (FM Act); Marine Park sanctuary zone (no fishing) – PSGLMP.
Size	82.3 hectares (combined with Little Seal)
Occurrence (from Otway and Louden, 2025)	GNS were observed at Little Seal Rock throughout the year with aggregations predominantly on the northern side (Amphitheatre) and on the western side (Shark Gutter). Relative abundance, gender, and size-composition varied both within and among years. Adult males were most prevalent in Summer/Autumn but typically absent during Winter/Spring. Juvenile and resting-phase females were prevalent in Autumn and Summer. Reproductively active individuals migrated north in late Spring to mate. Pregnant GNS occupied the site in Autumn/Winter and likely pupped in the local vicinity. Observed residence periods lasted up to 15 days. At Little Seal Rock, GNS were observed swimming close to the seabed at a mean depth of 22.4 m (range: 17.3-28.2 m). GNS exhibited a diurnal usage pattern at Little Seal Rock, spending more time at the site during the day.
Cyclicity	Yes, every year
Present (months)	All months of year (from acoustic tags). Peak: January - June
Sex	Male and Female
Shark Age	YOY, juveniles and adults. Predominantly adults
Number of sharks (tagged)	19 tagged individuals detected (12,183 detections)
Number of sharks (observational)	30+ observed on several occasions (D. Harasti & B. Louden, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.



Location	**Little Broughton Island, NSW**
GPS Coordinates	Little Broughton: 32° 37' 04.33" S 152° 20' 00.02" E East Head: 32° 37' 26.65" S 152° 20' 11.51" E Looking Glass: 32° 37' 44.62" S 152° 19' 03.32" E
Legislative status	Critical Habitat (FM Act); Marine Park sanctuary zone (no fishing) – PSGLMP.
Size	36.2 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at Little Broughton Island, predominantly at Looking Glass and East Head, throughout the year. However, GNS have not been observed at the historically primary site, Little Broughton Shark Gutters, for the past 10 years. North Rock (1.5 km north of Destiny Rock) where large aggregations (80+ individuals) can be observed lies outside of the protected zone. Where present, relative abundance, gender, and size-composition varied both within and among years. Adult males were most prevalent during Winter and coinciding with the northly migration to Queensland waters; then again in Summer following mating in late Spring. Juvenile and resting-phase females were prevalent in Autumn and Summer. Reproductively active individuals migrated north in October/November to mate. Observed residence periods lasted up to nine days. At Little Broughton Island, GNS were observed swimming close to the seabed at a mean depth of 18.5 m (range: 13.7-25.5 m). GNS exhibited a diurnal usage pattern at Little Broughton Island, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	January - May
Sex	Male and Female
Shark Age	Juveniles and adults
Number of sharks (acoustic tagged)	No data
Number of sharks (observational)	Approx. 15 years ago, 20+ GNS were regularly observed at the Little Broughton Shark gutter over the warmer summer-autumn months; however, sightings at this site are now rare. GNS are now more commonly observed at the East Head shark gutter. The most observed at the east head site was 50+ sharks approximately 13 years ago (D. Harasti, pers obs.).
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.

Location	**Magic Point, NSW**
GPS Coordinates	33° 57' 21.54" S 151° 15' 51.84" E
Legislative status	Critical Habitat (FM Act); Section 8 closure (FM Act) - Line fishing using bait is prohibited*.
Size	9.8 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at Magic Point throughout the year. Relative abundance, gender, and size-composition varied both within and among years. Adult males were most prevalent from late Spring to early Winter and absent during the period when GNS migrate north to Queensland waters. Observed residence periods lasted up to five days. At Magic Point, GNS were observed swimming close to the seabed at a mean depth of 18.0 m (range: 11.8-23.7 m). GNS exhibited a diurnal usage pattern at Magic Point, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	January - June
Sex	Male and Female
Shark Age	All ages
Number of sharks (acoustic tagged)	Five tagged individuals detected (1,019 detections)
Number of sharks (observational)	Up to 20 grey nurse sharks have been recorded on a single dive (B. Louden, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

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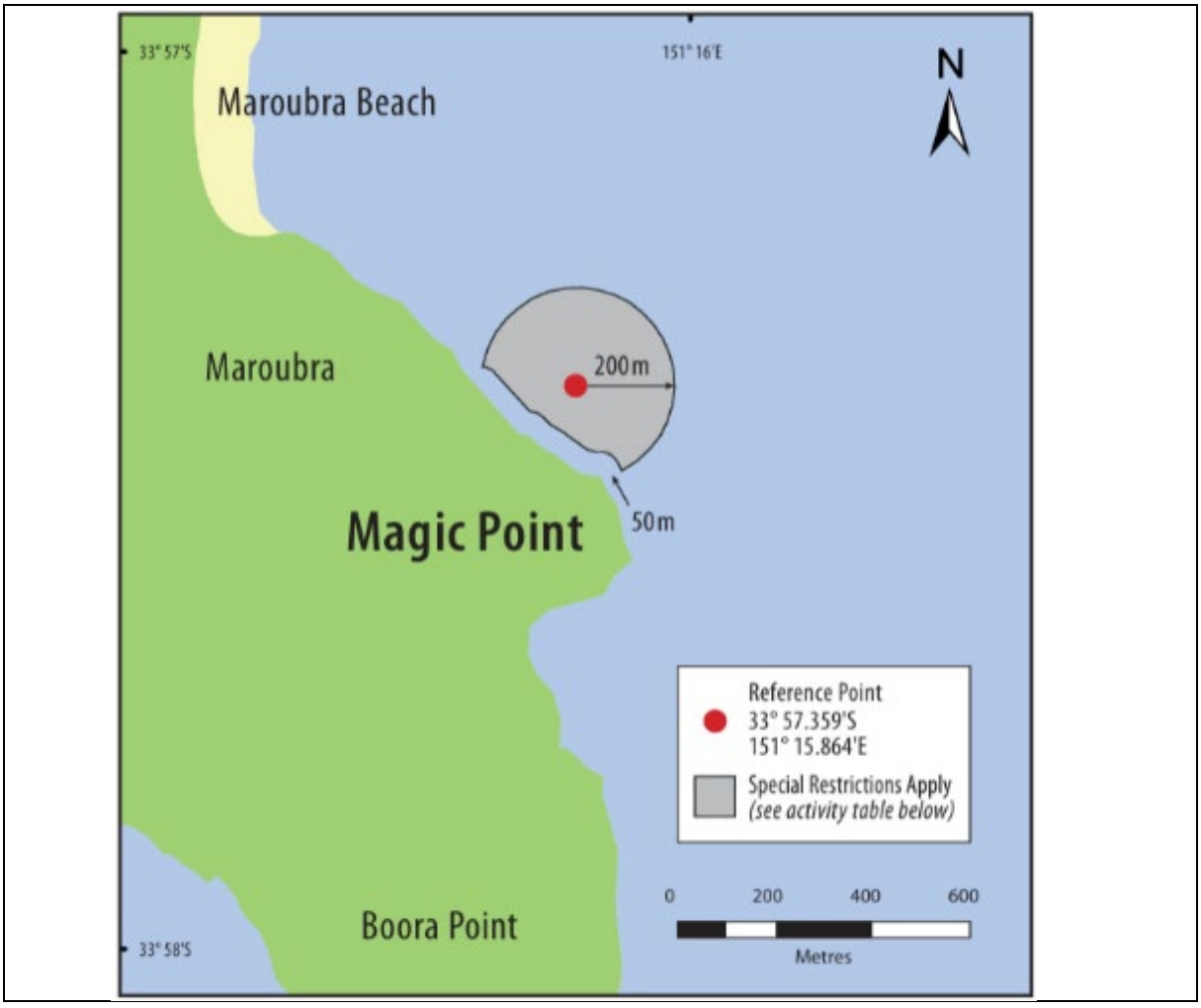


Location	**Tollgate Islands, NSW**
GPS Coordinates	35° 45' 00.15" S 150° 15' 43.14" E
Legislative status	Critical Habitat (FM Act); Marine Park sanctuary zone (no fishing) - BMP
Size	17.8 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at the Tollgate Islands throughout the year – only juvenile and adult females are present. Relative abundance and size-composition varied both within and among years. Juveniles and resting-phase females were prevalent over Spring to mid-Winter. Pregnant GNS occupied the site in Winter/Spring and likely pupped in the local vicinity. Observed residence periods lasted up to four days. At the Tollgate Islands, GNS were observed swimming close to the seabed at a mean depth of 19.4 m (range: 16.4-25.5 m). GNS exhibited a diurnal usage pattern at the Tollgate Islands, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	December - April
Sex	Female
Shark Age	All ages
Number of sharks (acoustic tagged)	Six tagged individuals detected (474 detections)
Number of sharks (observational)	Up to 20 grey nurse sharks have been recorded on a single dive (B. Louden, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.

Location	**Montague Island, NSW**
GPS Coordinates	Northern gutter: 36° 14' 32.73" S 150° 13' 44.64" E Western gutters: 36° 14' 53.21" S 150° 13' 23.09" E
Legislative status	Critical Habitat (FM Act); Habitat Protection Zone – Restricted – BMP. 1. line fishing permitted 1 May - 31 October. 2. between 1 November - 30 April: a. No fishing with bait; b. No fishing at anchor; c. No fishing with a wire trace line; d. No nets (but landing nets are allowed).
Size	16.7 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at Montague Island throughout the year – predominantly juvenile females, no adult males have been observed. Relative abundance and size-composition of females varied both within and among years. Females were most prevalent from Spring through to early Winter, with pregnant individuals thought to have pupped at the site. Observed residence periods lasted up to 15 days. At Montague Island, GNS were observed swimming close to the seabed (depth range: 16.4-25.5 m). GNS exhibited a diurnal usage pattern at Montague Island, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	All year, but typically December to March
Sex	Mainly immature females
Shark Age	All ages, but mainly immature
Number of sharks (tagged)	Three tagged individuals detected (38,088 detections)
Number of sharks (observational)	Up to eight grey nurse sharks have been recorded on a single dive (B. Louden, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

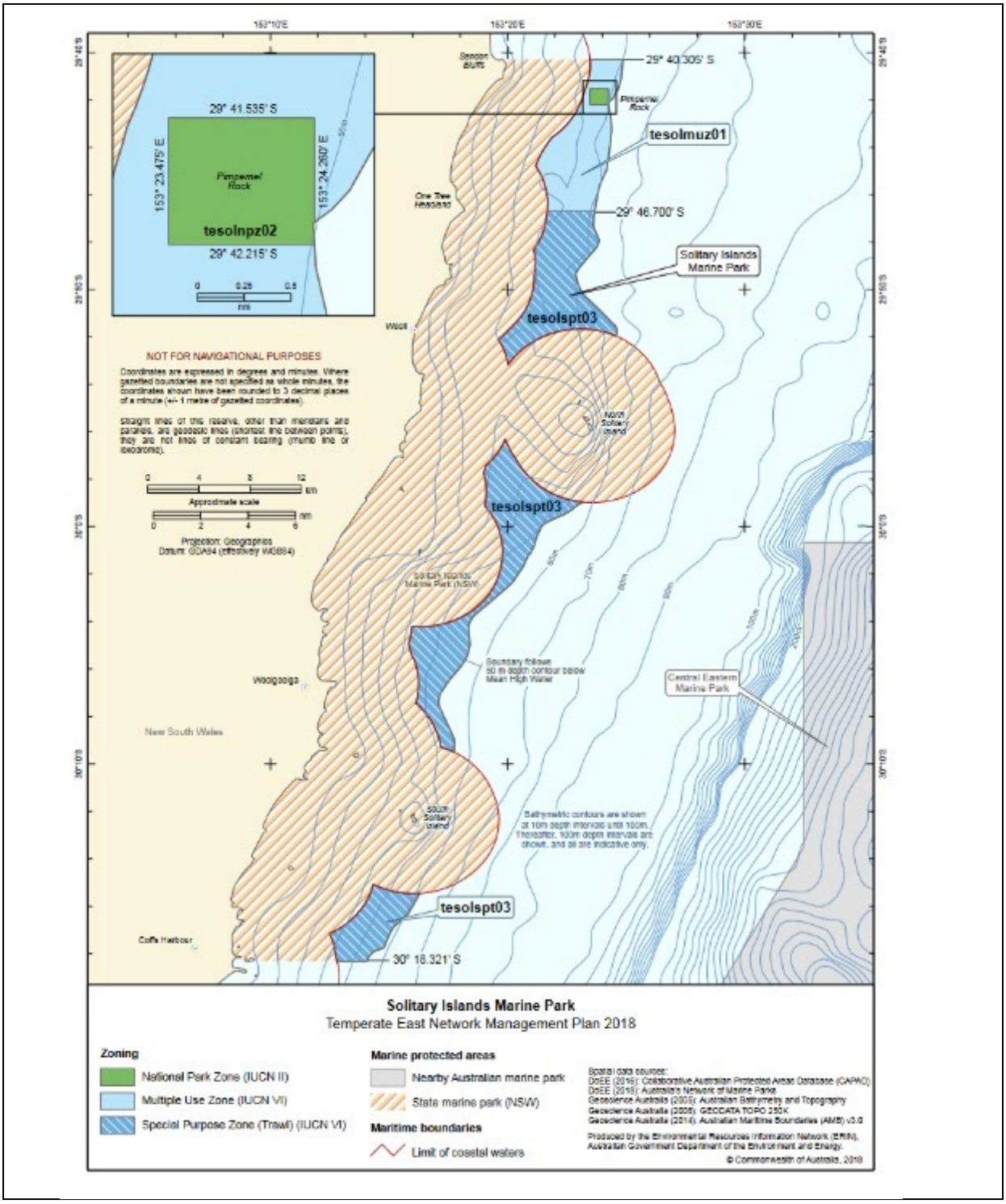
Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.

Table notes on NSW GNS aggregation sites:

- The ‘Occurrence (from Otway and Louden, 2025)’ is direct text from the Otway and Louden, 2025 NSW DPIRD Fisheries report: “Occupation of aggregation sites and migratory movements of the Greynurse shark (*carcharias taurus*) off eastern Australia”.
- Number of sharks (acoustic tagged): This is based on the movements of 31 GNS (10 males, 21 females) were tagged at Fish Rock in 2011 and 2012 (See Otway and Louden, 2025).
- FM Act = Fisheries Management Act 1994;
- Full details of the legislative fishing restrictions at the sites can be seen here:
    - Commercial: https://gazette.nsw.gov.au/gazette/2021/12/2021-620.pdf
    - Recreational: https://gazette.nsw.gov.au/gazette/2022/7/2022-320.pdf
- *denotes that soft plastics, artificial baits and vegetable baits are permitted

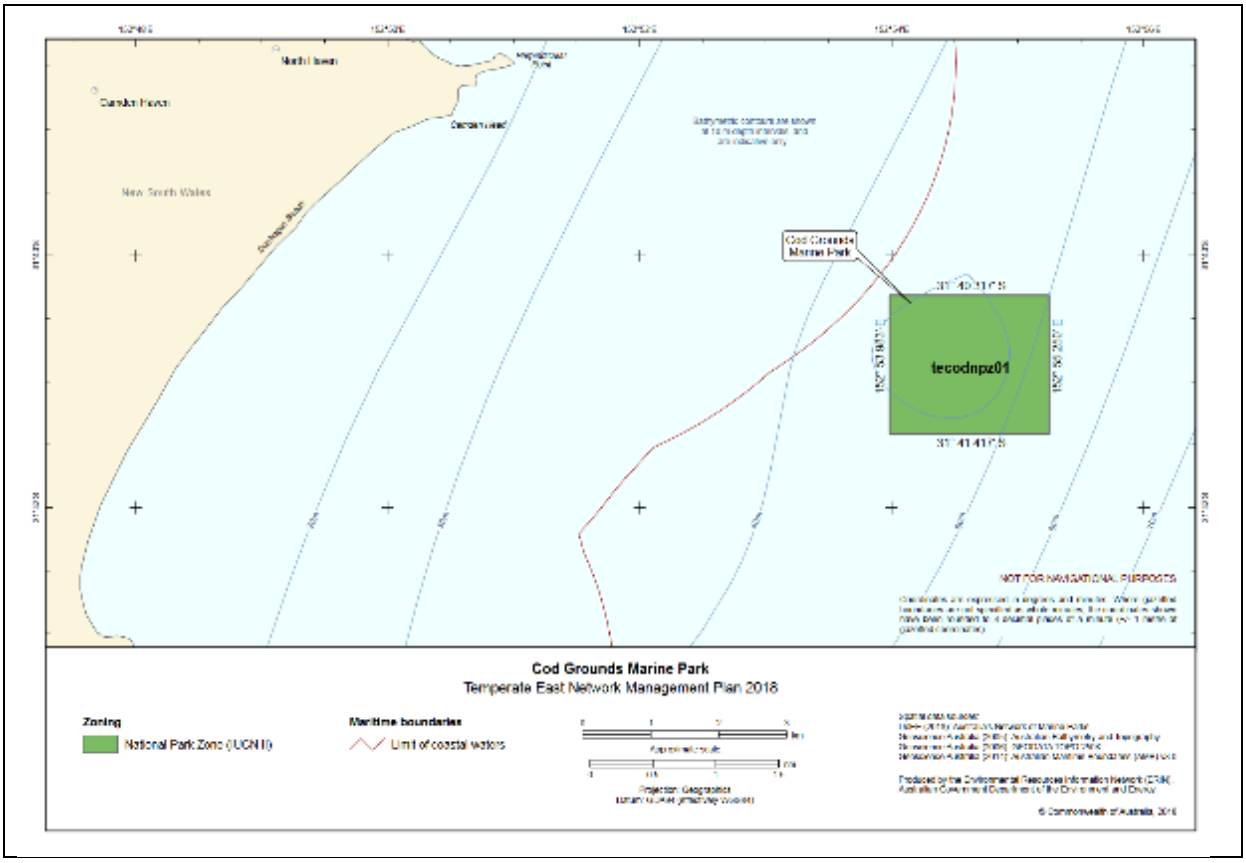
Location	**Pimpernel Rock, NSW (Cmwth)**
GPS Coordinates	29° 41' 52.50" S 153° 23' 52.05" E
Legislative status	National Park Zone (IUCN II)
Size	160 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at Pimpernel Rock throughout the year. Relative abundances, gender and size-composition varied within and among years. Adult males were most prevalent in Autumn/Winter coinciding with the annual northly migration to Queensland waters. Females were most prevalent in Autumn/Spring with pregnant females migrating south to pup and resting-phase females migrating north to mate. Observed residence periods lasted up to 19 days. At Pimpernel Rock, GNS were observed swimming at a mean depth of 36.2 m (range 17.3-48.2 m) around the four peaks that make up Pimpernel Rock, in the cave, or close to the seabed. GNS exhibited a diurnal usage pattern at Pimpernel Rock, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	All year but typically June - December
Sex	Male and Female
Shark Age	All ages
Number of sharks (tagged)	11 tagged individuals detected (11,069 detections)
Number of sharks (observational)	Over 40 grey nurse sharks have been recorded on a single dive (H. Malcom & B. Louden, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD. https://australianmarineparks.gov.au/parks/temperate-east-marine-parks-network/solitary-islands-marine-park/#solitary-islands-map-section

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.



Location	**Cod Grounds, NSW (Cmwth)**
GPS Coordinates	31° 40' 52.02" S 152° 54' 36.99" E
Legislative status	National Park Zone (IUCN II)
Size	400 hectares
Occurrence (from Otway and Louden, 2025)	GNS were observed at the Cod Grounds throughout the year. Relative abundances, gender and size-composition varied within and among years. Adult males were most prevalent in Autumn/Summer, with absences in late Spring during the annual northly migration to Queensland waters. Females were most prevalent over late Autumn to early Spring and included juvenile and pregnant individuals migrating south to pup as well as reproductively active females ready to migrate north to mate. Observed residence periods lasted up to 18 days. At the Cod Grounds, GNS were observed swimming near the seabed at a mean depth of 28.4 m (range 14.6-32.8 m). GNS exhibited a diurnal usage pattern at the Cod Grounds, spending more time at the site during the day.
Cyclicity	Annually
Present (months)	All year but typically larger numbers May - November
Sex	Male and Female
Shark Age	All ages
Number of sharks (tagged)	23 tagged individuals detected (70,982 detections)
Number of sharks (observational)	Over 50+ grey nurse sharks have been recorded on a single dive (B. Louden, pers obs.)
Other comments	Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD. https://australianmarineparks.gov.au/parks/temperate-east-marine-parks-network/cod-grounds-marine-park/#cod-grounds-map-section

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.



Location	**Wolf Rock, Queensland**
GPS Coordinates	25° 54' 00.00" S 153° 10' 59.88" E
Legislative status	Located in Great Sandy Marine Park and Designated as a GNS Area by Queensland Government. Activities are highly regulated in the designated area and restrictions relating to the interference of GNS and their habitat apply.
Size	Prior to 2024, Wolf Rock was protected by a 1.2 km radius MPA boundary around a central point, approximating 450 ha. Wolf Rock also had an additional 300 m 'buffer zone' that prohibited all fishing except trolling beyond the MPA boundary. In May 2024, the zone was expanded from 6.4 km² to 18.0 km² in response to new research showing GNS regularly undertake excursions beyond the original boundary to nearby habitats (DESI, 2024). This also encompasses the areas of known GNS habitat at the base of Double Island Point, Round Rock and The Pinnacles, and rocky reef habitat adjacent to Wolf Rock.
Cyclicity	Males return annually, Females return biannually or triannually (Dwyer et al., 2025)
Present (months)	All year round (January – December)
Sex	Mostly mature females at the site which are present year-round. Some mature males during July - November
Shark Age	Mature
Number of sharks (tagged)	Between 01/05/2013 and 27/07/2021, 18 out of 34 GNS with acoustic tags (15 females, 3 males) were detected at receivers deployed within the Wolf Rock MPA
Number of sharks (observational)	Monthly residency of tagged sharks was greatest in May and June, and diver-led counts revealed GNS also had their greatest relative abundance at this time, when up to 56 sharks were observed during surveys (May mean MaxN = 24 sharks)
Other comments	Available Photo ID data on Sharkbook.ai: 22/02/2003 to 29/07/2024 (21+ years) • 231 unique sharks identified • 582 total records Dwyer, R. G., Rathbone, M., Foote, D. L., Bennett, M., Butcher, P. A., Otway, N. M., Louden, B. M., Jaine, F. R., Franklin, C. E., Kilpatrick, C. (2023). Marine reserve use by a migratory coastal shark, *Carcharias taurus*. *Biological Conservation*, **283**: 110099. DOI: 10.1016/j.biocon.2023.110099 Roelfsema, C., Bansemer, C., McMahon, K., Joyce, K. (2020): 2003 Habitat Maps derived from Grey Nurse Shark (GNS) Project of Wolf Rock, Double Island Point, Queensland, Australia. .dataset. https://metadata.imas.utas.edu.au/geonetwork/srv/eng/catalog.search#/metadata/7f6db557-c947-4080-a10d-fa4b3ff0e41e

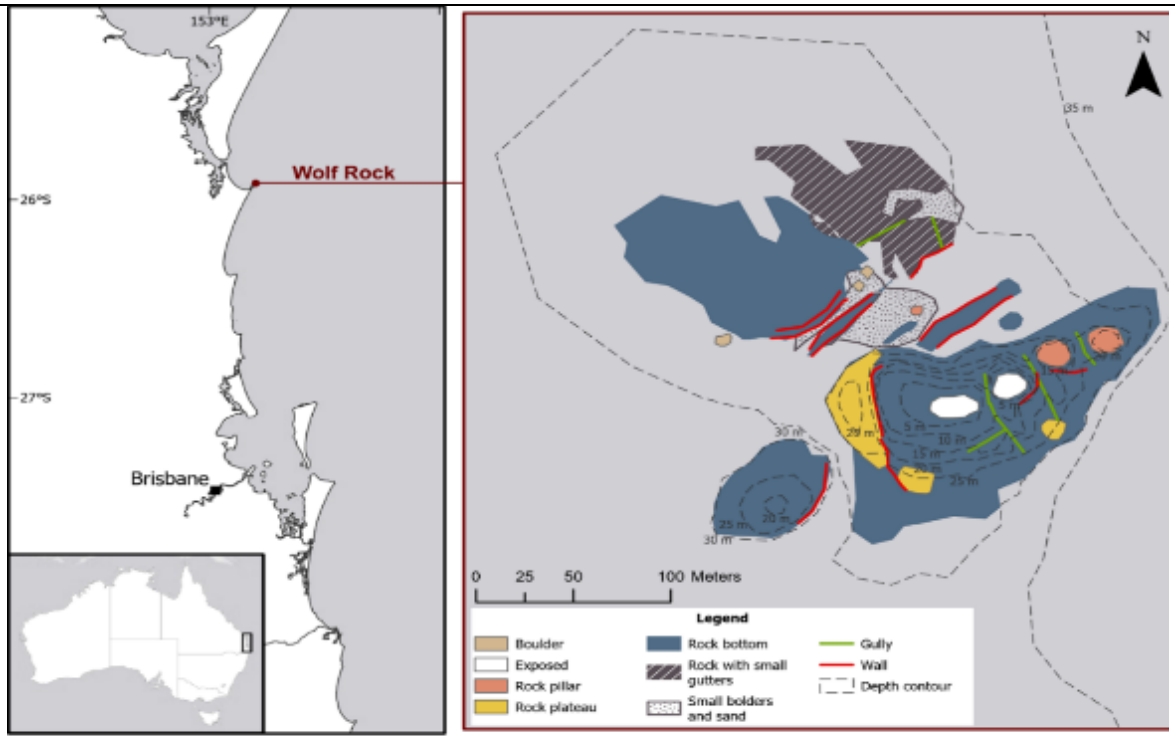


Figure 13 Location and habitat map of Wolf Rock, Queensland, Australia. Habitat classification conducted by Roelfsema et al. (2016).

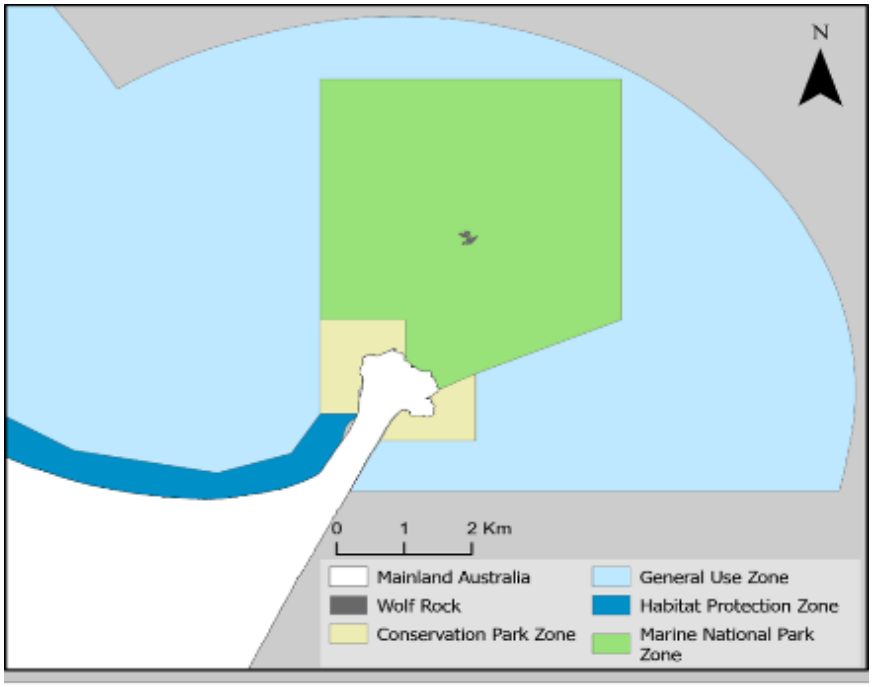
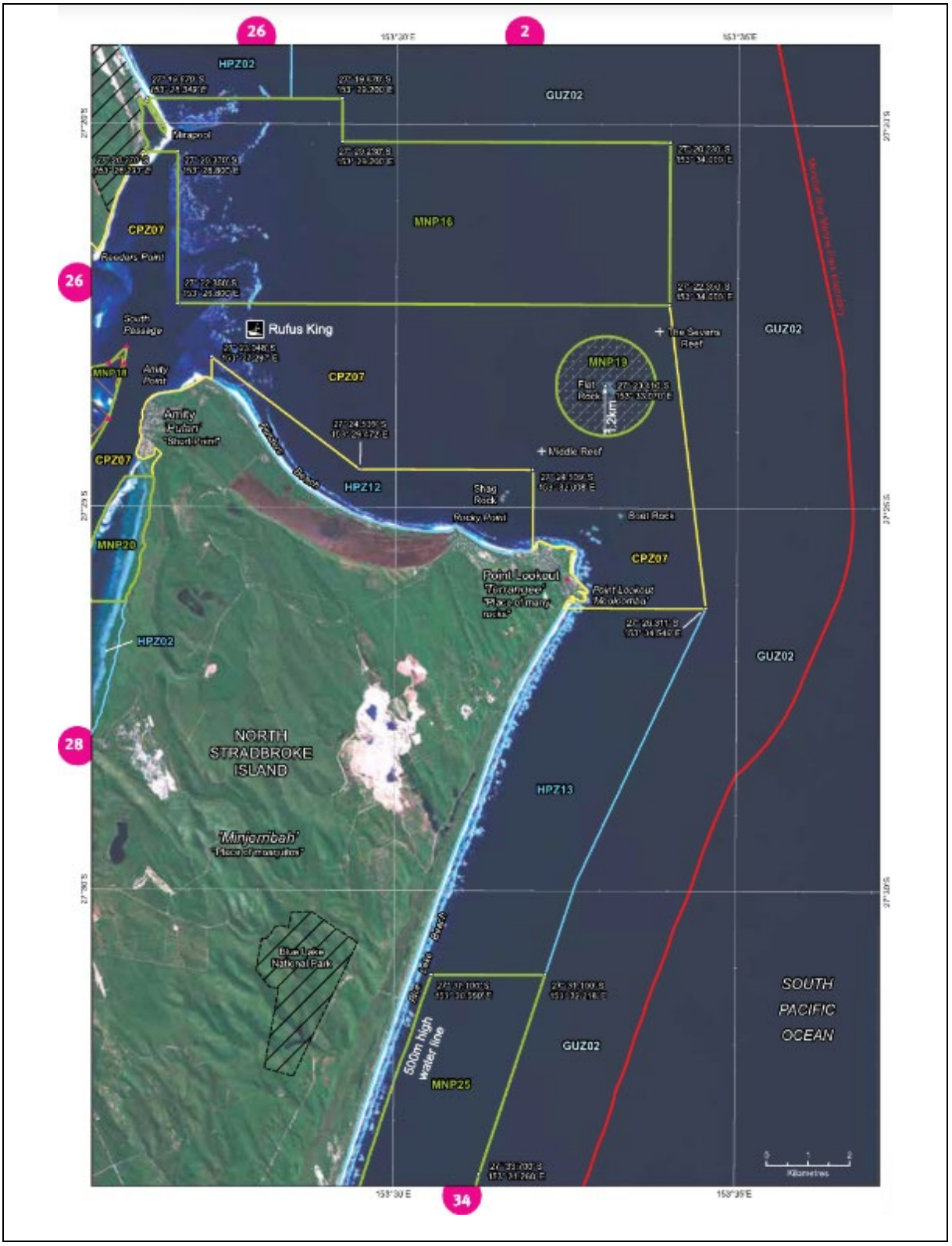


Figure 15 Marine usage zoning around Wolf Rock, Queensland Australia. Zoning data from State of Queensland (Department of Environment, Science and Innovation) 2024.

Location	**Flat Rock, Queensland**
GPS Coordinates	27° 22' 59.88" S 153° 33' 00.00" E
Legislative status	Located in Moreton Bay Marine Park and Designated as a GNS Area by Queensland Government. Activities are highly regulated in the designated area and restrictions relating to the interference of GNS and their habitat apply.
Size	Flat Rock is protected by a 1.2 km radius MPA boundary around a central point, approximating 450 ha.
Cyclicity	Annual for mature males. Biannual or triannual for mature females.
Present (months)	Tagged sharks detected annually from June to December; highest numbers July to September.
Sex	Male and female
Shark Age	Mature
Number of sharks (tagged)	Between 29/08/2013 and 27/07/2021, 22 GNS with acoustic tags (14 males, 8 females) were detected at the Flat Rock MPA. Of these, 13 were tagged at Flat Rock (9 males, 4 females) and 9 were tagged at Fish Rock by NSW DPI (5 males, 4 females).
Number of sharks (observational)	Greatest relative abundance at Flat Rock observed in July–August (i.e., during the Austral winter) when up to 30 GNS were recorded on dive surveys (mean July MaxN = 23 GNS, mean August MaxN = 12 GNS). Survey frequencies at Flat Rock ranged between 3 and 28 diver-led counts per month (mean = 14, total = 68).
Other comments	Available Photo ID data on Sharkbook.ai: 06/07/1991 to 14/09/2024 (33+ years) • 276 unique sharks identified • 488 total records Dwyer, R. G., Rathbone, M., Foote, D. L., Bennett, M., Butcher, P. A., Otway, N. M., Louden, B. M., Jaine, F. R., Franklin, C. E., Kilpatrick, C. (2023). Marine reserve use by a migratory coastal shark, *Carcharias taurus*. *Biological Conservation*, **283**: 110099. DOI: 10.1016/j.biocon.2023.110099

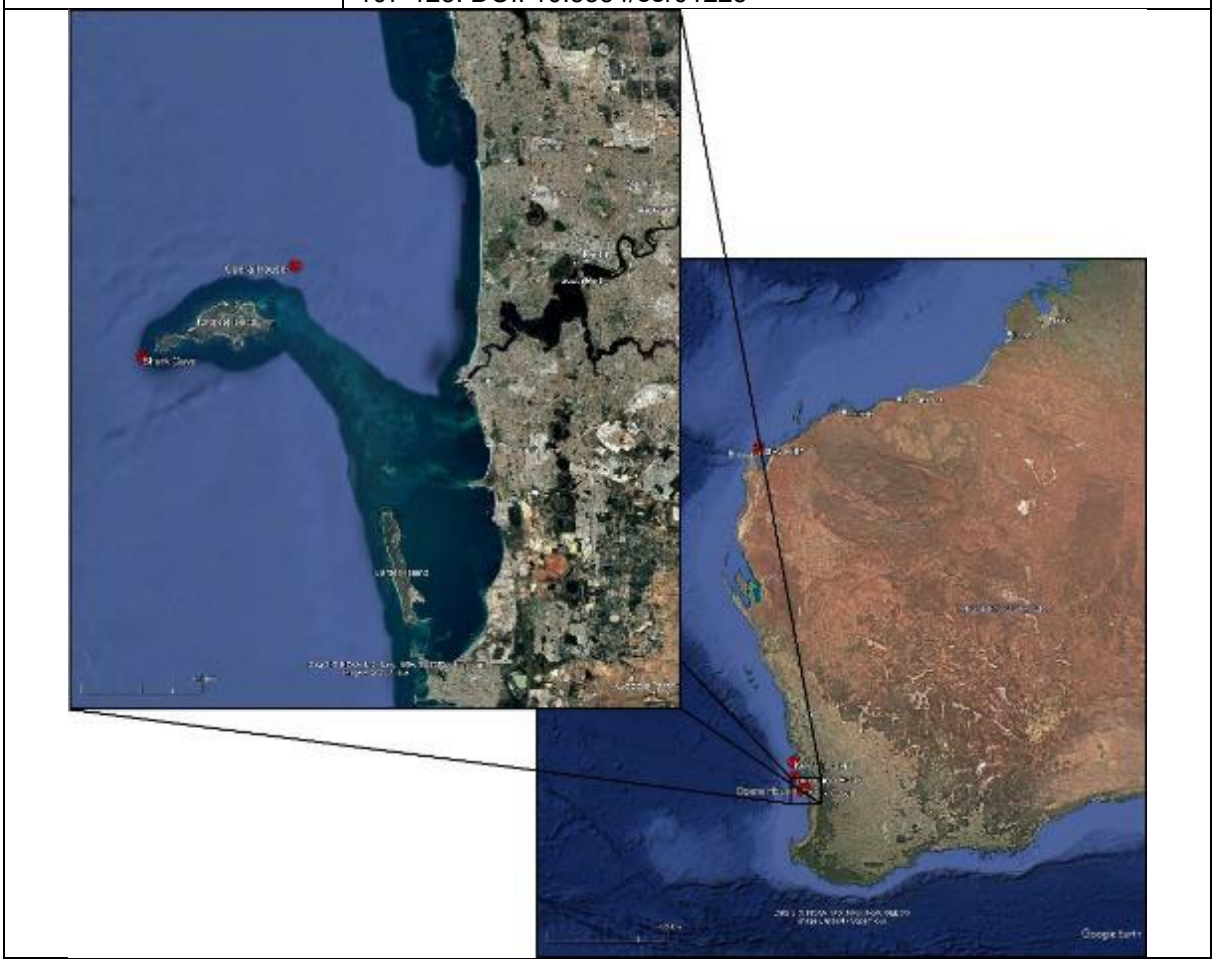
Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.



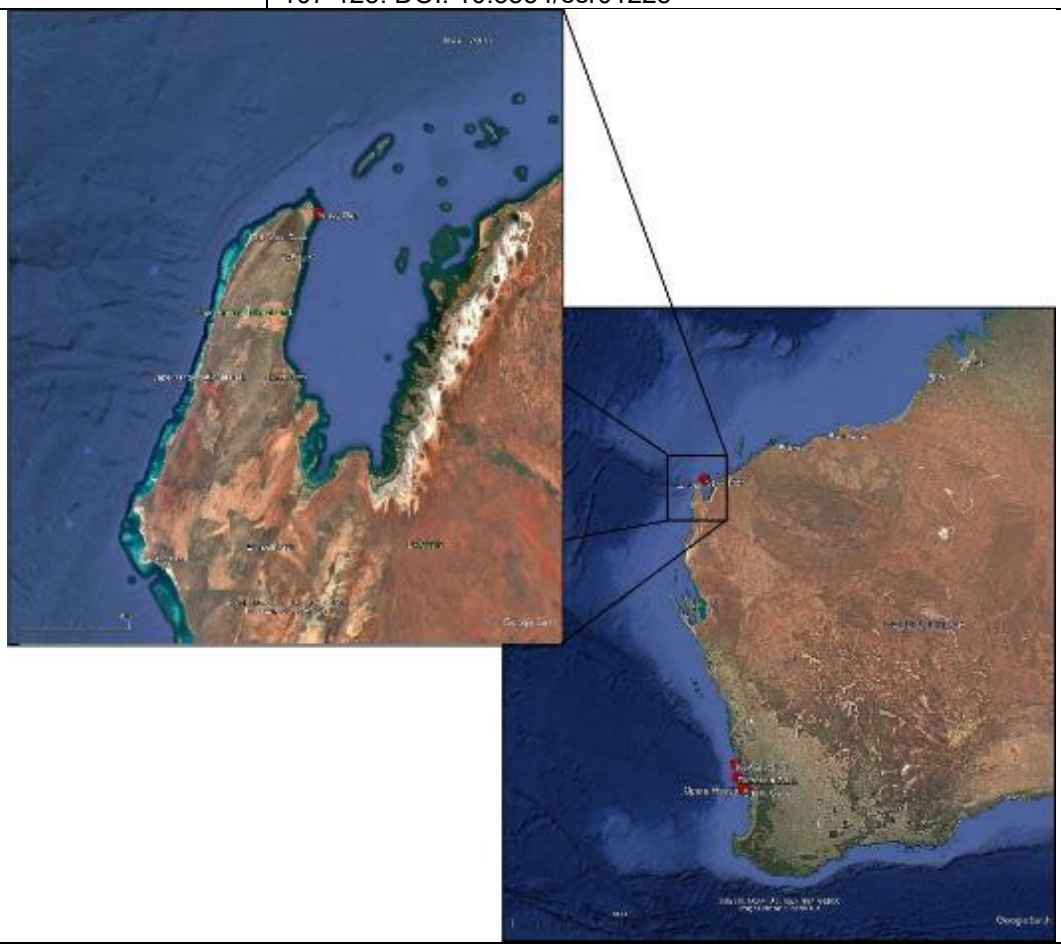
Location	**Cherub's Cave & Henderson Rock, Queensland**
GPS Coordinates	Cherub's Cave: 27° 7' 00.12" S 153° 28' 00.12" E Henderson Rock: 27° 7' 00.12" S 153° 28' 00.12" E
Legislative status	Located in Moreton Bay Marine Park and Designated as a GNS Area by Queensland Government. Activities are highly regulated in the designated area and restrictions relating to the interference of GNS and their habitat apply.
Size	Cherubs Cave and Henderson Rock are encapsulated by a single no-take MPA of 3520 ha that is at least 1.2 km around a central point at each aggregation site.
Cyclicity	Annual for males; biannual or triannual for females.
Present (months)	Tagged males were present between July and January. Tagged female GNS were present between June and December only.
Sex	Male and female
Shark Age	Mature
Number of sharks (tagged)	Between 24/11/2015 and 17/03/2022, 18 out of 34 tagged GNS (10 males, 8 females) were detected at the receivers positioned in the Cherubs Cave-Henderson Rock MPA. Of these, 1 female was tagged at Cherubs Cave, 7 were tagged at Flat Rock (5 males, 2 females) and 10 were tagged at Fish Rock (5 males, 5 females).
Number of sharks (observational)	
Other comments	Available Photo ID data on Sharkbook.ai: Cherubs Cave: 16/11/2004 to 27/07/2024 (19+ years) • 28 unique sharks identified • 39 total records Henderson Rock: 14/10/2004 to 27/09/2005 (less than 1 year) • 6 unique sharks identified • 6 total records Dwyer, R. G., Rathbone, M., Foote, D. L., Bennett, M., Butcher, P. A., Otway, N. M., Louden, B. M., Jaine, F. R., Franklin, C. E., Kilpatrick, C. (2023). Marine reserve use by a migratory coastal shark, *Carcharias taurus*. *Biological Conservation*, **283**: 110099. DOI: 10.1016/j.biocon.2023.110099

Appendix A: Summary of available data on listed and potential grey nurse shark aggregation sites.

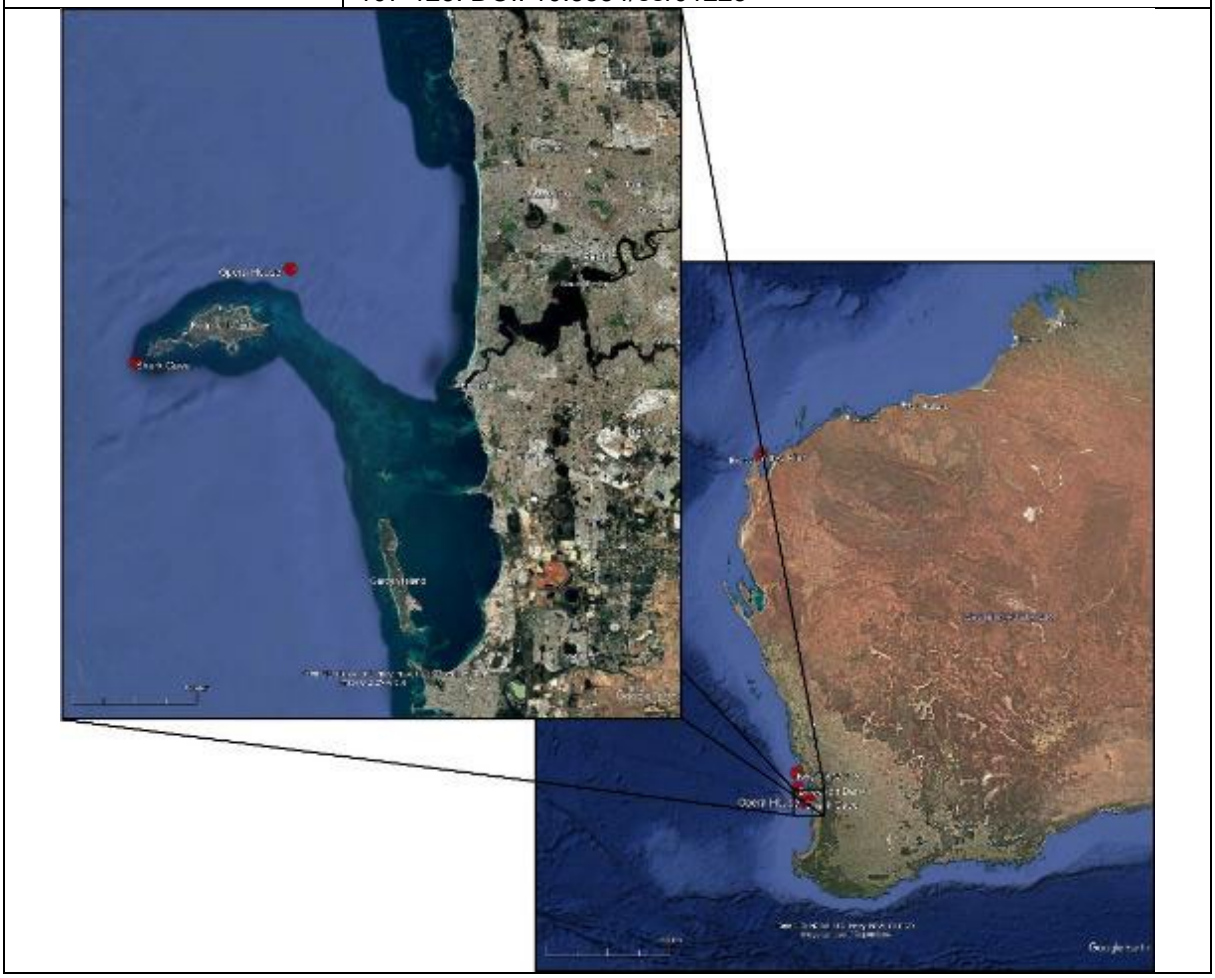
Location	**Shark Cave (Perth), Western Australia**
GPS Coordinates	32° 01' 50" S 115° 26' 09" E (approximate)
Legislative status	Within a demersal fishing closure and Fisheries exclusion zone of the Temperate Demersal Gillnet and Demersal Longline Fishery (TDGDLF).
Size	
Cyclicity	Annually
Present (months)	Year-round, peaking in April
Sex	Female bias
Shark Age	Unknown
Number of sharks (tagged)	None
Number of sharks (observational)	
Other comments	Identified through a Community Monitoring Program (Citizen Science). Hoschke et al. 2023. Population distribution, aggregation sites and seasonal occurrence of Australia's western population of the grey nurse shark *Carcharias taurus*. Endangered Species Research **50**: 107-123. DOI: 10.3354/esr01225



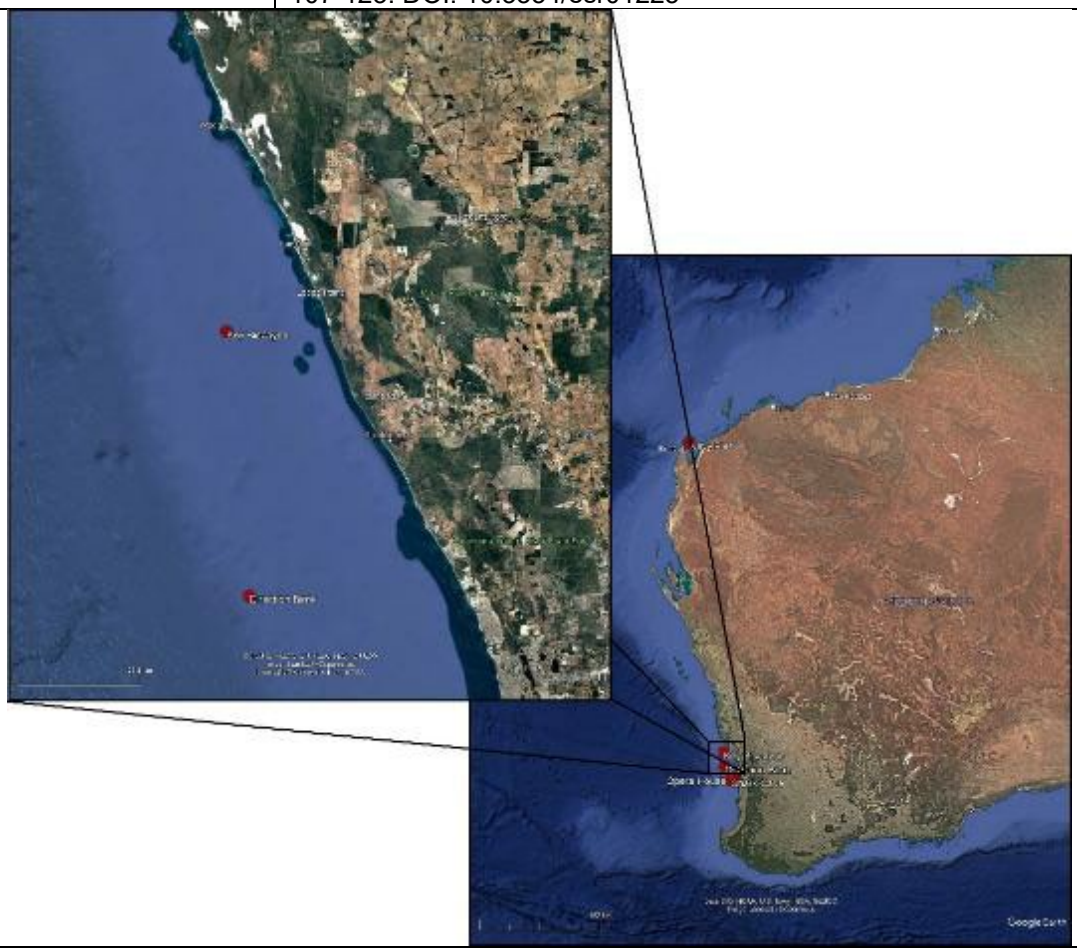
Location	**Exmouth Navy Pier (Exmouth), Western Australia**
GPS Coordinates	21° 49' 00.82" S 114° 11' 29.63" E
Legislative status	Unknown
Size	Primarily 1.5 – 2.5 m TL
Cyclicity	Annually
Present (months)	May/June – mid/late November (~7 months per year)
Sex	Male and female
Shark Age	Primarily immature
Number of sharks (tagged)	Average 5.5 per year (photo-tagged)
Number of sharks (observational)	
Other comments	Observations extend over approx. 15 years. Scientific and Community Monitoring Program. Hoschke et al. 2023. Population distribution, aggregation sites and seasonal occurrence of Australia's western population of the grey nurse shark *Carcharias taurus*. Endangered Species Research **50**: 107-123. DOI: 10.3354/esr01225



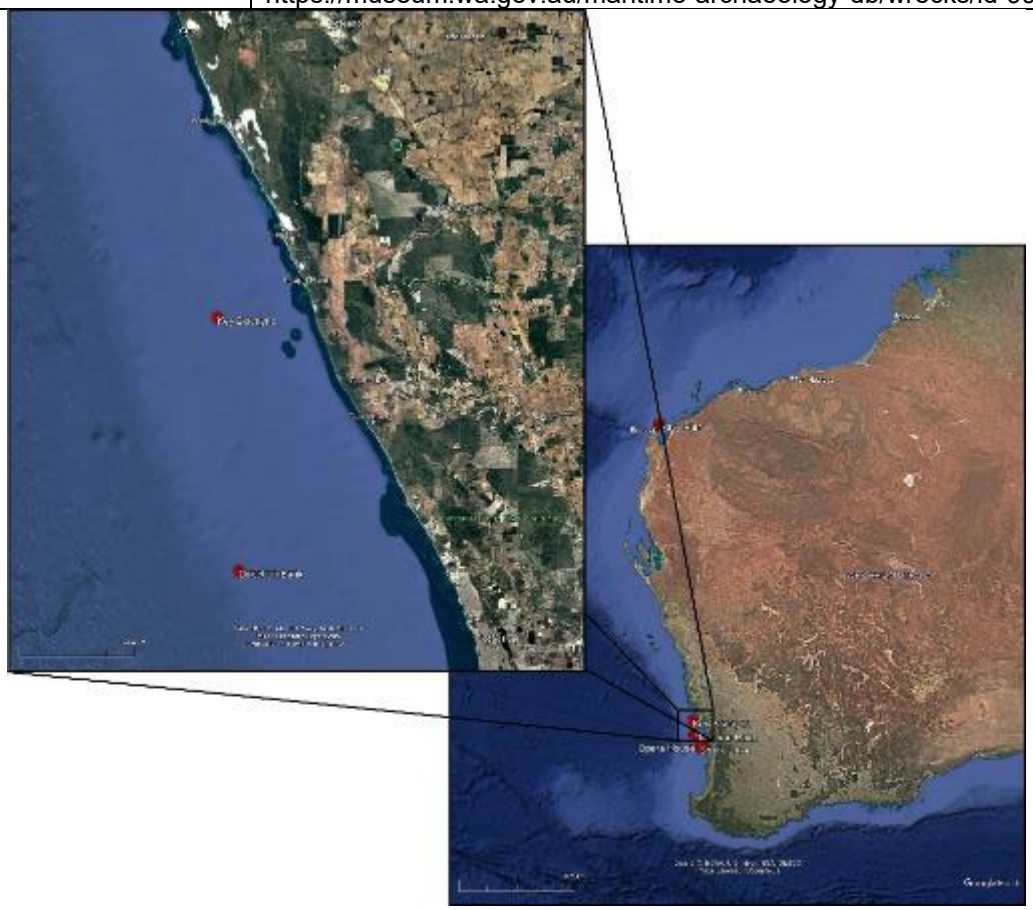
Location	**Opera House (Perth), Western Australia**
GPS Coordinates	31° 58' 30" S 115° 35' 16" E (approximate)
Legislative status	Open
Size	
Cyclicity	Annually
Present (months)	Year-round? – peaking in November
Sex	Data unavailable
Shark Age	Primarily immature
Number of sharks (tagged)	
Number of sharks (observational)	MaxN of ≥5 sharks recorded in 6 out of 9 years of surveys (average 3 dives per year). Average of ~ 4 sharks observed per dive.
Other comments	Data from Community Monitoring Program. Hoschke et al. 2023. Population distribution, aggregation sites and seasonal occurrence of Australia's western population of the grey nurse shark *Carcharias taurus*. Endangered Species Research **50**: 107-123. DOI: 10.3354/esr01225



Location	**Direction Bank (Two Rocks), Western Australia**
GPS Coordinates	31° 35' 49" S 115° 11' 25" E (approximate)
Legislative status	Open
Size	
Cyclicity	Annual?
Present (months)	May and October (biased by diver accessibility)
Sex	Male and female
Shark Age	Predominantly immature
Number of sharks (tagged)	
Number of sharks (observational)	87 observations across 11 dives 7.9 per dive
Other comments	Data from Community Monitoring Program. Only a small number of dives at this site. Hoschke et al. 2023. Population distribution, aggregation sites and seasonal occurrence of Australia's western population of the grey nurse shark *Carcharias taurus*. Endangered Species Research **50**: 107-123. DOI: 10.3354/esr01225



Location	**Key Biscayne (Lancelin), Western Australia**
GPS Coordinates	31° 10' 19" S 115° 12' 13" E (approximate)
Legislative status	Open
Size	
Cyclicity	Annual
Present (months)	February – April, August, October
Sex	
Shark Age	Mature sharks in March
Number of sharks (tagged)	
Number of sharks (observational)	3.4 per dive (23 dives)
Other comments	Data from Community Monitoring Program. Key Biscayne is a shipwreck dive site. Hoschke et al. 2023. Population distribution, aggregation sites and seasonal occurrence of Australia's western population of the grey nurse shark *Carcharias taurus*. Endangered Species Research **50**: 107-123. DOI: 10.3354/esr01225 https://museum.wa.gov.au/maritime-archaeology-db/wrecks/id-995



8. Appendix B: Compilation of acoustic data for monitored grey nurse aggregation sites in NSW.

Data from: Otway and Louden. (2025). Occupation of aggregation sites and migratory movements of the greynurse shark (*Carcharias taurus*) off eastern Australia. Report to NSW DPIRD.

Total count of tag detections of grey nurse shark individuals by month.

a) Julian Rocks.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	763							757			6		
2	Female	Immature	12									12			
3	Female	Immature	4									4			
4	Female	Immature	448			4				24	388	32			
5	Female	Immature	739								198	541			
6	Female	Immature	8									8			
7	Female	Immature	187								176	11			
8	Female	Mature	7								7				
9	Female	Mature	11								11				
10	Male	Immature	56						18	17	1		20		
11	Male	Mature	192							78	85	22	5	2	
12	Male	Mature	410								406		4		
13	Male	Mature	1705						497	258	680	223		6	41
14	Male	Mature	99						31	1				67	
15	Male	Mature	201						11	145					45
16	Male	Mature	71						51		1			19	
17	Male	Mature	2128							519	1600	9			
	Total no. individuals		17	0	0	1	0	0	5	8	11	9	4	4	2
	Female		9	0	0	1	0	0	0	2	5	6	1	0	0
	Male		8	0	0	0	0	0	5	6	6	3	3	4	2
	Immature		8	0	0	1	0	0	1	3	4	6	2	0	0
	Mature		9	0	0	0	0	0	4	5	7	3	2	4	2

b) Pimpernel Rock.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	1320			514	806								
2	Female	Immature	37								37				
3	Female	Immature	399								26	258	115		
4	Female	Mature	1						1						
5	Female	Mature	22						22						
6	Male	Immature	1												1
7	Male	Mature	43							1				31	11
8	Male	Mature	1003						606	184		134	48	19	12
9	Male	Mature	3901	732	927		1438		328		25				451
10	Male	Mature	633						238						395
11	Male	Mature	3709	313										750	2646
	Total no. individuals		11	2	1	1	2	0	5	2	3	2	2	3	6
	Female		5	0	0	1	1	0	2	0	2	1	1	0	0
	Male		6	2	1	0	1	0	3	2	1	1	1	3	6
	Immature		4	0	0	1	1	0	0	0	2	1	1	0	1
	Mature		7	2	1	0	1	0	5	2	1	1	1	3	5

c) North Solitary Island.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	16056						380	274		4369	4027	5964	1042
2	Female	Immature	303							303					
3	Female	Immature	1387											1387	
4	Female	Immature	24								1		23		
5	Female	Immature	3936							3772	164				
6	Female	Immature	394							1					393
7	Male	Immature	2395										87	1761	547
8	Male	Immature	88												88
9	Male	Mature	3660						132	391	87		1739	1310	1
10	Male	Mature	23488	1						4705	5054	6118	5748	1862	
11	Male	Mature	5603						4825						778
12	Male	Mature	1130	807	49					2	54				218
13	Male	Mature	461						435	25					1
14	Male	Mature	272						8					264	
15	Male	Mature	3												3
	Total no. individuals		15	2	1	0	0	0	5	8	5	2	5	6	9
	Female		6	0	0	0	0	0	1	4	2	1	2	2	2
	Male		9	2	1	0	0	0	4	4	3	1	3	4	7
	Immature		8	0	0	0	0	0	1	4	2	1	3	3	4
	Mature		7	2	1	0	0	0	4	4	3	1	2	3	5

d) South Solitary Island.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	11820							2185	4989	2700	1291	655	
2	Female	Immature	4											4	
3	Female	Immature	741						677	64					
4	Female	Immature	5									2	2	1	
5	Female	Immature	114972	5613	10378	14838	15651	9050	7432	3774	5433	11869	15381	9392	6161
6	Female	Immature	15137							2	1354	6132	6490	1078	81
7	Female	Mature	2030		1					2	806	58	983	180	
8	Female	Mature	716												716
9	Female	Mature	195							195					
10	Male	Immature	171							171					
11	Male	Mature	1763						1393	320	50				
12	Male	Mature	7867						1258	1549	3033	1062	880	85	
13	Male	Mature	2110					822	336	131				608	213
14	Male	Mature	4270					61	4141	68					
15	Male	Mature	712						522						190
16	Male	Mature	613							277				336	
17	Male	Mature	610							610					
	Total no. individuals		17	1	2	1	1	3	7	13	6	6	6	9	5
	Female		9	1	2	1	1	1	2	6	4	5	5	6	3
	Male		8	0	0	0	0	2	5	7	2	1	1	3	2
	Immature		7	1	1	1	1	1	2	5	3	4	4	5	2
	Mature		10	0	1	0	0	2	5	8	3	2	2	4	3

e) Fish Rock.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	5809						399	4064	15		1	994	336
2	Female	Immature	13074	3982	663	92					2003	619	635	1997	3083
3	Female	Immature	8284	324							336	4055	1052	1012	1505
4	Female	Immature	24606	1948	1475	1142	1180	1447	6027	1782			1358	2194	6053
5	Female	Immature	6931							739	2309	1929	1180	521	253
6	Female	Immature	234373	28770	25840	15217	20431	19771	16731	16999	20734	29039	14086	11471	15284
7	Female	Immature	1076							605		470		1	
8	Female	Immature	11666					51	4036	3145	1106	2123	954	251	
9	Female	Immature	68959	340		402	2993	10525	12189	13461	6920	9443	3919	5383	3384
10	Female	Immature	16685	1364			1	663	5770	145				2637	6105
11	Female	Immature	29686	5221	3036	978					6696	5460	216	967	7112
12	Female	Immature	24550						246	9148	6224	6329	2603		
13	Female	Immature	6099							1016	515	608	488	434	3038
14	Female	Immature	33217	4777	2086	1618				3895	3822	6046	3254	2386	5333
15	Female	Immature	2480						1140	90	1	454	793	2	
16	Female	Immature	17235	2493	32	155				143	8154	662		4487	1109
17	Female	Mature	2											2	
18	Female	Mature	2											2	
19	Female	Mature	3963							601	243	3118		1	
20	Female	Mature	6503			1			807	3734		456		480	1025
21	Female	Mature	1073										1047	3	23
22	Female	Mature	108						1				105	1	1
23	Female	Mature	10	3							1			3	3
24	Male	Immature	30622	3989					1738	2147	6888	3084	1334	6290	5152
25	Male	Immature	15092	2		4	1	2299	6309	3290				1737	1450
26	Male	Mature	16831						2095	2705	1465	1946	2078	3331	3211
27	Male	Mature	6049						1514	2427	1985			82	41
28	Male	Mature	2329					79	1734					489	27
29	Male	Mature	2322											1901	421
30	Male	Mature	3276					181	2696					6	393
31	Male	Mature	7287						1793	1543		2222	630	786	313
32	Male	Mature	19140	2851	1155	4101	2124	3079	1913	1664					2253
33	Male	Mature	3532					713	1636	1				530	652
	Total no. individuals		33	13	7	10	6	10	19	22	18	18	18	31	26
	Female		23	10	6	8	4	5	10	15	15	15	15	22	16
	Male		10	3	1	2	2	5	9	7	3	3	3	9	10
	Immature		18	11	6	8	5	6	10	15	14	14	14	17	14
	Mature		15	2	1	2	1	4	9	7	4	4	4	14	12

f) Green Island.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	9							9					
2	Female	Immature	266										13	253	
3	Female	Immature	1										1		
4	Female	Immature	5					3					2		
5	Female	Immature	114									114			
6	Female	Immature	21							21					
7	Female	Immature	1189					32	421	597			131	5	3
8	Female	Immature	78	1				20	57						
9	Female	Immature	4												4
10	Female	Immature	11								1	10			
11	Female	Immature	1060							708	352				
12	Female	Immature	521								374	14		4	129
13	Female	Immature	4										4		
14	Male	Immature	3							3					
15	Male	Immature	6						6						
16	Male	Mature	1						1						
17	Male	Mature	1597							25	2	62	1426		82
18	Male	Mature	3						3						
19	Male	Mature	129						129						
20	Male	Mature	1							1					
21	Male	Mature	4						4						
22	Male	Mature	29						29						
	Total no. individuals		22	1	0	0	0	3	8	7	4	4	6	3	4
	Female		13	1	0	0	0	3	2	4	3	3	5	3	3
	Male		9	0	0	0	0	0	6	3	1	1	1	0	1
	Immature		15	1	0	0	0	3	3	5	3	3	5	3	3
	Mature		7	0	0	0	0	0	5	2	1	1	1	0	1

g) Cod Grounds.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	4984						3092	247		1431	214		
2	Female	Immature	5189	211			43			1946	243	2746			
3	Female	Immature	702	341		223				138					
4	Female	Immature	2093		423				808	146	625		91		
5	Female	Immature	1260							1260					
6	Female	Immature	874						731			143			
7	Female	Immature	349										349		
8	Female	Immature	7772		575	2302	2568	1918	409						
9	Female	Immature	1213	1213											
10	Female	Immature	2463						573	849	1041				
11	Female	Immature	1										1		
12	Female	Mature	19439	3699	2761	1024	2498			2477	2684	754	60	156	3326
13	Female	Mature	2938					220		25	1863	45	767	18	
14	Female	Mature	1251								7	1244			
15	Female	Mature	2577					1497	806	24	246	2	2		
16	Male	Immature	246							16		1	229		
17	Male	Mature	767						631					136	
18	Male	Mature	2108							1720				388	
19	Male	Mature	841					214	575						52
20	Male	Mature	1518	1119					305					94	
21	Male	Mature	10013				573	646	4363	420	105	185	351	142	3228
22	Male	Mature	252					252							
23	Male	Mature	2132			235		1708	189						
	Total no. individuals		23	5	3	4	4	7	11	12	8	9	9	6	3
	Female		15	4	3	3	3	3	6	9	7	7	7	2	1
	Male		8	1	0	1	1	4	5	3	1	2	2	4	2
	Immature		12	3	2	2	2	1	5	7	3	4	5	0	0
	Mature		11	2	1	2	2	6	6	5	5	5	4	6	3

h) Pinnacle.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	23									23			
2	Female	Immature	2653	2021				232			206				194
3	Female	Immature	125		125										
4	Female	Immature	24	24											
5	Female	Immature	1201	597				339			265				
6	Female	Immature	2737	1325			794				618				
7	Female	Immature	544	330					213					1	
8	Female	Immature	2												2
9	Female	Immature	307		2									305	
10	Male	Immature	206							105					101
11	Male	Immature	5315	1	295	273	4085	661							
12	Male	Mature	3214				1320		162	683	626	406		17	
13	Male	Mature	760		466	147		1						30	116
14	Male	Mature	640					640							
15	Male	Mature	4492	64	241	803	2769	154		440					21
16	Male	Mature	370		13	144								213	
17	Male	Mature	4599	1221		283	2478	617							
18	Male	Mature	3				2	1							
	Total no. individuals		18	8	6	5	6	8	2	3	4	2	0	5	5
	Female		9	5	2	0	1	2	1	0	3	1	0	2	2
	Male		9	3	4	5	5	6	1	3	1	1	0	3	3
	Immature		11	6	3	1	2	3	1	1	3	1	0	2	3
	Mature		7	2	3	4	4	5	1	2	1	1	0	3	2

i) Big Seal Rocks.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	539							52	104	383			
2	Female	Immature	2690					169	1729		792				
3	Female	Immature	8314		2384	2726	2326				860		18		
4	Female	Immature	4616	1129			881	428	314		1641			55	168
5	Female	Immature	182	182											
6	Female	Immature	3154	2658											496
7	Female	Immature	45362	4624	9755	7339	3040	2180	2910	883	4995	2486	474	5053	1623
8	Female	Immature	188										188		
9	Female	Immature	33441	10649	2382	4378	3922	1822	1013	1247	630	107	1331	1172	4788
10	Female	Immature	12132	576	3086	4297	2994		232	164	624			159	
11	Female	Immature	622	419	203										
12	Female	Immature	15822	9015	4694	133	83	282	143	590	89	343		450	
13	Female	Mature	6155	209			75	998	1240	147	857	1273	202		1154
14	Female	Mature	312						1		178	2		7	124
15	Female	Mature	728								353	375			
16	Female	Mature	5			1	3						1		
17	Male	Immature	325				1			77					247
18	Male	Immature	8097	2868	1362	3561	295	8	3						
19	Male	Mature	6134	58	84			2482	3329	181					
20	Male	Mature	5163	1756	512				785	110	82				1918
21	Male	Mature	13077	221	830	247	1385	6282	633						3479
22	Male	Mature	24662	752	1168	6033	5709	6745	1295	193				1794	973
23	Male	Mature	8576	1820	1128	580	1346		2492						1210
24	Male	Mature	492			492									
	Total no. individuals		24	15	12	11	13	10	14	10	12	7	6	7	11
	Female		16	9	6	6	8	6	8	6	11	7	6	6	6
	Male		8	6	6	5	5	4	6	4	1	0	0	1	5
	Immature		14	9	7	6	8	6	7	6	8	4	4	5	5
	Mature		10	6	5	5	5	4	7	4	4	3	2	2	6

j) Little Seal Rocks.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	21					21							
2	Female	Immature	420			420									
3	Female	Immature	235	223				7	1						4
4	Female	Immature	503												503
5	Female	Immature	3564	835	470	674	1408	1			173	2		1	
6	Female	Immature	807	434	52	71				134				75	41
7	Female	Immature	173	2	88					54	10			19	
8	Female	Immature	1							1					
9	Female	Immature	233		233										
10	Female	Mature	1123				60		2	111	285	665			
11	Female	Mature	1								1				
12	Female	Mature	35								35				
13	Male	Immature	73	72											1
14	Male	Immature	2839	1432	85		1322								
15	Male	Mature	421				242	179							
16	Male	Mature	153	53	73		11	16							
17	Male	Mature	1171	2	49		552	483	82						3
18	Male	Mature	405	33	117	191		15	36						13
19	Male	Mature	5		5										
	Total no. individuals		19	9	9	4	6	7	4	4	5	2	0	3	6
	Female		12	4	4	3	2	3	2	4	5	2	0	3	3
	Male		7	5	5	1	4	4	2	0	0	0	0	0	3
	Immature		11	6	5	3	2	3	1	3	2	1	0	3	4
	Mature		8	3	4	1	4	4	3	1	3	1	0	0	2

k) Magic Point.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	3												3
2	Female	Immature	610						610						
3	Female	Immature	345						345						
4	Female	Mature	48								48				
5	Male	Mature	13					13							
	Total no. individuals		5	0	0	0	0	1	2	0	1	0	0	0	1
	Female		4	0	0	0	0	0	2	0	1	0	0	0	1
	Male		1	0	0	0	0	1	0	0	0	0	0	0	0
	Immature		3	0	0	0	0	0	2	0	0	0	0	0	1
	Mature		2	0	0	0	0	1	0	0	1	0	0	0	0

l) Tollgate Islands.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	109	9		32	1						11	1	55
2	Female	Immature	6							6					
3	Female	Immature	293	56	34	91								3	109
4	Female	Immature	1						1						
5	Female	Immature	39	38				1							
6	Female	Immature	26				2	1	4			2	17		
	Total no. individuals		6	3	1	2	2	2	2	1	0	1	2	2	2
	Female		6	3	1	2	2	2	2	1	0	1	2	2	2
	Male		0	0	0	0	0	0	0	0	0	0	0	0	0
	Immature		6	3	1	2	2	2	2	1	0	1	2	2	2
	Mature		0	0	0	0	0	0	0	0	0	0	0	0	0

m) Montague Island.

Shark	Sex	Maturity	Total no. tag detections	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Female	Immature	35	35											
2	Female	Immature	9											9	
3	Female	Immature	38044	5846	6082	3940	2817	569	704	999	3399	4956	4767	2161	1804
	Total no. individuals		3	2	1	1	1	1	1	1	1	1	1	2	1
	Female		3	2	1	1	1	1	1	1	1	1	1	2	1
	Male		0	0	0	0	0	0	0	0	0	0	0	0	0
	Immature		3	2	1	1	1	1	1	1	1	1	1	2	1
	Mature		0	0	0	0	0	0	0	0	0	0	0	0	0

Total count of tag detections of grey nurse shark individuals by year.

a) Julian Rocks.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	763							757		6		
2	Female	Immature	12											
3	Female	Immature	4			4								
4	Female	Immature	448			64				4			380	
5	Female	Immature	739				318		8	413				
6	Female	Immature	8				8							
7	Female	Immature	187				187							
8	Female	Mature	7								7			
9	Female	Mature	11			11								
10	Male	Immature	56		2	16	20	18						
11	Male	Mature	192			112			8	16			56	
12	Male	Mature	410					287		4			119	
13	Male	Mature	1705			4	44	285	3	502		667	200	
14	Male	Mature	99			1	66	32						
15	Male	Mature	201				36	11	8	114	1		31	
16	Male	Mature	71			1		18		2	50			
17	Male	Mature	2128		2128									
	Total no. individuals		17	0	2	8	7	6	4	8	3	2	5	0
	Female		9	0	0	3	3	0	1	3	1	1	1	0
	Male		8	0	2	5	4	6	3	5	2	1	4	0
	Immature		8	0	1	3	4	1	1	3	0	1	1	0
	Mature		9	0	1	5	3	5	3	5	3	1	4	0

b) Pimpernel Rock.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	1320										1320	
2	Female	Immature	37									37		
3	Female	Immature	399				399							
4	Female	Mature	1				1							
5	Female	Mature	22				22							
6	Male	Immature	1			1								
7	Male	Mature	43							32	3	8		
8	Male	Mature	1003			19					382		477	12
9	Male	Mature	3901			303	3364	234						
10	Male	Mature	633				395				238			
11	Male	Mature	3709			2457	1062	190						
	Total no. individuals		11	0	0	4	6	2	0	1	3	2	2	1
	Female		5	0	0	0	3	0	0	0	0	1	1	0
	Male		6	0	0	4	3	2	0	1	3	1	1	1
	Immature		4	0	0	1	1	0	0	0	0	1	1	0
	Mature		7	0	0	3	5	2	0	1	3	1	1	1

c) North Solitary Island.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	16056				1592	3806	8611		1185	862		
2	Female	Immature	303			303								
3	Female	Immature	1387			1387								
4	Female	Immature	24				24							
5	Female	Immature	3936		3936									
6	Female	Immature	394		394									
7	Male	Immature	2395		69		2326							
8	Male	Immature	88			88								
9	Male	Mature	3660			3133			132	3	233	1	158	
10	Male	Mature	23488			1	367		6266	34	11467	1875	3478	
11	Male	Mature	5603				240		1150	1392		592	2229	
12	Male	Mature	1130			1071	2	57						
13	Male	Mature	461							89		1	371	
14	Male	Mature	272			264			8					
15	Male	Mature	3		3									
	Total no. individuals		15	0	4	7	6	2	5	4	3	5	4	0
	Female		6	0	2	2	2	1	1	0	1	1	0	0
	Male		9	0	2	5	4	1	4	4	2	4	4	0
	Immature		8	0	3	3	3	1	1	0	1	1	0	0
	Mature		7	0	1	4	3	1	4	4	2	4	4	0

d) South Solitary Island.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	11820			5904	4236	691	939	50				
2	Female	Immature	4								4			
3	Female	Immature	741					741						
4	Female	Immature	5		1	2			2					
5	Female	Immature	114972		4330	5110	2075	819	24736	44006	29762	373	3761	
6	Female	Immature	15137		4083	1859		4411	4747	37				
7	Female	Mature	2030		12	796	1163		58		1			
8	Female	Mature	716	716										
9	Female	Mature	195			195								
10	Male	Immature	171					171						
11	Male	Mature	1763			50			213	164	257	194	885	
12	Male	Mature	7867			2879	2594	1689		57	2	1	645	
13	Male	Mature	2110					412	125	100	614		859	
14	Male	Mature	4270			2934		1336						
15	Male	Mature	712				180	113	98		1		320	
16	Male	Mature	613			240	334	33				1	5	
17	Male	Mature	610			348	262							
	Total no. individuals		17	1	4	11	7	10	8	6	7	4	6	0
	Female		9	1	4	6	3	4	5	3	3	1	1	0
	Male		8	0	0	5	4	6	3	3	4	3	5	0
	Immature		7	0	3	4	2	5	4	3	2	1	1	0
	Mature		10	1	1	7	5	5	4	3	5	3	5	0

e) Fish Rock.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	5809		1324	2905	1152	190		238				
2	Female	Immature	13074		1778	2165	5272	3614	245					
3	Female	Immature	8284		2374	324	1560	766	3125					
4	Female	Immature	24606		5208	5874	2047	8138	59	358		95	2827	
5	Female	Immature	6931			735	2552		3360	284				
6	Female	Immature	234373		10256	131099	78625	1127	16	8708	4391	6	136	9
7	Female	Immature	1076		1	1075								
8	Female	Immature	11666			1008	2532	3994		3268	864			
9	Female	Immature	68959		4478	8231	10157	8842	5395	14989	5906	5502	4090	752
10	Female	Immature	16685		2195	1791	6959	686	1153		2302	1522	63	14
11	Female	Immature	29686		972	3277	15190	5882	1767	354	2244			
12	Female	Immature	24550			336	1857	573	21784					
13	Female	Immature	6099	3472	107	496	381	1274	369					
14	Female	Immature	33217	3486	11028	2773	11173	4757						
15	Female	Immature	2480	2	936	492	1049	1						
16	Female	Immature	17235	3814	8659	1821	154	2787						
17	Female	Mature	2		2									
18	Female	Mature	2		2									
19	Female	Mature	3963		1		3274	688						
20	Female	Mature	6503	1505	4541				456			1		
21	Female	Mature	1073	26		1047								
22	Female	Mature	108	2	106									
23	Female	Mature	10	6	2		1	1						
24	Male	Immature	30622	6015	9611	5970	4659	4367						
25	Male	Immature	15092	2549	5177	3560	3458	348						
26	Male	Mature	16831		2447	5731	5996	504	612	532	257	255	477	20
27	Male	Mature	6049		1					81	2034	3171		
28	Male	Mature	2329		2	487	431	424		79		906		
29	Male	Mature	2322		2322									
30	Male	Mature	3276		1	5	625	391	348	26	798	47	853	
31	Male	Mature	7287		1099	10	2852	3034		16		46	226	
32	Male	Mature	19140	2253	15662	523	590	112						
33	Male	Mature	3532	1179	1931	422								
	Total no. individuals		33	12	29	25	24	23	13	12	8	10	7	4
	Female		23	8	19	17	17	16	11	7	5	5	4	3
	Male		10	4	10	8	7	7	2	5	3	5	3	1
	Immature		18	6	15	18	17	16	10	7	5	4	4	3
	Mature		15	6	14	7	7	7	3	5	3	6	3	1

f) Green Island.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	9				9							
2	Female	Immature	266					266						
3	Female	Immature	1				1							
4	Female	Immature	5			2		3						
5	Female	Immature	114			114								
6	Female	Immature	21			21								
7	Female	Immature	1189		3	340	843	3						
8	Female	Immature	78				77		1					
9	Female	Immature	4				4							
10	Female	Immature	11			10	1							
11	Female	Immature	1060				1060							
12	Female	Immature	521		133	90	298							
13	Female	Immature	4			2	2							
14	Female	Mature	1			1								
15	Male	Immature	3				3							
16	Male	Immature	6			2		4						
17	Male	Mature	1597		82		1490	25						
18	Male	Mature	3					3						
19	Male	Mature	129				129							
20	Male	Mature	1				1							
21	Male	Mature	4				4							
22	Male	Mature	29			29								
	Total no. individuals		22	0	3	10	14	6	1	0	0	0	0	0
	Female		14	0	2	8	9	3	1	0	0	0	0	0
	Male		8	0	1	2	5	3	0	0	0	0	0	0
	Immature		15	0	2	8	10	4	1	0	0	0	0	0
	Mature		7	0	1	2	4	2	0	0	0	0	0	0

g) Cod Grounds.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	4984				3092	1892						
2	Female	Immature	5189			1301	2035	669			1141	43		
3	Female	Immature	702				138			1		222	341	
4	Female	Immature	2093			215	208	954	91	625				
5	Female	Immature	1260			1260								
6	Female	Immature	874					98	776					
7	Female	Immature	349					226			123			
8	Female	Immature	7772			2326			1		2803			2642
9	Female	Immature	1213								1213			
10	Female	Immature	2463			1041	849	289	284					
11	Female	Immature	1			1								
12	Female	Mature	19439			6450	6872	1687	2634	529	1093	174		
13	Female	Mature	2938			45	962	1786	145					
14	Female	Mature	1251		1065	186								
15	Female	Mature	2577		2551	7	17	2						
16	Male	Immature	246		1	229	16							
17	Male	Mature	767				136	458			173			
18	Male	Mature	2108			197	24		1	379		1507		
19	Male	Mature	841					234			372	6	197	32
20	Male	Mature	1518			94						31	558	835
21	Male	Mature	10013		235	4844	4687	152			1	94		
22	Male	Mature	252			252								
23	Male	Mature	2132		1959	173								
	Total no. individuals		23	0	5	16	12	12	7	4	8	7	3	3
	Female		15	0	2	10	8	9	6	3	5	3	1	1
	Male		8	0	3	6	4	3	1	1	3	4	2	2
	Immature		12	0	1	7	6	6	4	2	4	2	1	1
	Mature		11	0	4	9	6	6	3	2	4	5	2	2

h) Pinnacle.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	23						23					
2	Female	Immature	2653		194	232	2021		206					
3	Female	Immature	125				125							
4	Female	Immature	24			24								
5	Female	Immature	1201			604	597							
6	Female	Immature	2737		1325	794			618					
7	Female	Immature	544		213	330			1					
8	Female	Immature	2		2									
9	Female	Immature	307			2			305					
10	Female	Mature	3214			2116			1032	66				
11	Female	Mature	760		1	146	613							
12	Female	Mature	640		640									
13	Male	Immature	206		101	105								
14	Male	Immature	5315			5314	1							
15	Male	Mature	4492			594	64		3834					
16	Male	Mature	370			370								
17	Male	Mature	4599			3095	1504							
18	Male	Mature	3			3								
	Total no. individuals		18	0	7	14	7	0	7	1	0	0	0	0
	Female		12	0	6	8	4	0	6	1	0	0	0	0
	Male		6	0	1	6	3	0	1	0	0	0	0	0
	Immature		11	0	5	8	4	0	5	0	0	0	0	0
	Mature		7	0	2	6	3	0	2	1	0	0	0	0

i) Big Seal Rocks.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	539					383	156					
2	Female	Immature	2690						427			2094	169	
3	Female	Immature	8314			7436	423	437	18					
4	Female	Immature	4616		1	1900	17		1780	918				
5	Female	Immature	182			182								
6	Female	Immature	3154		496	2658								
7	Female	Immature	45362			5968	383	3384	22871	5624		5354	430	1348
8	Female	Immature	188					188						
9	Female	Immature	33441		3898	10316	5974	13253						
10	Female	Immature	12132		2999	8642	287	201	3					
11	Female	Immature	622		620			2						
12	Female	Immature	15822		418	7447	618	677	6662					
13	Female	Mature	6155			2246	272			1843	25	1716	53	
14	Female	Mature	312			133	1	178						
15	Female	Mature	728			728								
16	Female	Mature	5			4		1						
17	Male	Immature	325			78	247							
18	Male	Immature	8097		8	7572	477	40						
19	Male	Mature	6134			3481	94		84	2475				
20	Male	Mature	5163		1917	1772	80	184	581		249	59	321	
21	Male	Mature	13077		3127	1998	1663	1082	291	13	44	3168	1167	524
22	Male	Mature	24662		2599	6108	881	6242	1905	1995	529	2639	350	1414
23	Male	Mature	8576				3353	2836	1041	12	766	568		
24	Male	Mature	492			1	491							
	Total no. individuals		24	0	10	19	16	15	12	7	5	7	6	3
	Female		16	0	6	12	8	10	7	3	1	3	3	1
	Male		8	0	4	7	8	5	5	4	4	4	3	2
	Immature		14	0	7	10	8	9	7	2	0	2	2	1
	Mature		10	0	3	9	8	6	5	5	5	5	4	2

j) Little Seal Rocks.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	21										21	
2	Female	Immature	420			420								
3	Female	Immature	235		3	207	20		5					
4	Female	Immature	503		503									
5	Female	Immature	3564			3389	1			5		169		
6	Female	Immature	807		490	159	158							
7	Female	Immature	173		61	112								
8	Female	Immature	1				1							
9	Female	Immature	233			233								
10	Female	Mature	1123			2				3	26	1092		
11	Female	Mature	1			1								
12	Female	Mature	35		35									
13	Male	Immature	73		72	1								
14	Male	Immature	2839		985	1854								
15	Male	Mature	421				421							
16	Male	Mature	153				68		13		3		53	16
17	Male	Mature	1171		3	1055	95		16		1		1	
18	Male	Mature	405				341		27		21	13	3	
19	Male	Mature	5				5							
	Total no. individuals		19	0	8	11	9	0	4	2	4	3	4	1
	Female		12	0	5	8	4	0	1	2	1	2	1	0
	Male		7	0	3	3	5	0	3	0	3	1	3	1
	Immature		11	0	6	8	4	0	1	1	0	1	1	0
	Mature		8	0	2	3	5	0	3	1	4	2	3	1

k) Magic Point.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	3		3									
2	Female	Immature	610			610								
3	Female	Immature	345		114	231								
4	Female	Mature	48		48									
5	Male	Mature	13			13								
	Total no. individuals		5	0	3	3	0	0	0	0	0	0	0	0
	Female		4	0	3	2	0	0	0	0	0	0	0	0
	Male		1	0	0	1	0	0	0	0	0	0	0	0
	Immature		3	0	2	2	0	0	0	0	0	0	0	0
	Mature		2	0	1	1	0	0	0	0	0	0	0	0

l) Tollgate Islands.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	109			7	1	37		55	9			
2	Female	Immature	6				6							
3	Female	Immature	293			3	52			104	5	129		
4	Female	Immature	1				1							
5	Female	Immature	39				38	1						
6	Female	Immature	26				19	3	4					
	Total no. individuals		6	0	0	2	6	3	1	2	2	1	0	0
	Female		6	0	0	2	6	3	1	2	2	1	0	0
	Male		0	0	0	0	0	0	0	0	0	0	0	0
	Immature		6	0	0	2	6	3	1	2	2	1	0	0
	Mature		0	0	0	0	0	0	0	0	0	0	0	0

m) Montague Island.

Shark	Sex	Maturity	Total no. tag detections	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Female	Immature	35								35			
2	Female	Immature	9			9								
3	Female	Immature	38044							154	12831	7983	13650	3426
	Total no. individuals		3	0	0	1	0	0	0	1	2	1	1	1
	Female		3	0	0	1	0	0	0	1	2	1	1	1
	Male		0	0	0	0	0	0	0	0	0	0	0	0
	Immature		3	0	0	1	0	0	0	1	2	1	1	1
	Mature		0	0	0	0	0	0	0	0	0	0	0	0

9. Appendix C: Important Shark and Ray Areas (ISRA).

https://sharkrayareas.org/wp-content/uploads/isra-resources/ISRA-Guidance-document.pdf

ISRA CRITERIA

CRITERIA	DESCRIPTION
Criterion A Vulnerability	Areas important to the persistence and recovery of threatened sharks. *(This criterion must be associated with an additional criterion.)*
Criterion B Range Restricted	Areas holding the regular and/or predictable presence of range-restricted sharks, that are occupied year round or seasonally.
Criterion C Life-History	Areas that are important to sharks for carrying out vital functions across their life-cycle (i.e., reproduction, feeding, resting, movement, or undefined aggregations).
Sub-criterion C1 Reproductive Areas	Areas that are important for sharks to mate, give birth, lay eggs, or provide refuge and other advantages to the young.
Sub-criterion C2 Feeding Areas	Areas that are important for shark nutrition at one or more life-cycle stages.
Sub-criterion C3 Resting Areas	Areas that are important for sharks to conserve energy, often related to environmental conditions or temporal factors.
Sub-criterion C4 Movement	Areas used by sharks regularly or predictably during their movements, such as migrations, which contribute to connectivity of other functionally important areas.
Sub-criterion C5 Undefined Aggregations	Areas where an aggregation or assemblage of sharks regularly and/or predictably occur, year round or seasonally, but the function of the aggregation or assemblage is currently unknown.
Criterion D Special Attributes	Areas important for sharks considered for distinct biological, behavioral, or ecological attributes (unique or associated with a unique habitat type), or which support an important diversity of species.
Sub-criterion D1 Distinctiveness	Areas with sharks that display distinct biological, behavioral, or ecological characteristics.
Sub-criterion D2 Diversity	Areas that sustain an important diversity of sharks.

10. Appendix D: Flyer distributed within the Gippsland community to seek reports of grey nurse shark sightings.

11. Appendix E: Remote Operated Vehicle transect paths during grey nurse shark surveys of the Gippsland region of Victoria.

Figure 17. Remote operated vehicle transect paths around Rabbit Island, Victoria.

Figure 18. Remote operated vehicle transect paths around Cliffy Island, Victoria.

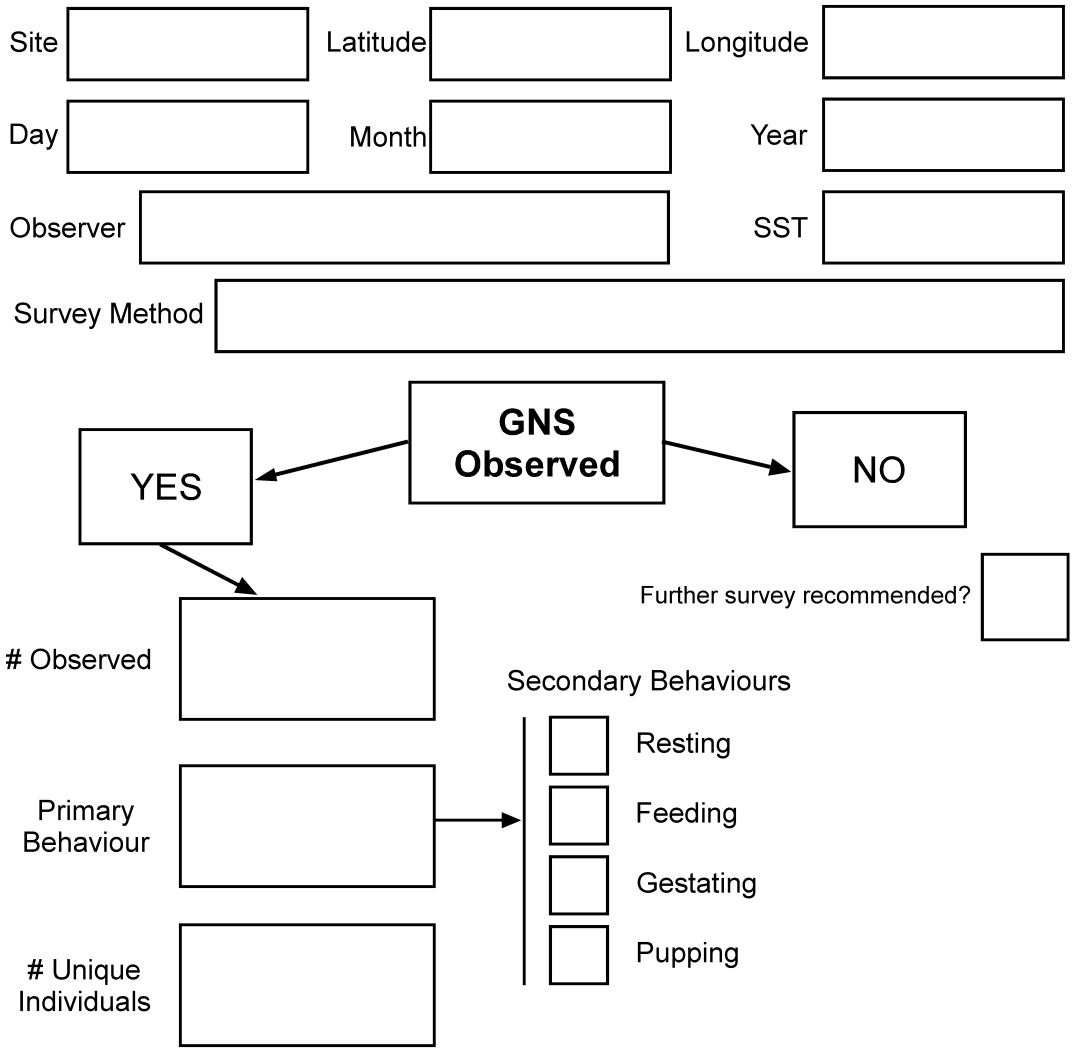
Figure 19. Remote operated vehicle transect paths around Rag Island, Victoria.

Figure 20. Remote operated vehicle transect path around Notch Island, Victoria.

Figure 21. Remote operated vehicle transect path around Seal Island, Victoria.

12. Appendix F: Site survey log.

Grey Nurse Shark Site Survey



	Tag	Photo	Tissue Sample	Unique marks
S1				
S2				
S3				
S4				
S5				
S6				

For additional sharks, please put data on reverse of this form

CONTACTS

Name: David Harasti

Email: david.harasti@dpi.nsw.gov.au

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