Fishery and spatial management solutions to inform the protection and recovery of Australia's threatened endemic elasmobranchs.

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Executive Summary

This report is about Australian, endemic elasmobranchs (hereafter 'sharks and/or rays') that require immediate action to conserve, manage, and recover populations according to the 2021 Action Plan for Australian Sharks and Rays. Thirteen Australian endemic sharks and rays are threatened. This report identifies ten which interact with the Southern and Eastern Scalefish and Shark Fishery (SESSF). The SESSF fishery was used as a best-case scenario of data availability.

Mitigation measures that will see these species moved to lower threat categories, or removed from threatened species status, is the primary conservation goal. A three-step approach towards achieving this is used in this report. Firstly, insights into the changing threats from Commonwealth Fisheries are presented; secondly, a case is made to support the retention and/or expansion of existing spatial closures to support breeding success and connectivity between adult and juvenile habitats; and lastly, an improved mapping approach to support design of effective spatial closures or protected areas under or across various jurisdictions is recommended. This process identified six Candidate Areas for consideration into marine spatial planning that should limit and/or halt declines and support the recovery of the identified threatened Australian endemic sharks and rays.

Candidate Area selection was based on identification of areas of critical habitats with lower historical removals, and existing State and Commonwealth fisheries closures and/or MPAs. Critical habitat was defined through published scientific knowledge on the biological, ecological, and geographical requirements and attributes of the selected species. This was complemented by tracking data for two of the endemic shark species. Tracking data was also used to consider closure size for those species. Spatial distribution of removals was considered by analysis of Australian Fisheries Management Authority (AFMA) fisheries and logbook data, broken down by fishing zone. Recent AFMA observer data was also examined but found not adequate to estimate depletions or determine demographic structure of populations. Recommendations for improvements to data quality for informing spatial protections, as well as maps of the identified Candidate Areas, are presented for the ten threatened Australian endemics.

Objectives

The primary aim of this report was to assess fisheries impacts and identify possible protected areas necessary for the persistence and recovery of threatened Australian endemic sharks and rays. Specific objectives include:

1. Identify spatial areas within the Southern and Eastern Scalefish and Shark Fishery (SESSF) with the potential to support the recovery of threatened endemic sharks and rays as identified in the Australian Action Plan for Sharks and Rays (Kyne et al., 2021);

2. Project the estimated degree of recovery of each identified species over their respective three-generation time length, based on the protections afforded by proposed spatial protections and/or fisheries closures;

3. Present specific case studies of both deep-water and coastal species which examine the feasibility and projected outcomes of proposed spatial protections;

4. Produce maps as a visual aid to communicate the results and support the inclusion of the endemic species and their essential and/or critical habitats into SESSF fisheries closures, State-based MPA and AMP Network Plans, and onto the Finalised Priority Assessment List (FPAL) of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Key Findings

This report considered conservation of ten threatened endemic Australian sharks and rays at the strategic, tactical and implementation levels. At the strategic level, a combined fisheries and spatial management approach is key. Tactical considerations to achieve this include the location, size, number, and connectivity of closures and/or protected areas, as well as activity restrictions within those areas. Tactical considerations are challenged by limited data. Implementation of strategic and tactical measures are challenged by jurisdictional complexity.

Key findings of this report are:

1. Threatened endemic sharks and rays in southern and eastern Australia remain under-represented in current management and/or conservation arrangements. Mapping analysis found there is minimal overlap between critical habitat and current spatial protective measures (e.g., SESSF fisheries closures, Australian Marine Park [AMP] networks or State MPAs). Currently there is limited co-ordination across jurisdictional boundaries (e.g., State-to-Commonwealth or State-to-State). Effective implementation of additional protections can be achieved but will need cohesive strategies implemented across multiple jurisdictions.

2. The ten threatened endemic species will remain highly susceptible to further declines under current SESSF fishing activities without inclusion into spatial protection measures. Some of these species have previously undergone major population declines (~30-90%) from demersal fisheries operating across their ranges for over 40 years.

3. Ongoing threats from the SESSF fishery to the species of concern are changing. There was a substantial (60%) reduction in the number of trawl operations between 2000 and 2021. For non-trawl methods, effort has increased in some areas since 2008. The consequence of these changes for fisheries is that new risks are emerging inshore, on different habitats, with cumulative effects.

4. Depletion levels for *Cephaloscyllium albipinnum* across its full range from trawl activity was not as severe as previously thought, however this species now faces further threat from increased auto line fishing effort. Inshore skates and stingarees are predicted to be heavily impacted by increased Danish Seine efforts, but increased gillnet effort in Bass Strait is not expected to have substantial impact to the sharks and rays as very few are selected by this fishing method despite range overlaps.

5. Improved core habitat distribution maps for the endemic sharks and rays presented in this report support the identification and delineation of proposed Candidate Areas and subsequent map outputs. The maps predict distributions based on abiotic data (i.e., temperature and depth) and were further refined with bathymetric (e.g., seafloor depth) data. This approach is simplistic but realistic for demersal species, particularly skates and rays, because they are strongly associated with the sea floor. The maps presented provide a more reliable basis for spatial planning because they are more representative of where the highest numbers of individuals would be found.

6. Six Candidate Areas for spatial protections are proposed. These are based on a set of selection criteria which identify species critical habitats using biological, ecological, and environmental information. Objectivity and repeatability of Candidate Area identification can be maintained by consistent application of these criteria.

The criteria and sub-criteria are:

Criterion 1.	Suitable Habitat
Criterion 2.	Biological Importance
Sub-criterion 2a.	Breeding Habitat
Sub-criterion 2b.	Essential Habitat
Criterion 3.	Ecological Importance
Sub-criterion 3a.	Threat
Sub-criterion 3b.	Diversity
Criterion 4.	Abundance and Extent

7. Spatial management strategies for the Candidate Areas should be considered on a case-by-case basis according to the species and habitat type selected. Proposed Candidate Areas are intended to correlate with existing State and Commonwealth fisheries closures and/or MPAs. Candidate Areas represent locations where sufficient information to meet the criteria exists, and where existing closures or protected areas could be modified by zoning review to include the endemic sharks and rays specifically. Further application of the criteria and identification of additional Candidate Areas is recommended to comprehensively meet conservation objectives for these species. Effective implementation of any spatial protections for each Candidate Area can be achieved but will need cohesive strategies implemented across multiple jurisdictions.

8. Tracking data results for *Cephaloscyllium albipinnum* and *Squalus chloroculus* in Candidate Area 4 emphasise that some knowledge of individual movement scale is essential for designing effective closures. This means that the existing paradigm of protecting a sum of 30% of habitat in the combined closures for a species will not necessarily be enough to conserve that species.

9. Zoning is critical to the performance of marine parks in State MPA and Commonwealth AMP networks. Only Marine Sanctuaries (IUCN Ia), Marine National Parks (IUCN II) or Habitat and/or Species Protection Areas (IUCN IV) as defined by the EPBC Act and implemented in State and Commonwealth Marine Parks will meet the conservation objectives of this study. Substantial increases in size and rezoning would be needed for Candidate Areas to meet or fully meet all criteria. This would have major economic consequences.

10. Improved life history data for the endemic sharks and rays will support accurate recovery predictions and assist in development of effective spatial protections. Without further knowledge on habitat use for movements, reproduction, and/or feeding, or the species demographics (e.g., size, sex), size considerations for any MPA or fisheries closures cannot be comprehensive.

Recommendations

Key findings from the mapping and effort analysis in this report contribute to knowledge of critical habitats and current threats for endemic Australian sharks and rays. The recommendations below are intended to translate these findings into actions that can support the conservation status, recovery, and persistence of these species. We also highlight improvements to data quality and assessment methods that would reduce the substantial uncertainty risks in managing and conserving these species. Recommendations include:

Actionable Steps Towards Conservation

1. Maintain and consolidate AFMAs Upper Slope Dogfish Management Strategy. Broaden the strategy in conjunction with the Commonwealth Department of Environment to include *Cephaloscyllium albipinnum* and *Dipturus canutus*.

2. In the South-east region consider expanding areas closed to all fishing methods in Bass Strait to protect endemic skates and stingarees. Importantly such expansion would need to consider the potential impacts of effort displacement onto protected species, such as school sharks and Australian sea lions.

3. In the Temperate East Australian Marine Park Network, consider expanding areas closed to all fishing methods in the Jervis Marine Park by changing boundaries and rezoning of special purpose fishing zones. Develop complimentary closed area measures with Jervis Bay Marine Park in New South Wales to link offshore adult habitat to inshore breeding and juvenile habitat. Obtain effort data from NSW fisheries to explore alternative scenarios of closure size.

4. Maintain and consolidate the Tasmanian Shark Nursery Areas. Consider further restrictions on fishing in Storm Bay to increase migration of sharks and rays from egg-laying and pupping areas in enclosed waters to adult habitat in coastal waters. Consider further restrictions of fishing in the coastal waters adjacent to Storm Bay where suitable adult habitat occurs.

5. Off South Australia, maintain areas closed to all fishing methods, and modify the current MPA zoning in the northeast of Kangaroo Island primarily to conserve *Urolophus orarius*, as this is the species with the most restricted range of any endemics considered here.

6. Overall deep-sea fisheries management arrangements for sharks and rays should be considered, and developed in a more precautionary manner, in light of data deficiency on species composition, biology and habitats given the high risk of mortality for these species in bycatch, their current rates of population decline, and future impacts of environmental change.

Data and Analysis Improvements

1. Improve access to existing State and Commonwealth fishing effort data and catch data for bycatch species (noting that catch data for commercial species needs to remain confidential).

2. Develop a comprehensive strategy for the collection of future data. Periodically undertake detailed onboard observations/surveys of endemic shark and ray catch rates to support ongoing CPUE analysis. Undertake a statistical analysis of the coverage required. Develop data limited methods to standardise CPUE considering longitude, latitude, and depth and apply these to trawl effort at minimum across the full geographic range of the fishery. Develop methods to examine CPUE in the auto longline and Danish Seine sectors.

3. Improve resourcing for on-board observers in the SESSF. Collect length frequency and sex data for endemic sharks and rays during on board observations (observer data). Provide training in species identification to resolve misidentifications and improve data validity. Increase the number and geographic range of on-board observations. While the implementation of e-monitoring holds potential for more cost-effective monitoring in the future (at least for State fisheries that have no ongoing onboard observer programs), this is not considered an effective replacement for onboard observations in the SESSF at this time.

Contents

List of Tables

List of Figures

Abbreviations

AFMA	Australian Fisheries Management Authority
AMCS	Australian Marine Conservation Society
AMP	Australian Marine Park
ABNJ	Areas Beyond National Jurisdiction
BIA	Biologically Important Area
BRD	Bycatch Reduction Device
CMR	Commonwealth Marine Reserve
CPUE	Catch per Unit Effort
CR	Critically Endangered
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTS	Commonwealth Trawl Sector
DI	Daily Detection Index
DUR	Duration
EEZ	Exclusive Economic Zone
EN	Endangered
EPBC	*Environment Protection and Biodiversity Act 1999*
ERA	Ecological Risk Assessment
FPAL	Finalised Priority Assessment List of the EPBC Act
GAB	Great Australian Bight
GABT	Great Australian Bight Trawl
GIS	Geographic Information Systems
GBRMP	Great Barrier Reef Marine Park
GHAT	Gillnet Hook and Trap
HSI	Humane Society International Australia
ISRA	Important Shark and Ray Area
IUCN	International Union for the Conservation of Nature
MLD	Maximum Linear Days
MPA	Marine Protected Area
MSP	Marine Spatial Planning
NOAA	National Oceanic and Atmospheric Administration
NSW	New South Wales
NT	Near Threatened
PVA	Population Viability Assessment
QLD	Queensland
SA	South Australia
SARRI	Shark and Ray Recovery Initiative
SESSF	Southern and Eastern Shark and Scalefish Fishery
SET	Southeast Trawl Fishery
TAS	Tasmania
VIC	Victoria
VU	Vulnerable
WA	Western Australia

Background

Australia is a hotspot of endemic and evolutionarily distinct sharks and rays. Over 320 species (182 sharks, 132 rays and 14 chimaeras) occur in Australian waters, with 42% (138spp) of these being endemic (Kyne et al., 2021). Multiple fisheries impact the conservation status and hinder the recovery of these species. The Southern and Eastern Scalefish and Shark Fishery (SESSF) region is a hotspot for threatened endemics which have been identified as priority species for conservation in the Australian Action Plan for Sharks and Rays (Kyne et al., 2021). Of 39 Australian threatened shark and ray species, 10 are endemics which interact with the SESSF primarily as bycatch/byproduct from trawl and Gillnet Hook and Trap (GHAT) activities (Walker et al., 2007, 2008; Simpfendorfer et al., 2019; Daley and Gray, 2020). Most have undergone major population declines (up to 90%) as a direct result of fishing impacts over the past 40 years or longer (Daley and Gray, 2020). Species such as the whitefin swellshark (*Cephaloscyllium albipinnum*), greeneye spurdog (*Squalus chloroculus*) and longnose skate (*Dentiraja confusa*) are still caught despite their status of Critically Endangered on the IUCN Red List of Threatened Species (hereafter 'IUCN Red List') (Daley and Gray, 2020; Kyne et al., 2021; IUCN, 2023).

Endemic sharks and rays are high priority species for conservation as their restricted distributions mean the species' entire global population is geographically confined (Field et al., 2009; Finucci et al., 2021). Endemics are also more susceptible to anthropogenic threats (e.g., habitat degradation and fishing) given their smaller population sizes, range and/or environmental (e.g., depth) constraints, and *K*-selected[1] life-history characteristics (Ebert et al., 2013; Pollum et al., 2022). Spatial and temporal management of sharks and rays, and fisheries with which they interact, have the potential to reduce mortality, halt declines, and promote recovery (Birkmanis et al., 2020; Hyde at al., 2022). If incorrectly managed, shark fisheries (e.g., the SESSF) will likely contribute substantially to further population declines (Daley and Gray, 2020). Protecting threatened[2] endemic sharks and rays from fishing and other pressures is a global priority, with conservation responsibility for endemic species falling solely on the country and/or region where they occur (Davidson and Dulvy, 2017; Davidson, 2018).

Conservation of sharks and rays is challenging for fisheries managers, who must deal with competing objectives of economically viable harvesting of more productive species whilst conserving less productive species, particularly endemics (Jaiteh et al., 2016; Dulvy et al., 2017; Sherman et al., 2022). Full or partial fisheries closures have shown some success in establishing or maintaining sustainable shark fisheries (e.g., 'Bright Spots' as described in Simpfendorfer and Dulvy, 2017). Yet, insufficient research to determine the full ecological impact of closures to shark populations or the socio-economic response of fishers to these closures, exists (Jaiteh et al., 2016; Dulvy et al., 2017). The emerging challenge for most fisheries management methods is to ensure continued fisheries for the most productive species whilst also minimising the risk to, and allowing recovery of, less productive species (Jaiteh et al., 2016; Dulvy et al., 2017; Sherman and Simpfendorfer, 2022).

In Australia, endemics are not intentionally targeted and are of low commercial value. Yet, where endemics share key habitats with commercially managed species, they are likely to have high exposure to fishing risk (Daley et al., 1997). In the SESSF, shared fishery habitats where endemic sharks and rays are likely impacted include offshore reef patches, the ancient coastline near the 80m bathymetric contour, the shelf break near the 200m contour, and the upper continental slope between the 300 - 600m bathymetric contours (Daley et al., 2019; Daley et al., 2002). Whilst risks

[1] *K*-selected denotes species with slow growth, delayed maturation, long gestation, and the production of few young (Ebert et al., 2013).
[2] Species assessed as Critically Endangered, Endangered or Vulnerable on the IUCN Red List of Threatened Species (IUCN, 2023).

have been reduced to some extent (e.g., effort reduction, gear restrictions, and existing fishery closures), endemic sharks and rays remain vulnerable, even as bycatch. Existing closures aimed at commercial and protected species have potential to conserve endemics without major economic losses if they can be adapted for broader purpose. If knowledge of essential or critical habitats for endemic species can be mapped and presented to fisheries managers, the combined approach of spatial and temporal fisheries closures and implementation of protected areas which safeguard and provide refuge, they will directly contribute to persistence and recovery of these species (Simpfendorfer and Dulvy, 2017; Hyde et al., 2022).

Designing coherent marine spatial planning and fisheries management strategies for shark and ray populations is complex and, for most species, beyond the jurisdiction of any single regulatory authority in Australia. Successful strategies have included reduced-take areas, no-take[3] marine protected areas (MPAs), habitat protection areas, nursery closures, and spatial and/or temporal restrictions to fisheries methods or target species (Simpfendorfer and Dulvy, 2017; AFMA 2023). In Australia, protected areas can include Commonwealth fishery managed closures, Commonwealth Marine Reserves (CMRs) such as the Australian Marine Park (AMP) networks, and/or State managed MPAs. Successful conservation of endemic sharks and rays is dependent on spatial protections that encompass a substantial proportion of critical habitat[4] in Australian waters (Weigand et al., 2011; Hyde et al., 2022; Simpfendorfer, 2022). The characteristics of these critical habitats, however, often lack detailed consideration and supporting data to solve the problem of balancing both fisheries and biodiversity targets (Weigand et al., 2011; Hyde et al., 2022).

Development of habitat representative, and ecologically connected, networks of spatial protections including fisheries closures and MPAs, are urgently required for the recovery of endemic species (Davidson and Dulvy, 2017; Birkmanis et al., 2020; Hyde at al., 2022). This is especially important in areas of high fishing pressure, where identification and protection of critical habitats will help achieve management and conservation goals (Jabado et al., 2018; Mackeracher et al., 2018). Multidisciplinary spatial protections are widely considered the best approach to shark and ray management and conservation and are advocated as a key strategy in protecting or restoring their populations (Birkmanis et al., 2020). Protection of critical habitats required by species across all lifecycle stages[5] (e.g., reproductive or feeding sites) is also a key factor to achieving conservation objectives (Davidson and Dulvy 2017; MacKeracher et al., 2018). This is particularly crucial to consider where juveniles and adults of a species use different habitats, and fragmentation between these (e.g., loss of connectivity to nursery areas) will hinder reproductive success (Heupel et al., 2007; Kinney and Simpfendorfer, 2009). Kinney and Simpfendorfer (2009) highlight the need to develop management strategies which link juvenile and adult habitats, noting that protection of nursery areas and the young which use them is a critical component to shark and ray population recovery.

Despite their strategic value however, spatial protections for sharks and rays are challenging to implement. Key design challenges are size, location, and connectivity. Current global protected area (e.g., MPA) networks because of these challenges, do not overlap with geographic distributions of the most at-risk shark and ray species, most of which are threatened endemics (Davidson and Dulvy, 2017; Mackeracher et al., 2018). Presently, only 12% of globally threatened endemic sharks and rays have ranges which occur within no-take MPAs (Jabado et al., 2018;

[3] A no-take zone is an area set aside by a government where no extractive activity is allowed (i.e., any action that extracts, or removes, any resource). (National Oceanic and Atmospheric Administration [NOAA] 2023).

[4] Critical habitats for sharks and rays are defined as places within a species' (or group of species') distribution identified as serving one or more demographically important roles where the implementation of effective management actions will contribute to an improvement in the conservation status of the species (NOAA, 2023).

[5] Lifecycle stages of sharks, generally classified into four stages based on size and age of the species, including: (1) newborn or young-of-year; (2) juvenile; (3) sub-adult; and (4) adult. Age and size for each stage differ across species. (IUCN SSG, 2022).

Cheok et al., 2021). To inform temporal or spatial closures or MPAs of all threatened endemics within the SESSF region, knowledge of life history, distribution, abundance, and fishery interactions (e.g., catch data) is required. Establishing areas for possible fisheries closures or MPAs also requires identification of overlaps between existing protected area networks (e.g., AMPs), existing closures, key habitat features, and an understanding of movement behaviour and vital function aggregation sites (Lascelles et al., 2014; Birkmanis et al., 2020). The criteria and framework set out by the recently developed shark conservation initiatives Important Shark and Ray Areas (ISRAs) (Hyde at al., 2022) and the Shark and Ray Recovery Initiative (SARRI) (Simpfendorfer, 2022), provide guidance in determining critical and essential habitats and management strategies for threatened shark and ray endemics in the SESSF region. Additionally, SESSF observer and commercial catch data obtained from Australian Fisheries Management Authority (AFMA) may also provide information on shifts in fishing pressures over time.

Improved implementation of locally appropriate tools for endemic sharks and rays in the SESSF is required. Enhanced or increased closures and/or MPAs are a suitable approach for conserving these species. This report assesses and identifies fishing incident hotspots and areas of suitable habitat for ten threatened endemics which occur in the region. It also proposes Candidate Areas for additional spatial protections within existing, or for the consideration of future, SESSF closures, Australian Marine Parks (AMPs), and/or State-based fisheries closures and MPAs. This knowledge, in conjunction with the effects of fisheries impacts and predictions and/or projections of SESSF fisheries closures on threatened endemics, allows us to present recommendations addressing conservation needs and contribute to the recovery of threatened Australian endemic sharks and rays.

Objectives

The primary aim of this report is to assess fisheries impacts and identify possible protected areas necessary for the persistence and recovery of threatened Australian endemic sharks and rays. Specific objectives include:

1. Identify any potential spatial areas within the Southern and Eastern Scalefish and Shark Fishery (SESSF) (Figure 1) that will provide protection and support the recovery of threatened endemic sharks and rays as identified in the Australian Action Plan for Sharks and Rays (Kyne et al., 2021);

2. Project the estimated degree of recovery of each identified species over their respective three-generation time length (used to determine threatened status), based on the protections afforded by proposed spatial protections under the following scenarios (all scenarios factor in fishing effort displacement):

a) All proposed areas (incl. existing) are/have: (i) closed to all fishing; (ii) current fishing effort reduced by half.
b) Half of proposed areas (incl. existing) are/have: (i) closed to all fishing; (ii) current fishing effort reduced by half.
c) One third of proposed areas (incl. existing) are/have: (i) closed to all fishing; (ii) current fishing effort reduced by half.

3. Use existing movement/behavioural data of both whitefin swellshark and greeneye spurdog to present specific case studies under each of the above scenarios (2a, 2b, and 2c);

4. Produce maps as a visual aid to communicate the results of the above scenarios (2a, 2b and 2c);

5. Provide recommendations based on findings of actionable steps which will facilitate the conservation and recovery of the selected threatened endemics.

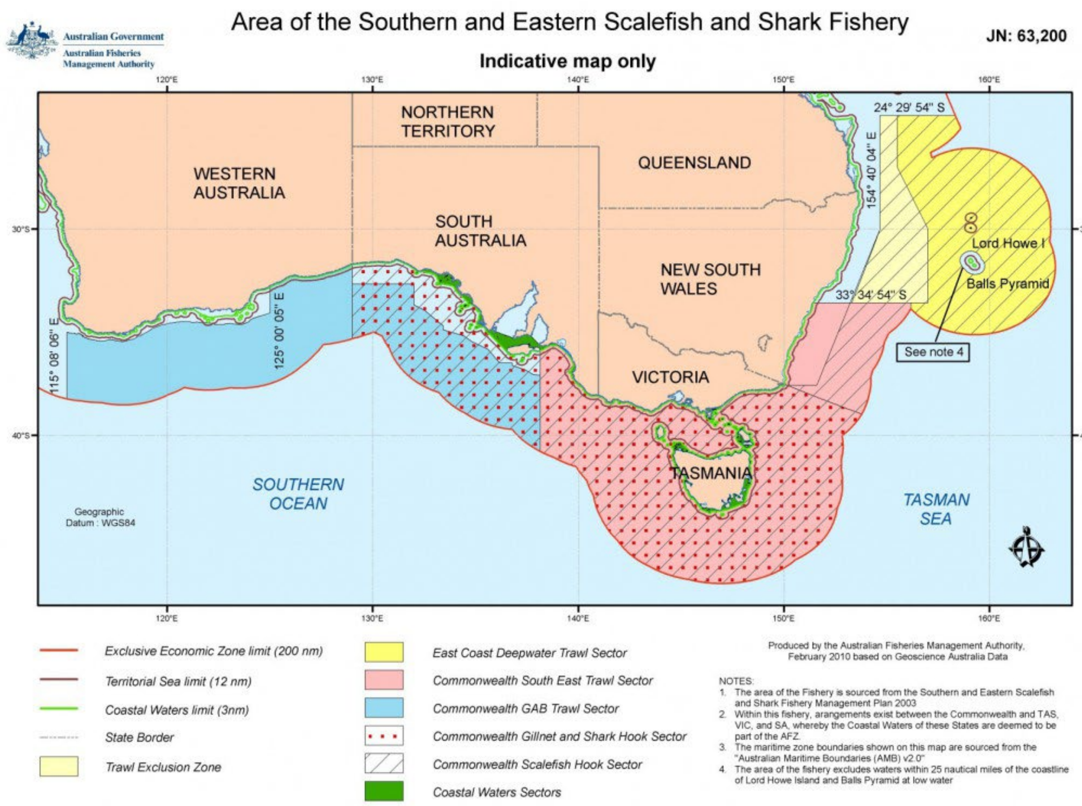

Figure 1. Map of the Southern and Eastern Scalefish and Shark Fishery (SESSF) activity zones (Source: Australian Fisheries Management Authority).

Methodology

The study comprised four main components: (1) identification of threatened Australian endemic sharks and rays; (2) analysis of fisheries data; (3) habitat mapping; and (4) identification of suitable areas for spatial protections (i.e., Candidate Areas).

Species selected were those identified in the Australian Action Plan for Sharks and Rays 2021 as threatened endemics whose geographic range occurred within operational areas of the SESSF. Interpretation of AFMA fisheries data included analysis of logbook, onboard observer, and onboard length data to investigate change in fishing pressures since 2003 and measurements of depletion. Habitat mapping was based on geographic and environmental features required by each species across its life history to identify suitable habitat areas within its range and determine accurate spatial distribution. Evaluation of components 1-3 determined recommendations for Candidate Area locations.

Species

Ten Australian endemic sharks and rays were selected from the Action Plan for Australian Sharks and Rays (Kyne et al., 2021) that met the criteria of both being a threatened species (i.e., assessed as Critically Endangered, Endangered or Vulnerable on the IUCN Red List and/or Australian Action Plan for Sharks and Rays) and having interactions with the SESSF. Each species is restricted to the territorial waters of Australia's Exclusive Economic Zone (EEZ) (Table 1). We note that IUCN Red List reassessment of *Dentiraja australis* in 2021 downlisted this species to Near Threatened but have included it in this study as it remains as Vulnerable on the Action Plan for Australian Sharks and Rays.

Table 1. Threatened Australian endemic sharks and rays including global and Australian conservation status, and distribution.

Species and Common Name	IUCN	Action Plan for Australian Sharks and Rays	Distribution (State/s)
Whitefin swellshark *Cephaloscyllium albipinnum*	CR	CR – Consider Listing	NSW, SA, TAS, VIC
Longnose skate *Dentiraja confusa*	CR	CR – Consider Listing	NSW, TAS, VIC
Greeneye spurdog *Squalus chloroculus*	EN	EN – Consider Listing	NSW, SA, TAS, VIC
Eastern angelshark *Squatina albipunctata*	VU	VU – Consider Listing	NSW, QLD, VIC
Grey skate *Dipturus canutus*	EN	EN – Prioritise Data Collection	NSW, SA, TAS, VIC
Coastal stingaree *Urolophus orarius*	EN	EN – Prioritise Data Collection	SA
Yellowback stingaree *Urolophus sufflavus*	VU	VU – Prioritise Data Collection	NSW, QLD
Greenback stingaree *Urolophus viridis*	VU	VU – Prioritise Data Collection	NSW, QLD, TAS, VIC
Melbourne Skate *Spiniraja whitleyi*	VU	VU – Prioritise Data Collection	NSW, SA, TAS, VIC, WA
Sydney skate *Dentiraja australis*	NT	VU – Prioritise Data Collection	NSW, QLD

A synopsis of each species is provided in Annex A. These outline key aspects of each species' biology, ecology, and life-history; distribution and range; required habitat/s; fisheries interactions and impacts; and conservation actions. Information on each species was predominantly sourced from the IUCN Red List and the Australian Action Plan for Sharks and Rays 2021, with additional data sources referenced for each species. Of relevance in this annex are the notes on detailed habitat associations that have been used to assist in interpreting distribution patterns in fisheries data.

Fisheries Data

Three types of Commonwealth fishery data were obtained from the Australian Fisheries Management Authority (AFMA): (i) logbook data; (ii) onboard observer data; and (iii) onboard length data.

Assessment focussed on understanding the likely bycatch mortality of endemics, based on the spatial distribution of effort, overlap with refined species distribution, and the catchability of different fishing gears. Logbook catch data were not adequate for analysis due to unreported discarding and species misidentifications (Daley and Gray, 2020). Logbook effort data were provided by AFMA as summaries only, due to commercial confidentiality. These data represent all fishing effort, whether the species of interest were recorded or not, giving the full sample size, geographic spread, and seafloor depth range of the fishery. To limit a potential loss of precision, the summaries were split geographically by AFMA Scalefish Zones (Figure 4: see Results) and by gear type. Gear type was used to consider selectivity, and species overlap by depth zone, as most gears have some depth restrictions.

Examination of the onboard observer data focused on determining if catch per unit effort (CPUE) can still be used as an indicator of trends in abundance. A previous study using the same methods has been successful in the past (Walker and Gason, 2007). *Cephaloscyllium albipinnum* was used as a case study for the trial, due to fewer misidentifications than that of other species, and it being a priority for EPBC Act listing consideration in 2023.

Observer onboard length frequency data were obtained with the intention of informing the locations of nursery habitats (small individuals) and breeding females (large individuals). These data were entirely lacking for most species and not adequate for the intended purpose for the remaining species due to very low numbers.

Mapping Habitat and Distribution

Habitats and/or areas used by sharks are influenced by interacting abiotic factors (e.g., temperature, depth) and biotic factors (e.g., reproduction, feeding) (Bangley et al., 2018). This section considered overall adult habitat and breeding habitat. Overall habitat is treated first, as some information was available for all the species considered. Breeding habitat was examined for just two species (*Cephaloscyllium albipinnum* and *Squalus chloroculus*) that had some tracking data available, as there was no fishery data and very little published data on breeding habitat for the other species. Geospatial data on each species' geographic range was obtained from the IUCN Red List[6]. Other geospatial layers were obtained from AFMA[7], Australian Marine Parks[8], CSIRO Marine Benthic Substrate Database[9], Geoscience Australia AusSeabed Database[10], and Seamap Australia[11]. Tasmanian Shark Refuge Areas[12] which included data on nursery areas for *Dentiraja confusa* and *Spiniraja whitleyi* obtained from the Tasmanian Recreational Sea Fishing Areas shapefiles available on the Tasmanian Government open access database theLIST. All maps were created using QGIS v3.22. For two species, *Cephaloscyllium albipinnum* and *Squalus chloroculus*, depth and temperature ranges were refined using sensor data from electronic tags (see Breeding Habitat below).

Suitable Habitat

Identifying habitat variables which influence a species occurrence is required to determine the spatial distribution of suitable habitat for threatened species (Giodano et al., 2010). In this report, suitable habitat is defined as the extent of area where one, or more, abiotic environmental feature preferred by the species, occurs. We used depth (m) and temperature (°C) as previous studies have identified these as the most reliable predictors of occurrence for sharks and rays (e.g., Sequeira et al., 2013; White et al., 2019). Data on temperature and depth for each species was collated from the IUCN Red List, the Action Plan for Australian Shark and Rays, and FishBase[13] (Table 2). Using QGIS, v3.22, we extracted the extent of area matching the preferred abiotic features within the species IUCN Red List range to identify its margin of suitable habitat. This allowed us to identify where the selected endemic species most likely occur to inform Candidate Area selection.

[6] IUCN Red List of Threatened Species
[7] Australian Fisheries Management Authority
[8] Australian Marine Parks
[9] CSIRO Marine Benthic Substrate Database
[10] Geoscience Australia AusSeabed Database
[11] Seamap Australia
[12] Tasmanian Shark Refuge Areas
[13] Fishbase

Table 2. Abiotic factor ranges influencing distributions.

Species	Depth Range (m)	Temperature Range (°C)	Habitat Features
Cephaloscyllium albipinnum	126-554	10.9 – 15.1	Outer continental shelf and upper-slope terraces, pinnacles, canyon heads
Dentiraja confusa	20-390	14.2 – 27.7	Continental shelf (and upper-slope)
Squalus chloroculus	216-1360	6.9 – 14.7	Continental upper-slope terraces, pinnacles, canyon heads
Squatina albipunctata	35-414	14.2 – 20.7	Continental shelf and upper slope
Dipturus canutus	155-1050	2.1 – 10.0	Upper continental slope (and outer shelf)
Urolophus orarius	5-50	16.3 – 18.5	Continental shelf, intertidal coastal
Urolophus sufflavus	45-320	12.7– 20.2	Continental shelf, intertidal coastal
Urolophus viridis	20-330	13.1 – 20.4	Continental shelf, intertidal coastal
Spiniraja whitleyi	1-345	14.2 – 18.5	Continental shelf and upper slope
Dentiraja australis	20-325	18.3 – 21.5	Continental shelf, intertidal coastal

Breeding Habitat

Distribution and scale of breeding habitat are key considerations for the design of effective closures. Species with individual home ranges of intermediate scales (tens of kilometres wide) are most likely to be managed effectively with closures (Bonfil, 1997). For all but two species in this study, there is very limited data to assess breeding habitat and/or movement. For *Cephaloscyllium albipinnum* and *Squalus chloroculus* we obtained passive acoustic telemetry data from the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Sharks were tracked for 15 months using an array of Vemco VR2 receivers arranged in a closure designed to manage fishery impacts on gulper sharks (Centrophordae) (Daley et al. 2015; Daley et al. 2019) (Figure 2). Sharks were fitted with Vemco v16 acoustic transmitter tags fitted to the dorsal fin of *Cephaloscyllium albipinnum* and surgically implanted in the peritoneal cavity of *Squalus chloroculus*. Tags were also fitted with temperature and depth sensors.

Other upper slope sharks are known to move along over seafloor along a very narrow corridor on seasonal scales, and across the corridor on daily (diurnal feeding) scales (Daley et al., 2015) Here we examined movement along slope, based on the spacing of receivers and movement across slope, based on the depth sensor data (Figure 2).

Along slope range was examined by summarising individual tag data using four metrics (Bond et al., 2012). Number of days (NDays) is a count of the different calendar days that an individual was detected. Duration (DUR) was the number of days from the first detection to the last. Maximum linear distance (MLD) is the linear point-to-point distance (displacement) between the western most and easternmost receivers that detected an individual. Daily detection index (DI) was the number of days detected/days at liberty, represented as a fraction. The sensor data were used to understand how biotic factors control distribution at fine scales by physiological constraint. Across rage was calculated as the mean depth recorded by the depth sensors ±2x stdev, equivalent to 90% of observations.

Temperature ranges were calculated for the two species as the mean temperature recorded by the sensors ±2x stdev, equivalent to 90% of observations. These ranges were used to refine published values to improve habitat maps.

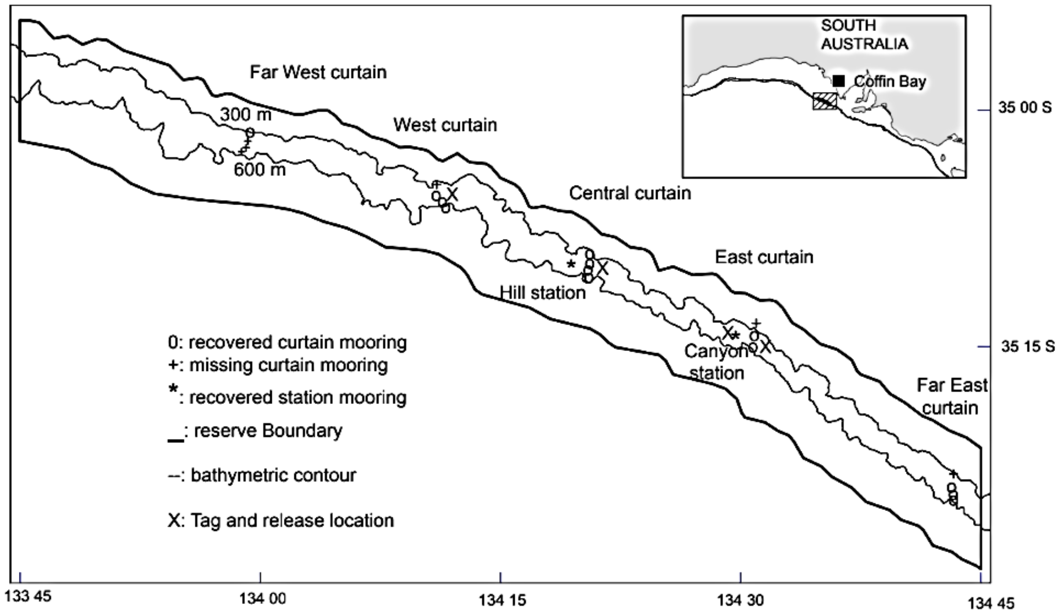

Figure 2 (and inset). Location of the study site and configuration of acoustic receiver study of *Cephaloscyllium albipinnum* and *Squalus chloroculus* on the upper continental slope off Southern Australia. Modified after Daley et al. 2015.

Selection of Candidate Areas

Using the data and scientific information collated in this report, we developed a set of criteria intended to evaluate and spatially refine potential candidate protected areas (e.g., closures and/or MPAs) and identify sites which may provide the best conservation outcomes for each species (Table 3). Candidate Areas represent locations where sufficient information to meet the criteria exists, and where existing closures or protected areas could be modified by rezoning to include the endemics specifically. The identification of Candidate Areas for protection is intended to inform the facilitation and uptake of the endemics and their critical habitats into existing management arrangements.

Management of Candidate Areas should be considered for both fisheries closures and/or as MPAs. Full exclusion of demersal fishing gear types and spatial-temporal closures to fisheries is recommended. We additionally propose the endemics in each Candidate Area should be referred to by species in State and/or Commonwealth protected area management arrangements either a: (a) Marine Sanctuary (IUCN Ia); (b) Marine National Park (IUCN II); or (c) Habitat/Species Management Area (IUCN IV).

The following criteria were developed based on methodology, criteria, and framework of the area-based conservation approaches of Important Shark and Ray Areas (ISRAs)[14] (Hyde et al., 2022) and the Shark and Ray Recovery Initiative (SARRI)[15] (Simpfendorfer, 2022). Effective spatial management of sharks requires consideration of several factors. Primarily, the identification of critical habitat/s, and the known, or inferred, ability of these habitats to support the species across its life cycle. Support can refer to the availability of biotic or abiotic resources (e.g., nutrition or environmental features contributing to reproductive success) and/or refuge from threats (e.g., predation, fishery activities or habitat degradation).

[14] Important Shark and Ray Areas (ISRAs)
[15] Shark and Ray Recovery Initiative (SARRI)

Candidate Areas were assessed by the criteria hierarchically to ensure representativeness of suitable and essential habitat. This included areas which may support vital functions, provide refuge for reproductive success or recovery from threats, or which may preserve the species diversity and/or the regional biodiversity. Each area should meet Criterion 1 for its location, then be justified by one, or more, criterion which identifies the importance of the area to the persistence of the species (Criterion 2 and/or 3). Each area should then be considered at a spatial scale relative to maintaining or increasing the species conservation status (e.g., enable recovery) (Criterion 4). Criteria and framework of ISRAs and SARRI are provided in Annex B and Annex C.

Table 3. Selection criteria developed to identify Candidate Areas for fisheries and/or spatial protections for threatened endemics in the southern and eastern regions of Australia.

<table>
<tr><td>Location</td><td colspan="3">Criterion 1. Suitable Habitat
The area is within the species global geographic range;
and is representative of its suitable biotic and abiotic habitat/s.</td></tr>
<tr><td rowspan="4">Justification</td><td colspan="3">Criterion 2. Biological Importance</td></tr>
<tr><td>Criterion 2a. Breeding Habitat
The area is recognised as, or is representative of, essential breeding habitat; (i) adult females and/or juveniles are present in the area; and/or (ii) the area meets criteria for a shark nursery area[1]</td><td>AND/ OR</td><td>Criterion 2b. Essential Habitat[2]
The area is recognised as, or is representative of, a habitat or site used regularly by the selected species for any other life history vital function; (i) feeding; (ii) movement/migration; (iii) refuge or resting</td></tr>
<tr><td colspan="3">Criterion 3. Ecological Importance</td></tr>
<tr><td>Criterion 3a. Threat
The species are considered high risk (i.e., threatened). The species are highly impacted by fishing activities of the SESSF (or similar fishery) and require refuge to achieve recovery and maintain their persistence: (i) assessed as IUCN Red List and/or Action Plan for Australian Sharks and Rays as Critically Endangered, Endangered, or Vulnerable; (ii) Spatial or temporal overlap of habitats or catch rate of target species; (iii) bycatch rates</td><td>AND/ OR</td><td>Criterion 3b. Diversity
The area is representative of, or supports, unique or distinctive species biodiversity. The area supports more than one species and/or habitat important to the maintenance of ecological connectivity and the persistence of the species: (i) maintenance of biological and/or ecological diversity; (ii) endemic species. (iii) horizontal and/or vertical migration corridors</td></tr>
<tr><td>Scale</td><td colspan="3">Criterion 4. Abundance and Extent
The size or extent of the area is sufficient to maintain or improve the conservation status of the selected species: (i) it is large enough to support an abundance[3] of individuals of the selected species to perform one, or more, life history vital functions; (ii) habitat representativeness and ecological connectivity will be maintained or enhanced for the selected species in the identified area; (iii) the area will sufficiently provide refuge from threatening pressures (e.g., fisheries, habitat degradation); and, (iv) the size or extent of the area is large enough to feasibly manage, maintain, and monitor to achieve the conservation objectives of the selected species and habitat/s.</td></tr>
</table>

[1] Nursery areas as defined in Huepel et al. (2007) and Martins et al. (2018)
[2] Area required by the species for vital function activities at one or more life-cycle stage. (NOAA, 2023).
[3] Relative abundance as defined in Johnson (2010)

Results

Species

The species selection and their basis for inclusion is described in Table 1 (See: Methodology). Full species synopses are presented in Annex A. All the species considered in this report are demersal, that is living mainly on, or near the sea floor. The bathymetric (seafloor depth) ranges vary widely from estuaries to continental shelf, to upper slope. This leads to jurisdictional complexity, which is considered in the Discussion section below.

Fisheries Data

When the logbook effort summaries were considered, each sector showed a different pattern. Overall, the results indicate that impact of the trawl sector on the species of interest has decreased since 2007. For the other sectors there is evidence of increased spatial overlap between effort and some endemic species. The extent that this will lead to additional mortality will depend on selectivity/catchability of the fishing gear, and post capture mortality.

The trawl effort summary showed total effort was 1.99 million hours with a declining trend. Effort increased from 89,598 hours in 2000 to peak at 143,236 hours in 2004, then declined to 119,121 hours by 2006 (Figure 3). In 2007 there was a buyout program and effort fell to 60% of the peak level. Further declines followed and by 2021, annual effort was 59,310 hours,41% of peak levels. The post buyback reductions were widespread across most zones in the fishery (Figure 4) including New South Wales (NSW) (10), eastern Victoria (20), western Tasmania, (40) western Victoria (50), and the Great Australian Bight (GAB). Effort off eastern Tasmania (30) remained variable throughout the entire period. These results indicate that the overall impact of the trawl sector on the species of concern has decreased.

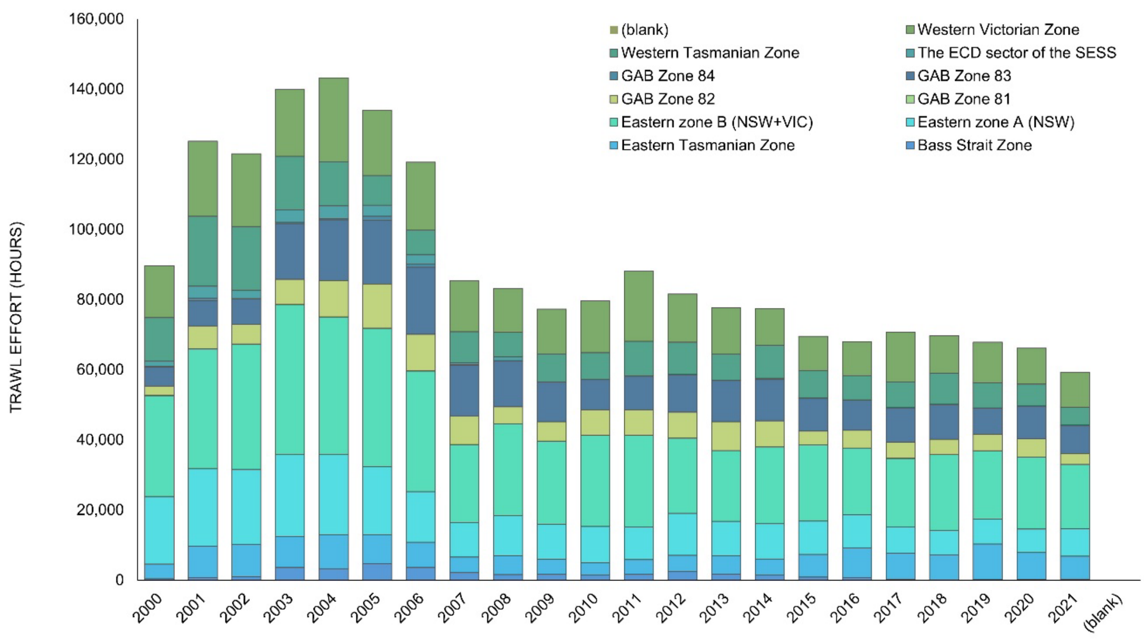

Figure 3. Changes in logbook effort-trawl sectors

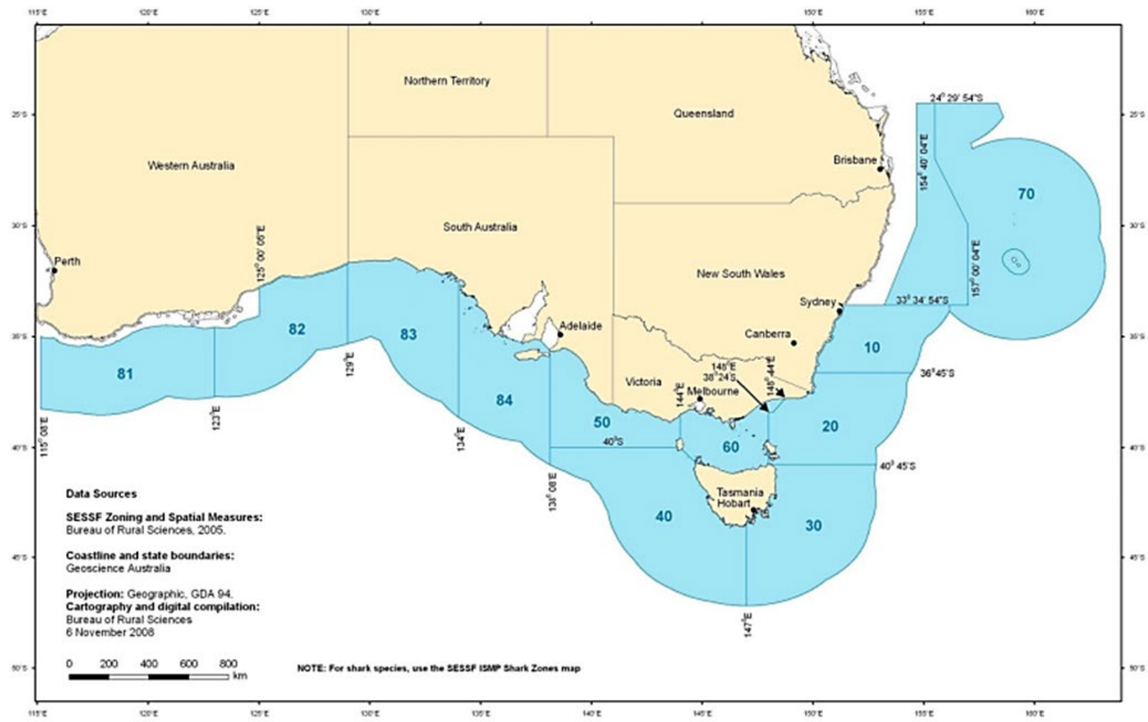

Figure 4. Map of the Southern and Eastern Scalefish and Shark Fishery (SESSF) Integrated Scientific Monitoring Program (ISMP) Scalefish Zones (Source: Australian Fisheries Management Authority).

When the non-trawl effort data were considered, three sectors showed recent patterns of increased overlap with endemics in some areas. Shark gillnet showed total effort was 807,855 km of lifted net with an overall declining trend (Figure 5), but an increase in some areas. During the period, effort almost halved from 45,273 km of lifted net in 2000 down to 23,855 km in 2021 (52.7% of initial levels). Most of the reductions in effort occurred off western Victoria (50) and in the GAB. Bass Strait is now clearly the focus of effort by the sector. In this zone, effort initially increased after the buyback from 2009 – 2018 but subsequently was steady or falling. This result indicates that there will be greater spatial overlap between gillnetting and skates and stingarees in Bass Strait but less overlap with *Urolophus orarius*.

The extent that this increased overlap will lead to increased mortality will depend on gillnet selectivity and post capture mortality. Published data indicates that gillnet catches of endemics off South Australia and In Bass Strait are likely to be in the order of 1% of the number of individual targeted gummy sharks taken by the fishery (Walker et al. 2005). When the effort pattern is considered with published selectivity data, the overall result is that commercial gillnetting is unlikely to be a substantial threat to endemic skates and stingarees. Previous studies based on observer catch data estimated the gillnet catches of skates and stingarees between 2007 – 2018 were 27 and 3t respectively; these were much lower than other fishing methods, particularly trawl (Daley and Gray, 2020).

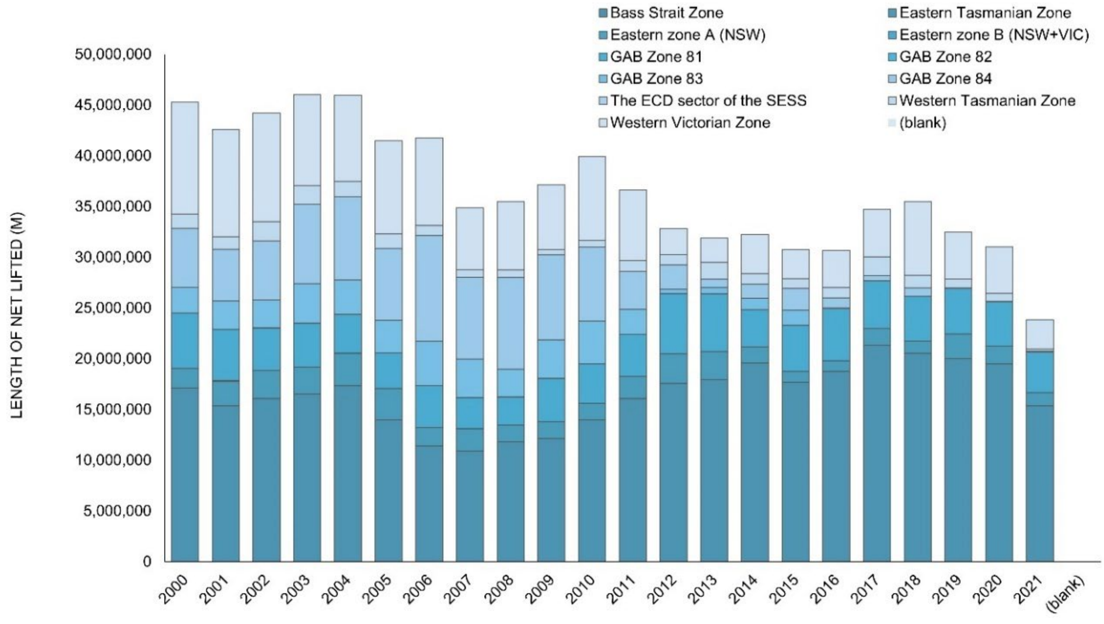

Figure 5. Changes in logbook effort - Gillnet.

For the hooks sector analysis, effort data was split between automatic longline and shark longline as the gears are restricted to different seafloor depth ranges: automatic longline method operates on the upper slope targeting deep-sea commercial scalefish; shark longline fishery targets gummy shark in shallower waters on the mid-shelf. When the shark longline effort data were examined, it showed been a major increase in the number of hooks from less than 1 million hooks per year for most years prior to 2012 (except for 2006). From 2017 – 2021, effort increased to more than 1.5 million hooks per years (Figure 6). This increase has occurred almost entirely in the eastern Great Australian Bight (84) and western Victoria and can be attributed to a switch from gillnets to hooks in response to Australian Sealion closures and gear restrictions (Figure 7). This change is likely to impact on mid-shelf skates and stingarees because hooks have higher selectivity for chondrichthyans than nets (Walker et al., 2005; Williamson et al., 2023). This result is a compromise with the conservation requirements for Australian Sealions.

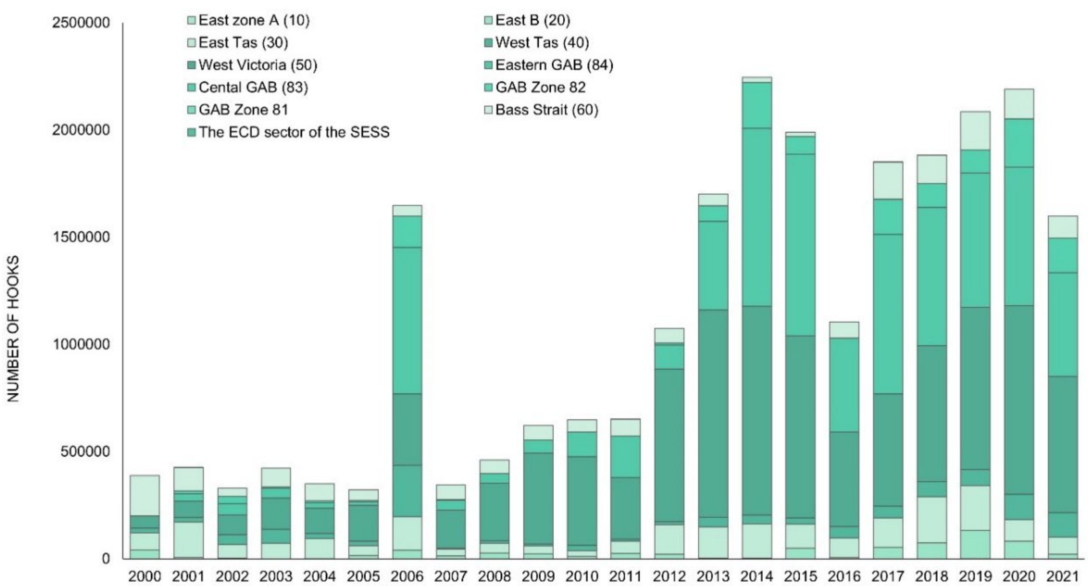

Figure 6. Changes in logbook effort – Shark Longline Hooks

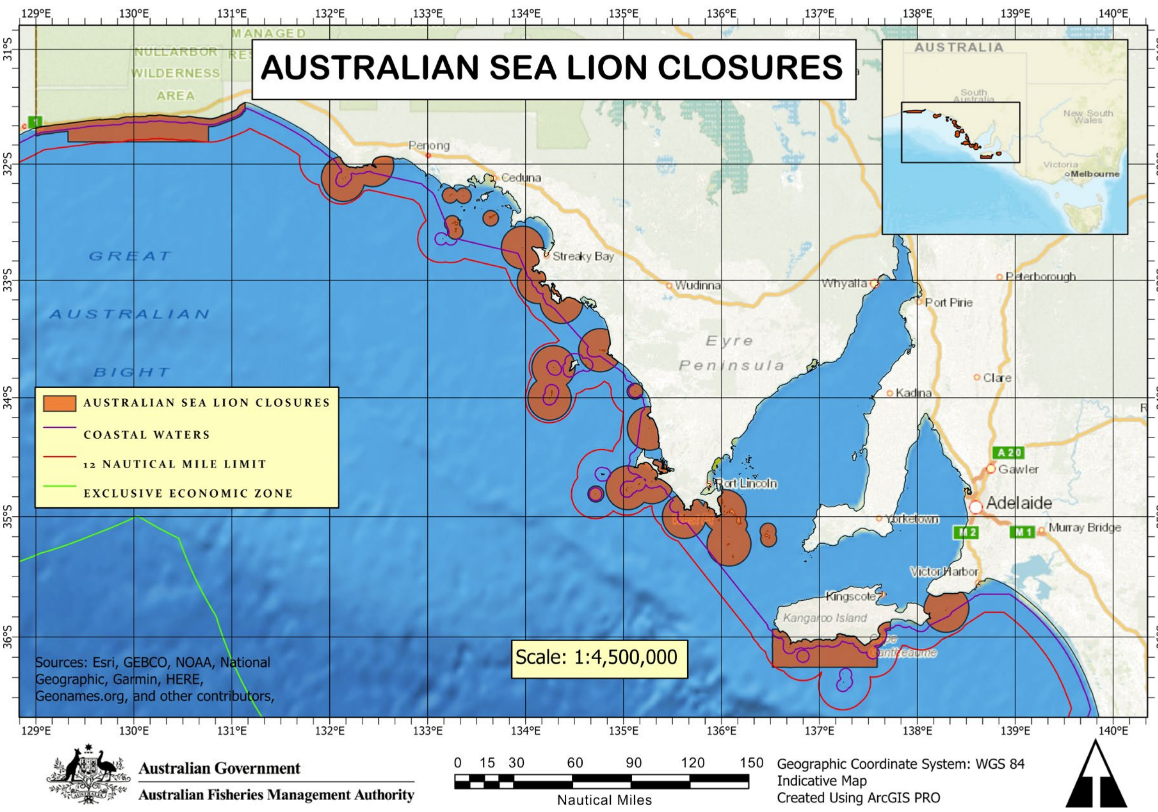

Figure 7. Australian sea lion closures. (Source: Australian Fisheries Management Authority).

Combined automatic longline for the period was showed total effort was 99.4 million hooks; trends varied across the zones (Figure 8). Overall effort increased from <1 million hooks in 2000 to more than 9.8 million hooks in 2005. This increase is attributed to an increase in the number of permits for automatic longline fishing equipment. After the buyback, effort declined substantially to 6.3 million hooks in 2007 and subsequently declined further to 2.3 million hooks by 2015).

This reduction in effort is likely to have made a substantial reduction to mortality of *Cephaloscyllium albipinnum, Dipturus canutus,* and *Squalus chloroculus*, as observer data shows these are caught by this method (Daley and Gray, 2020). This is important because these species may previously have had some refuge in the GAB away from the more heavily fished areas to the east. The automatic longline data shows one trend of concern, that is a recent increase in effort in the Eastern and Central GAB between 2014 and 2021. This has the potential to reduce refuge for these three species if the trend continues.

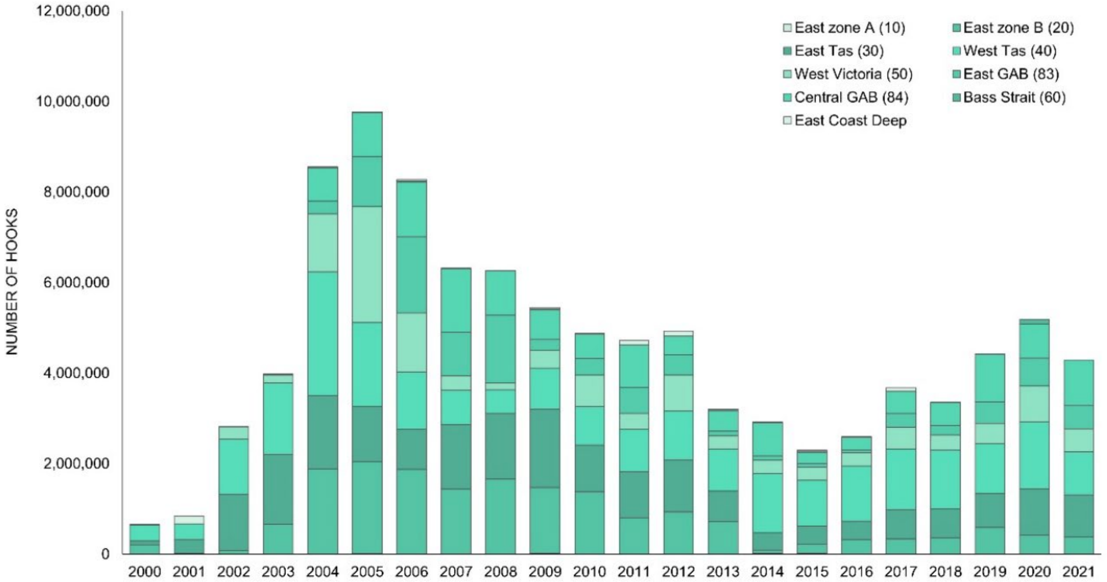

Figure 8. Changes in logbook effort – Automatic Longline Hooks

The effort summary for the Danish seine sector showed total effort was 205,062 shots with a double rise peak decline pattern (Figure 9). Effort initially rose from 7,426 shots in 2000 to the first peak of 10,655 shots in 2003. Effort then declined to 6,866 shots at the time of the buyback in 2007. This was followed by an increase to the recent second and major peak at 12,165 shots in 2020. Most of the effort is in Bass Strait and off eastern Victoria, and most of the recent effort increase has been off eastern Bass Strait. This recent increase in effort has the potential to impact on inshore habitat for *Urolophus viridis* and *Dentiraja confusa*. This potential impact could be mitigated in part at least by monitoring of best handling practices for released bycatch.

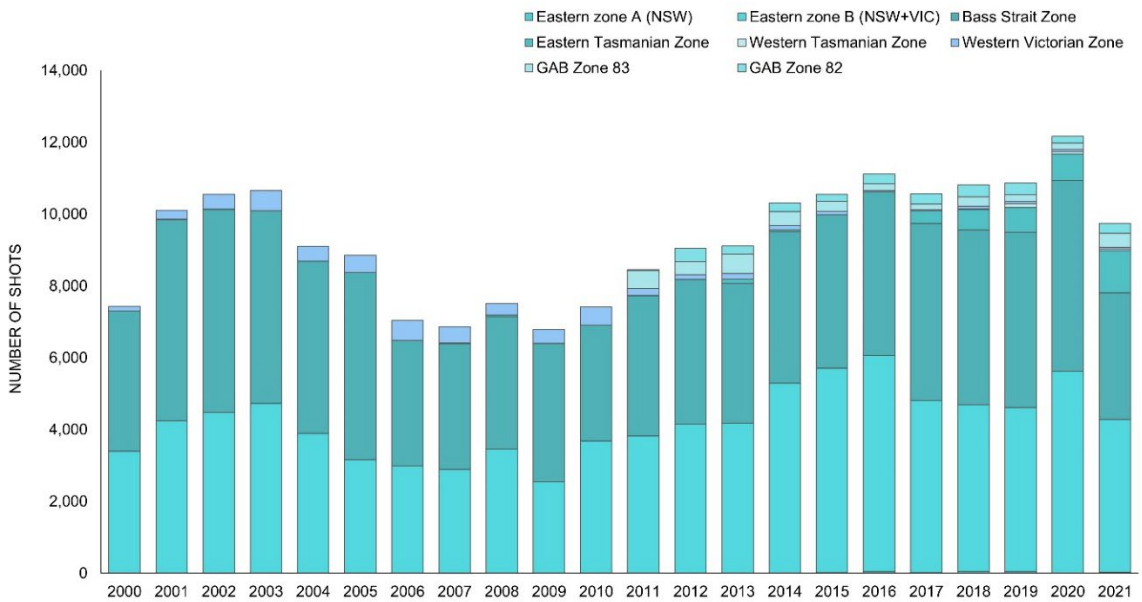

Figure 9. Changes in logbook effort – Danish seine.

The onboard observer catch and effort data were examined to see if sample size and spatial extent were sufficient to assess populations. Overall, reduced effort in the trawl sector in particular and other factors have reduced the utility of these data. When observer data were summarised by gear and year, the total number of observed fishing operations between 2000 and 2022 was 9,699. The southeastern trawl sector (combined southeast trawl [SET] central trawl sector [CTS]) was represented by most of the data with 7,115 observations (Figure 10A). The GAB trawl had 685 observations. For the CTS/SET, the number of observations declined dramatically after 2006 when the observer program was changed from an external contractor, to be managed internally by AFMA. The automatic longline sector had 1,653 observations and the Shark Gillnet sector had only 246 observations (Figure 10B). For the automatic longline sector, the number of observations increased until 2014 and then fell substantially with no observations at all in some years, and less than 50 fishing operations observed in others.

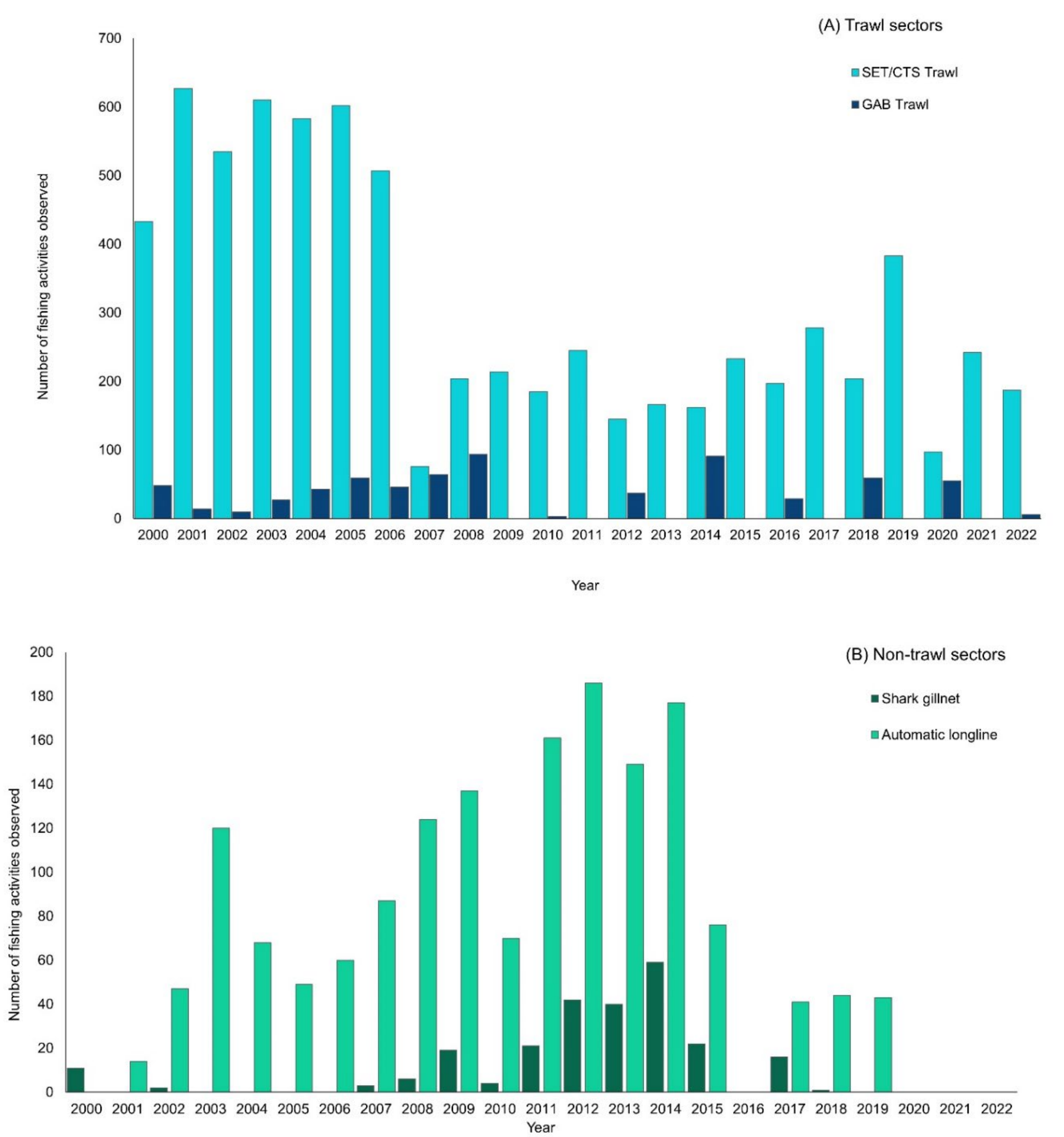

Figure 10. Variation in time in the number of fishing operations (activities) observed on board in the Southern and Eastern Scalefish and Shark Fishery. All depths: (A) Trawl Sectors; (B) Non-trawl Sectors.

Unstandardised trawl observer catch per unit effort data for *Cephaloscyllium albipinnum* shows complex but encouraging patterns. There was a decline in CPUE in the species-specific depth range of 375–705 m (selected based on tracking data) between 2000 and 2007 (Figure 11). After 2010, the CPUE was variable, and sample sizes were smaller (Figure 12). After 2007 the CPUE values were variable. In 2021 the CPUE value exceeded the historical peak. When the data for all years were plotted there seemed to be spatial patterns in average catch/shot, though these were not simple to interpret (Supplementary Material). For example, in 2013, when observer effort was concentrated near Portland, catch rates averaged > 50 kg/hr (Figure 13A). By contrast, in 2014, when observer data was concentrated off northwest Tasmania and off New South Wales, catch rates averaged <30 kg/hr (Figure 13B). There are several possible explanations for this result. One possibility is that this species may still have some refuge from trawling at least away from traditional trawl grounds that have been heavily fished in the east. The simplest explanation though, is that trawls near Portland have longer durations than trawls off Southern New South Wales, noting catch rates are kg/shot. This explanation would be simple to test using shot-by-shot logbook effort data, but these data were not available to this project (only data summaries). Converting the observer CPUE units to kg/hr would be desirable but tow period was not included in the compiled observer data.

Further work to standardise the CPUE for a number of factors could be considered to disentangle abundance from the spatial extent of observer coverage, though this is challenged by sample size. Previous studies found that standardised trawl CPUE models for this species did not converge when the sample size fell below 500 tows (Walker and Gason, 2007). There have not been 500 trawl tows/year observed since 2006 (Figure 10A), and the number of shots observed within the core depth range of this species has not exceeded 100 since 2006 (Figure 12). Walker and Gason (2007) point to more complex methods statistical methods that could be used to try and resolve the CPUE standardisation, particularly how to select the zero values to be excluded. The tracking study depth data from this study would likely be useful for this purpose (shots out of species depth range) but such complex models are beyond the scope of this project.

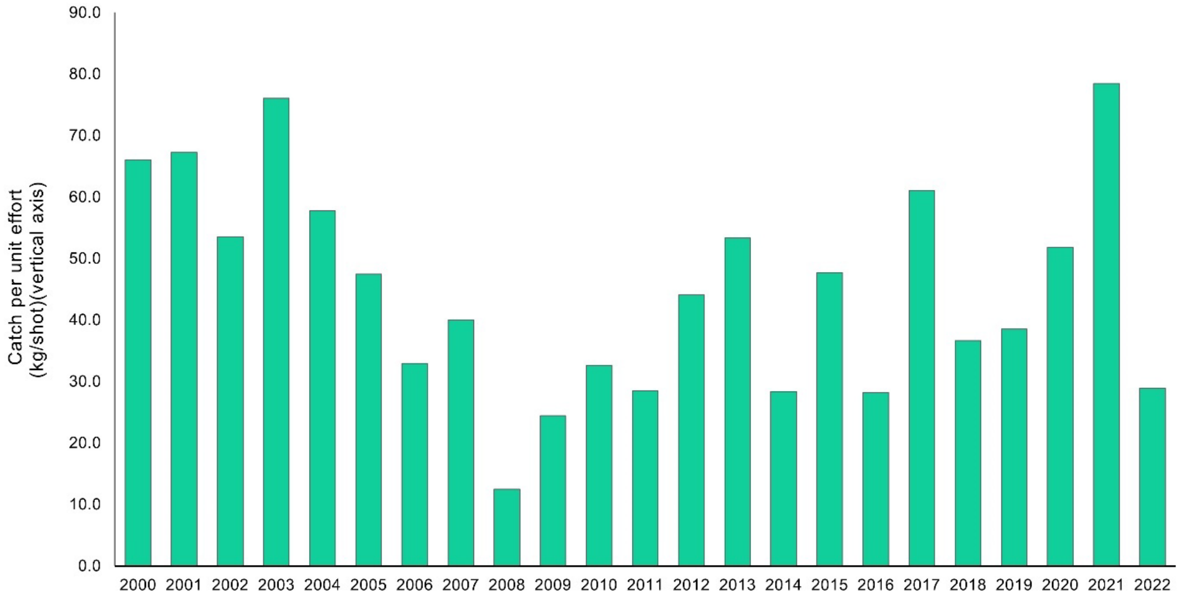

Figure 11. Variation in Catch per unit effort of *Cephaloscyllium albipinnum* in observed trawl shots in the CTS/SET between 375 – 705m only

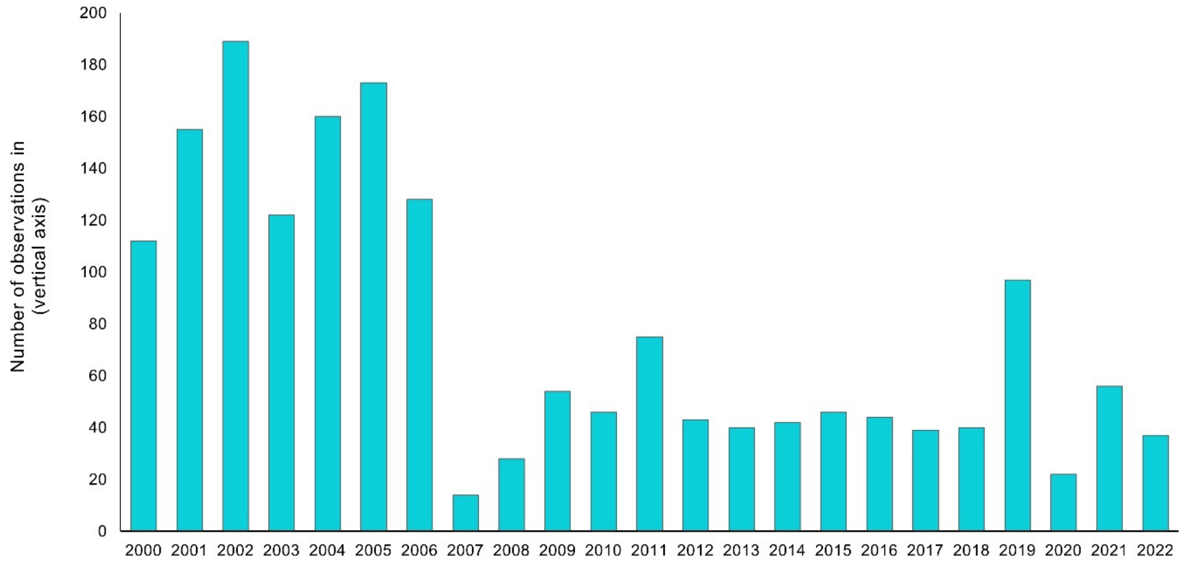

Figure 12. Number of onboard observations of SESSF trawl operations within the depth range of *Cephaloscyllium albipinnum* (375 – 705m only) - excluding the Great Australian Bight

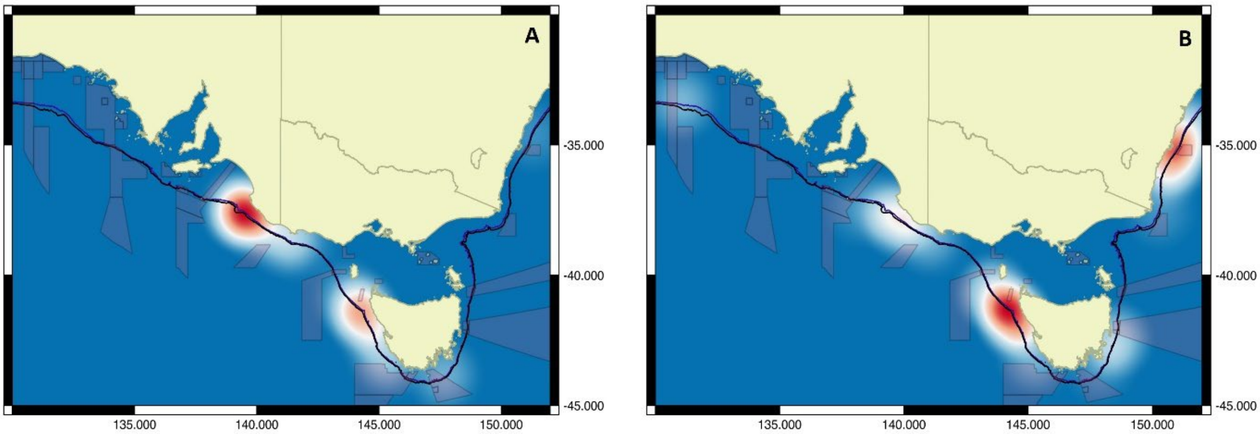

Figure 13. Differences in the spatial distribution of observer coverage between years: (A) Year 2013, observer effort concentrated near Portland; (B) Year 2014, observer effort concentrated off northwest Tasmania and southern NSW.

Habitat and Distribution Maps

Suitable Habitat

Data extracted on each species geographic range and biotic or abiotic requirements, allowed suitable habitat to be identified. All species (apart from *Squatina albipunctata* and *Dentiraja australis)* had suitable habitat entirely encompassed within fishery activity regions of the SESSF (Figures 14-23).

Suitable habitats for *Dentiraja confusa, Squatina albipunctata, Dipturus canutus, Urolophus orarius, Urolophus sufflavus, Urolophus viridis, Spiniraja whitleyi*, and *Dentiraja australis* occurred on the coastal shelf at depths between 1m – 100m primarily within 3nm offshore. *Cephaloscyllium* *albipinnum, Dipturus canutus,* and *Squalus chloroculus* suitable habitat occurred in narrow corridors along the inner boundary of their known range, intersecting at few points with AMP network areas. Compared to the continental shelf, the upper-slope seafloor is steeper and therefore much narrower. Here, mapping of candidate closure areas needs to be matched to suitable seafloor depth with precision to avoid misrepresentation of critical habitat and the species distribution in management plans.

Three species, *Urolophus sufflavus, Squatina albipunctata* and *Dentiraja australis,* had suitable habitats and geographic range which predominantly occurred outside of SESSF boundaries in coastal waters of New South Wales and Queensland. Inshore spatial management of these species would largely fall to regional State jurisdictions but in some instances can benefit from AMP inclusion.

Urolophus orarius has only been recorded in a very small region of South Australia in shallow inshore waters with suitable habitat identified largely outside the boundaries of its geographic range. Some closure of the SESSF occurs in waters adjacent to Kangaroo Island, South Australia, where the species occurs, but this closure is not sufficient in encompassing suitable habitat for *Urolophus orarius.*

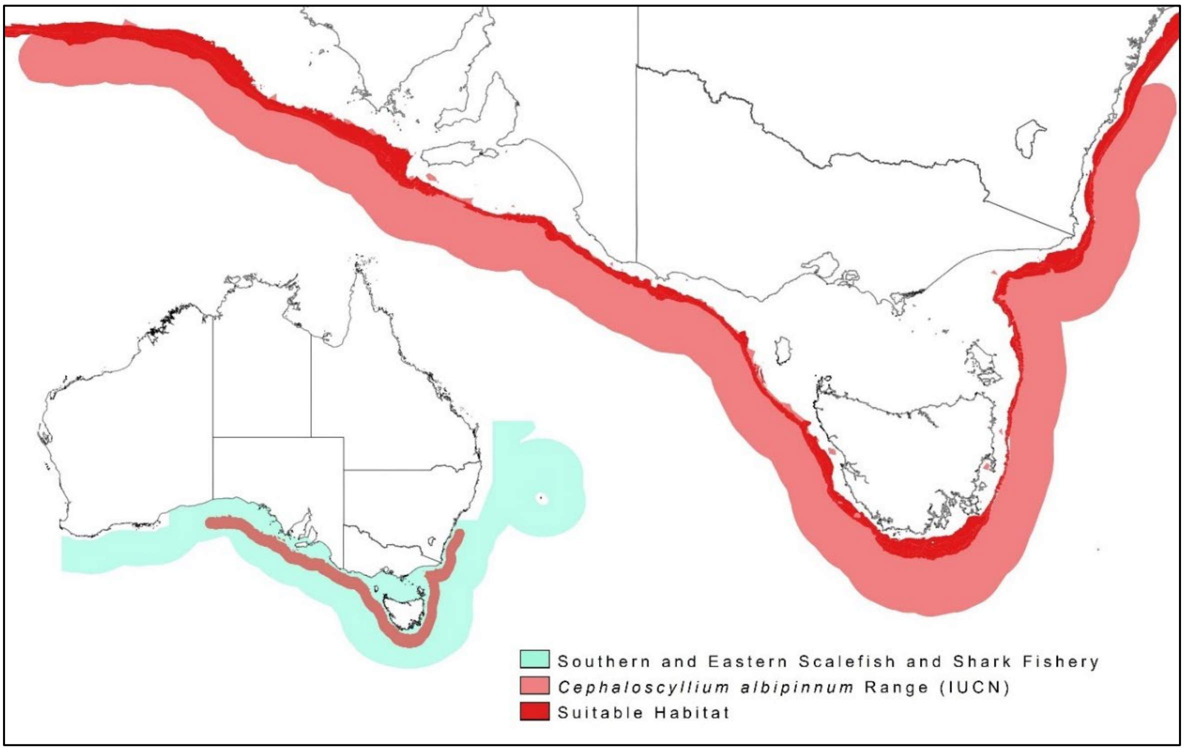

Figure 14. ***Cephaloscyllium albipinnum*** **range and extent of suitable habitat.**

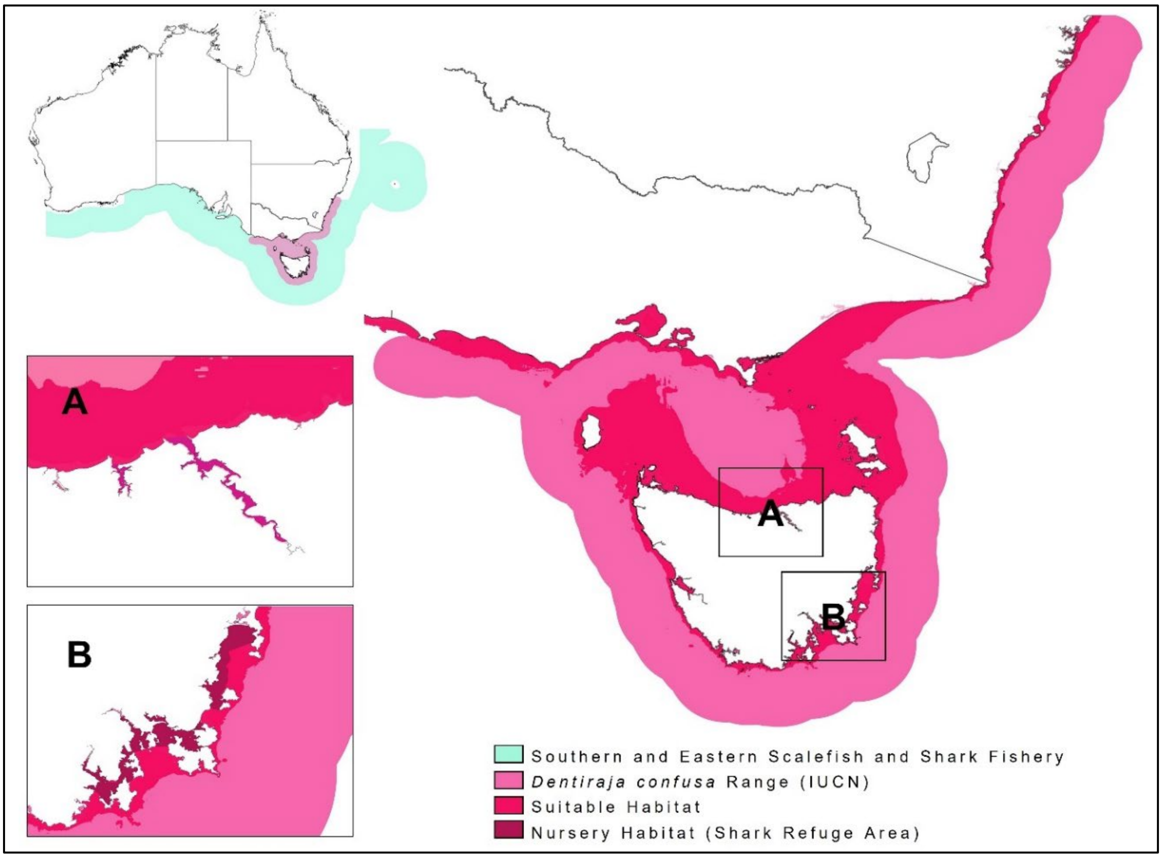

Figure 15. *Dentiraja confusa* range and extent of suitable habitat. Inset: Shark refuge areas of (A) Port Sorrell and Kanamaluka/Tamar River; (B) Blackman Bay,Derwent River,Frederick Henry Bay and Norfolk Bay, D'Entrecasteaux Channel, Georges Bay, Great Oyster Bay, East Coast Waters and Mercury Passage.

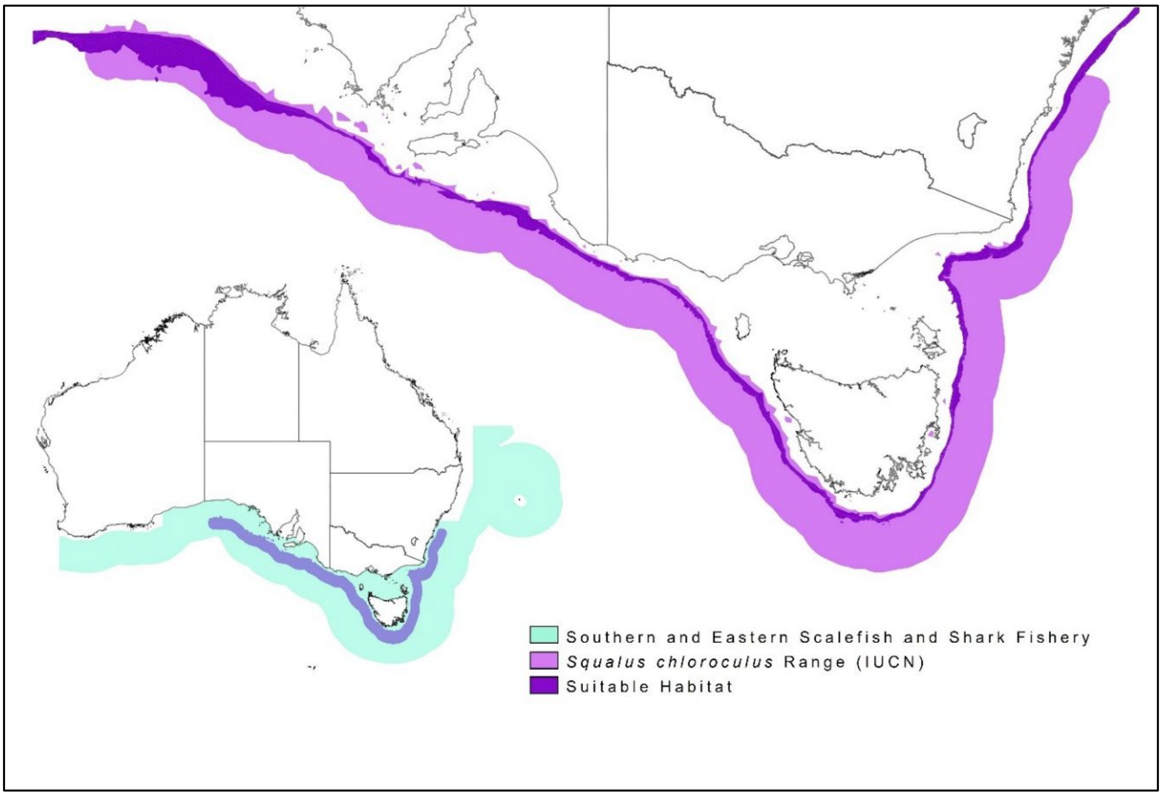

Figure 16. *Squalus chloroculus* range and extent of suitable habitat.

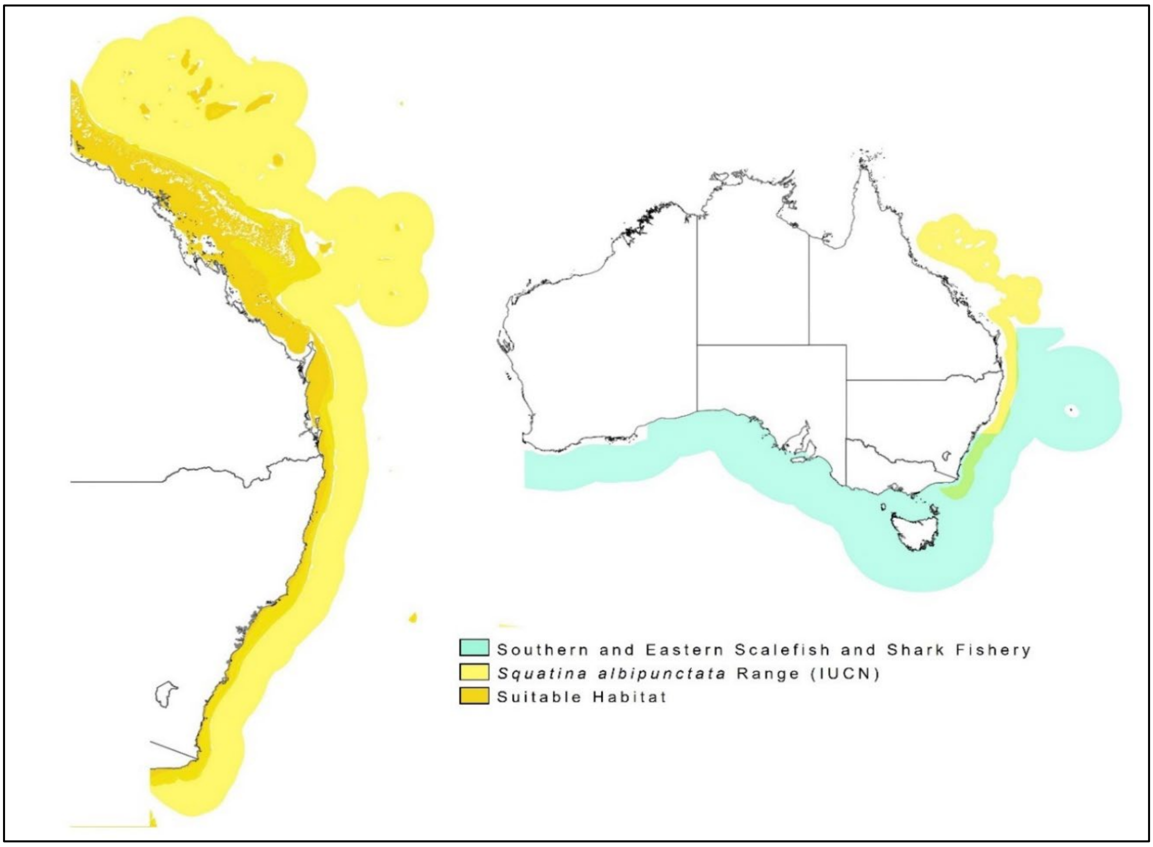

Figure 17. *Squatina albipunctata* range and extent of suitable habitat.

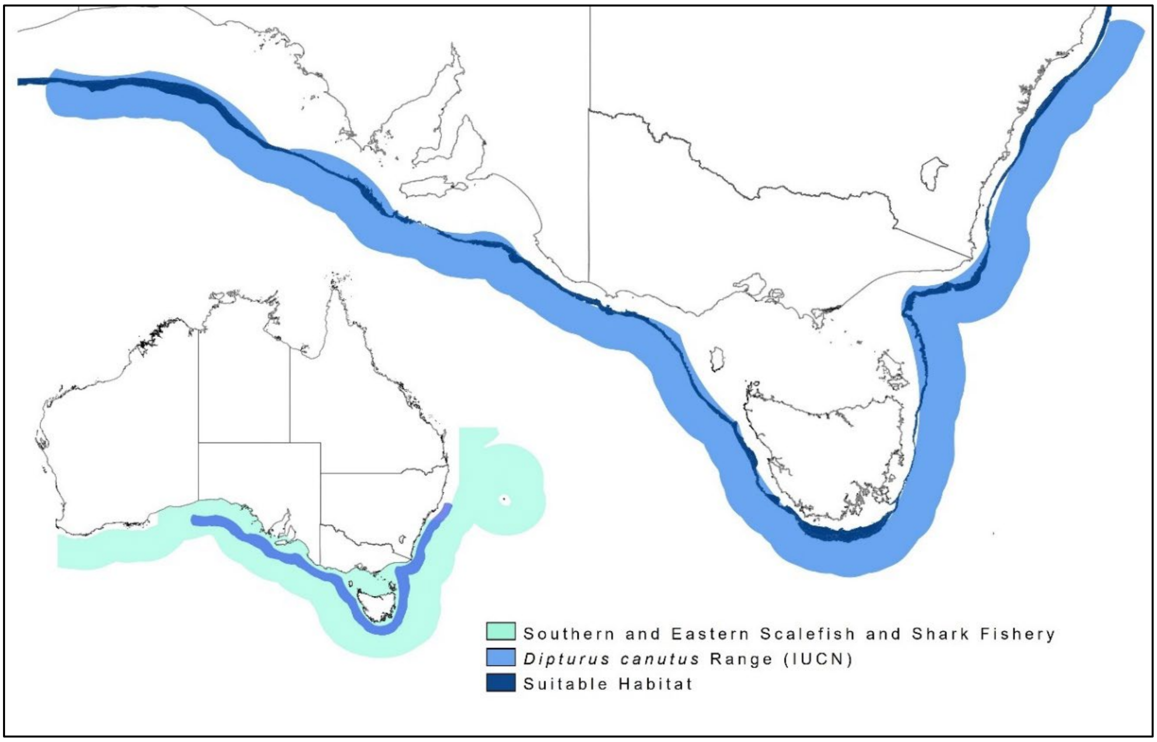

Figure 18. *Dipturus canutus* range and extent of suitable habitat.

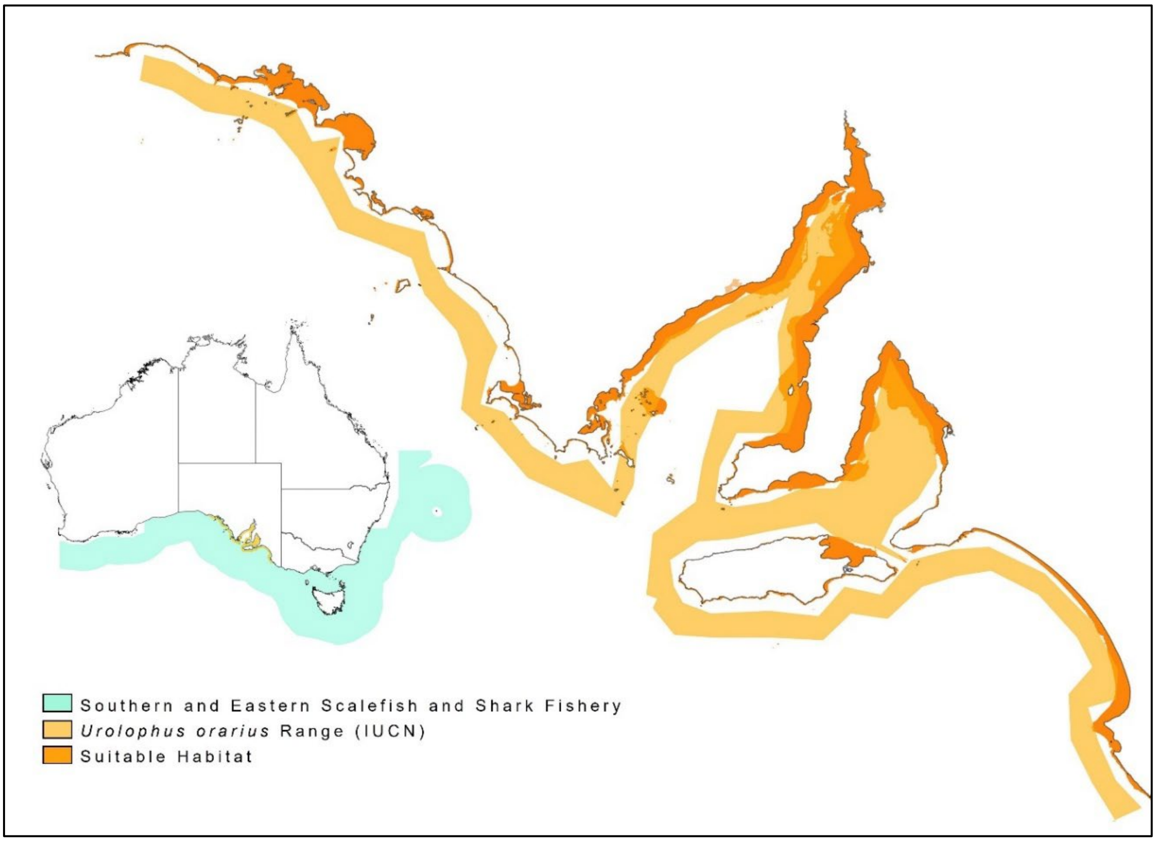

Figure 19. *Urolophus orarius* range and extent of suitable habitat.

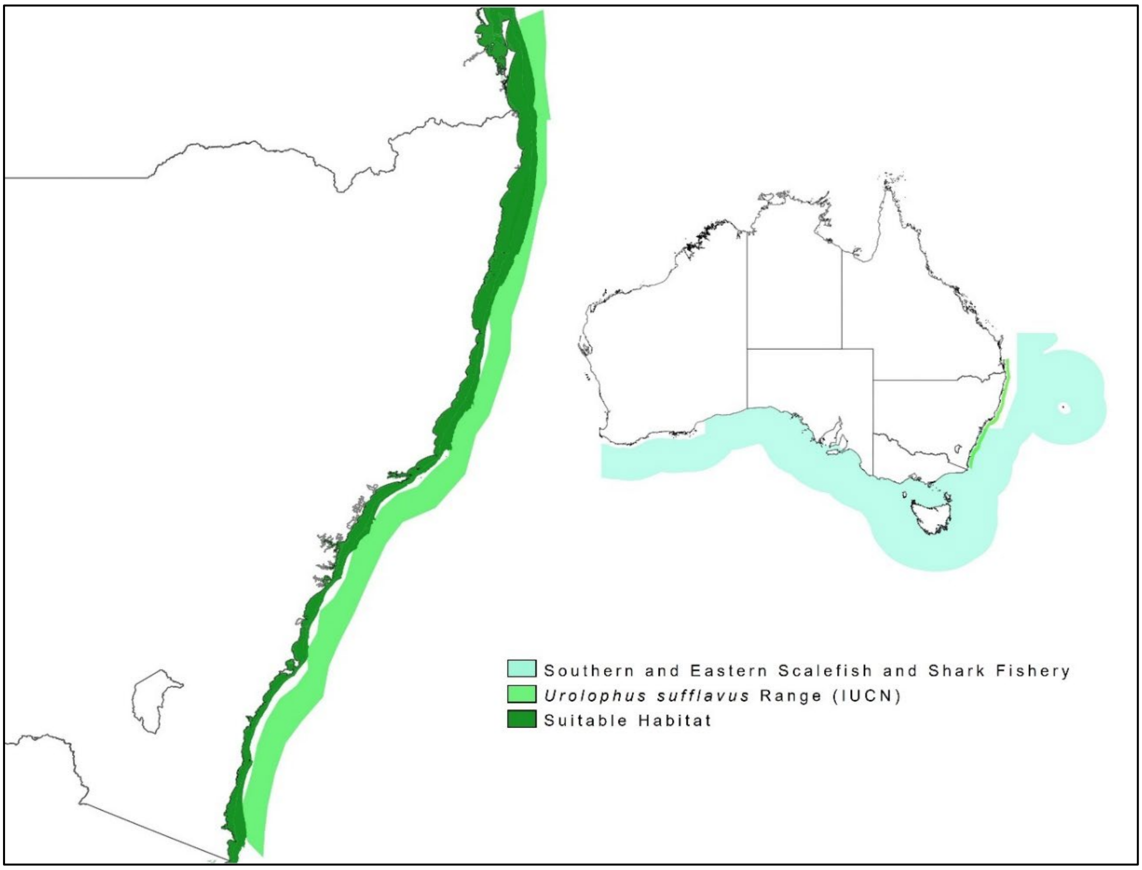

Figure 20. *Urolophus sufflavus* range and extent of suitable habitat.

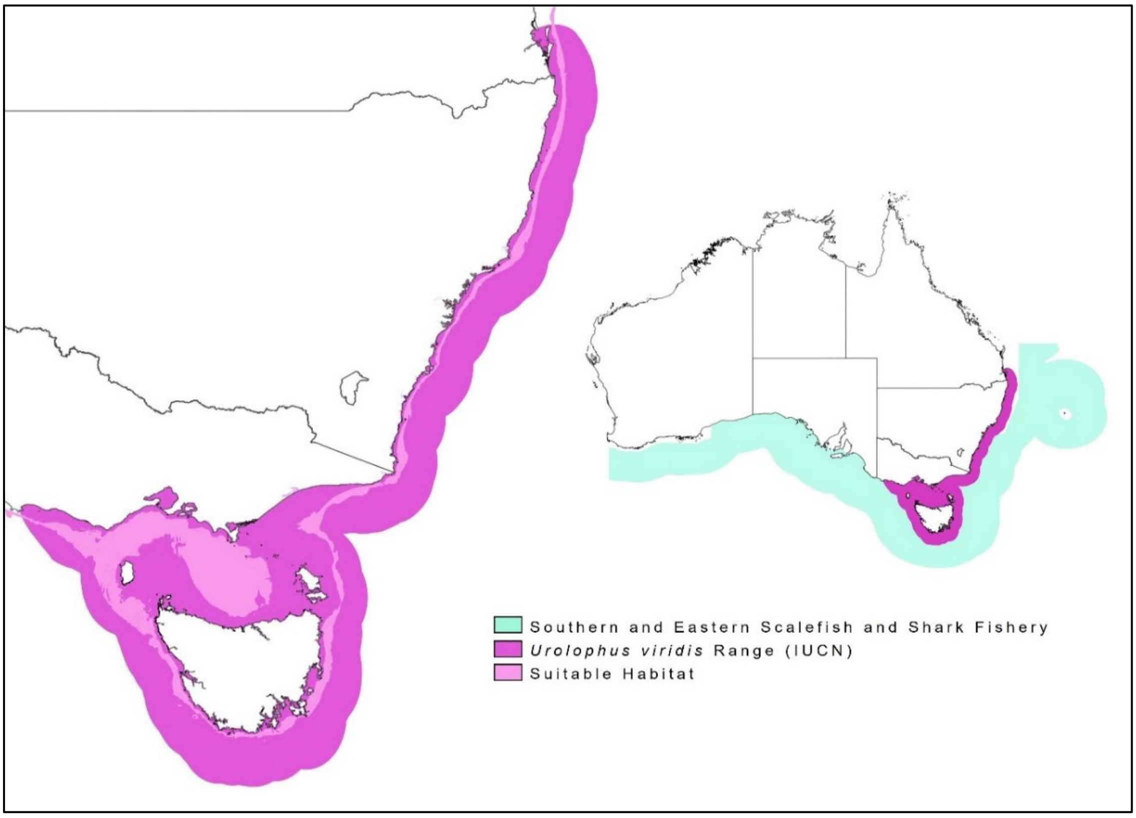

Figure 21. *Urolophus viridis* range and extent of suitable habitat.

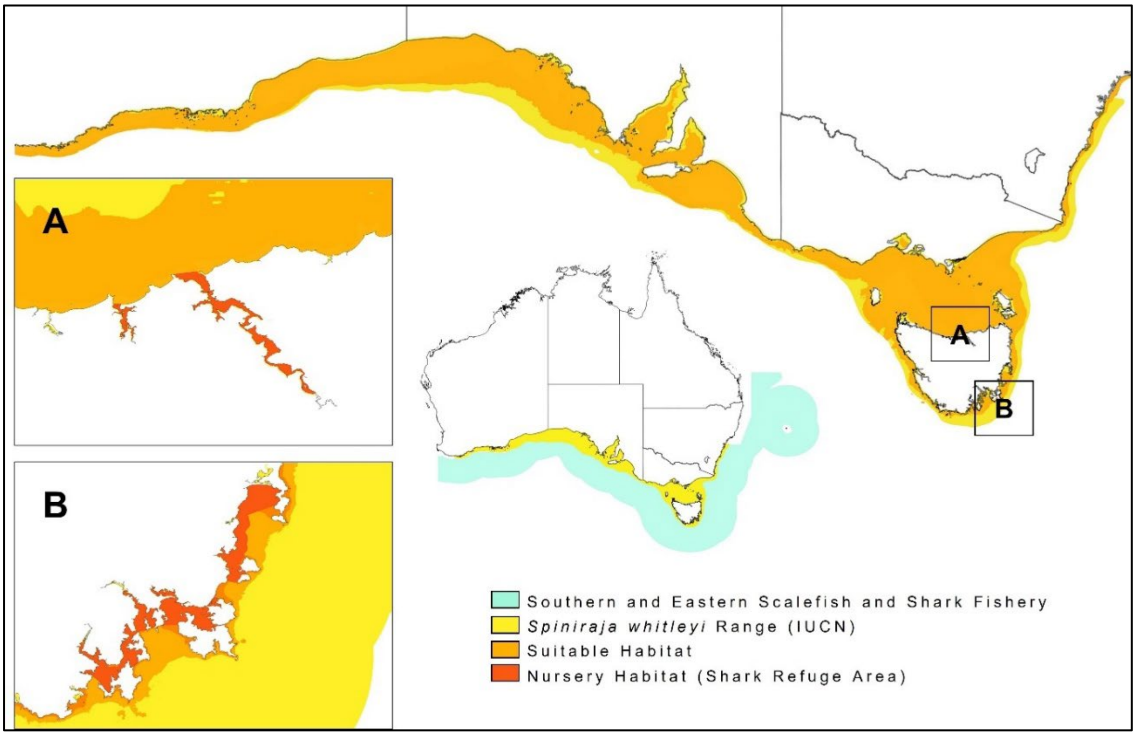

Figure 22. *Spiniraja whitleyi*. range and extent of suitable habitat. Inset: Shark refuge areas of (A) Port Sorrell and Kanamaluka/Tamar River; (B) Blackman Bay, Derwent River, Frederick Henry Bay and Norfolk Bay, D'Entrecasteaux Channel, Georges Bay, Great Oyster Bay, East Coast Waters and Mercury Passage

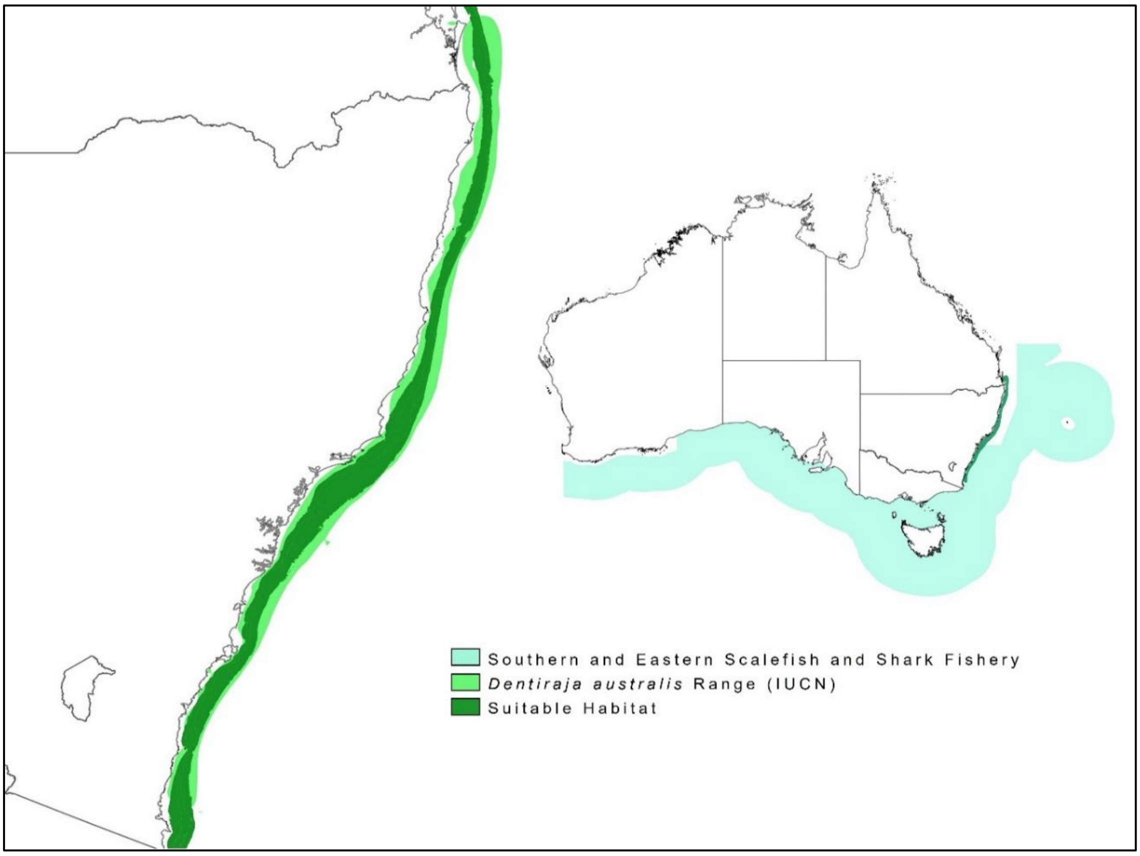

Figure 23. ***Dentiraja australis*** **range and extent of suitable habitat.**

Breeding Habitat and Corridors

When tracking data summary metrics for eleven *Cephaloscyllium albipinnum* were considered, six individuals were not detected following release (no duration) (Table 4). There are two possible explanations for this: (1) the individuals had much smaller ranges than the receiver spacing; or (2) tagging mortality. Virtual tagging studies indicate tagging mortality is likely to be low. *Cephaloscyllium albipinnum* is regularly captured with hooks or tears in the mouth, indicating release survivorship after capture during fishing (Williams et al. 2012). Two individuals were detected for medium durations (>50 days) but only on a few different days and only at the start of the study (<10 days). These were female 727, and female 735 (Figure 25). It is possible that these individuals were resident but mainly undetected between receiver curtains for some time.

Only three individuals of *Cephaloscyllium albipinnum* continued to be detected during most of the study (DUR > 300 days) (Figure 24, Figure 25). These included female 741 and two males, 729 and 731. All showed different individual patterns of behaviour. Female 741 remained resident near the centre of the closure making brief excursions to both the western and eastern margins (Figure 24). Male 729 was only detected near the eastern margin of the closure. Male 731 was mainly detected near the eastern margin of the closure, making movements to the western and eastern margins, and then returning.

All individuals of *Squalus chloroculus* were detected for durations of at least 16 days, indicating high release survivorship (Table 5). For females, duration ranged from 18- 351 days. All the individual females moved from their release point, to one, or both the eastern and western margins of the closure and appeared to traverse the closure and leave at least once (Figure 26, Figure 27). These results indicate that females were highly mobile and not resident at the study location.

By contrast, most of the males in the study appeared to remain resident near the centre/west of the closure (Figure 26, Figure 28).

There were two exceptions. Male 723 appeared to leave the closure to the east near the end of the study and not return (Figure 28) and Male 816 showed a remarkable pattern, traversing the entire closure, leaving, and re-entering it on multiple occasions more than 100 days apart (Figure 29). Overall, these results show that size of the closure is large enough to encompass individual movements, for most males at least, but the size/location does not accommodate the breeding movements of female *Squalus chloroculus*.

Table 4. Key summary metrics from acoustic tracking - *Cephaloscyllium albipinnum*. N Days = number of different calendar days detected. DUR - duration, DI = detection index (% of days detected). MLD= maximum linear distance.

ID	Tag Date	Sex	TL (cm)	N Days	DUR (days)	MLD (km)	DI
724	9/8/2009	F	106	0			
725	9/8/2009	F	96	1			
726	9/8/2009	F	92	0			
727	9/8/2009	F	94	9	82	16.8	0.11
728	9/8/2009	F	103	1			
735	10/8/2009	F	110	7	53	16.8	0.135
739	11/8/2009	F	110	1			
741	11/8/2009	F	102	39	330	60,2	0.118
805	12/8/2009	F	102	0			
729	10/8/2009	M	108	38	371	1.97	0.102
731	10/8/2009	M	108	153	379	60.2	0.403

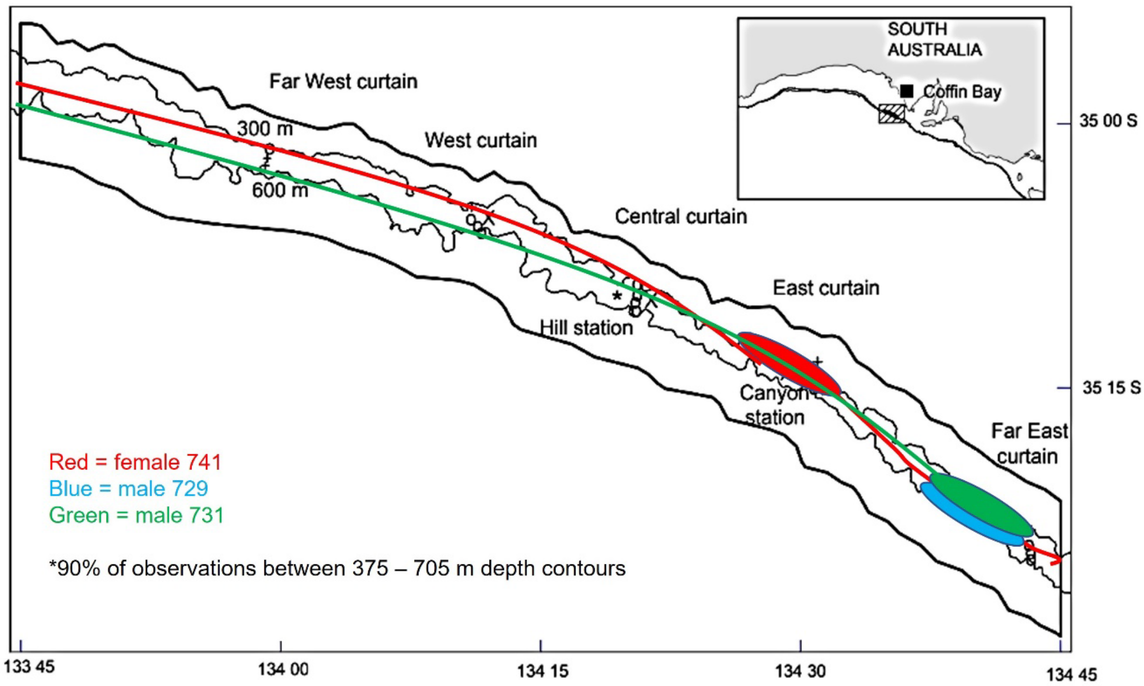

Figure 24. Summary of movements for *Cephaloscyllium albipinnum*, (n=3)

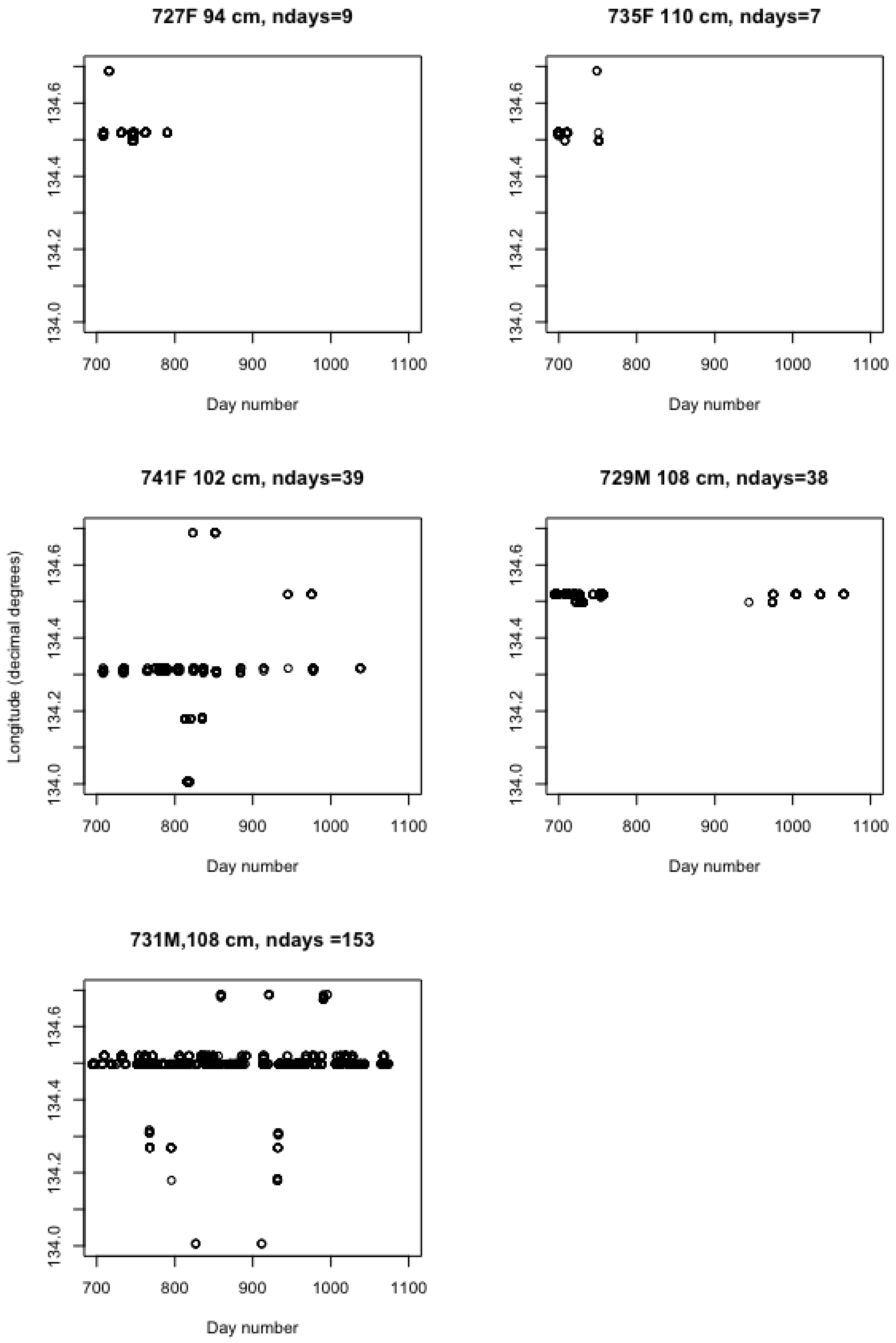

Figure 25. Along slope (longitude) range of male and female *Cephaloscyllium albipinnum*. Day 600 = 13 Aug 2009

Table 5. Key summary metrics from acoustic tracking – *Squalus chloroculus.* N Days = number of different calendar days detected. DUR – duration, DI = detection index (% of days detected). MLD= maximum linear distance.

ID	Tag Date	Sex	TL (cm)	N Days	DUR (days)	MLD (km)	DI
714	12/08/09	F	92	18	18	36.7	1.00
715	12/08/09	F	85	17	295	46.1	0.58
718	12/08/09	F	93	54	329	30.1	0.16
720	11/08/09	F	81	14	64	36.8	0.22
817	10/08/09	F	78	12	101	59.5	0.11
820	10/08/09	F	88	106	158	60.7	0.68
823	10/08/09	F	91	69	351	60.2	0.20
716	12/08/09	M	77	17	25	21.1	0.68
717	11/08/09	M	79	267	447	36.3	0.60
719	12/08/09	M	77	327	338	7.9	0.96
721	11/08/09	M	74	55	323	1.6	0.17
722	11/08/09	M	75	52	438	10.5	0.12
723	11/08/09	M	76	13	16	12.2	0.81
814	10/08/09	M	77	203	447	45.0	0.45
815	10/08/09	M	76	68	444	30.0	0.15
816	10/08/09	M	77	16	358	60.7	0.04
818	10/08/09	M	77	201	338	2.0	0.59
819	10/08/09	M	78	152	446	9.1	0.34
822	10/08/09	M	77	61	354	9.1	0.17

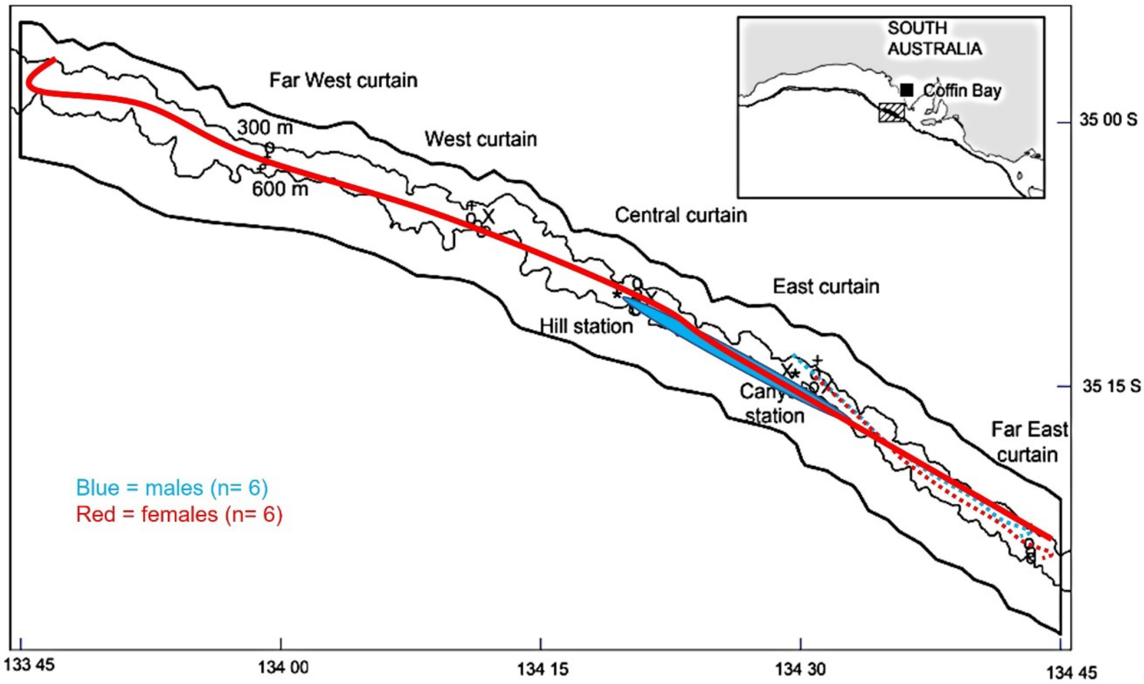

Figure 26. Summary of movements for *Squalus chloroculus*, (n=12)

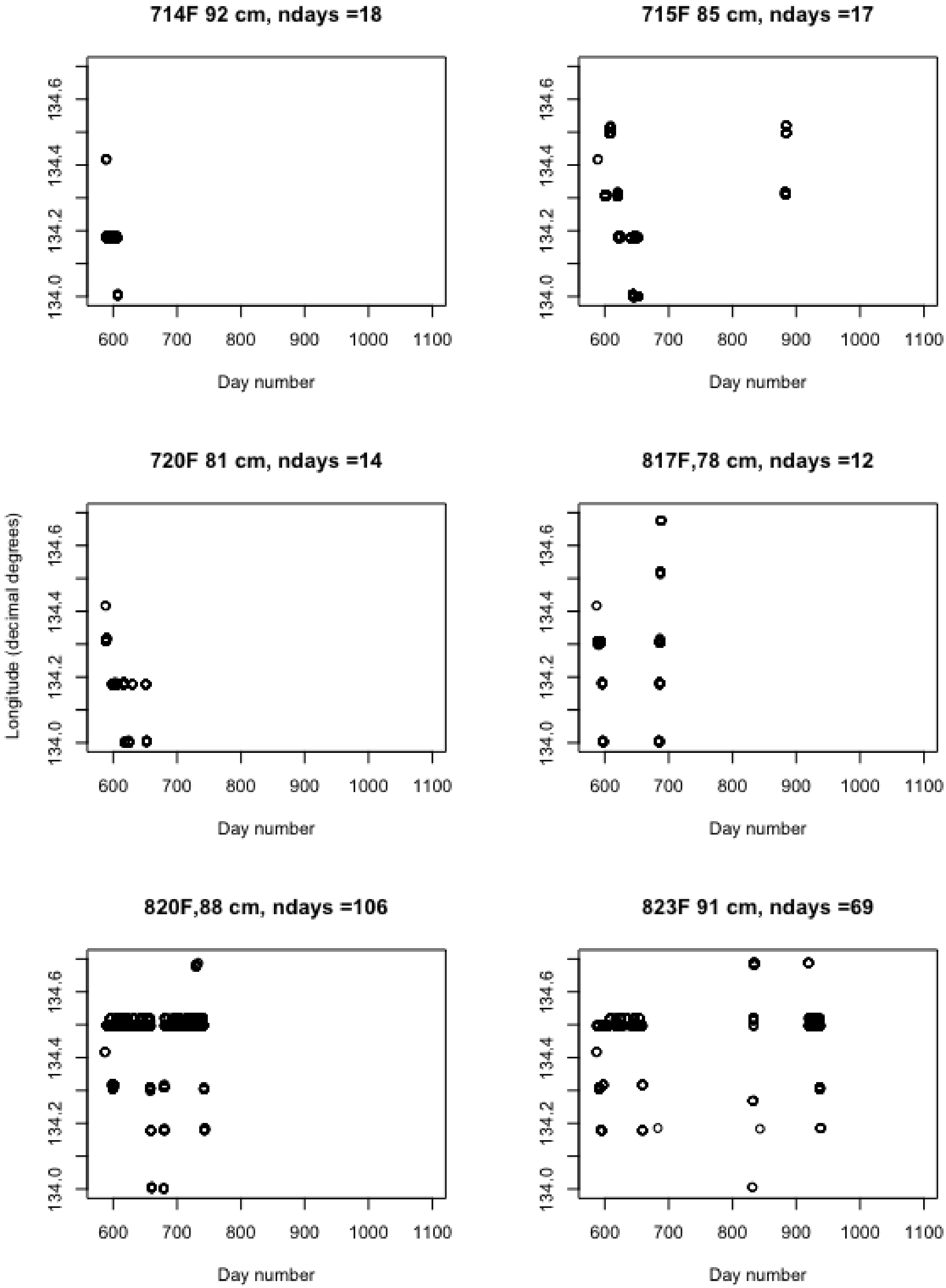

Figure 27. Along slope (longitude) range of female *Squalus chloroculus.* Day 600 = 13 Aug 2009

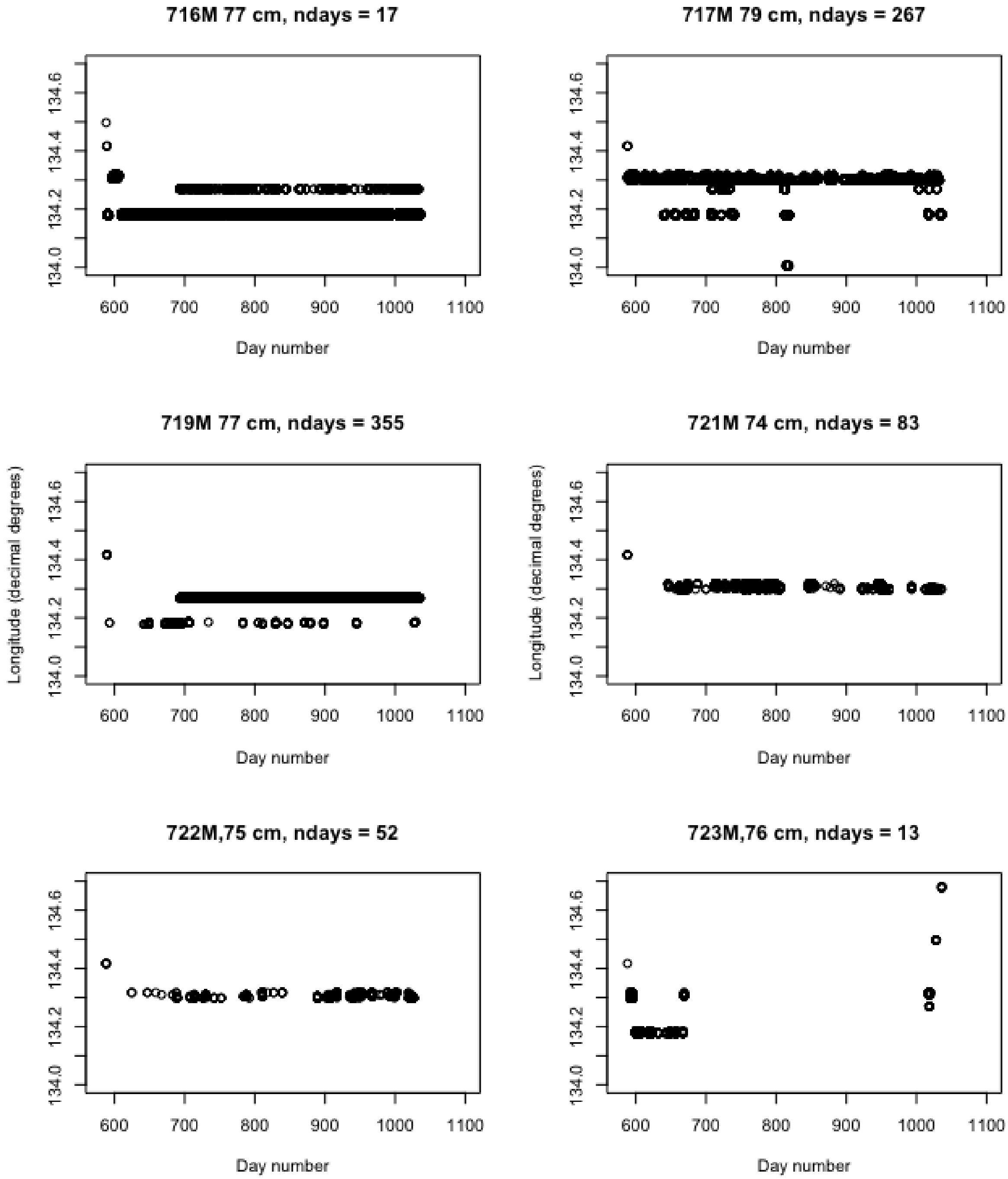

Figure 28. Along slope (longitude) range of male *Squalus chloroculus*. Day 600 = 13 Aug 2009

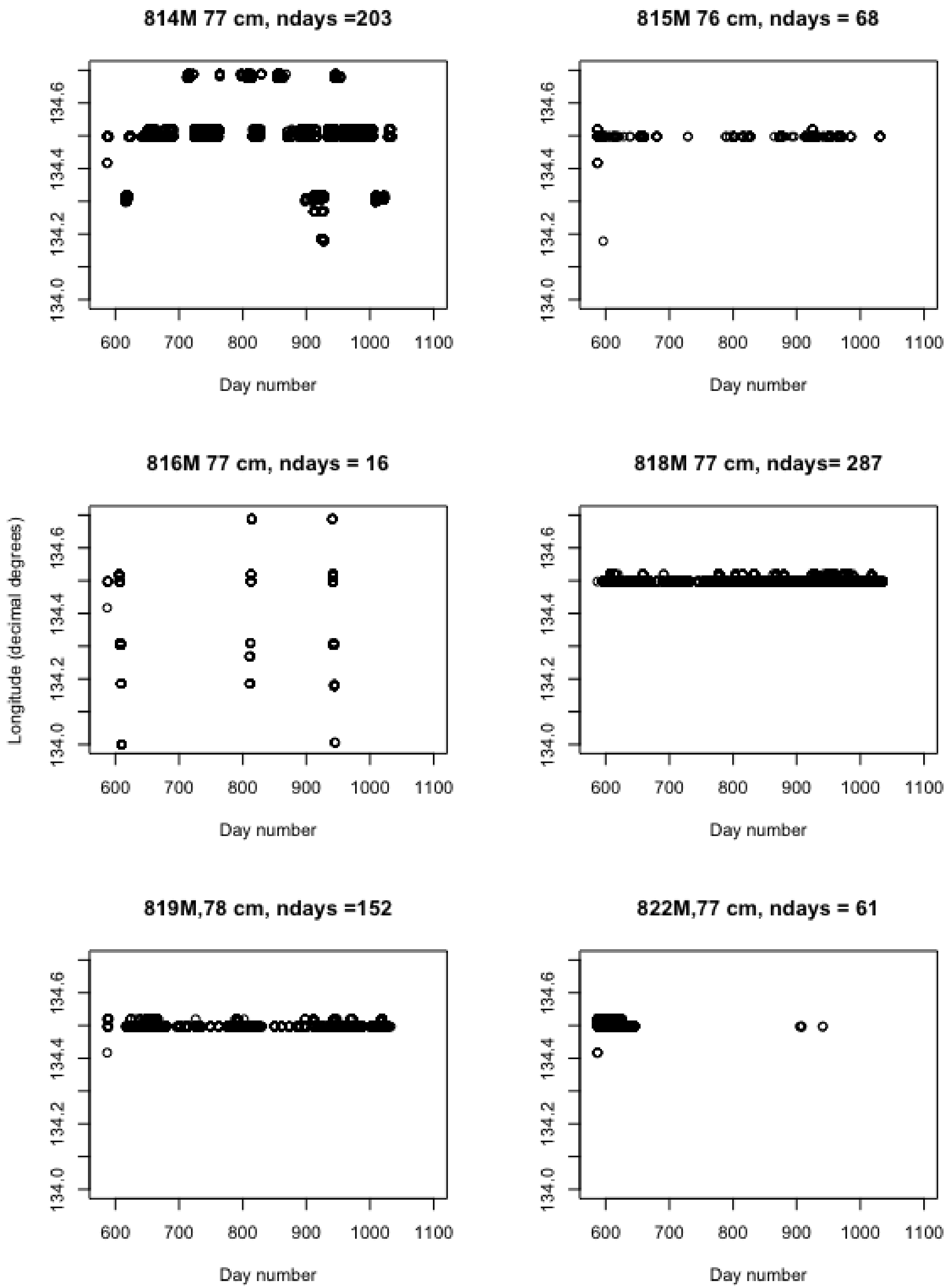

Figure 29. Along slope (longitude) range of male *Squalus chloroculus*. Day 600 = 13 Aug 2009

Candidate Areas

A total of six Candidate Areas were identified (Figure 30). Each considered the occurrence of one, or more, species and the occurrence of spatially defined environmentally and geographically suitable habitat features. The Candidate Areas have capacity to mitigate threats to the endemic shark and/or ray species and contribute to their conservation. Connectivity between habitats and biological dispersal patterns were considered, and where possible, Candidate Areas were selected to coincide with existing Australian Marine Park (AMP) areas, State-based MPAs, and/or SESSF closures. These arrangements cross multiple jurisdictions. Australian Marine Parks (AMPs) occur from three nautical miles (nm) offshore and further seaward. Waters inshore of 3nm are designated under State jurisdictions.

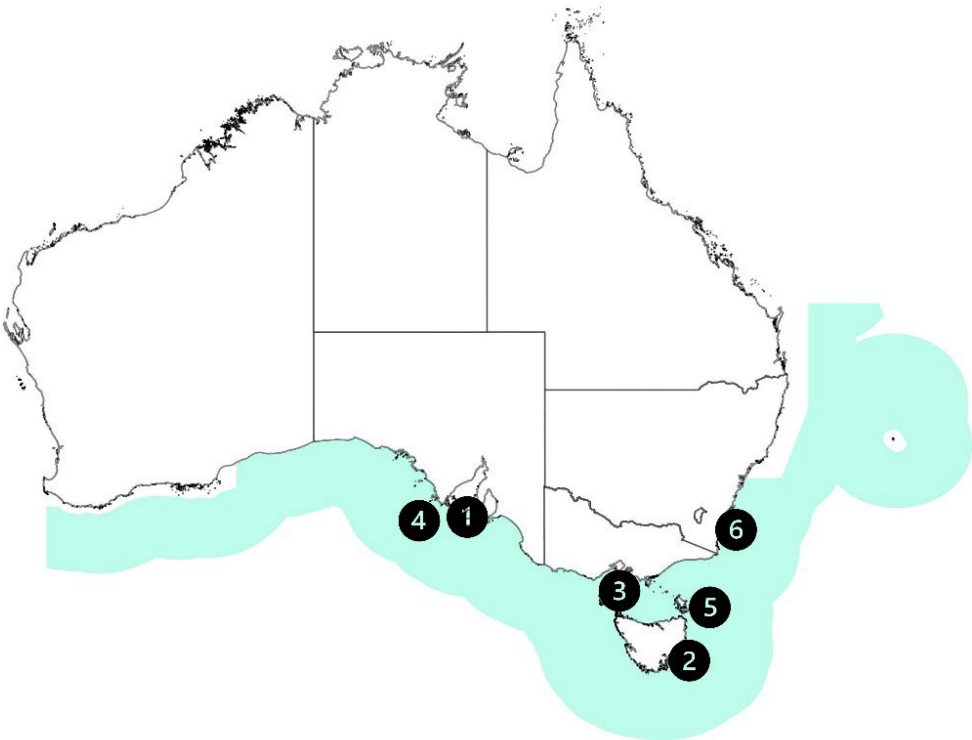

Figure 30. Location of the six candidate areas identified corresponding to SESSF boundaries (light blue).

Minimal overlap occurred between most species' suitable habitats and AMP areas. Candidate Areas in inshore waters and could be considered for inclusion into State fisheries closures and/or marine protected areas (MPAs). Only offshore Candidate Areas could be considered into AMP networks or Commonwealth fisheries closures. Three of the Candidate Areas are within (or partially within) inshore coastal waters (i.e., State-managed waters) and would require co-operative management between Commonwealth and State governments. Much of the suitable adult habitat identified in this report for the endemics exists in unprotected waters. Where overlap with AMPs or State MPAs do occur, connectivity has generally not been considered (e.g., probable inshore juvenile movement to adult suitable habitat offshore for *Dentiraja confusa,* and *Spiniraja whitleyi*).

Candidate Areas 4 and 5 are adjacent to current SESSF closures under the Upper-slope Dogfish Management Strategy which aims to promote recovery of Harrison's dogfish (*Centrophorus harrisoni*) and the southern dogfish (*Centrophorus zeehaani*). These areas are likely candidates for inclusion into the existing Commonwealth Upper Slope Dogfish Management Strategy. Candidate Area 1 is also within the Schedule 5 South Australian Gillnet Closure – Backstairs Passage Closure which currently refers specifically to school sharks but not occurring endemics. Management of these SESSF closures is currently undertaken through AFMA electronic or observer monitoring.

Inclusion of *Squatina albipunctata* into the Candidate Areas was minimal except for Candidate Area 6. *Squatina albipunctata* has the largest proportion of IUCN range and suitable habitat occurring outside of SESSF areas and within the Great Barrier Reef Marine Park (GBRMP). We recommend that this species EPBC Act Threatened Species nomination is prioritised to facilitate its inclusion into GBRMP management arrangements.

Only the state-managed waters of Tasmania had protected inshore coastal waters specifically for any of the endemic sharks and rays listed within this report, with the inclusion of *Dentiraja confusa*, and *Spiniraja whitleyi* nursery habitats into Shark Refuge Areas. Candidate Area 2 identifies where connectivity between adult and juvenile habitats through extension of Shark Refuge Areas can be facilitated for these species.

Candidate Area 1 – North-eastern Kangaroo Island, South Australia

This area was primarily considered for *Urolophus orarius* as it encompasses a sufficient proportion of the species geographic range and suitable habitat, as well as for the occurrence of *Spinijara whitleyi* . Inshore conditions are representative of essential breeding habitat and nursery areas as identified elsewhere for other Urolophus species. Given the very restricted geographic range and suitable habitat of *Urolophus orarius* it can be assumed that all vital functions for the species occur in the area. Minimal suitable habitat of *Urolophus orarius* occurs outside of SESSF boundaries apart from in St Vincent and Spencer Gulfs which are in South Australian State waters.

The area is partially included into the South Australian State-managed Encounter Marine Park which is primarily zoned for Habitat Management (IUCN IV) with small sections zoned as no-take Marine Sanctuary (IUCN Ia) or Marine National Park (IUCN II). *Urolophus orarius* or *Spinijara whitleyi* are not listed or recognised in any current South Australian State MPA Management Plans. The area is currently closed to SESSF gillnet, longline and trawls (Schedule 5 South Australian Gillnet Closure – Backstairs Passage) to protect breeding school sharks and sea lions. It is also outside of current Australian Marine Parks jurisdiction being too far inshore (<3nm) for inclusion into the current South-west or South-east AMP networks. The entire bay from North Cape to Kangaroo Head should be considered under fisheries and MPA spatial protection. A continued lack of adequate spatial protections for *Urolophus orarius* place this species' entire global population at high risk of extinction thus impacting shark/ray and regional biodiversity.

Candidate Area 1 meets: Criterion 1 Suitable Habitat; Criterion 2 Biological Importance for (a) Breeding Habitat, and (b) Essential Habitat; Criterion 3 Ecological Importance for (a) Threat, and (b) Diversity; and Criterion 4 Abundance and Extent (Figure 31).

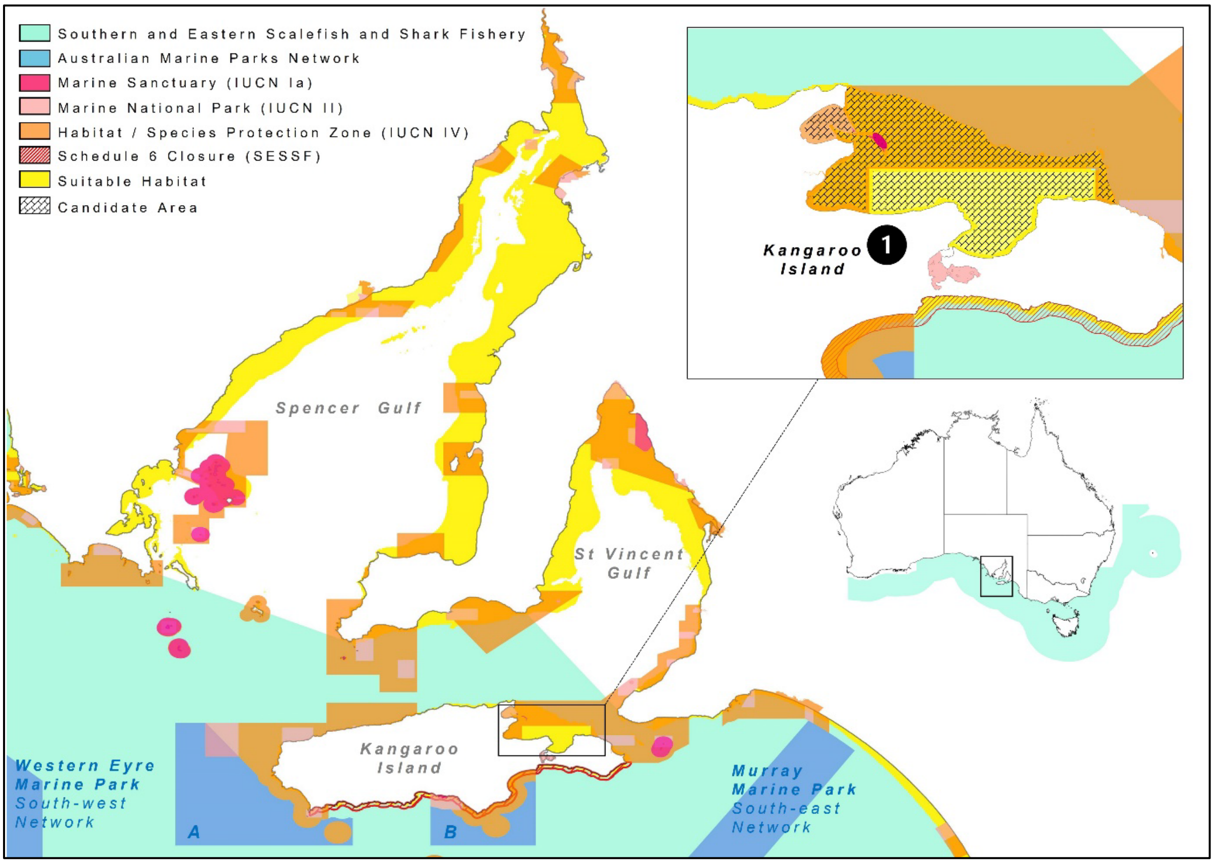

Figure 31. Candidate Area 1 (inset) North-eastern Kangaroo Island, South Australia, for *Urolophus orarius* and *Spiniraja whitleyi*.

Candidate Area 2 – Storm Bay and Shark Refuge Areas, Tasmania

This area is within the global range, adult habitat, and nursery areas of both *Dentiraja confusa* and *Spiniraja whitleyi*. Inshore areas are classified under Fishing Tasmania's Shark Refuge Areas, but adjacent adult habitat is outside of both SESSF and Australian Marine Parks jurisdiction. Any inshore fishing in Storm Bay places both species at risk of discarded bycatch mortality. Adequate spatial protection requires additional connection between juvenile inshore habitat and offshore adult habitat to achieve reproductive success. Consequently, Storm Bay should be an area of high consideration for ecological connectivity. The minimum extent of this connection should extend up to 50km from shore.

Candidate Area 2 meets: Criterion 1 Suitable Habitat; Criterion 2 Biological Importance for (a) Breeding Habitat; Criterion 3 Ecological Importance for (a) Threat, and (b) Diversity; and Criterion 4 Abundance and Extent (Figure 32).

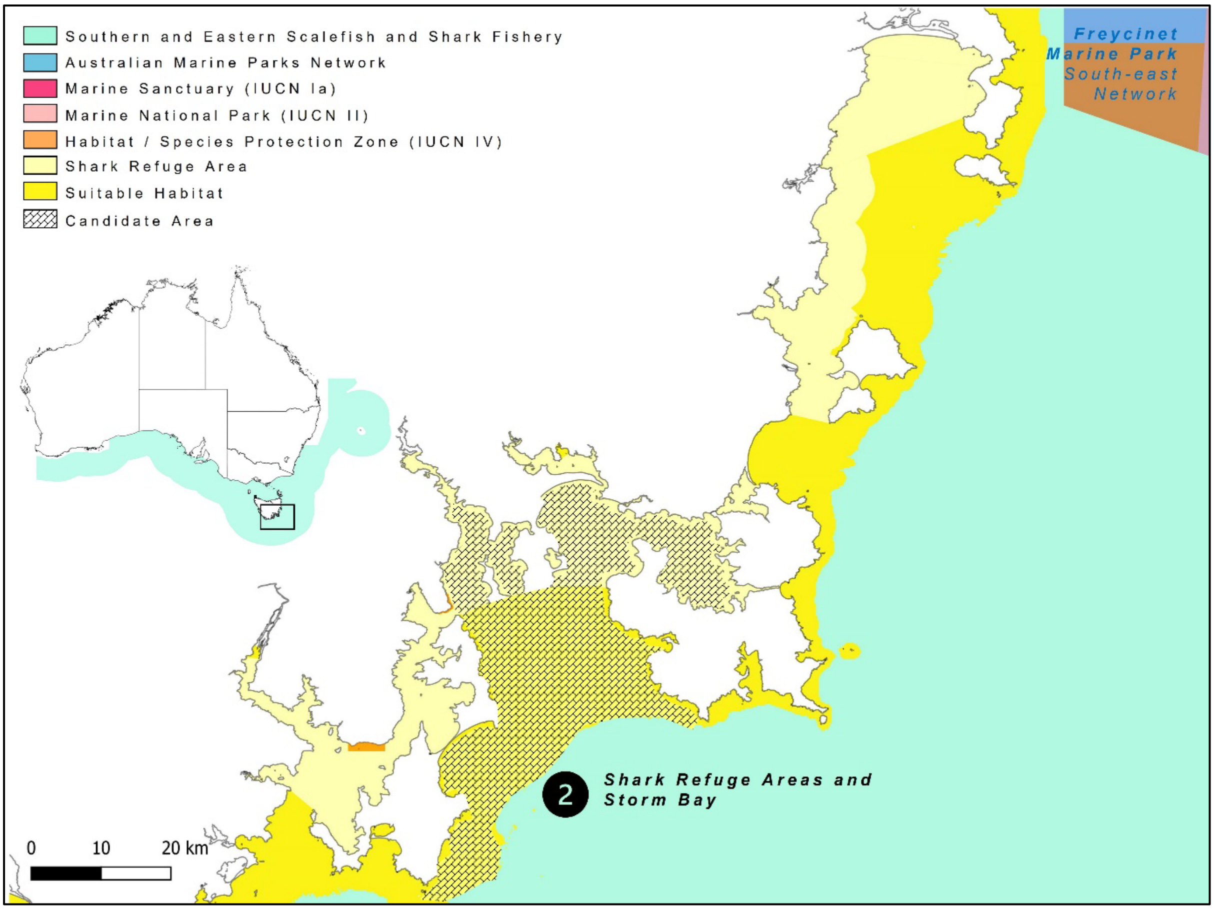

Figure 32. Candidate Area 2, Shark Refuge Areas and Storm Bay, Tasmania *for Dentiraja confusa* and *Spiniraja whitleyi*.

Candidate Area 3 – Apollo Marine Park, Western Bass Strait, Victoria

The area is at the western extent of *Urolophus viridis* range and within the largest proportion of its suitable habitat. Suitable habitat for *Spiniraja whitleyi* also occurs. Evidence of *Urolophus viridis* reproductive activity occurring adjacent to the area has been reported in Trinnie et al. (2015). Like other stingarees and skates, both species are subject to bycatch mortality in the SESSF. Part of the area is closed to SESSF trawl closures (Schedule 2 Bass Strait Trawl Closure) but largely remains open to gillnet and longline fishing. Relative abundance of *Urolophus viridis* in the area is reported as *common* in Trinnie et al. (2015) but declines may have occurred. A 50-100km extension of Apollo Marine Park's eastern boundaries would encompass more suitable habitat of both species, and breeding grounds of *Urolophus viridis* leading to ongoing reproductive success.

Candidate Area 3 meets: Criterion 1 Suitable Habitat; Criterion 2 Biological Importance for (a) Breeding Habitat; Criterion 3 Ecological Importance for (a) Threat, and (b) Diversity; and Criterion 4 Abundance and Extent (Figure 33).

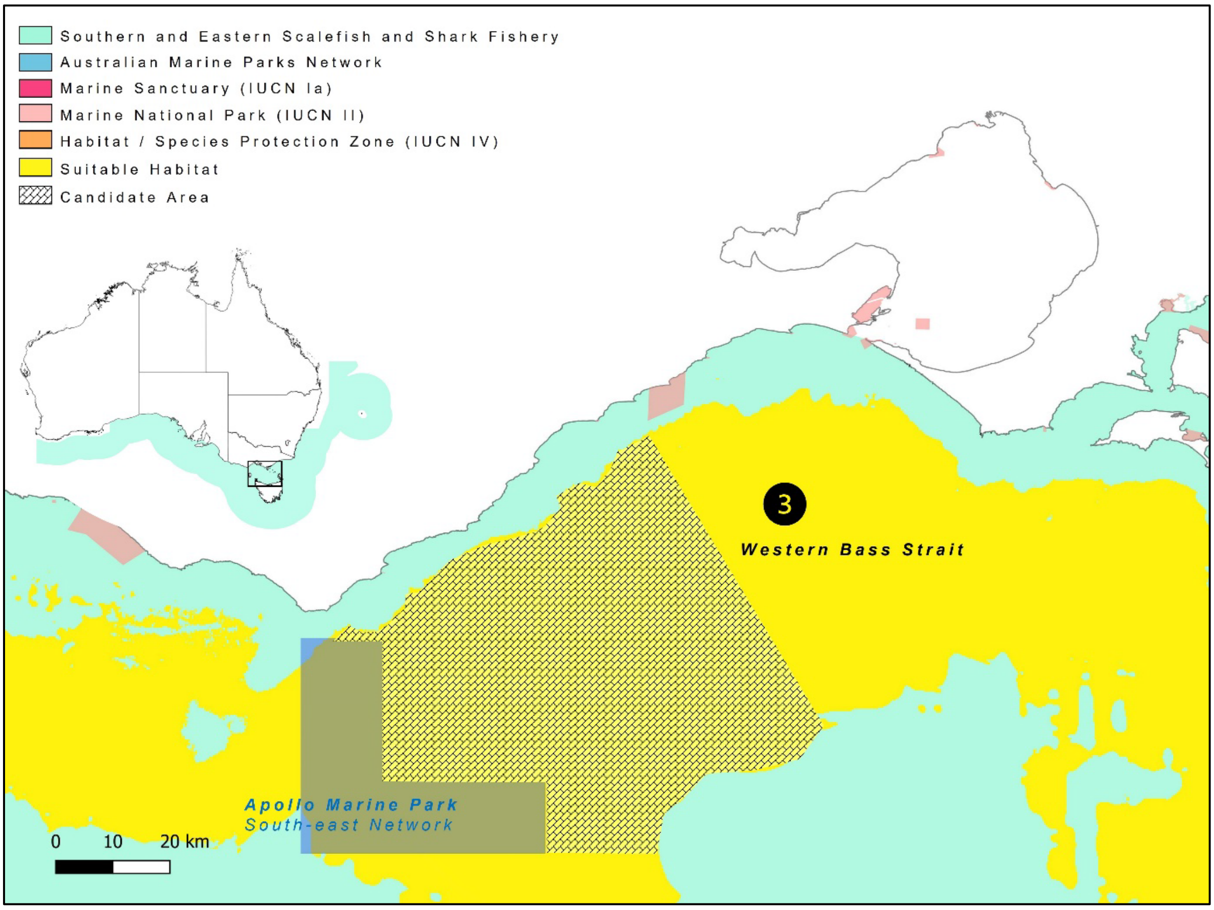

Figure 33. Candidate Area 3, Apollo Marine Park, Western Bass Strait, Victoria for *Urolophus viridis* and *Spiniraja whitleyi.*

Candidate Area 4 – Great Australian Bight, South Australia

The area is within the geographic range of *Cephaloscyllium albipinnum*, *Squalus chloroculus*, *and Dipturus canutus*. Observer and tracking data show the existing SESSF hook and trawl closure (Schedule 10 Commonwealth Gulper Shark Closure – Southern Dogfish) is within the core adult habitat depth range. Further, the tagging data shows mature females of *Cephaloscyllium albipinnum* and *Squalus chloroculus* are present. Effort summaries show that depletion is likely to be low here because historical trawl effort has been lower than eastern areas. The area is too deep for gillnet and was not substantially impacted by auto line gear prior to 2000. Three species of interest co-occur here in an area of mixed habitat consisting of interspersed steep terraces, small canyons, and pinnacles (Daley et al. 2015). The area is an important site for maintenance of biological and ecological diversity in the region. Tracking data suggest that spatial protections extending at least 80km along the upper slope are likely to be effective.

Candidate Area 4 meets: Criterion 1 Suitable Habitat; Criterion 2 Biological Importance for (a) Breeding Habitat, and (b) Essential Habitat; Criterion 3 Ecological Importance for (a) Threat, and (b) Diversity; and Criterion 4 Abundance and Extent (Figure 34).

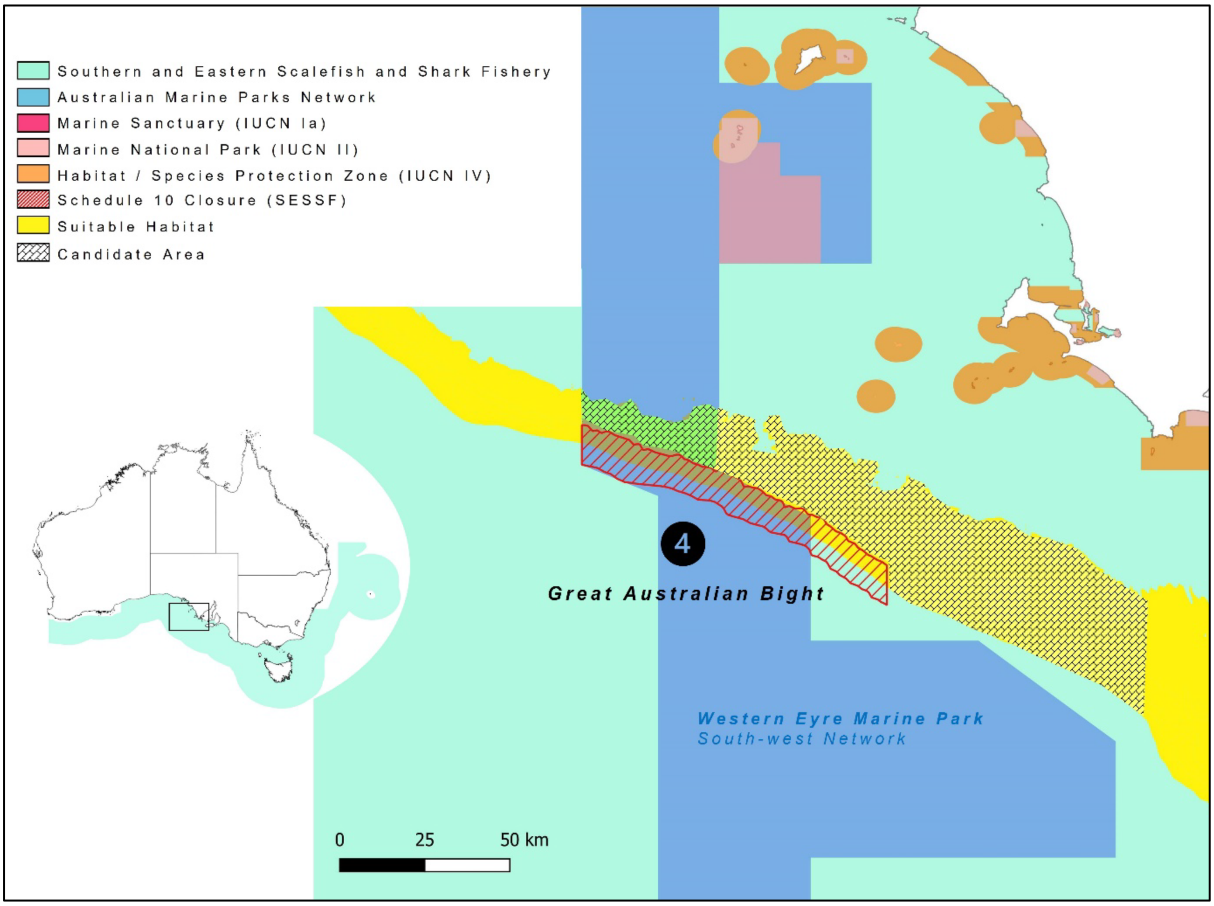

Figure 34. Candidate Area 4, Great Australian Bight off Coffin Bay, South Australia for *Cephaloscyllium albipinnum, Squalus chloroculus,* and *Dipturus canutus.*

Candidate Area 5 – Flinders Island, Tasmania

This area is proposed for *Cephaloscyllium albipinnum*, *Squalus chloroculus*, *Dipturus canutus and Spiniraja whitleyi* and has similar value to Candidate Area 4 for habitat. There has been greater historical fishing in adjacent fishing grounds therefore depletion is likely to have been higher. Current SESSF hook closures to protect upper-slope dogfish (Schedule 12 Gulper Shark Closure – Harrison's dogfish and Schedule 39 Flinders Research Zone Closure) occur within the area. There has not been tracking in this area. Tracking results from similar habitats suggest reserves should extend 80km along slope to encompass individual home range. The outer extent of *Dentiraja confusa* and *Spiniraja whitleyi* suitable habitat also occurs in the area.

Candidate Area 5 meets: Criterion 1 Suitable Habitat; Criterion 2 Biological Importance for (a) Breeding Habitat, and (b) Essential Habitat; Criterion 3 Ecological Importance for (a) Threat, and (b) Diversity; and Criterion 4 Abundance and Extent (Figure 35).

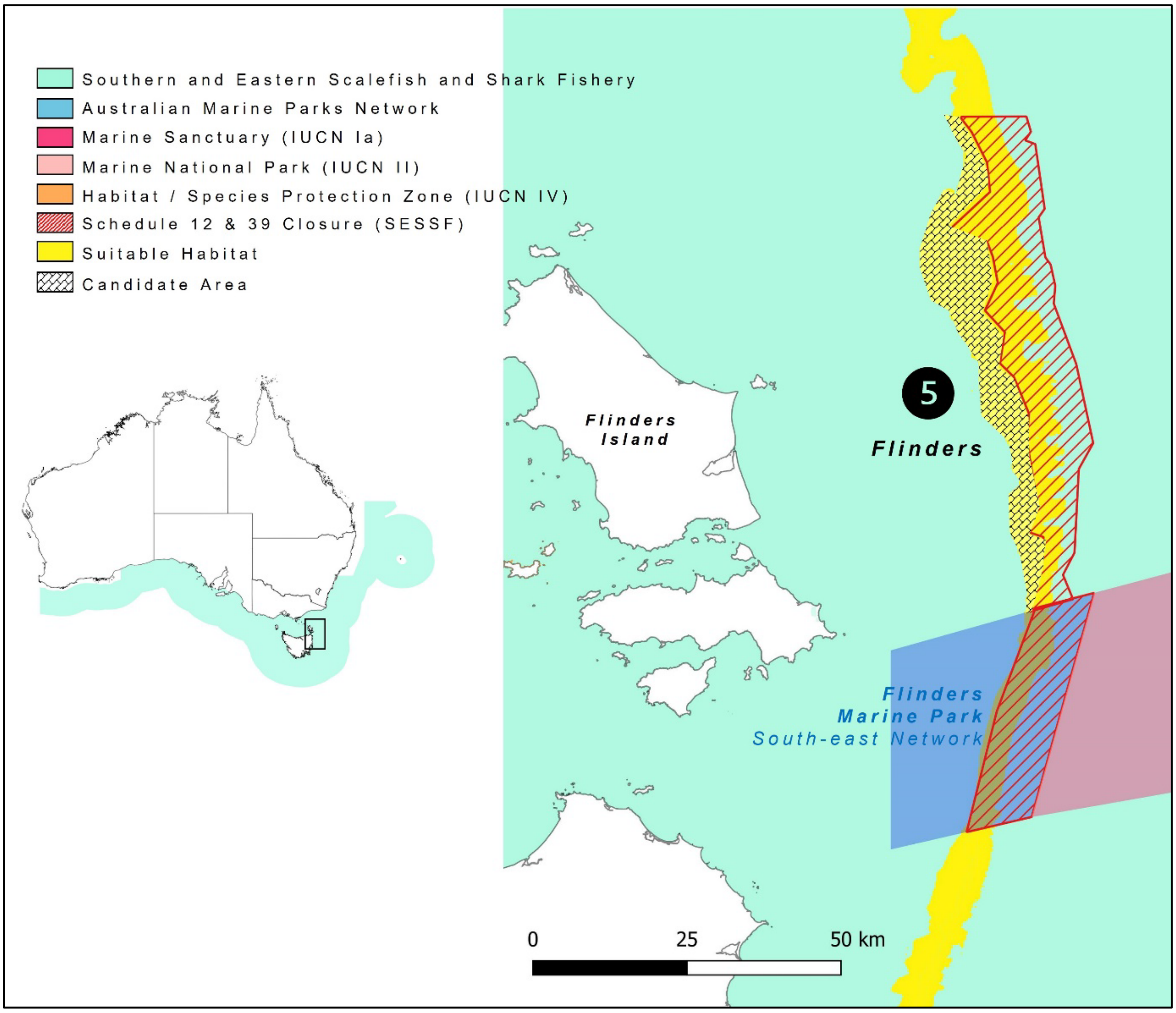

Figure 35. Candidate Area 5, Flinders Island, Tasmania for *Cephaloscyllium albipinnum, Squalus chloroculus, Dipturus canutus* and *Spiniraja whitleyi.*

Candidate Area 6 – Jervis Bay Marine Park and Jervis Marine Park, New South Wales

Suitable habitat for 9 of the 10 endemics occurs in the area from inshore Jervis Bay Marine Park (NSW State-managed) to offshore Jervis Marine Park (AMP Temperate East Network). A proportion of the AMP Jervis Marine Park designated as a Special Use Trawl Zone also covers an extent of suitable habitat area placing any of the species at high risk of bycatch and associated mortality. Inshore, the current Jervis Bay Marine Park area is classified either Marine National Park (IUCN II) or Habitat Management (IUCN IV) zones, yet none of the endemics which occur here are identified in its management plan. The area is within the SESSF and may also be subject to inshore State fisheries, particularly in habitat which is outside of both the current State MPA and AMP boundaries. This is especially important to consider for *Dentiraja confusa*, *Squatina albipuntata*, *Urolophus sufflavus, Urolophis viridis, Spiniraja whitleyi*, and *Dentiraja australis* which move between shallow (1-50m depth) and deep waters (~350m) and may become disconnected from inshore breeding areas.

Recent research has identified other rays (i.e., smooth stingrays [*Bathytoshia brevicaudata*]) exhibiting philopatry at Jervis Bay, repeatedly moving out of the bay and returning (Pini-Fitzsimmons, 2022). This suggests the area has importance to a wider diversity of elasmobranch species which is an important biodiversity consideration. Removal of trawl fisheries pressures and adequate spatial protections by an extension of the Jervis Bay Marine Parks eastern and Jervis Marine Park's western boundaries to meet will encompass connectivity between areas of inshore habitat and suitable adjacent offshore habitat for all species and will maintain the species and areas' biological and ecological diversity. It will also allow the area to act as a connective corridor between the northern and southern extent of each nominated species' ranges.

Candidate Area 6 meets: Criterion 1 Suitable Habitat; Criterion 2 Biological Importance for (a) Breeding Habitat, and (b) Essential Habitat; Criterion 3 Ecological Importance for (a) Threat, and (b) Diversity; and Criterion 4 Abundance and Extent (Figure 36).

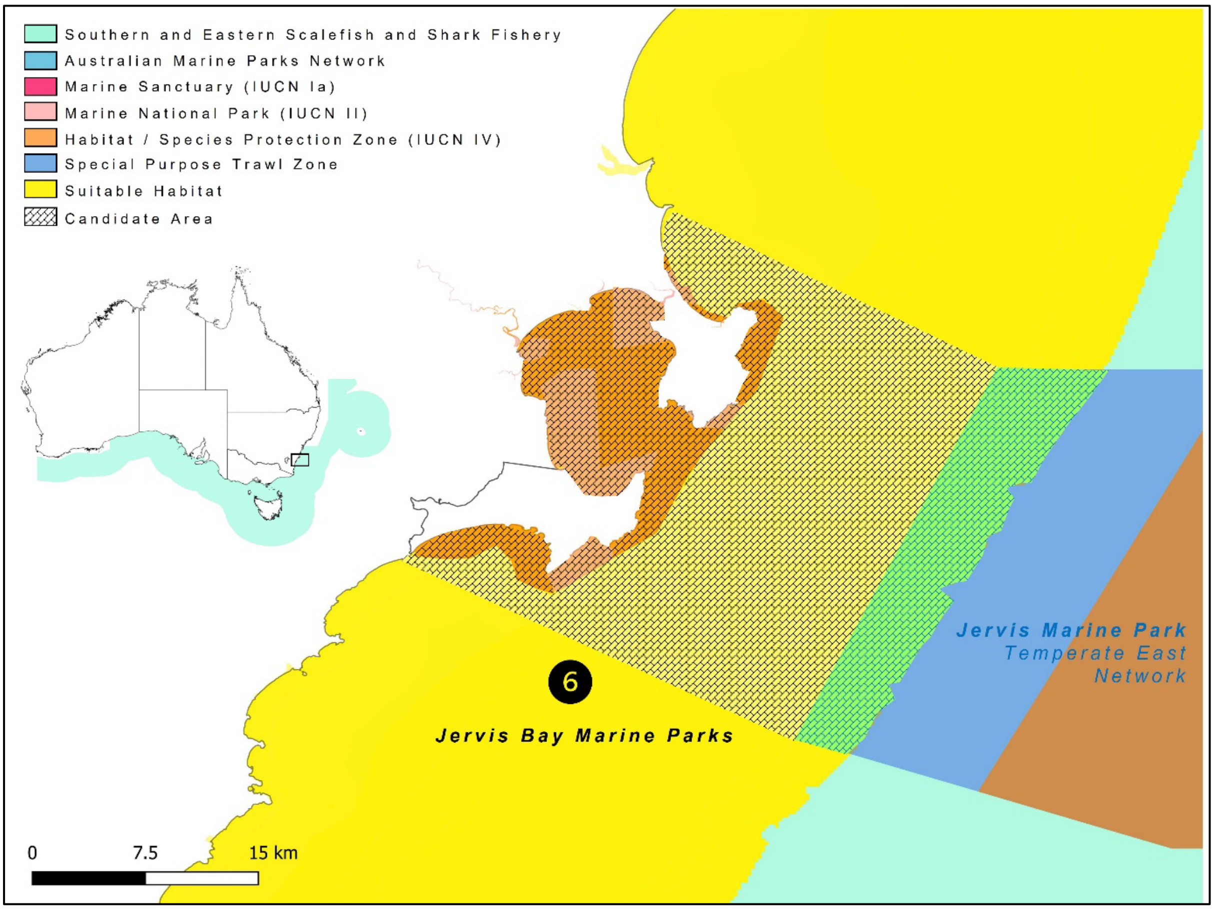

Figure 36. Candidate Area 6, Jervis Bay and Jervis Marine Park, New South Wales for *Cephaloscyllium albipinnum, Squalus chloroculus, Dipturus canutus, Spiniraja whitleyi. Dentiraja confusa, Squatina albipuntata, Urolophus sufflavus, Urolophis viridis,* and *Dentiraja australis.*

Discussion

The scope of this report is data intensive, yet available data are extremely limited. Compromises were needed in terms of method selection and analysis. The discussion that follows considers how effectively the methods can be integrated, and what improvements could reasonably be made to data quality. We also identify some data needs that can't be compromised, if the full objectives of this report are to be met in the future.

Species

The species examined interact with the SESSF to varying extents. Three upper-slope species (*Cephaloscyllium albipinnum, Squalus chloroculus* and *Dipturus canutus*) are distributed entirely within the SESSF area. Management of this group is potentially the least complex and could be achieved by expanding the existing Commonwealth Upper-slope Dogfish Management Strategy to be the Upper-slope 'Shark and Ray' Strategy. At the other extreme, the adult habitat of *Squatina albipunctata* lies largely outside the jurisdiction of the SESSF in marine parks off Queensland (e.g., the GBRMP) where its inclusion into State management arrangements would assist in achieving the conservation objectives for this species. Similarly, for *Urolophus orarius*, inshore state waters of South Australia will be most important. Conservation of the remaining five species will require co-management between state fisheries managers and the Commonwealth Department of Environment. Four of these species extend from inshore to offshore waters: *Dentiraja confusa, Spiniraja whitleyi, Urolophus sufflavus* and *Urolophus viridis.* The remaining species, *Dentiraja australis* lives mainly on the outer shelf off NSW, which is managed by the Commonwealth south of the Hawkesbury River and by the state of NSW to the north. Progress for species in this group will require effective communication and co-operation between jurisdictions.

Fisheries Data

The effort summaries obtained from AFMA were particularly useful for understanding how changes in effort will affect recovery potential and the selection of candidate closure locations. The approach provides a useful alternative to catch data for species with unreported discarding in logbook data and limited observer coverage. The results show changes in the overall amount of effort, the gear types used, and the spatial distribution of effort. Effort distribution needs to be considered with the selectivity and post capture mortality of the different fishing gears, and in light of refined species maps. The results of this study are mixed for endemic sharks and rays.

The 60% reduction in the amount of trawl effort is certain to have a positive effect, both directly via reduced mortality, and indirectly via reduced habitat disturbance. The spatial reductions in trawl effort were widespread and include NSW, eastern Victoria, Central GAB, and western Victoria. It would have been desirable to undertake a more detailed breakdown of the trawl effort by depth based on shot-by-shot effort data, or more detailed summaries, if confidentiality requirements could be managed. For the non-trawl methods, it was easier to determine which species were likely to be impacted based on gear-based depth restrictions.

When the non-trawl effort summaries were considered, there are mixed results. Changes from gillnet to shark line will likely have a negative impact on some species, but needs to be considered alongside other conservation objectives, like those for Australian Sealions. Recent increases in automatic longline effort places upper slope species at higher risk, but this needs to be weighed against the conservation benefits of the closures in the Upper Slope Dogfish Management Strategy. A quantitative evaluation of these trade-offs is not possible until more knowledge of movements and biology is collected. For the Danish Seine, the recent increase in effort off eastern

Victoria will have increased the impacts to *Urolophus viridis* particularly as this species doesn't have refuge elsewhere in Tasmanian shark nurseries.

This report highlighted challenges for estimating depletion using observer based CPUE methods. For the existing data set, some form of advanced standardisation may be possible. Walker and Gason (2007) describe some options when sample sizes fall below 500 trawl shots. Those options are well beyond the scope of this study at least. Further, for some endemics the number of observations has not reached 100 observations within narrow depth range habitats. Higher sample numbers could be possible with less frequent sampling and periodic focus on different areas/depth ranges.

Fundamentally this report raises questions about what "targeted" fishing means. For example, If the effort data are considered alongside tracking data and habitat mapping, results indicate targeting *Hyperoglyphe antarctica* (blue eye) and *Genypterus blacodes* (pink ling) effectively targets *Cephaloscyllium albipinnum* and *Squalus chloroculus* in the narrow seafloor corridor they share between 300 – 600 m (Figure 24,26) (Daley et al. 1997; Zhou et al., 2011). In this example at least the terms targeted vs non-targeted simplistic. Spatial overlap, catchability, and post capture mortality are valuable alternatives (Hobday et. al., 2011; Murua et al., 2022).

Overall, it seems remarkable that the endemic sharks and rays considered are not managed in a more precautionary manner in the SESSF. There is a heavy reliance on Ecological Risk Assessments (ERAs) to assess non-target sharks and rays in Commonwealth Fisheries. These ERAs have several untested assumptions and cannot be relied upon to avoid extinction risks. Importantly, ERAs do not consider historical removals, reports are out of date for non-trawl sectors, cumulative effect predictions are largely lacking, and biological inputs often use proxies from closely related species from different habitats. Most importantly but less surprisingly ERA predictions are not tested by measuring depletion, because conventional CPUE analysis is problematic using observer data due to inadequate sample size and limited geographic coverage.

Prediction of recovery time is more challenging and requires two key inputs. These are demographic data (sex and length) and breeding habitat use – mainly through tracking data. Attempts to determine recovery using population viability analysis (PVA) through the Monte-Carlo simulation program Vortex, were hindered by this lack of data, and provided pessimistic outcomes for all species (e.g., population collapse within 40 years). With sufficient data to input into the model, PVA could provide reliable estimates to inform conservation actions.

Observer programs have under-utilised seagoing capacity to collect demographic data, although they would require additional staffing. Time will tell if cameras become a suitable alternative but for now at least they do not perform well at weighing, measuring determining the or sex sharks and rays or distinguishing between closely related species that are very similar in appearance. Understanding breeding movements is the most challenging aspect of this work. Without at least some understanding of the scale of movements, candidate closures are likely to be too small, and/or incorrectly located.

Habitat Modelling

Shark and ray physiology and life-history is diverse and complex (Barnett et al., 2019). The habitats utilised by species and the variance in biotic and abiotic features which influence their distribution can subject each species to constraints or pressures disproportionality across their range (McAllister et al., 2015; Barnett et al., 2019). This means that management approaches cannot take a uniform 'one size fits all approach' but rather needs to be a bilateral, or multi-disciplined approach addressing species, habitat and/or fisheries management. The underlying driver for conservation, however, should be the requirement to provide refuge and promote species persistence and/or recovery. This study showed that despite the operation of SESSF fisheries activities within the species ranges, minimal or limited biotic information to inform habitat use was available. As noted above, the inclusion of biotic data into fisheries observations records would be a useful tool allowing for habitat association (combined with abiotic data) to be determined. Without this information, areas crucial for reproductive success or other vital functions remain overlooked and unrepresented therefore species remain at risk.

This report has shown that abiotic data collected across the full range of a species is important for mapping habitat. Shark and ray species are particularly sensitive to temperature, which limits physiology (Schlaff et al., 2014). In some species of skates (e.g., Maugean skate [*Zearaja maugeana*]), movement between deep and shallow habitats can be associated with water temperature which influences oxygen consumption rate (Moreno et al., 2020). Additionally, abiotic factors such as temperature and depth may also influence movement of other sharks and rays across habitats by direct physiological need, particularly warmer waters for gestation and pupping, or indirectly via abundance and distribution of prey (Cerutti-Pereyra et al., 2014; Schlaff et al., 2014). As mobile species, sharks and rays leave an environment when conditions change moving to areas with sufficient abiotic requirements. As evident in this report, using abiotic factors to identify suitable habitat range and identifying where environmental conditions remain stable for a given species' requirements, is essential for informing spatial protections.

Biotic inputs to habitat maps were generally patchy. The tracking data for *Cephaloscyllium albipinnum* and *Squalus chloroculus* allowed us to link residency to temperature and depth range indicated by the tag sensors with some precision. This was then used to map the physiological limits of adult habitat at least across the full species range with confidence. For breeding habitat, we found only a few species with sufficient data to select or even characterise breeding habitat locations. The best example of appropriate location is the inclusion of *Dentiraja confusa* and *Spiniraja whitleyi* in Tasmanian Shark Refuge Areas located within these species' suitable habitat range. The study by Trinnie et al. (2013) additionally identified breeding activity in individuals of *Urolophus viridis* in areas identified in this report as suitable habitat for the species which were additionally within SESSF boundaries. These examples highlight that the abiotic proxies we identified for each species are justifiable by biological data when this is available and provide case studies useful to test the effectiveness of candidate protected areas. Increased biological data collection by fisheries will serve to enhance and refine future selection of spatial protection locations.

Species suitable and critical habitat map outputs from this project differed substantially from IUCN Red List species geographic range maps. Overall, our results indicate core range which is much smaller than the IUCN Red List ranges. This has important implications for risk assessment because while recent developments have refined effort mapping to smaller areas, species mapping has not received the same attention. Our predictions are likely to lack precision where temperature mapping is imprecise due to localised effects. Other methods may be biased towards inshore observations where fishing is mainly in state waters. This loss of precision is of minor consequence for selecting spatial management locations. Overall, the mapping approach used here will provide more accurate understanding of jurisdictional responsibility and more strategic consideration of habitats into spatial planning options.

Results from the tracking data showed that thorough testing of proposed closed areas is needed, and that performance cannot be assumed. For *Squalus chloroculus,* the mature females left the closure. If other locations with resident breeding females could be found and closed to fishing, they would offer more to breeding success than the area studied, (which was closed to fishing for gulper shark conservation).

Selection of Candidate Areas

Regardless of how much simpler it is to develop criteria at the strategic network scale, any network is going to fail if population viability is not maintained at the scale of individual closures. Here shark and ray specific data are needed, and the data needs to come from the fishery. Despite data deficiencies, we were able to utilise current species information to develop a set of criteria based on qualitative features (e.g., presence and relative abundance) and quantitative data where these are available, to identify and spatially refine six candidate protected areas.

The importance of the selected Candidate Areas is their representation of not only species biotic attributes, but also their abiotic requirements. In most MPAs, these factors are rarely considered together for marine species, let alone sharks and rays. Whist the current AMP Networks has identified some species of sharks into several marine reserves based on vital function activities or essential habitats (e.g., foraging areas for white sharks [*Carcharodon carcharias*]; or essential habitat of Harrisons dogfish [*Centrophorus harrissoni*]), no habitats and/or mentions of endemic species of sharks and rays are noted. Similarly for most State-based MPAs, sharks and rays are underrepresented in current arrangements. Presently, all State and Commonwealth (AMP) MPA management plans outline that inclusion of species into marine park planning or development is limited to those protected under the EPBC Act. Five of the endemics identified in this report are due to be assessed for EPBC Listing in 2023. The Candidate Areas identified in this report would assist in protecting these most at risk Australian species.

Current spatial and/or temporal closures of the SESSF do represent a marginally more effective management strategy for some of the endemics identified. Yet these closures do not specify or spatially protect the habitats within closure areas, focusing solely on removal of fishing pressure of commercial species with positive flow-on effects to bycatch species (e.g., skates, stingarees). Trawl activities, in particular, are recognised to be detrimental to benthic marine habitats, altering the physical environment and extracting limited resources (Perry et al., 2022; Vrooman et al., 2022). Whilst SESSF trawl effort has been reduced by 60%, other trawl effort in South Australian and New South Wales state waters continues. If these impacts are not addressed through habitat preservation, the effectiveness of closures to any species is reduced. Implementing multidisciplinary habitat and species based MPAs in areas already designated as SESSF closures is likely the best solution for some threatened endemics in the region and a recommendation of this report.

We identified quantitative data deficiencies and limitations which hindered the ability to adequately calculate depletions, or precisely estimate recovery times. Whilst we attempted to address the specific objectives outlined at the start of this report to inform spatial protections, accurate predictions were not possible because of a lack of species-specific catch and demographic data. It is possible to measure the percentage of area of occupancy to inform spatial protections but setting a meaningful threshold without understanding breeding is arbitrary. Similarly, extent of occurrence is commonly used to measure criterion that can be used as a proxy for genetic diversity. Again, we considered this measurement not informative without data to determine breeding success. We were unable to simulate population trends under harvest scenarios using PVA, as exact population numbers for these species are unknown. At the scale of individual closures, there is little reliable data to base the size or even location of suitable closures around breeding success, and without further data on size, sex, or movements, the effectiveness of any closure network for the species considered here, present or future remains uncertain.

The data limitations we encountered are common for global shark and ray species which are widely under-researched (see: Ducatez, 2019; Gupta et al., 2021). Representation of sharks and rays into closures, MPAs or other area-based conservation strategies has therefore been minimal despite knowledge of global population declines (see: Dulvy et al., 2021). The development of Important Shark and Ray Areas (ISRAs; Hyde et al., 2022) and the Shark and Ray Recovery

Initiative (SARRI; Simpfendorfer 2022) was in response to this poor inclusion of sharks and rays in marine spatial planning by allowing for the identification of their important habitats based on qualitative data. The criteria developed for use in this report was guided by ISRAs and SARRI, however unlike ISRA Criteria which is biocentric, we consider fishery activities and unlike SARRI Framework, we have included Vulnerable as well as Critically Endangered and Endangered species. We anticipate that the criteria developed can be applied, and further justified regionally, with increased fisheries data collection and collation of data from regional, relevant, scientific publications.

Conclusions

This report set out to explore data sources and analysis methods for the conservation of threatened endemic sharks and rays in Australia. The SESSF fishery was used as a best-case scenario of data availability. Most of the species examined inhabit ranges that cross multiple jurisdictions. These will require co-ordination between the States and Commonwealth to conserve and manage species and better communication and co-operation between jurisdictions. Three exceptions are species from the upper slope that can be studied cost effectively with gulper sharks by AFMA.

The fishing effort summaries were particularly useful for understanding changes to fishing pressure. They showed a substantial reduction in trawl effort that will reduce the ongoing direct (mortality) and indirect (habitat) impacts of the trawl sector on endemic sharks and rays, particularly on the traditional trawl ground to the east. This suggests that the major declines reported for some species caused by trawling must have at least been slowed. These data do not provide any evidence of recovery. There are some concerning trends in non-trawl effort. An increase in seine effort off eastern Victoria and a refocussing of gillnet effort in Bass Strait will potentially increase pressure on rays and skates in these inshore and mid-shelf areas. A recent increase in hook effort over the last five years in the Great Australian Bight will increase pressure on three species from the upper-slope, although as noted above, these species should benefit from gulper shark closures.

Quantitative predictions of the level of depletion were limited by sample sizes and quality of observer data. There are two possible measures to address this issue. Advanced statistical approaches may assist with existing data sets. Going forward less frequent, more detailed data could provide a cost-effective solution to sample size issues. It was not possible to estimate recovery times because of a lack of biological and demographic data. Going forward the key contribution that observer programs can contribute is the collection of demographic data. Sex specific size data are essential. This will require additional resources.

Closure or protected areas options were evaluated mainly at the network scale based on location with respect to improved adult habitat maps. We provide a framework for future consideration of closure networks to guide prioritised data collection. Identification of current processes and threats affecting endemics in the SESSF region through the application of the criteria and selection of protected areas should encourage increased fisheries data collection and uptake of these species into State and Commonwealth fisheries closures and/or MPAs and threatened species nominations under the EPBC Act. This will also facilitate performance monitoring at the strategic network scale and the operational scale of individual closures.

The overall conclusion apparent even from limited data, is that populations of the species of concern remain at risk and only urgent action can prevent extinctions. The extent that this report could meet its objectives in confidently identifying spatial protections was limited by the available data. Any closure network implemented for the endemic sharks and rays considered here will need ongoing monitoring and targeted data collection in an adaptive management framework.

Performance Against Objectives

Rationale on the ability and/or success of this report to meet the desired objectives are presented in Table 6.

Table 6. Outcomes of this report to each objective

Objective	Outcome
1. Identify any potential spatial areas within the Southern and Eastern Scalefish and Shark Fishery (SESSF) that will provide protection and support the recovery of threatened endemic sharks as identified in the Australian Action Plan for Sharks and Rays (Kyne et al., 2021)	This objective was met based on biotic and abiotic predictors of adult habitat.
2. Project the estimated degree of recovery of each identified species over their respective three-generation time length, based on the protections afforded by proposed spatial protections under three scenarios (all scenarios factor in fishing effort displacement):	This objective could not be met due to data deficiencies.
3. Use existing movement/behavioural data of both whitefin swellshark and greeneye spurdog to present specific case studies under each of the above scenarios;	Tracking data was used to refine adult habitat maps but not in relation to objective two as there was insufficient data available on mature females at the location studied.
4. Produce maps as a visual aid to communicate the results of the above scenarios	This objective was met successfully with production of suitable habitat and candidate protected area maps where recoveries are likely.
5. Provide recommendations based on findings of actionable steps which will facilitate the conservation and recovery of the selected threatened endemics.	Recommendations are provided in the summary above which outline actionable steps for species management, conservation, and recovery, as well as improving data quality.

Addendum

Following compilation, review and submission of this report in July 2023, the Australian Fisheries Management Authority (AFMA) provided updated information on recent changes to the Commonwealth Trawl Sector (CTS) occurring from May 2023, including: a further reduction in the number of trawl Statutory Fishing Rights from 57 to 36; implementation of five new spatial closures (Schedules 40-44); and an increase in mesh size for Danish seine operators (from 75mm to 80mm).

A brief review of these closures by the authors notes useful overlap with suitable adult habitat for several of the endemics, mainly on the outer shelf from 120-180m. However, these closures do not extend across the full depth-range of any one species, and do not link adult habitat to juvenile habitat or nursery areas. One new closure, Schedule 43 – Babel Island Trawl Closure does overlap with Candidate Area 5 and prohibits the use of otter trawl methods, the operation of Danish seine fishing is not prohibited.

AFMA details that the new closures implemented are aimed at assisting the recovery of *Nemadactylus macropterus.* Evidence of recovery or effective avoidance strategies for this quota managed species will need to be identified before any potential changes to these closures are considered in the future. Being an equally long-lived species (≥16 years) potential recovery for some of the endemics within these new fishery closure areas exists. Full closures and/or protection of the endemics' core habitat, however, remains the best-case scenario for full species' recovery and persistence.

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Annex A – Species Information

Primary information on each species is sourced from IUCN Red List and Australian Action Plan for Sharks and Rays 2021 taxon profiles and additional scientific publications.

Whitefin Swellshark
Cephaloscyllium albipinnum

Critically Endangered (Decreasing) – IUCN Red List 2022
Critically Endangered (Consider Listing) – Action Plan for Australian Sharks and Rays
Not Listed (Assessed for listing; Finalised Priority Assessment List 2019) Nominated) – Australian EPBC Act.

Habitat: Continental shelf and slope
Depth: 126-554m
Maximum Size: 110cm TL

Distribution and Biology

Whitefin swellshark (*Cephaloscyllium albipinnum*) is a previously-abundant small shark (to 110cm total length) endemic to south-eastern Australia on the outer continental shelf and upper slope at depths of 126–554 m. Its range is restricted to southern Australia from Bateman's Bay on the central coast of New South Wales to Eucla (Western Australia), including Tasmania but not the Bass Strait.

Habitat

This species is oviparous and utilises egg-laying/hatching sites where egg cases can be attached to a substrate. Whitefin swellsharks are predominantly demersal and nocturnal, utilising rocky reef or seaweed bed substrate areas to rest during the day, usually in aggregations, before actively feeding at night. They are considered otherwise non-migratory remaining at length in established feeding and preferred habitats.

Population Estimates

Population reductions have determined a 32% reduction over 20 years (equivalent of a 58% population reduction over three generations) across a broader area of the SESSF. Standardized catch-per-unit-effort in the SESSF has decreased by 73% over the period 1994 to 2006. This decline is the equivalent of a ~99% population reduction over the past three generations (45 years).

Primary Threats

The distribution and depth range of the whitefin swellshark overlaps with current and historical intensive fishing effort of the SESSF where it is one of the most abundantly caught elasmobranchs across several different fishing sectors. The SESSF fully encompasses the outer shelf and upper slope depth range of the whitefin swellshark, and fishing pressure is ongoing.

Conservation and Management

There are no specific conservation actions for this species. There are general conservation measures for other deep-water sharks off south-eastern Australia, including spatial closures for gulper sharks (Centrophoridae) and the Upper Slope Dogfish Management Strategy that have potential to benefit this species. Bycatch mitigation, and potentially spatial management is required to allow the population to recover.

Longnose Skate
Dentiraja confusa

Critically Endangered (Decreasing) – IUCN Red List 2022
Critically Endangered (Consider Listing) – Action Plan for Australian Sharks and Rays
Not Listed (Assessed for listing; Finalised Priority Assessment List 2019) – Australian EPBC Act

Habitat: Continental shelf and slope
Depth: 20-390m
Maximum Size: 70cm TL

Distribution and Biology

The longnose skate (*Dipturus confusus*) is a range-restricted, Australian endemic skate found in south-eastern Australia from Sydney, New South Wales to Portland, Victoria and including Tasmania. It occurs on the continental shelf and upper slope at depths of 20-600 m, although is most common at 20-120m. This is a moderately-sized skate growing to 70 cm total length (TL), potentially larger; males mature at ~47 cm TL, corresponding to an approximate age of 6 years; females mature at ~53 cm TL, corresponding to an approximate age of 7 years; maximum age 12 years; resulting generation length is 9.5 years.

Habitat

Longnose skate preferred habitat is soft substrate areas on the continental shelf and slope. The species is oviparous, and females utilises egg-laying/hatching sites to deposit egg cases in sandy or muddy flats.

Population Estimates

Considerable declines are estimated for this species equating to a 93-95% population reduction over a three-generation span of 28.5 years. More recent observer data from a limited, but heavily fished area of the species' range shows the equivalent of a >99.9% population reduction over three generations. Fishing effort is ongoing in these areas.

Primary Threats

Caught by a variety of fishing gears in several sectors of the SESSF, mainly by otter trawls and less frequently by Danish seine and deep-water longlines. During 2000-2006, about two-thirds of the catch was retained and marketed. Parts of its range have been subject to heavy fishing pressure for many decades (evidence of decline since 1970s). Annual catch is estimated to be 25 tonnes with 67% retained and the rest discarded. Over 90% of catches occur in water <199m deep.

Conservation and Management

No species-specific conservation measures are in place for the Longnose Skate. It likely occurs in some spatial closures and in marine protected areas of the Commonwealth Marine Reserve network. The utility of these closures and reserves to mitigate population reduction needs to be investigated. Species-specific reporting of bycatch data from observers in the SESSF would increase knowledge of catch frequency and fishery susceptibility. Some areas of its range do not receive the same level of trawl effort as where declines were documented (e.g., Bass Strait), and population status may be more secure there.

Greeneye Spurdog
Squalus chloroculus

Endangered (Decreasing) – IUCN Red List 2022
Endangered (Consider Listing) – Action Plan for Australian Sharks and Rays
Not Listed (Assessed for listing; Finalised Priority Assessment List 2020) - Australian EPBC Act

Habitat: Continental Slope; coastal and oceanic mesopelagic to bathypelagic zone
Depth: 216-1360m
Maximum Size: 99cm TL

Distribution and Biology

The greeneye spurdog (*Squalus chloroculus*) is endemic to southern Australia occurring from Ulladulla, New South Wales to Eucla, Western Australia in the Great Australian Bight. It occurs on the upper to mid-continental slope at depths of 216–1,360m. Females reach 99.0 cm total length (TL), and males 62.9 cm TL for males. Age estimates indicate a maximum age of at least 26 years for females and 24 years for males; females are estimated to mature at ~16 years and males at ~9–12 years. The generation length based on female age at maturity and longevity is 21 years.

Habitat

The greeneye spurdog is a demersal species which occupies a temperate bathyal environment usually associated with high productivity related to geological or hydrological features (e.g., continental shelves or seamounts).

Population Estimates

The population has undergone a major reduction from the effects of fishing in some localities and is now rare in New South Wales, eastern Victoria, and Tasmania. There has been a documented decline in catch-per-unit-effort (CPUE) in some areas that equates to a >99% population reduction over the past three generations (63 years). The species has low biological productivity based on late age at maturity and low reproductive output. An overall population reduction of 50–75% is suspected to have occurred over the past three generations (63 years) based on actual levels of exploitation and a long history of fishing.

Primary Threats

Most of the geographic range of this species has previously been intensively fished but not the complete depth range. Catch is taken by demersal trawl (89%), automatic longline (7%), and other methods (4%), with 95% of the catch taken from depths less than 600m and 5% of the catch from depths greater than 600m. Since 2006, management measures have been implemented (see Conservation section) that have markedly reduced the high fishing intensity threat to the species.

Conservation and Management

Several management measures are in place which benefit the conservation of greeneye spurdog including fisheries management (i.e., closures, catch reductions, landing requirements, licence buy-backs and fisheries depth limitations), and spatial management (i.e., the South-East Marine Parks Network).

Grey Skate
Dipturus canutus

Endangered (Decreasing) – IUCN Red List 2022
Endangered (Prioritise Data Collection) – Action Plan for Australian Sharks and Rays
Not Listed (being assessed for listing; Finalised Priority Assessment List 2019) – Australian EPBC Act

Habitat: Continental slope
Depth: 155 – 1050m
Maximum Size: 90cm TL

Distribution and Biology

The grey skate (*Dipturus canutus*) is an Australian endemic skate, found on the continental slope off southern Australia from Crowdy Head (New South Wales) to Eucla (Western Australia). It occurs on the continental slope where it is most abundant at depths of 400-600 m; it is rarely found outside 330-730 m, although its possible depth range is 155-1,050m. It is a medium-sized skate attaining 90 cm total length (TL), potentially larger, with males mature at ~71 cm TL and females mature at ~84 cm TL. Generation length is estimated to be 12 years based on age data available for other Dipturus species, and hence the three-generation span is 36 years.

Habitat

Like other skates, this species is found in soft substrate areas on the continental shelf and slope. The species is oviparous, and females utilise egg-laying/hatching sites to deposit egg cases in sandy or muddy flats.

Population Estimates

Fishery independent surveys off southern New South Wales have shown that catch rates have declined by 85-88% between 1976-1977 and 1996-1997 for grouped 'skates'. Mean catch data suggests >97% decline in the species over three generations, equivalent to an average annual decline rate of 9%.

Primary Threats

The grey skate is caught as bycatch in the SESSF. This species is caught in the greatest abundances by otter trawl in the South East Trawl Fishery sector (SETF) and Great Australian Bight Trawl Fishery sector (GABTF) and is also caught in lower abundances by deepwater longlines in the Gillnet, Hook and Trap Fishery sector (GHATF). Over 90% of catches occur in water >200 m deep.

Conservation and Management

There are some fishery closures and reserves in the Southeast Commonwealth Marine Reserves Network that afford refuge areas for the grey skate. While these closures do provide refuge, there are more conservation efforts that should be made for this species including species-specific reporting of bycatch in the SESSF to increase knowledge of catch frequency and fishery susceptibility.

Coastal Stingaree

Urolophus orarius

Endangered (Decreasing) – IUCN Red List 2022
Endangered (Prioritise Data Collection) – Action Plan for Australian Sharks and Rays
Not Listed (Nominated 2021) – Australian EPBC Act

Habitat: Continental shelf: benthic intertidal coastal zone
Depth: 5-50m
Maximum Size: 31cm TL

Distribution and Biology

The coastal stingaree (*Urolophus orarius*) is endemic to southern Australia in the Eastern Indian Ocean from eastern Great Australian Bight between Ceduna and Beachport, South Australia and is recorded from inshore waters of the continental shelf at depths of 5-50 m. It reaches a maximum size of ~31 cm total length (TL); male maturity is ~23 cm TL. Like other urolophids, it is likely to have low fecundity (as low as 1-2 pups/year). Age data are not available for this species, but data from the lobed stingaree (*Urolophus lobatus*) can be used to estimate a generation length of 9 years.

Habitat

Coastal stingarees have a restricted distribution in shallow inshore waters at depths of 5-50 m. They are a benthic species which favours sand flats or rocky reefs and can be found in mangrove fringed intertidal zones. Instances of coastal stingarees have been recorded from upstream brackish estuaries.

Population Estimates

No data are available on population size and structure of the coastal stingaree, although it is considered sparsely-distributed with low abundance. Based on the overlap between the species' distribution and South Australian trawl fisheries, the long history of trawling within its range, and its occurrence only at sites of low trawling intensity, it is suspected that the species has undergone a population reduction of >50% over the last three generations (27 years). It may find refuge in shallower waters outside of the trawl fisheries (<10 m), however, the bulk of the species' depth range (5-50 m) overlaps with those of the trawl fishery.

Primary Threats

The range of the coastal stingaree is outside of fishing grounds of the Great Australian Bight Trawl Sector of the SESSF, although there is some overlap with the Commonwealth Trawl Sector at the eastern edge of its range. Where the species is taken as bycatch, a concern is the demonstrated low post-release survivorship of trawl caught stingarees and the fact that urolophids frequently abort pups upon capture and handling; even if gravid females survived capture, their reproductive output can be lost.

Conservation and Management

Critical data gaps exist for the coastal stingaree. Given its restricted distribution which overlaps with trawl fishing, spatial management may be key to securing the species. Habitat use and movement/residency patterns are unknown for this species, thus it is difficult to assess the benefits of South Australia's inshore marine park network with regards to the coastal stingaree. Bycatch monitoring and mitigation are a priority.

Eastern Angelshark

Squatina albipunctata

Vulnerable (Decreasing) – IUCN Red List 2022
Vulnerable (Consider Listing) – Action Plan for Australian Sharks and Rays
Not Listed (Assessed for listing; Finalised Priority Assessment List 2020) -– Australian EPBC Act

Habitat: Continental shelf and slope; benthic intertidal coastal to benthic mesopelagic zone.
Depth: 35-414m
Maximum Size: 130cm TL

Distribution and Biology

The eastern angel shark (*Squatina albipunctata*) is an eastern Australian endemic species distributed from the Cairns region, Queensland, southwards to Lakes Entrance, Victoria occurring on the outer continental shelf and upper slope at depths of 35–415 m. There is limited information on its biology, but it is known to attain 130 cm total length (TL) (males mature by 91 cm TL and females at around 107 cm TL). Generation length is also unknown for this species, but the taxonomically similar Pacific angel shark (*Squatina californica*) has an estimated generation length of 23 years.

Habitat

Eastern angel sharks are benthopelagic preferring soft substrate habitats (e.g., sand) which allow it to conceal itself from prey during the day (up to several days at a time) before becoming more active at night.

Population Estimates

There are no estimates of population size of this species, but population declines of 96% in their relative abundance have been reported for the central-southern New South Wales part of its distribution over two decades (1976–77 to 1996–97). Graham et al. (2001) documented a 96% decline in catches of this species across all surveyed areas in fishery-independent trawl surveys from the Sydney area (central New South Wales) to the Eden/Gabo Island Area (southern New South Wales/Victoria border). Calculated over three generation lengths, this decline could range from 98–100% over three generations.

Primary Threats

Angel sharks are not very susceptible to line or mesh netting techniques but are susceptible to trawling as they lay on the bottom and are thus regularly taken as bycatch. Demersal trawling within the New South Wales Prawn Trawl Fishery and the SESSF threaten its populations.

Conservation and Management

There are no conservation measures in place for this species. It may occur in some spatial closure areas and marine protected areas.

Yellowback Stingaree

Urolophus sufflavus

Vulnerable (Decreasing) – IUCN Red List 2022
Vulnerable (Prioritise Data Collection) – Action Plan for Australian Sharks and Rays
Not Listed (Nominated 2021) – Australian EPBC Act

Habitat: Continental shelf and slope; benthic intertidal coastal to benthic mesopelagic zone
Depth: 45-320m
Maximum Size: 42cm TL

Distribution and Biology

The yellowback stingaree (*Urolophus sufflavus*) is a small-sized ray endemic to eastern Australia in the Western Central and Southwest Pacific Ocean where it is known from North Stradbroke Island, Queensland to Green Cape, New South Wales. It has a relatively restricted distribution and is near-endemic to the state of New South Wales, ranging only marginally into Queensland waters. It occurs on the continental shelf and upper slope at depths of 45-320 m (mainly on the outer continental shelf at 100-160 m). It reaches a maximum size of ~42 cm total length (TL); male maturity is ~23 cm TL; fecundity is low. Age data are not available for this species, but data from the similar-sized lobed stingaree (*Urolophus lobatus*) can be used to estimate a generation length of 9 years.

Habitat

Similar to *Urolophus orarius*, yellowback stingarees are common in inshore coastal waters on soft substrates, being most often observed in shallow coastal estuaries (including intertidal mangrove fringe) and reefs.

Population Estimates

No data are available on population size and structure of the yellowback stingaree. Fishery-independent trawl surveys comparing bycatch between 1976-77 and 1996-97 off the upper slope of New South Wales documented an overall decline in the catch rate of urolophids of ~66%, and up to ~90% on one survey ground. These declines were documented mostly prior to the last three generation period (27 years; 1991-2018), however fishing pressure has been ongoing in the region and there is no reason to suspect that declines have ceased since the 1996-97 surveys. It is suspected that declines of >30% over the last three generations (27 years) have occurred.

Primary Threats

A considerable proportion of the species' relatively restricted distribution overlaps with trawl fishing. The yellowback stingaree is taken as incidental bycatch in commercial shelf fisheries (Danish seine, trawl), particularly in the SESSF. This species is of no commercial value and is discarded when caught (Walker and Gason 2007). Where the species is taken as bycatch, a concern is the demonstrated low post-release survivorship of trawl caught stingarees and the fact that urolophids frequently abort pups upon capture and handling as noted for *Urolophus orarius,* which can hinder reproductive success.

Conservation and Management

There are no species-specific measures in place for the yellowback stingaree. Existing State and Commonwealth marine protected areas may provide some refuge for this species, but specific spatial management measures are required to recover the population, and bycatch should be monitored in fisheries which interact with the species.

Greenback Stingaree
Urolophus viridis

Vulnerable (Decreasing) – IUCN Red List 2022
Vulnerable (Consider Listing) – Action Plan for Australian Sharks and Rays
Not Listed (Nominated 2021) – Australian EPBC Act

Habitat: Continental shelf and slope; benthic intertidal coastal to benthic mesopelagic zone.
Depth range: 20-330m
Maximum Size: 51cm TL

Distribution and Biology

The greenback stingaree (*Urolophus viridis*) is another small-sized ray endemic to southeastern Australian in the Eastern Indian and Western Central and Southwest Pacific Oceans where it is known from North Stradbroke Island, Queensland to Portland, Victoria, including Tasmania. It has been recorded from the continental shelf and upper slope at depths of 20-330 m (mainly 80-180 m). Greenback stingarees reach a maximum size of 51 cm total length (TL); male maturity is ~28 cm TL; female maturity is 26-31 cm TL; reproduction is annual; fecundity is low (1-3 pups/litter) Age data are not available for this species, but data from the similar-sized masked stingaree (*Trygonoptera personata*) can be used to estimate a generation length of 10 years.

Habitat

Usually found over soft substrates in inshore coastal and estuarine waters including sandflats and estuarine areas including fringing mangrove forests.

Population Estimates

No data are available on population size and structure of the greenback stingaree. Overall, it is suspected that the greenback stingaree has declined by >30% (but up to 90% in some areas) over the last three generations (30 years) given actual levels of exploitation (bycatch) across areas of its range, together with areas of lower fishing effort where declines are unlikely to have been as severe as those previously documented off eastern Australia.

Primary Threats

The greenback stingaree is a significant bycatch of otter trawlers and Danish seiners in the SESSF. This species is of no commercial value and is discarded when caught. The species' range also overlaps with state-managed fisheries, including the Eastern King Prawn Sector of the Queensland East Coast Trawl Fishery and the New South Wales Ocean Prawn Trawl Fishery. In southern Queensland, a developmental deep-water trawl fishery at 250-800 m may take the yellowback stingaree as bycatch. Where bycatch occurs, as with other urolophid rays, low post-release survivorship of trawl caught stingarees has been recorded and reproductive output can be affected by post capture/handling abortion of pups.

Conservation and Management

There are no species-specific measures in place for the greenback stingaree. Existing State and Commonwealth marine protected areas may provide some refuge for this species, but specific spatial management measures are required to recover the population, and bycatch should be monitored in fisheries which interact with the species.

Melbourne Skate
Spiniraja whitleyi

Vulnerable (Decreasing) – IUCN Red List 2022
Vulnerable (Prioritise Data Collection) – Action Plan for Australian Sharks and Rays
Not Listed – Australian EPBC Act

Habitat: Continental shelf and slope: benthic intertidal coastal to benthic mesopelagic zone.
Depth: 1 – 345m
Maximum Size: 200cm TL

Distribution and Biology

The Melbourne skate (*Spiniraja whitleyi*) is a large ray endemic to Australia with a patchy distribution on the continental shelf and slope between Sydney (New South Wales) and Albany (Western Australia), as well as Tasmania. The Melbourne skate is demersal on the continental shelf and slope from close inshore to a depth of 345 m but has been documented at >600 m by. The species reaches a maximum size of ~200 cm total length (TL); males mature at 127 cm TL and the smallest mature female found was 160 cm TL . Age-at-maturity was 8 years for males and 14 years for the youngest female observed and maximum age was 12 and 16 years, respectively. This gives an estimated generation length of 15 years.

Habitat

The Melbourne skate can be found in soft substrate areas (e.g., silt, mud or sand) near reefs on the continental shelf and slope. It is one of a few hard substrate habitat-dwelling skates occurring on reefs. The species is oviparous, and females utilises egg-laying/hatching sites to deposit egg cases.

Population Estimates

The species is relatively rare in outlying areas of Western Australia and New South Wales; it probably has a narrow home range making it susceptible to localised depletion (P. Last pers. comm. 02/09/2008). Fishery independent surveys off southern New South Wales (NSW) showed that catch rates for grouped 'skates' declined by 83% between 1976–77 and 1996–1997. When scaled to three generation lengths of the Melbourne Skate (45 years), these declines off Ulladulla and Eden indicate population reductions of 99% and 98%, respectively. Overall, it is inferred that the Melbourne Skate has undergone a 30–49% population reduction over the last three generation lengths (45 years) across its range.

Primary Threats

The Melbourne skate is a significant by-product and bycatch in the SESSF. Annual catch was estimated at 176 t from 2000 to 2006 with 30% of the catch retained; it represents the largest batoid catch of the SESSF. Large individuals are most vulnerable to hook and line and gillnets. This species does have some refuge from fishing in parts of their distribution and in coastal habitats, however, they are at higher risk to predation in inshore waters and are frequently preyed upon by broadnose sevengill sharks (*Notorynchus cepedianus*).

Conservation and Management

There are no species-specific conservation measures in place for the Melbourne skate. It occurs in spatial closure areas of the SESSF and in marine protected areas of the Commonwealth Marine Reserve network. Further research is needed on population size and trend, and life history, and catch rates should be monitored.

Sydney Skate

Dentiraja australis

Near Threatened (Decreasing) – IUCN Red List 2022
Vulnerable (Prioritise Data Collection) – Action Plan for Australian Sharks and Rays
Not Listed (Nominated 2020) – Australian EPBC Act

Habitat: Continental shelf and slope: benthic intertidal coastal to benthic mesopelagic zone.
Depth: 20-325m
Maximum Size: 55mTL

Distribution and Biology

The Sydney skate (*Dentiraja australis*) is a small restricted-range skate, endemic to eastern Australia between Moreton Bay (Queensland) and Tathra (New South Wales). It is demersal on the continental shelf and upper slope at depths of 20–325 m but it mostly occurs at depths of 100–199 m. It reaches a maximum size of 55 cm total length (TL), males mature at 43–48 cm TL and female size-at-maturity is unknown. Age parameters are inferred from the similar, white-spotted skate (*Dentiraja cerva*), that has a female age-at-maturity of 5 years and maximum age of 9 years, resulting in a generation length of 7 years.

Habitat

Similar to the grey skate, this species is found in soft substrate areas on the continental shelf and slope. The species is oviparous, and females utilises egg-laying/hatching sites to deposit egg cases in sandy or muddy flats.

Population Estimates

Prior to the past three generation lengths (21 years), fishery independent surveys off southern New South Wales indicated that catch rates for "skates" combined declined by 83% between 1976–77 and 1996–97. Although in the past three generation lengths catch monitoring indicated a stable and/or increasing population, prior to that, the previous heavier fishing pressure had resulted in a dramatic decline in skates, including the Sydney skate, indicating it is susceptible to fishing pressure. Given its restricted distribution, and taking a precautionary approach, it is suspected that the species has undergone a population reduction of 20–29% over the past three generation lengths due to levels of exploitation.

Primary Threats

The Sydney skate is taken as bycatch in the SESSF. It is captured in several sectors, but mostly taken in the trawl sector, and was discarded rather than retained due to its small size. In recent years, some large individuals (adults) have been retained for the meat for local markets. At-vessel mortality and post-release mortality (PRM) is unknown for this species, but based on other skates, it is suspected that when discarded it has a high survival rates. The Sydney skate has refuge from regular trawling as it occupies large areas of lightly or non-trawled sea floor off central and northern New South Wales, and southern Queensland.

Conservation and Management

There are currently no specific conservation actions for the Sydney Skate. However, trawl fisheries in its range are under quota management. Fisheries management in Australia now includes ecosystem management, and all fisheries now have Bycatch Action Plans, must be assessed for ecological sustainability, and are required to meet certification standards to continue operating. It may receive some refuge in marine protected areas of the Temperate and Southeast Australian Marine Parks Networks. Further research is needed on population size and trend, and life history, and catch rates should be monitored.

Annex B - Important Shark and Ray Area (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.

Annex C – Shark and Ray Recovery Initiative (SARRI) Framework