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Guiding research and best practice standards for the sustainable development of offshore renewables and other emerging marine industries in Australia

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This report is available on the NESP Marine and Coastal Hub website: www.nespmarinecoastal.edu.au

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Glossary of Terms

Abbreviation	Definition in full
AIATSIS	Australian Institute of Aboriginal and Torres Strait Islander Studies
ALA	Atlas of Living Australia
AODN	Australian Ocean Data Network
BOEM	Bureau of Ocean Energy Management
CARS	CSIRO Atlas of Regional Seas
DCCEEW	Department of Climate Change, Energy, the Environment and Water
EAC	East Australian Current
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
EPBC Act	Environmental Protection & Biodiversity Conservation
FAIR	Findable, Accessible, Interoperable, and Reusable
HIPP	Hydroscheme Industry Partnership Program
IEA	International Energy Agency
ILUA	Indigenous Land Use Agreement
IPA	Indigenous Protected Area
IUCN	International Union for Conservation of Nature
KEF	Key Ecological Feature
LADS	Laser Airborne Depth Sounding
LiDAR	Light Detection and Ranging
MARS	Marine Sediments Database
MNEs	Matters of National Environmental Significance
NESP	National Environmental Science Program
NM	Nautical Mile
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NASEM	National Academies of Sciences, Engineering, and Medicine
O&G	Oil and Gas
OBP	Ocean Best Practice
OEI Act	Offshore Electricity Infrastructure Act 2021
OES	Ocean Energy Systems
ORE	Offshore Renewable Energy
OWF	Offshore Wind Farm
RMEBS	Regional Marine Environmental Baseline Studies
RODEO	Realtime Opportunity for Development Environmental Observations
SNES	Species of National Environmental Significance
SOP	Standard Operating Procedure
TO	Traditional Owner(s)
UKERC	The UK Energy Research Council
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
WFS	Web Feature Services
WMS	Web Map Services

Executive summary

Project purpose

Australia is entering a phase of rapid offshore renewable energy (ORE) development, with several areas declared to support offshore wind farms (OWFs) off the east, southern, and south-west coasts. A strong scientific evidence base is needed to underpin effective decision making and ensure developments are socially and ecologically sustainable.

This report aims to **establish inventories of existing environmental information and best-practice standards** to inform the research required to support decision-making under the *Environment Protection and Biodiversity Conservation Act 1999* and the *Offshore Electricity Infrastructure Act 2021*, the primary legal frameworks applicable to ORE development. These inventories and best-practice standards can be used by regulators, industry, and the research community to inform developments. This includes relevant regional-specific environmental, oceanographic and species information to inform baseline assessments and ongoing monitoring (including standardising techniques) that aim to understand and mitigate impacts over the life of an OWF project. It also includes publicly available information on Indigenous communities and values adjacent to the offshore wind areas. The report is focussed on one ORE sector – offshore wind, and is principally focused on environmental information in continental shelf waters at a regional scale surrounding each OWF declaration areas identified to date (Hunter, Illawarra, Bass Strait, Gippsland, Southern Ocean, and Bunbury (south-west).

Knowledge base and data inventories

The report provides a publicly available description and knowledge base relating to the key environmental factors:

- Seabed bathymetry, geology, geomorphology, sedimentology, benthic habitat biodiversity.
- Regional oceanography, including a summary of wave climate, tides and currents including major oceanographic features (e.g. upwellings).
- Threatened, migratory, marine and other species of interest sourced from published papers/reports and public repositories including Birdlife Australia, Atlas of Living Australia (ALA), Victorian Biodiversity Atlas and the Ocean Biodiversity Information System (OBIS), and the provision of collated spatial data products.
- Traditional Owner groups and publicly documented cultural values in each of the OWF regions.

This report provides accompanying data inventories that identify existing information and methods generated by researchers to inform the planning, development, operation, and decommissioning phases of the Australian offshore wind sector.

Best practice monitoring standards

Robust and standardised assessment and monitoring programs are required for assessment of baselines, impacts and change over time. As large-scale OWF projects are yet to be implemented in Australia, we draw on broad themes across international experience that are important for consideration in the Australian context. This includes delivery of an Australian database of monitoring best practice guidelines relevant to OWF projects leveraging guidelines through the Ocean Best Practices (OBP) repository, Field Manuals for Marine Sampling to Monitor Australian Waters, and identified gaps, including national approaches to seabird and cetacean surveys. We identify international programs and relevant guidelines available for monitoring and best practices for OWFs across program phases, including impact and mitigation surveys, monitoring surveys, and non-biological survey needs to inform engineering design, document ecosystem values and impacts.

Potential impacts of offshore wind farms

Mapping and mitigating effects of a stressor(s) generated by OWF activities on marine organisms requires understanding the aggregate exposure, i.e. the combined exposure of an individual (or defined population) to a specific stressor, and the sensitivity or vulnerability of an individual to characteristics of that stressor. We draw on international inventories from the United States and Europe to better understand the potential environmental impacts of developing and operating OWFs, and identify limitations and applicability to Australia's marine ecosystems. In response, we have developed an Australian-centric searchable database engaging subject-matter experts within the project team to provide key articles as references, and by conducting a non-systematic search on Google Scholar to populate an impacts inventory. We also provide three short case studies as example topics; impacts of impulsive noise from pile-driving on receptors; the effect of Australia's seabed substrate on the foundation requirements to install and operate a wind turbine; and assessment of oceanographic impacts.

Project recommendations

The comprehensive inventory across themes and proposed regions provides an opportunity to provide recommendations for OWF development needs in an Australian context.

- High resolution bathymetric data is limited on the continental shelf and slope of most OWF regions, hence full coverage bathymetry data should be acquired following Ocean Best Practice (OBP) guidelines and provided through established publicly accessible data platforms (i.e. AusSeabed). This is also important to support the establishment of appropriate reference sites for ongoing monitoring.
- In most OWF regions, further sub-bottom profile data are required to confirm the sub-seafloor structure across the continental shelf. Further sampling is also required in most areas to better characterise the surficial sediments.
- Application of Geoscience Australia's OBP seabed geomorphology mapping approach should be progressed as better seabed mapping coverage is achieved. Improved maps that illustrate the distribution of seabed features at improved resolution will provide the necessary confidence to understand their nature and composition, and associated risks.
- Regional 30 m bathymetry compilation grids are available for some OWF areas and can be used to map seabed geomorphology to provide broad understanding of the habitat extent and distribution and associated benthic biodiversity. However, higher resolution bathymetry data, derived (OBP) geomorphology maps, and structured (OBP) ecological surveys are required to more accurately evaluate environmental values and associated impacts and risks.
- Limited seabed mapping within the declaration areas has resulted in little understanding of the seafloor habitat extent and distribution and associated benthic biodiversity. Structured ecological surveys using Ocean Best Practice guidelines are required to evaluate these environmental values and associated impacts and risks.
- Adopting OBP approaches to assessment and monitoring reduces the bias and variance in sample data and increases confidence in the evaluation of environmental values and impacts. Importantly, it also enables integration across proponent locations and areas that, for example, could enable the

assessment of cumulative impacts and comparison with reference locations (e.g. Marine Parks estate).
- There is need for coordination and investment to build on the existing marine data portals to allow OWF research and industry data to move towards adopting data principles of being Findable, Accessible, Interoperable, and Re-useable (FAIR).
- There is a need for investment in best practice standards to inform data acquisition and FAIR management of data for threatened species. This includes progression and coordination of data collection efforts to inform impact mitigation and management strategies on priority species.
- The value of the impacts inventory containing information relevant to understanding impacts of OWFs would be increased if it captured information at all levels of the activity-exposure-response relationship, i.e. the impact pathway. This would require subject matter expertise and systematic literature searches across the numerous combinations of activity, stressor, and receptor responses. There is potential for this inventory to be a dynamic resource as new data and publications emerge.
- Assessing the cumulative effects of OWF at whole of life-cycle relevant scales will require a shift towards assessment methods that include ecological connectivity across regional scales. In addition, cumulative probabilistic risk assessment for migratory species will require innovative risk assessment approaches (refer to NESP Marine and Coastal Hub Project 4.7).
- Traditional Owner engagement early into the OWF development pipeline is recommended, and such engagement is part of referring and assessing actions under the *EPBC Act*. Traditional Owner engagement benchmark documents such as the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and the principles for engagement developed by the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) provide guidance to an emerging OWF industry.

An effective pathway to fill identified knowledge gaps would be through the development of a framework for realising integrated research questions related to the various impacts of OWFs, through consultation with scientists, regulators and industry. While a detailed description of recent and current industry led Australian OWF research was not included in this project, such a framework should be coordinated through a consortium of government, industry and stakeholders through a transparent, peer-reviewed process. It would aim to link targeted studies of varying size (and funding streams) to answer application-driven scientific questions. This means small, medium and large research studies can be conducted by institutes, industry and collaborations of various size, in the knowledge that they are contributing to a greater outcome. The key international ORE environmental research programs are described to guide this process. Development of a coordinated Australian OWF research program should review and evaluate the structure and governance of such programs that may be best suited to support OWF developments in Australia.

1. Project scope and objectives

This report seeks to identify existing information that can be used to inform efficient and compliant regulatory decision-making for OWF development with respect to the six current declared areas in Australia: Hunter (NSW); Illawarra (NSW); Gippsland (Vic); Bass Strait (Tas); Southern Ocean (Vic); and Indian Ocean off Bunbury (WA) (Figure 1). To provide information on the environmental values of these areas, current knowledge is presented at a regional scale across five regional extents associated with the six OWF declared areas. Specifically, the project provides:

1. Existing publicly available regional information on seabed mapping (bathymetry), seabed geomorphology and sedimentology, including shallow sub-seabed profiling, substrate composition and seabed habitats.
2. A description of the key oceanographic features of each region.
3. Spatial information from publicly available data and publications that document knowledge on the extent of overlap of priority threatened, migratory and marine species within each OWF region, including identifying species data gaps.
4. Information on the Indigenous communities in areas adjacent to OWF regions and publicly available information on their environmental and cultural values.
5. Details on existing ocean best-practice standards for surveys and monitoring to support mitigation, management and/or regulatory needs of OWF developments.
6. Information on potential noise impacts from OWF developments, and effects on oceanography and sediments.
7. A searchable resource database of priority and Australian-centric literature pertinent to the potential impacts of OWF installation, operation, and decommissioning with examples illustrating potential issues with transferring information on international experiences to Australia's environment.

The information gathered for points 1-3 above is summarised using a variety of methods that include maps (seabed geomorphology, species presence), report tables (species presence, seasonality – live links provided), and excel database (species inventory; bathymetry-sediments inventory). Importantly, spatial data for species is active and can be updated as needed, with visualisation and hosting on Seamap Australia marine spatial data portal. Information relating to points 5-7 above is also summarised in related excel databases (best practice inventory, impacts inventory). These 'inventories' can be used by stakeholders to inform decision-making.

The knowledge and data products produced in this study aims to inform decision-making under the *EPBC Act 1999* and the *OEI Act 2021*, the primary legal frameworks applicable to OWFs. Further information provided can be utilised by Government, proponents, traditional owners, researchers, and the broader community to inform the sustainable development of the OWF industry in Australia. This will improve effectiveness and refinement of future research and monitoring for biodiversity conservation, protected area management, regional planning and project approvals. It will also contribute to the process of ensuring research on OWFs is accepted and trusted by communities and interest groups to build social licence.

While emphasis is directed towards OWFs, the availability of content of the report and databases will likely be of broader value to other sectors. The inventories highlight selected knowledge gaps and provide a suggested pathway to identifying priority areas for future research relevant to future assessment of cumulative effects and interactions across multiple locations and sectors.

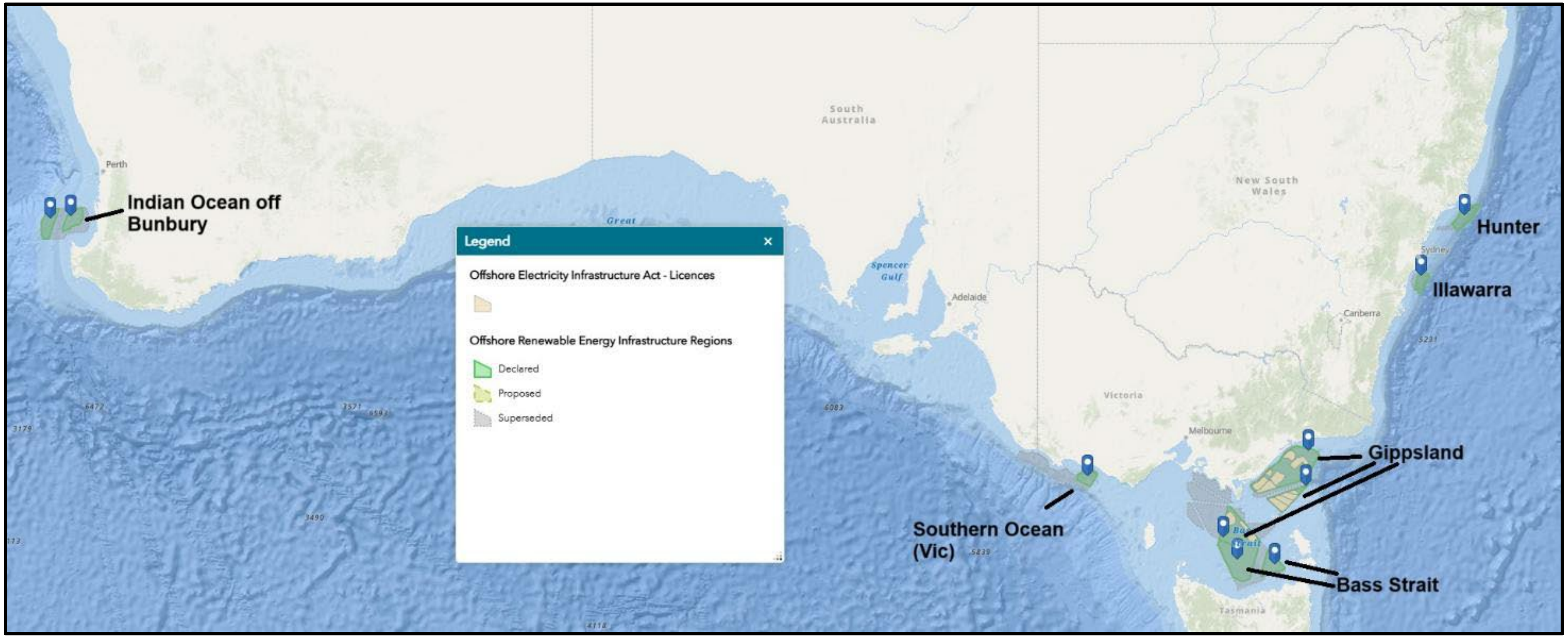

Figure 1: Current (December 2024) declared OWF areas in Australia (in green): Accessible at: Australian Marine Spatial Information System (AMSIS).

2. Background

2.1. Legislative context

To meet climate change targets (e.g. 2035 Emissions Reduction Targets, Net Zero, Paris Agreement) and match the current pace of the offshore energy industry interest in Australia, Commonwealth and State Government entities are facilitating the sustainable development of offshore energy industries. Licencing and regulatory processes for OWFs proposed in Australia's Commonwealth waters (which extends from >3 NM from shore, extending to the edge of Australia's economic exclusion zone, EEZ) are new and developing. The Department of Climate Change, Energy, the Environment and Water (DCCEEW) supports the Minister for Climate Change and Energy in identifying and declaring development areas, as well as the Minister for Environment and Water in the administration of the *EPBC Act* (e.g. regulating impacts to Matters of National Environmental Significance (MNES)). The offshore infrastructure registrar provides advice to the Minister responsible for the *Offshore Electricity Infrastructure Act 2021* (OEI Act) and issues licences. The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) is the offshore infrastructure regulator, assessing management plans, post-approval compliance, and enforcement. Lastly, the Director of National Parks (DNP) authorises any activity proposed to occur within or adjacent to Australian Marine Parks under the EPBC Act.

Guidance documents exist to inform proponents (and research agencies) with respect to process, requirements and responsibilities (see NOPSEMA 2022; DCCEEW 2023a). Regarding developments in coastal waters (within 3 NM from shore), legislation varies by jurisdiction and will be necessary for cable routes to enable connection to the grid and support the necessary coastal infrastructure.

2.2. Learnings from international Offshore Wind Farm research

A great deal of knowledge can be drawn from the international ORE sector, primarily with respect to OWFs, and particularly on their impacts on marine species and ecosystems, that can benefit Australia. The environmental and societal impacts of OWFs have been studied across the globe (e.g. Bailey et al., 2014; Bergstrõm et al., 2014; van Berkel et al., 2020). The importance of providing transparent decision-making processes, allowing community engagement, and addressing public concerns regarding environmental impacts is pivotal in gaining social acceptance for OWFs in Australia (Toke and Nielsen, 2015; Munro et al., 2017).

With respect to the environment and marine fauna, most research globally to date has focussed on the impacts of noise (Brandt et al., 2011; Thompson et al., 2013a; Holt et al., 2019), collision risks (Thompson et al., 2013b), entanglements (Scheidat et al., 2011), electromagnetic fields (Gill et al., 2020; Hermans et al., 2024), and habitat alteration through changes to water quality, sedimentation, and/or prey distribution (Shields et al., 2011). While similar environmental and social impacts may also occur in Australia, there are likely many differences reflecting our specific marine environmental conditions and species. A synthesis of potential impacts associated with offshore renewable energy generation in Europe and the USA have been documented (e.g. Galparsoro et al., 2022).

Robust monitoring is a pre-requisite for ensuring the sustainable development of OWF projects. Monitoring has a role in identifying the potential species and ecosystem services at risk, designing effective mitigation measures, and monitoring observed impacts to inform adaptive management and reporting (Bennun et al., 2021). With proposals to develop multiple OWF projects across Australia emerging, it is important that overseas experience informs government, proponents and scientists to the latest advice on monitoring of OWF (e.g., drawing from experiences in the North Sea with OWF and Australian standards for monitoring marine environments), and ensure the adoption of published best-practice standards. Similarly, opportunities exist to promote the development of consistent methodologies and data sharing protocols that ensure adherence to Findable, Accessible, Interoperable, and Reusable (FAIR) data principles (Wilkinson et al., 2016).

Precedents for data sharing and transparency are available. For example, the Gullen Range Wind Farm (onshore) in New South Wales publicly share their monitoring data building transparency and social licence whilst helping to support conservation planning and impact assessments by other proponents in the region (https://gullenrangewindfarm.com/the-project/project-approvals-and-documents/). Adhering to best practices and FAIR data principles will improve the reliability of monitoring programs, ensure decisions and projections are based on the best information, and improve social licence.

Listed below in Table 1 are international knowledge base platforms that, collectively, are powerful tools to better understand the potential ecological impacts of developing and operating OWFs but have limitations in that they are not exhaustive and not entirely applicable to Australia’s unique marine ecosystems.

Table 1. Examples of international knowledge base platforms that provide information on environmental management with respect to OWFs. There are also relevant programs and reports available from a number of European countries including Denmark, Belgium, and the Netherlands (see Section 14.4).

Knowledge Base & Link	Description
UK Marine Data Exchange	The Marine Data Exchange is a database of marine industry survey data, research and evidence, with a significant focus on offshore wind activities A key component of the Marine Data Exchange is the Offshore Wind Environmental Evidence Register (OWEER) which is a publicly accessible UK-wide register of evidence gaps and relevant research on the sustainable development of new OWFs across four main areas – the seabed, marine mammals, fish and seabirds. The Offshore Wind Evidence and Change Programme (OWEC) also brings together government organisations, industry bodies and environmental NGOs to progress a range of prioritised projects at a national scale, with the aim of creating a shared data and evidence base held on the Marine Data Exchange.
Offshore Renewable Impacts on Ecosystem Services (ORIES)	ORIES is an open-source web-based decision support tool (DST) that allows users to evaluate the effects of proposed fixed OWFs on marine habitats, biodiversity and ecosystem services
UK Energy Research Council Database of evidence	The UKERC Database of evidence for the impact of Offshore Wind Farms on Marine Ecosystem Services is a searchable database of peer-reviewed (global search) and grey (UK search) literature of impact studies directly originating from OWFs. It comprises ~120 references, split with individual entries for each combination of stressor and impact group, providing a database of >1000 entries.
OES-Environmental 'Tethys' knowledge base https://tethys.pnnl.gov/about-tethys	The Tethys repository is a publicly available database, containing information (9,460 references) relevant to understanding impacts of offshore wind (fixed and floating) and marine energy (wave and tides) installations from around the world. The platform facilitates knowledge transfer for the Ocean Energy Systems (OES) - Environmental, a multinational intergovernmental collaboration operating under the International Energy Agency (IEA).
Regional Wildlife Science Collaborative for Offshore Wind (RWSC)	The RWSC serves as a coordination hub for offshore wind research to facilitate collaboration across federal and states agencies, eNGOs, and the offshore wind industry in US Atlantic waters. This includes conducting and coordinating relevant regional monitoring and research of wildlife and marine ecosystems, suggesting common data standards, and increasing data sharing and transparency. It has developed a Science Plan with the research community to inform future offshore wind data collection and research (https://rwsc.org/science-plan/)
Bureau of Ocean Energy Management's (BOEM)	The BOEM 'Realtime Opportunity for Development Environmental Observations' (RODEO) platform provides information on selected experimental and monitoring programs that collect real-time measurements of the nature, intensity, and duration of potential stressors during construction and initial operations of selected offshore wind facilities in the U.S.
Wildlife and Offshore Wind (WOW)	The WOW is a collaboration of experts focused on evaluating the potential effects of offshore wind energy development on marine wildlife, and to provide a framework for effective assessment. The broad project objectives are to conduct gap analysis, risk assessment and research framework development; and undertake data collection and validation of specific technologies. It aims to provide wind energy developers, regulators, and other stakeholders in the United States frameworks that will facilitate the design, development, and responsible management of offshore wind energy.

2.3. Indigenous communities and Offshore Wind Farm regions

2.3.1. Indigenous peoples and legislation relevant to offshore wind farms

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) requires the Australian Government to recognise the role of Indigenous peoples in the conservation and ecological sustainable use of Australia's biodiversity and promote the use of Indigenous peoples' knowledge of biodiversity. DCCEEW 2023a guidance states that construction and operation of an OWF may result in the disturbance of cultural heritage including underwater cultural heritage. Furthermore, that identifying cultural heritage values that may be impacted should consider First Nations peoples' beliefs, practices and connection to Sea Country, places of cultural significance and cultural heritage sites in the Commonwealth Marine Area. The Australian Government has also released *The Interim Engaging with First Nations People and Communities on Assessments and Approvals under Environment Protection and Biodiversity Conservation Act 1999.*

The Australian Government's Australian Energy Infrastructure Commissioner has also provided guiding principles for OWF proponents to engage with the general public within which Traditional Owners (TOs) are specifically incorporated (Considerations for Offshore Wind Industry on Community Engagement | aeic - Nov 2023). Similarly, KPMG and the Clean Energy Council in collaboration with the First Nations Clean Energy Network published guiding principles for engaging with Australia's First Nations peoples on terrestrial-based renewables projects (New First Nations engagement guide for the renewables industry | Clean Energy Council). To date, three positional statement documents were identified from Aboriginal sources on the OWF sector, all located in Victoria. The first is from the Federation of Victorian Traditional Owner Corporations dated 30th August 2022. The second is a statement from the Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) in relation to the (declared) Gippsland OWF area in Gippsland dated 7th October 2022 (Microsoft Word - GLaWAC Position statement Offshore Windfarms October 2022 final (gunaikurnai.org)), and a third from Eastern Maar in early April 2024 (Facebook). Among stating the significance of Country and its original inhabitants, each echo the advice presented here from a TO perspective and provide good background reading to better understand the position and concerns of TOs in relation to the OWF industry.

2.3.2. Sea country, relationships, and cultural values

Traditional Owners have inherent obligations to look after Country and have an intimate knowledge and relationship with their land, sea and sky Country through spiritual, cultural, and practical environmental practices and connections (Davies et al., 2020) that go back thousands of generations (Horst and Wightman, 2001). Twenty thousand years ago, Australia's land mass was significantly larger than it is today (Figure 2). The coastal boundaries for saltwater peoples encompassed many of the low-lying shallow water areas that have now been proposed for OWF development (Nunn and Reid, 2016; Nunn et al., 2022). Today, approximately 50% of Australia is designated Indigenous Estate, provided through the legal mechanism of more than 450 Native Title determinations, 1,200 Indigenous Land Use Agreements (ILUAs), and 76 Indigenous Protected Areas (IPAs) (Archer et al., 2022), which includes areas identified as suitable for OWFs.

As custodians and rights holders of land, sea and sky Country exercising their rights to self-determination, TOs have legitimate and unique interests and concerns about the

OWF industry outside of those voiced by others such community groups. Examples include upholding, protecting, and maintaining underwater cultural heritage, environmental values, incursions/exclusions to spiritually significant sites and waterways, and ambiguous legal uncertainty on where Native Title and other legal agreements with government meet with OWF developments.

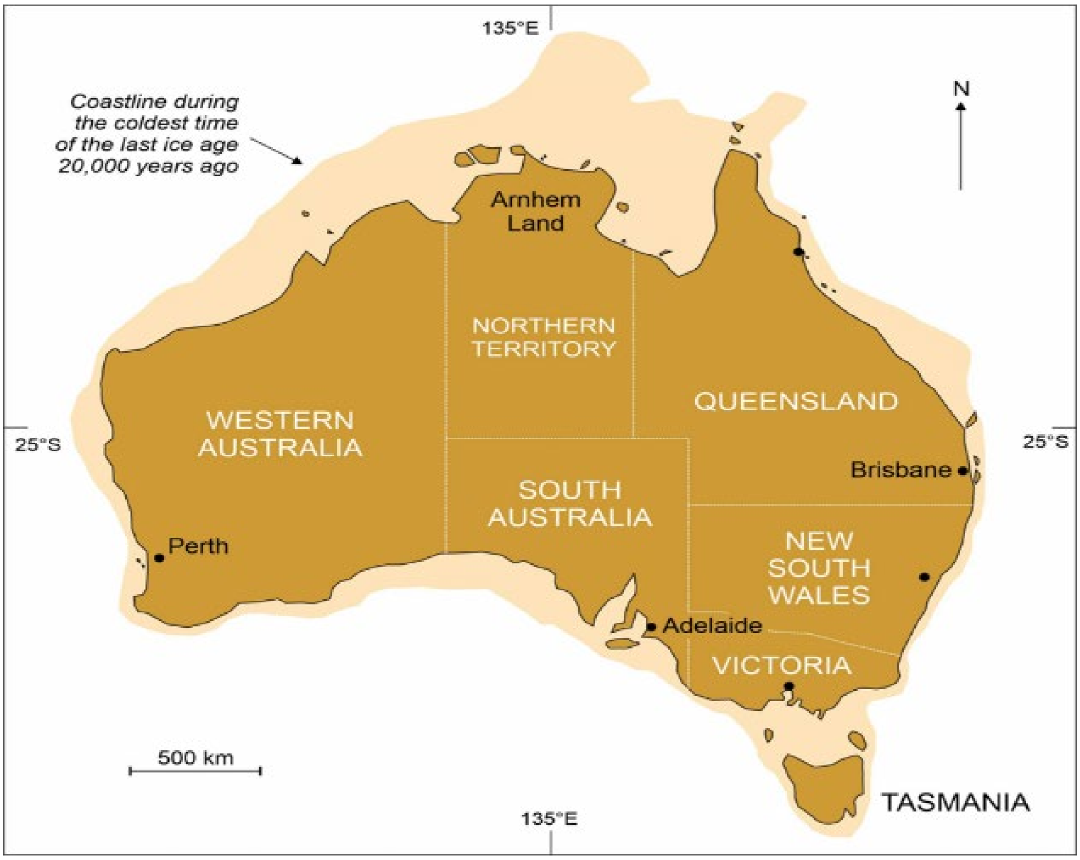

Figure 2: Extent of the Australian land mass 20,000 years ago. Taken from Nunn and Reid (2016).

3. Data inventory and compilation

3.1. Bathymetry and sediments

This report provides information on available bathymetric data, as measured by historical single-beam acoustic surveys and more recent multibeam echosounder seabed mapping surveys (published on AusSeaBed), and aerial Light Detection and Ranging (LiDAR) surveys. Marine seabed data include all publicly available bathymetry products published to the AusSeaBed portal. Coverage maps include those that indicate the extent of bathymetry data at the time of submission by third party contributors to the AusSeaBed Data Portal. Multibeam data figures in this report illustrate the total extent of these bathymetry data as ‘coverages’. These bathymetry data and further details on data inventory by OWF regions are provided in the separate database (Project 3.3 OWF bathymetry-sediments inventory). Additional compilation of data are grouped into ‘survey acquisitions’, ‘compilations’, ‘multi-resolution surveys’ and more locally restricted, high-resolution ‘reference surfaces’.

Sediment data are also available from the AusSeabed portal as both direct download and webservices. The inventory of existing bathymetry and sediments extends across the four broad regions and six OWF declaration areas as defined in Figure 1.

3.2. Geomorphology

Summary overviews of seabed geomorphology are provided for each OWF region and are based on published regional geomorphology maps (Heap and Harris, 2008), interpretations of available bathymetry (AusSeabed), sediment samples (MARS – Marine Sediments database: Geoscience Australia, 2024), sub-bottom profiles, and the scientific literature. These summaries use terminologies defined in the OBP-developed marine geomorphology mapping scheme (Dove et al., 2020; Nanson et al., 2023).

Further details on the diversity and definitions of geomorphic units’ data inventory by OWF region are provided in Appendix A, Section 17.1 . The geomorphic analysis extends across the four broad regions and six OWF areas as defined in Figure 1. More detailed and systematic analyses of higher resolution seabed data and geotechnical analyses will be required to create definitive, standardised marine geomorphology maps (following Dove et al., 2020; Nanson et al., 2023). These analyses will provide important insights into seabed features and processes, including sediment dynamics and seabed stability. The likely interactions between OWF activities and the geomorphic features are also outlined in Appendix A.

3.3. Seabed habitats and benthic biodiversity

Mapping the extent and composition of benthic habitats is often a key by-product of high-resolution bathymetric surveys and resulting analysis of seabed morphology. Converting these into robust maps of the distribution of habitat assemblages relies on adequate spatially balanced ground truthing information and validation, but the cost of obtaining this data can be prohibitive across deeper continental shelf waters.

Across southern Australia, there has been extensive historical and modern collections of benthic imagery over the continental shelf (e.g. Jordan et al., 2010, Langlois et al., 2020; Barrett et al., 2020). These data typically come from Baited Remote Underwater stereo-video systems/stations (stereo-BRUVs), autonomous underwater vehicles (AUVs), remote underwater vehicles (ROVs), towed video systems, and more recently a Benthic Observation Survey System (BOSS), using a wide combined field of view (~270°, see NESP Marine Sampling Field Manuals for Monitoring Australia's Marine Waters). Where these sampling platforms have been used to collect data across spatially balanced sampling designs, the benthic annotation collected from their horizontal fields of view has been found to provide suitable ground-truthing information for spatial modelling and prediction (Mastrantonis et al., 2024).

Many of these datasets can also be viewed through the Seamap Australia marine spatial data portal (https://seamapaustralia.org/map/). Further details on the available seabed habitat and biodiversity data inventory by OWF region are provided in Appendix A. In addition, details on introduced marine pests that may occur within the OWF regions is summarised in Appendix B (A-Table 9), and additional finfish, invertebrate and shark species in A-Figures 2-16.

3.4. Oceanography

OWFs have the potential to alter the physical characteristics of the local environment, with flow-on effects to biological ecosystems due to habitat modification. Scientific research focused on the impacts to the physical characteristics of the ocean (e.g., changes to currents, mixing, nutrient fluxes, turbidity, etc.) that result from the installation of OWF is at a nascent stage. Existing literature that has assessed these predicted impacts, either through numerical modelling or *in-situ* experiments, have primarily been published in the last five years. Much of the knowledge related to oceanographic impacts has come from studies elsewhere, particularly Europe, primarily related to offshore wind. As such, the potential impacts described in this report have been derived and interpreted in an Australian context based on the existing published literature. Fortunately, the outcomes of these international studies are directly applicable to the oceanographic environment Australia-wide, and these studies form the majority of references added to the database.

However, while the potential impacts from OWF are applicable Australia-wide, the realised impacts are likely to be highly site and project specific. For example, changing the layout of an array of structures may incur significantly different responses from the oceanic environment. Given the large size of the OWF development areas and the site and project specific nature of the impacts, only general oceanographic information has been provided in the regional summaries. Further details on available oceanographic data relevant to the inventory by OWF region are provided in Appendix A.

3.5. Threatened and migratory marine species

The project team liaised with DCCEEW and NOPSEMA to compile a list of priority species and species of secondary importance, including birds, cetaceans, bony fish, sharks, pinnipeds and marine turtles (A-Table 3). The species list focused on EPBC Act listed threatened species and other listing categories (Marine, Migratory), that were known/likely to and may occur in the OWF proposed and declared areas (Figure 1). State conservation listings were not considered in this report. Also included were EPBC Act listed invertebrates and macroalgae and seagrass. Some additional species of interest were included, which consisted of introduced pests and some important fisheries species that overlap OWF areas.

These additional species did not constitute a comprehensive list of all such species that may overlap OWF areas, rather were chosen as a small sub-subset of important species given that this study was focused on the DCCEEW and NOPSEMA priority and secondary priority species. A more restricted list of cetaceans and birds within the Bass

Strait region were also identified for a more detailed assessment as part of the NESP Marine and Coastal Hub project 3.21 ‘Identifying priority datasets for the Gippsland declaration area and pathways for their use in decision-making’ (https://www.nespmarinecoastal.edu.au/project/3-21/).

The project does not include a detailed description of threatened species biology and ecology – this is beyond the scope of this report.

The additional species of interest were chosen based on i) the project team’s knowledge of species colonising artificial structures in the Bass Strait (informed by separate research onto oil and gas structures in this area; McLean et al., 2024, Birt et al. 2024; Galaiduk et al., 2024); ii) a small subset of fisheries species known to occur in OWF areas (informed by https://www.afma.gov.au/species, DPIRD status of the fishery reports); and iii) invasive pest species known to occur in OWF areas (see A-Table 9).

In total, publications and data were sourced for ~100 species (Table 2).

Further details on the literature on spatial information data sources used in the inventory by OWF region are provided in Appendix A. In summary, to complement spatial data obtained from publications, observation data were also compiled for the priority species (and species of secondary importance) in our inventory from BirdLife Australia , Atlas of Living Australia (ALA), Ocean Biodiversity Information System (OBIS), and Victorian Biodiversity Atlas Victorian Biodiversity Atlas (VBA). These datasets include observations from volunteers/community members, resulting in potential for lower accuracy. In addition, for sharks, fishes, and rays we queried open access data from GlobalArchive, a repository of stereo-video annotations data, which is contributed by scientific organisations who have collected, analysed, and quality controlled these datasets.

When no/limited information was found for species in our inventory from the compiled published studies and observation data in the OWF areas, it was determined whether this was due to the species being absent from the area or whether it constituted data deficiency. To determine this, the distribution of each species was needed, and is available for EPBC listed species (threatened, migratory, marine and cetacean species) on the Species of National Environmental Significance (SNES) database. The area assessment used the initial proposed areas (current at the project start) for the regional analyses, and while areas were declared during the project, the analyses focussed on the proposed areas as they provided a broader geographic extent around the OWF regions to better account for spatial uncertainty of some collated data products.

Table 2: Summary of the marine flora and fauna inventory of priority species and species of secondary importance.

Fauna group	Number of species in inventory	Number of publications in inventory
Birds	43	90
Cetaceans	42	175
Pinnipeds	3	14
Reptiles (turtles)	2	4
Sharks	5	26
Bony fish	3	3
Cnidarians	1	1
Macroalgae	1	1
Thallophyta	1	1
Total	**100**	**330**

3.6. Indigenous peoples and offshore wind farms regions

In this report, we provide summary information from a desktop study identifying the Indigenous communities adjacent to OWF regions and their publicly available and documented cultural connections to these marine and coastal areas. We provide information about relevant Indigenous organisations for these TO and Indigenous peoples, and whether or not they have published their position regarding the OWF development. We also provide insights on their interests and capacity to engage in discussions about key environmental factors for OWFs based on considerations like existence of land and sea ranger programs and past or current participation in marine and coastal research.

It is important to note that the information provided here was based exclusively on available online documents and does not claim to be exhaustive. Neither can our methodology sufficiently capture the deep knowledge and spiritual connections that TOs have to land, sea and sky Country, much of which remains hidden to the outside world and generated over millennia. Instead, it is meant as a starting point for government, proponents, and marine scientists working in this emerging sector to engage early and ethically with TOs in their respective areas.

3.7. Potential impact of offshore wind farms in Australia

Thirteen broad types of impacts that are considered to be typically associated with OWF development and that could be expected in Australia have been outlined in DCCEEW (2023a). Identifying all the potential impact pathways from the activity, through the produced stressor, received exposure level, individual response, and the resulting individual or population impact, even for a small number of listed species, was beyond the scope of this project. Such a description would require significant dedicated effort. Thus, our focus was squarely on identifying where information on impacts associated with OWF's presently exists and can be accessed to inform developments in Australia. In addition to identifying existing resource databases, we developed a resource base of references that have particular application in Australia, and we provide a selection of references that highlight some impact pathways that are potentially relevant for each threatened, migratory, and marine species present in each OWF region.

Mapping and mitigating effects of a stressor generated by anthropogenic activities on Australian marine organisms requires understanding the aggregate exposure, i.e. the 'combined exposure of an individual (or defined population) to a specific agent or stressor via relevant routes, pathways, and sources' (Tyack et al., 2023), and the sensitivity or 'vulnerability' of an individual to characteristics of that stressor. The exposure is dependent on the temporal and spatial presence and intensity of the stressor, combined with the presence of individuals of the species being assessed. The vulnerability refers to the sensitivity of the species to characteristics of the stressor, the population status and trend, as well as the species' capacity to recover from disturbance (e.g., Nabe-Nielsen and Harwood, 2016; van Beest et al., 2015).

With respect to anthropogenic noise, for example, this would be whether the animals hear all or only some components of generated noise and at what level they can detect these noises. Understanding the full effects of stressors must extend from immediate/acute responses to protracted/chronic effects that may have long-term population consequences (Tyack et al., 2023).

A searchable database of publications was created by asking project team subject-matter experts to provide details of reports and information portals deemed relevant and by conducting a non-systematic search on Google Scholar using combinations of the categories and subcategories for stressors, impact groups and potential responses. As this was not a systematic search with equal time and effort dedicated to each topic, the results should not be interpreted as gaps in the literature in general.

The International Union for Conservation of Nature (IUCN) and DCCEEW have separately identified a selection of priority impact types (Bennun et al., 2021, DCCEEW 2023a). However, these are not exhaustive, and do not encompass all potential effects. We have, therefore, amalgamated the two impact type lists and added 'Cultural Heritage' and 'Entanglement' as two additional impact types of likely importance in Australia. This database was standardised so that entries could be incorporated into the Tethys global resource base repository to enhance that resource.

Specific details regarding formation of the database, including categories and sub-categories and their individual descriptions can be found in the instructions page of the inventory, with entries that form the resulting database in associated worksheets (Project 3.3 OWF Impacts Inventory). To avoid duplication of effort, unless a reference contained information specific to Australia, where possible, references were checked and included here only if they were identified as a high priority or missing from the Tethys knowledge base. The searchable database is designed to give quick and easy access to key publications of relevance to OWF in the Australian context. It may be used as a standalone resource base, or the user could search the Tethys database that also includes the imported Project 3.3 OWF Impacts Inventory reference list.

Further details on the approach to developing the inventory, searchable categories and scope is provided in Appendix A, Section 17.3.

3.8. Best practice guidelines

An Australian database of monitoring best practice guidelines relevant to OWF projects was developed as part of this project, drawing these from the literature. This includes cross searching for guidelines through the Oceans Best Practice repository, and NESP MAC Hub Field Manuals for Marine Sampling to Monitor Australian Waters. Where possible, Australian-specific best practice standards were identified (e.g., Magrath et al., 2010). Further details on the best practice and a list of specific methods considered by topic are provided in Appendix A, Section 17.4.

This report provides guidance on monitoring needs for OWF in the Australian context. As large-scale OWF projects are yet to be implemented in Australia, the report does not provide prescriptions on specifics of monitoring needs, but rather identify broad consistent themes, drawing from international experience, that are important for consideration in the Australian context.

A key component of best practice standards relates to the standardised provision of reliable and interoperable data, and this is a key component of the overall need for open-access data to support the OWF industry. Australia's Integrated Marine Observing System (IMOS) has developed a Quality Assurance (QA) and Quality Control (QC) framework outlining the requirements for the collection, treatment, management and delivery of IMOS data streams (see https://imos.org.au/data). Such frameworks contribute to the Ocean Best Practices System (OBPS), which aims to deliver open-access procedural documentation on Best Practice protocols related to ocean observing.

A detailed review of the best practice data requirements to support OWF data collection and management is outside the scope of this report, but is guided by the systems (such as the AODN) that are already in place.

4. Hunter Offshore Wind Farm region – knowledge base

4.1. Bathymetry

The extent and structure of the NSW continental shelf defined from the broadscale single beam acoustic derived bathymetry shows both regional and local variations reflecting the depth structuring of the shelf, regional changes in the angle of the coastline, local position of prominent headlands and embayments, and the presence of offshore reefs (Jordan et al., 2010).

The key feature of the shelf morphology within NSW coastal waters is the regional and local variation in the slope of the seabed of the inner-shelf regions (Figure 3). This results in considerable regional differences in the extent of shallow (0–20 m) and deeper (>20 m) seabed habitats. It also results in the depth at the State coastal waters boundary varying from around 40 m up to around 80 m in the region. There are also large differences in the distance to the shelfbreak, defined at around the 200 m doeth contour.

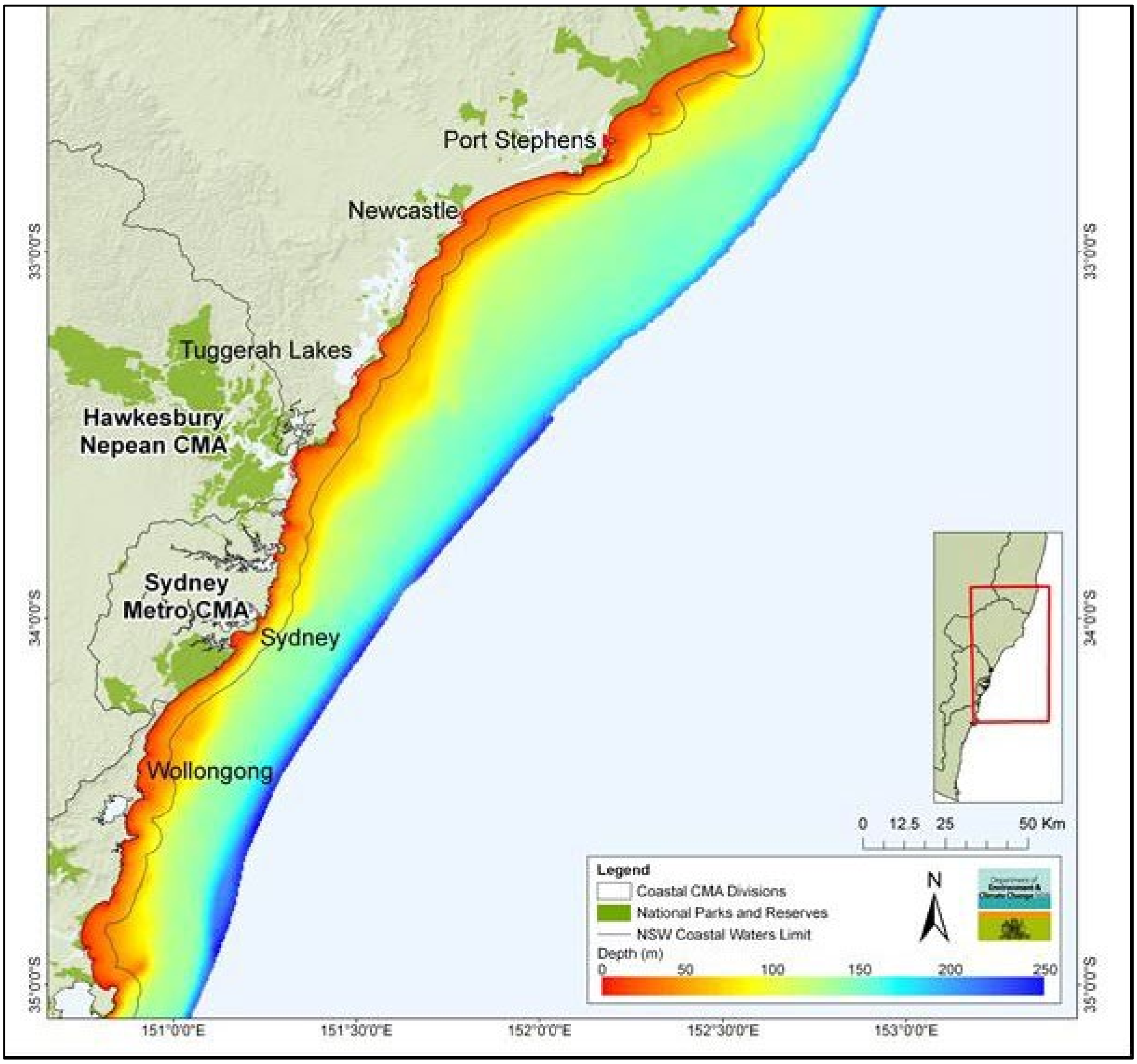

Figure 3. Interpolated broadscale bathymetry from the Hunter and Illawarra region of NSW (adapted from Jordan et al., 2010)

Further information on the depth and shape of the seafloor within the Hunter region is provided by bathymetric data as measured by multibeam echosounder on seabed mapping surveys (Jordan et al., 2010) (published on AusSeaBed) and LiDAR mapping. Multibeam bathymetry coverage for the region is varied, with data coverage on the outer shelf and continental slope extensive and continuous (although at low resolution), whereas data over the mid shelf is limited to narrow swaths from vessel transits (Figure 4). A focused hydrographic survey of the inner shelf region in Stockton Bight was conducted in 2020 as part of the HydroScheme Industry Partnership Program (HIPP) (https://www.hydro.gov.au/NHP/). The survey area (SI 10001) is defined as 130.8 NM^2, and extends across the continental shelf to depths of ~100 m.

LiDAR bathymetric coverage for the coastal and nearshore zone is continuous, extending the entire length of the region. This data provides high-resolution data from the mean high-water mark to ~200 m inland, and from the shore, seaward (Laser Airborne Depth Sounding - LADS - bathymetry) to the point of laser extinction (~20-40 m water depth depending on in-water conditions). The data is available as a combined gridded terrestrial (elevation) and subtidal marine (bathymetry) data at 5 x 5 m (horizontal resolution) Geotiffs (NSW DCCEEW 2019).

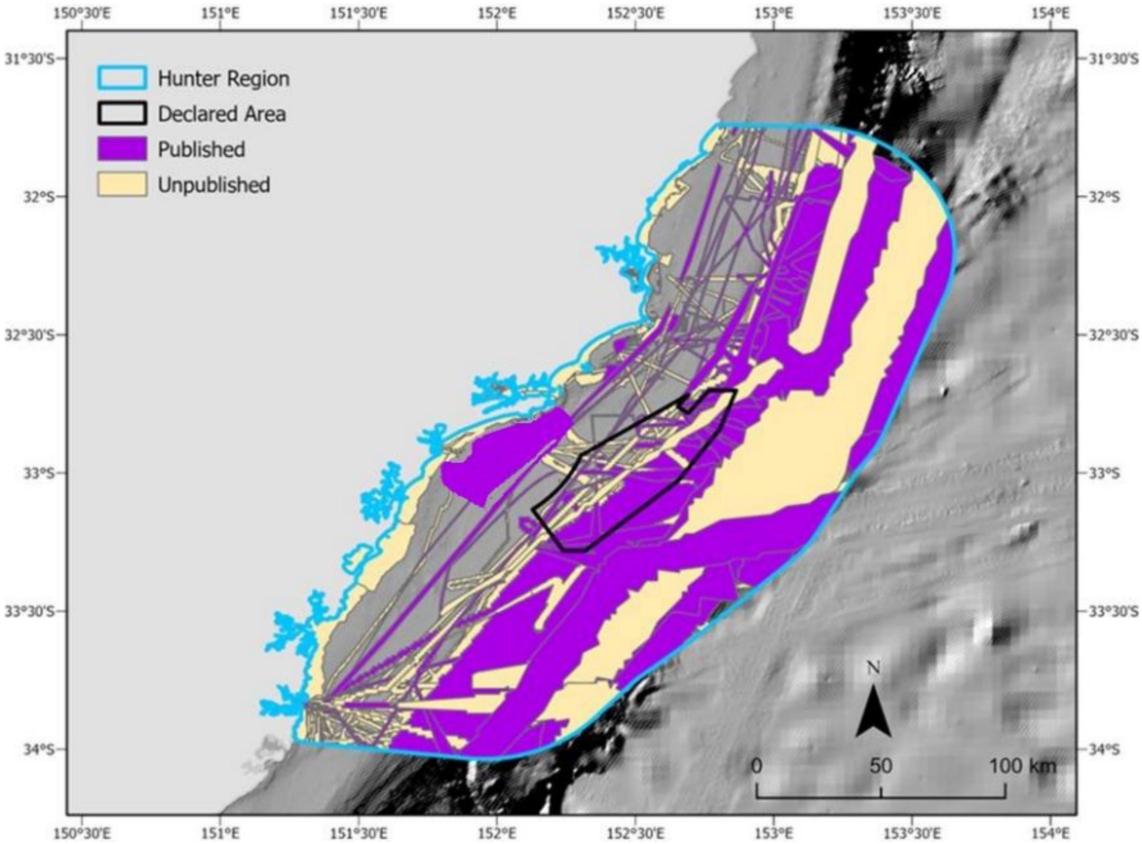

Figure 4: Bathymetry coverage for the Hunter Region (blue polygon) showing the spatial extent of bathymetry data (published and unpublished), including nearshore LiDAR data. Data extents are provided by third party contributors to the AusSeaBed Data Portal (listed in the Marine Baseline Data Inventory). Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

4.2. Seabed geology

The Hunter region spans two geological provinces that extend offshore from the eastern continental margin (Figure 5). The southern half of the region incorporates the eastern part of the Sydney Basin, which extends offshore beneath the continental shelf and upper to mid continental slope. Sydney Basin geology includes thick sedimentary successions of sandstones, siltstones and coal measures of Late Carboniferous to mid-Triassic age (323 – 230 Ma; Scheibner and Basden, 1998). These rocks are now buried beneath the Quaternary sediments that cover the continental shelf but may be exposed at the seabed in the submarine canyons and gullies that incise the continental slope and outer shelf. The northern half of the region is underlain by sedimentary and volcanic rocks that comprise the New England Fold Belt, which extend offshore and juxtapose a younger sedimentary sequence from the Tasman Element. Together, these geological units span the Middle Cambrian to late Triassic Periods (505 – 210 Ma; Glen, 2013) and are possibly exposed in the deeply incised canyons on the continental slope in the northern part of the Hunter region.

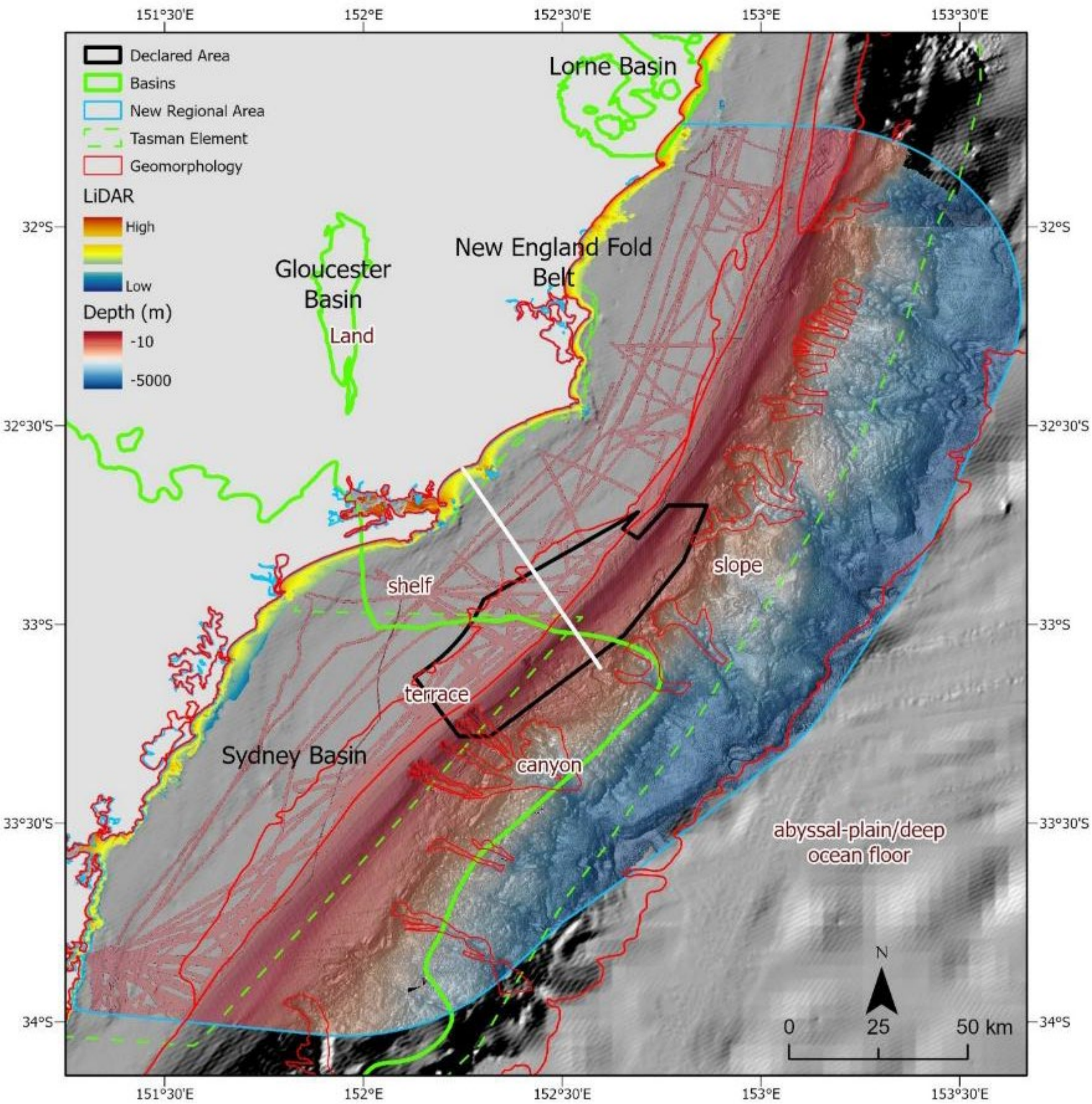

Figure 5: The Hunter declared area (black polygon) and the regional area (blue polygon), over the nearshore LiDAR 5 m (NSW DCCEEW 2019), regional 50 m (Parums and Spinoccia, 2019) and national 250 m (Beaman, 2022) bathymetry grids. Seabed geomorphology (red polygons) and sedimentary basins (green polygons) are shown in outline. The location of the cross-shelf seismic profile presented in Figure 7 is also indicated (white line). Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

A key geological feature of the continental shelf of the Hunter region is a buried rock surface that sits beneath the modern sediment cover (Figure 6). This surface was mapped offshore from Port Stephens using a shallow seismic (sub-bottom) profiler in the early 1990s (Thom et al., 2010). In that dataset, the rock surface is mapped as a continuous reflector that deepens across the continental shelf with a sediment cover that is ~10 m thick on the inner shelf and thickens seaward to form a wedge on the outer shelf. In places, the surface is incised by palaeo-valleys that are now sediment-filled. Of note is the absence of evidence for shallow faulting in the buried rock unit (lithology likely Triassic sandstones of the New England Fold Belt). However, additional sub-bottom profile data is required to confirm this preliminary observation.

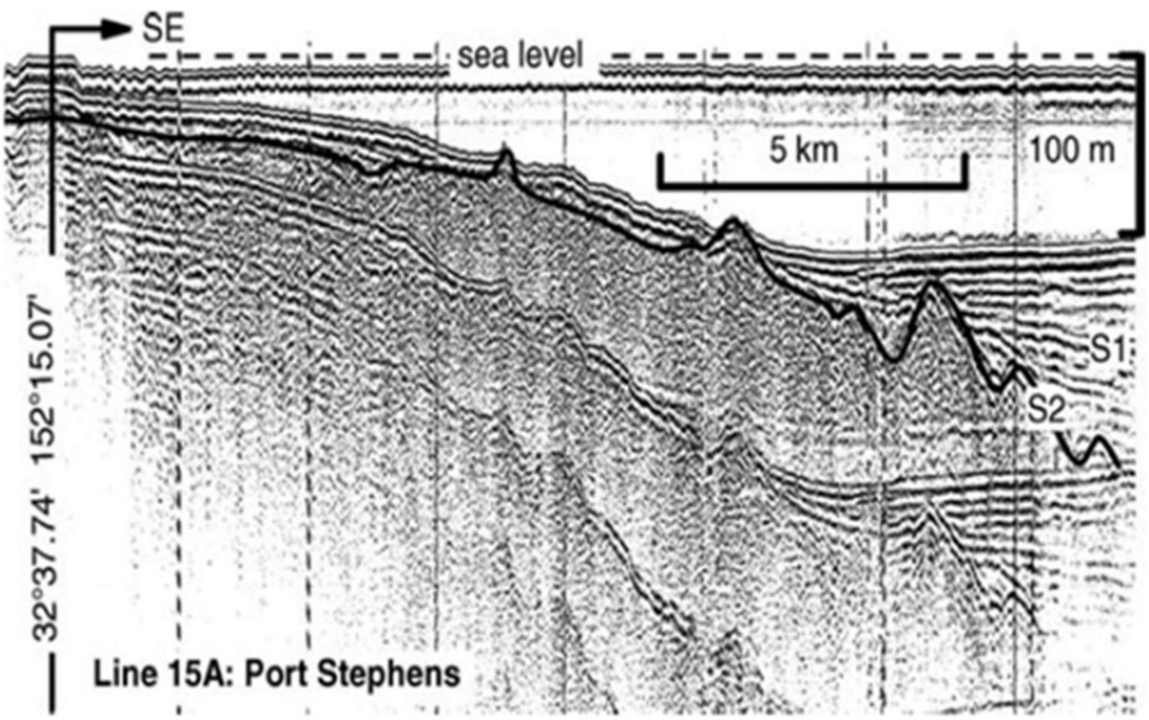

Figure 6: Seismic profile extending offshore from Seal Rocks north of Port Stephens, showing buried rock surface (S2, bold line) beneath modern sediment cover. Note – deeper reflectors are multiples of the seabed and buried rock surface. (Reproduced from Thom et al., 2010; see Figure 4 for location of seismic profile).

4.3. Seabed geomorphology

The extent of the NSW continental shelf defined from the broadscale single beam acoustic derived bathymetry shows both regional and local variations(Figure 7). Of particular significance is the depth and width of the NSW continental shelf, as defined by a rapid change in the slope of the seabed. There are considerable regional variations in the depth of the shelf break and the certainty in which it can be defined. This is represented in the interpolated broadscale bathymetry (Figure 3, 7). The width of the continental shelf varies considerably along the coast (generally close to the 200 m contour), with the broadest area in the Hunter region off Stockton Bight, with a shelf width of up to 47 km. However, the 60 m depth contour is only located at around 7 km off the coast.

Overall, the seabed within the Hunter region is characterised by a low gradient (2 degrees) continental shelf that incorporates flat terraces that extend the length of the region (~10 km wide) and localised reefs of rock outcrop (Heap and Harris, 2008; Figure 7). Reefs are more extensive on the inner shelf (<40 m water depth) where they occur offshore of major headlands (e.g. Seal Rocks, Port Stephens), and as isolated patches within many embayments. Many of these nearshore regions have been mapped at high resolution using swath acoustics (Jordan et al., 2010), with more recent high resolution continuous LiDAR data out to depths up to ~40 m. In deeper areas of the mid to outer shelf, reefs occur as long narrow ridges up to 5 m high and up to 40 km long in the northern half of the region (Williams et al., 2010). These ridges are potentially hardground areas of exposed rock with thin to negligible sediment cover.

Beyond the shelf break, the seabed steepens to gradients >10 degrees across the continental slope. The slope is ~60 km wide, extending to ~4800 m water depth where the seabed becomes flat at the edge of the abyssal plain along the eastern boundary of the region. Several submarine canyons extend from ~300 m to 1200 m water depth across the continental slope, with local water depths of several hundred metres (Figure 5, Figure 7). The largest of these are situated offshore of Newcastle where a canyon is incised into the shelf edge (Glenn et al., 2008). It is likely that the steeper parts of these canyons, including canyon heads, provide habitat for benthic communities (sponge, soft corals etc). However, these sites have not been studied in detail. Parts of the continental slope are also characterised by mass movement scars and deposits, as evidence for seabed instability (i.e. submarine landslides) over geological time scales (Boyd et al., 2010; Clarke et al., 2011, 2014).

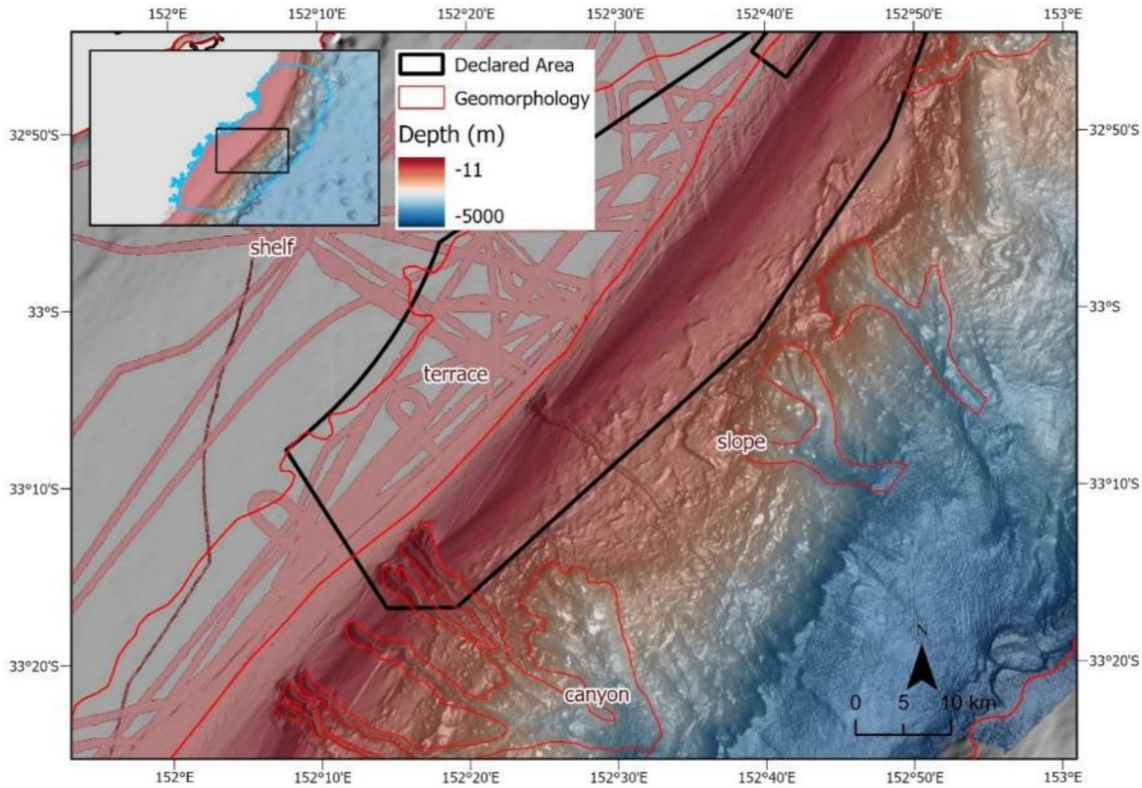

Figure 7: Multibeam sonar bathymetry grid (50 m resolution: Parums and Spinnoccia, 2019) offshore Newcastle, showing several submarine canyons (red polygons) on the continental slope that extend onto the shelf within the declared area for offshore renewable infrastructure. Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

4.4. Sedimentology

Seabed sediments over the continental shelf are dominated by sand and muddy sand, with moderate to high carbonate content (~40 to 70% CaCO3) (Figure 8; Keene et al., 2008). On the continental slope, seabed sediments are predominantly sandy mud, with moderate carbonate content (30 to 50%), but sample observations are very limited for these deeper areas (11 samples in the MARS database). Nearshore and inner shelf sediment transport is towards the north under the influence of wave-generated currents (Roy and Thom, 1981; Boyd et al., 2010). However, the embayed configuration of the coastline limits the extent of sediment transport between coastal compartments, particularly around large headlands (e.g. Seal Rocks). Within compartments, nearshore data shows complex patterns of sedimentary bedform fields (sand waves), scour depressions and channels as evidence for high energy depositional and erosional processes (Kinsela et al., 2023). On the outer shelf and continental slope the seabed is influenced seasonally by the southerly-flowing East Australian Current (EAC).

The surficial sediments throughout the central NSW region are characterised by fine sand along much of the inner shelf and a broad area of finer sediments on the mid-shelf, notably to the south of Port Stephens (Figure 9). These mid-shelf muddy sand areas are particularly prominent offshore of the Hunter River reflecting the historical transport of finer sediment from this system. There are also distinct areas of coarser sediment on the inner shelf and outer shelf north and east of the Port Stephens region.

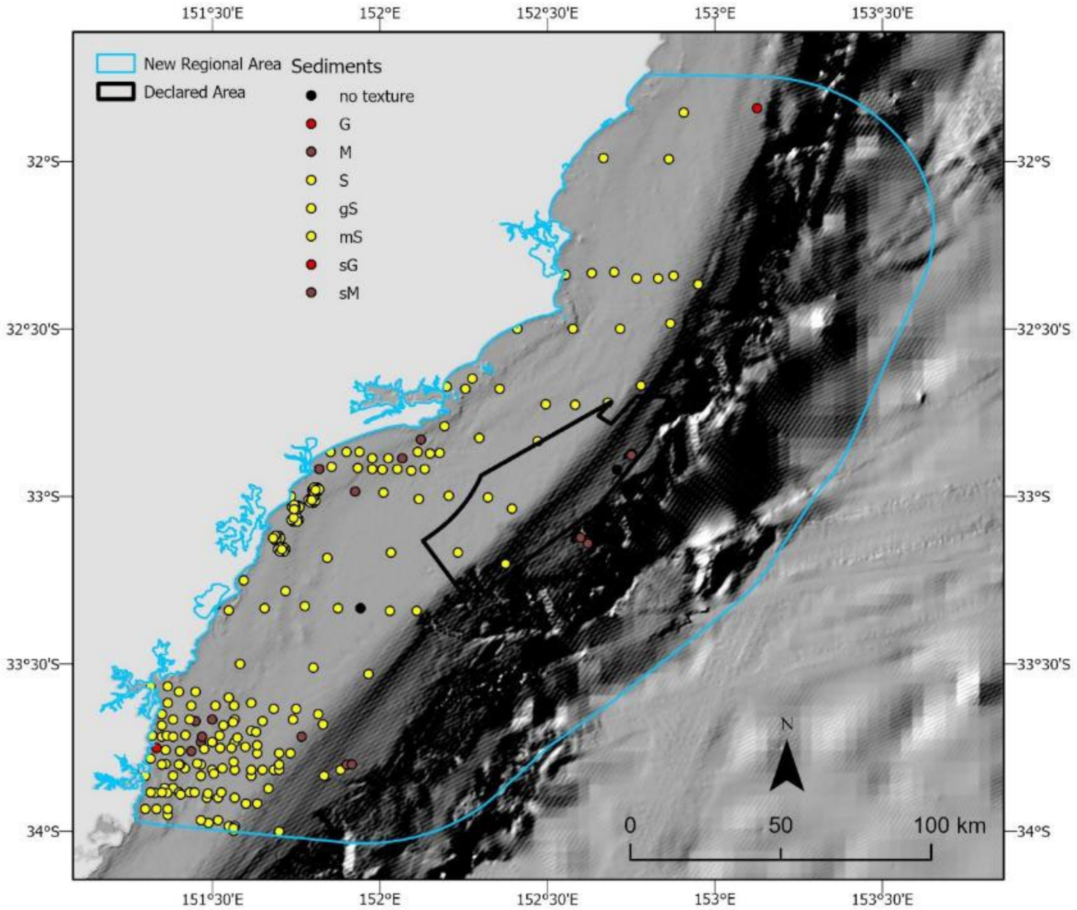

Figure 8: Map of seabed sediment samples for the Hunter region held in the MARS database, showing sediment texture at sample sites. Sediment sample textures (primary, secondary): G, g – gravel; S, s – sand; M, m – mud (MARS: Geoscience Australia, 2024). Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

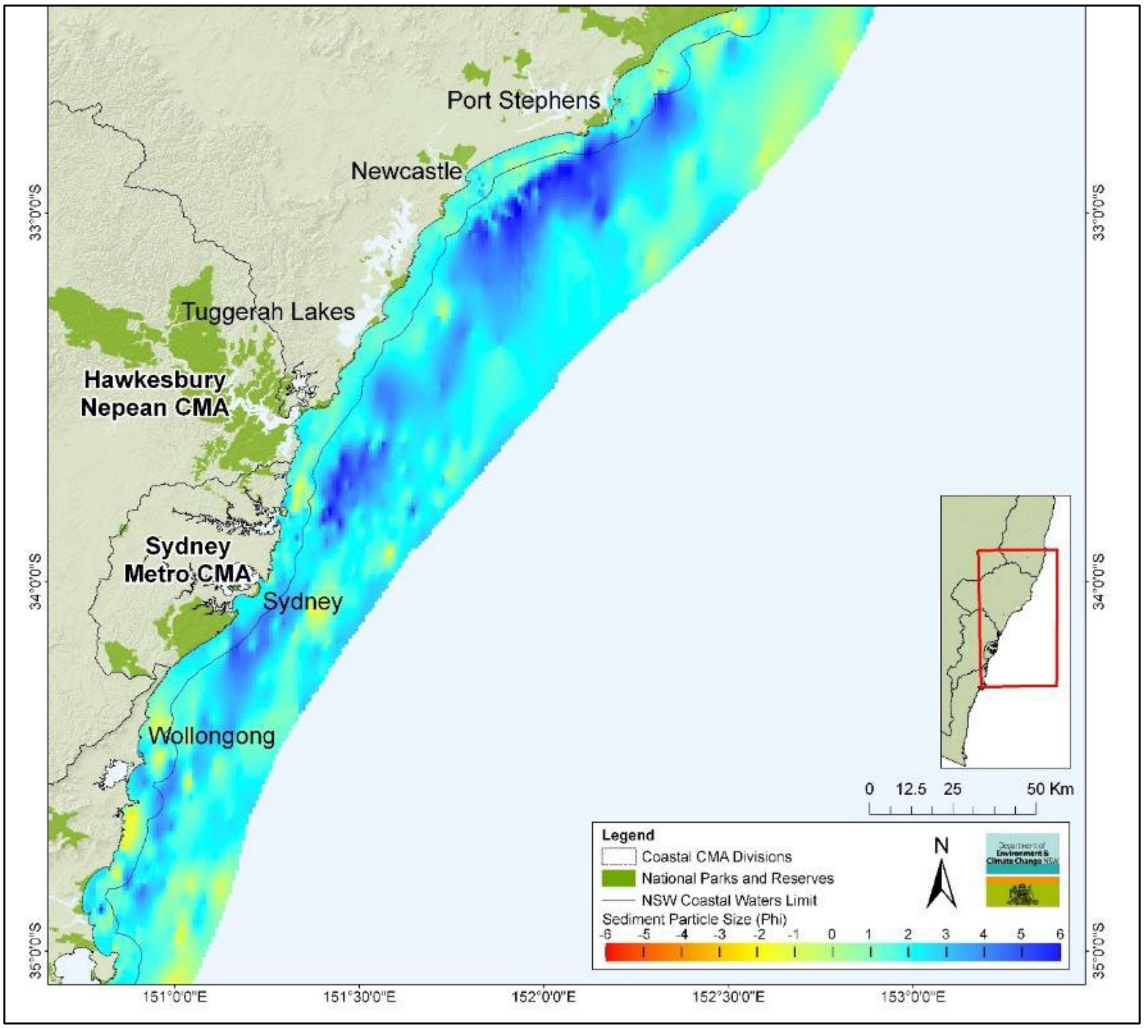

Figure 9: Interpolated broadscale surficial sediments from the Hunter and Illawarra regions of NSW (adapted from Jordan et al., 2010)

4.5. Seabed habitats and benthic biodiversity

In general, the continental shelf of NSW is characterised by an inner-shelf zone (shoreward from ~60 m water depth) and an outer zone (>~60 m depth). The inner-shelf zone contains considerable amounts of rocky reefs that are either outcropping or close to the surface, while the outer zone is the surface of a thick sediment wedge (Boyd et al., 2004). The shelf contains a complex arrangement of both rocky reef and unconsolidated (mostly sand to muddy-sand) habitats, the broad distribution of which reflects the inner shelf's patterns of bedrock geology, geological history and coastal inputs (Boyd et al., 2004; Roberts and Boyd, 2004, Jordan et al., 2010). Mapping of seabed habitats from high resolution acoustic surveys and associated imagery surveys is almost exclusively restricted to shallow inner shelf areas of the Hunter region (Figure 10).

Swath-mapping has revealed considerably more rocky reef throughout the inner shelf region than was defined previously from the broad-scale bathymetry, with the majority of this occurring in depths <80 m (Jordan et al., 2010). This confirms that the location and extent of all subtidal reefs has not yet been mapped, particularly those in greater depths within the defined declaration area. It is likely that much of the shallow reef in the region mapped using swath acoustics extends further offshore than currently defined. There is evidence of this extension of reef in several of the areas swath-mapped, including offshore of Seal Rocks. From Newcastle south, the majority of the coastline contains subtidal reef which is only broken up by small areas of ocean beaches. Overall, there is likely to be large areas of reef habitat yet to be mapped within the region. An area of less than 5.5 km^2 of the mapped inner shelf appeared to be mesophotic rocky reef (10% upper mesophotic; 90% lower mesophotic), and the remainder characterised by a range of soft sediment types.

The reefs vary considerably in their extent of patchiness, although there is no particular latitudinal or cross-shelf trend in reef structure. The high resolution of the swath bathymetric data also revealed considerable variations in the geomorphic structure of reefs (e.g. boulders, gutters, walls, pinnacles), often within the same continuous reef system. This variability in reef complexity is likely to influence the diversity of biota within the region, as reef complexity can significantly influence the diversity and assemblages present (Harman et al., 2003). The detailed bathymetry is important as there is evidence that because many rock types produce a range of structural complexity, it is this range that determines the structure of the biotic community, not the type of rock itself.

Overall, benthic communities on shallow rocky reefs throughout much of the region contain a mix of subtropical and temperate species (e.g. kelp and corals), reflecting latitudinal and cross-shelf gradients of water temperatures and ocean currents. Shallow inshore reefs are characterised by abundant macroalgae dominated by the kelp *Ecklonia radiata*, and various species of *Sargassum* and *Caulerpa* (Jordan et al., 2010). However, this is not consistent over all shallow reefs within this area as considerable broad-scale variability in assemblages can occur.

A gradual transition generally occurs at around 25-30 m where kelp and coral often decrease in abundance and become sparse within a mosaic of species of algae and sponge dominated assemblages. The mapped area of intermediate depth reef in the region indicates that this habitat type is present in these depths and often contains a range of sessile invertebrate species including sponges, ascidians, octocorals, soft corals, anemones and bryzoans (Jordan et al., 2010, Williams et al., 2020). Erect, vase, elongate, tubular and branching sponges were common, while black corals (*Antipathes* sp.), sea pens, sea whips and branching soft corals were also present, but sparsely distributed. In general, sessile invertebrate abundance and diversity is generally lowest in sections of intermediate reef consisting of cobble and boulders, with the more continuous reef with a high profile supporting greater densities. The high diversity in growth forms of sponges on much of the reef indicates a high species diversity as sponge morphological diversity can provide a qualitative estimate of sponge species diversity (Bell and Barnes, 2001).

On the deep reefs (i.e. >60 m) benthic assemblages are dominated by sponges and a mixed assemblage of sessile invertebrates. These include such groups as stalked ascidians, sea-whips, gorgonians, sea stars, hydrozoans, and black coral (Williams et al., 2020). In deeper areas, these communities are dominated by branching sponges, corals, sea whips with symbiotic brittle stars, and urchins. Overall, little deep reef has been surveyed for biota in the region. In a study of reefs of intermediate depths off Sydney, over 50 species of sponge were identified, with the number of sponge species increasing with depth, particularly for the erect or massive species (Roberts and Davis, 1996). There is also a large variety of morphologies ranging from encrusting to massive erect structures. The cover of encrusting sponges decreased with depth and small-scale spatial variation in sponge distribution and abundance was a feature of the habitat.

Fishes in coastal and continental shelf areas of NSW are diverse, often habitat specific, with large variations in the extent of movement either seasonally or all year round. They occupy a range of habitats, principally rocky reef, or soft sediment across of depth range from shallow rock pools to depths of up to around 200 m. Abundant fish species in these rocky reefs include snapper (*Chrysophrys auratus)*, red morwong (*Morwong fuscus*), yellowfin bream (*Acanthopagrus australis*), luderick (*Girella tricuspidate*), rock blackfish (drummer, *Girella elevata*), wobbegongs (*Orectolabrus* spp.), bullseyes (*Pempheris* spp.), eastern blue groper (*Achoerodus viridis*), and many species of wrasse and leatherjackets. Many pelagic migratory species also regularly occur on shallow reefs, including yellowtail kingfish (*Seriola lalandi*), silver trevally (*Pseudocaranx* spp.), and yellowtail scad (*Trachurus* spp.). These fishes vary considerably in their ecology and life-history characteristics (e.g. distribution, habitat use, movement, age, growth).

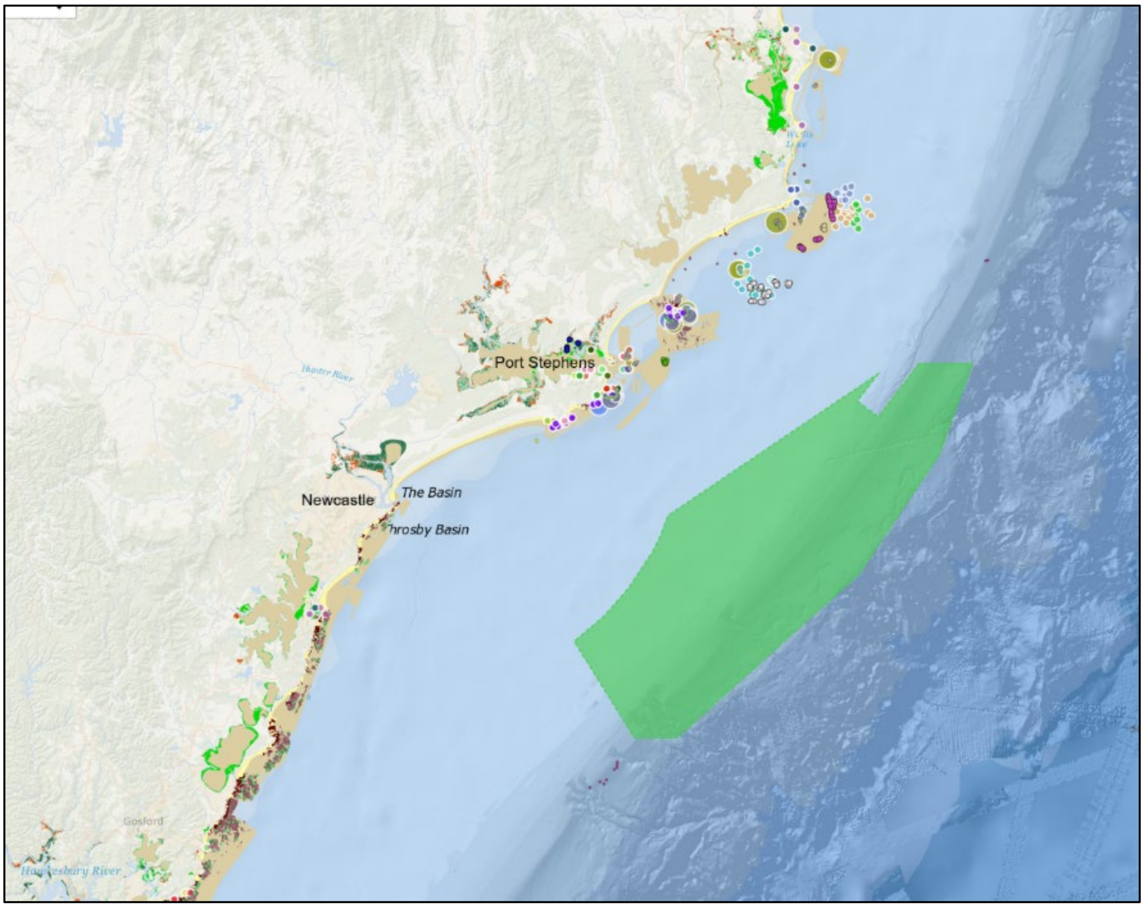

Figure 10: Available seabed ecological survey locations and habitat data for the Hunter OWF region represented in the Seamap Australia marine spatial data portal, including survey locations using towed video, Autonomous Underwater Vehicles and Baited Remote Underwater Videos represented as bubble plots. Details on habitat legend, deployment types and effort are available at:

https://seamapaustralia.org/map/#03432820-c971-4b28-b140-01b7de826367

4.6. Oceanography

The Hunter OWF region is micro-tidal (approximately 2 m tidal range at the coast) with maximum estimated tidal currents within the region of around 0.2 m s-1 (from TPXO8, Egbert and Svetlana, 2002). The shelf-scale oceanography is dominated by the EAC which flows southward through the proposed OWF development area at speeds up to an order of magnitude greater than tidal currents (Nilsson and Cresswell, 1980). Within the Hunter OWF region, the EAC typically occurs as a series of spatially variable, large-scale eddies that can generate seabed currents to water depths of ~1000 m, and force seasonal upwelling of cooler waters onto the shelf (Xie et al., 2021). The EAC dynamics in the region have been investigated extensively including exchange between the core of the EAC which sits off the shelf and the inner shelf (e.g. see Roughan et al., 2021).

Seasonal stratification has been observed using oceanographic moorings, for example offshore of Sydney (nearby to the Hunter OWF region) from a long-term subsurface mooring in 53 m of water. Stratification was near-zero in winter and present from October to April, peaking in February (Schaeffer et al., 2023). This indicates that the seasonal front position extends beyond the 50 m isobath each year. The EAC may vary the position of the oceanic stratification front significantly, negating basic predictions (e.g., Simpson and Hunter, 1974) that do not account for advection. Eddies associated with the EAC can have a significant impact on inner-shelf primary productivity (e.g. Roughan et al., 2021) and thus interaction of these eddies with OWF infrastructure and advection of OWF impacts away from the region will be important to consider, with potentially beneficial and detrimental outcomes.

Wave energy in the OWF region is low to moderate (Hemer et al., 2018), despite occasional high energy events. The distance between the OWF region and the coastline means that impacts to coastal geomorphology (shoreline changes) from wave energy absorption are expected to be insignificant (David et al., 2022). Moderate to strong wind energy in the OWF region is suitable for the development of offshore wind farms which may alter upwelling patterns. This effect may be negligible in the presence of strong advection but should be assessed.

4.7. Threatened and migratory marine species

All spatial layers from the fauna maps presented in text are available for viewing and download found through the following map and table links. These are live documents that are updated as new information is received.

Fauna Group		OWF Area overlap	Tables: Published data
	Cetaceans and pinnipeds	Map Link	Baleen, Toothed, Pinnipeds
	Birds	Map Link	Birds
	Sharks	Map Link	Shark
	Reptiles (turtles)	Map Link	Reptiles

Note that information on finfish, invertebrates and other species of interest can be viewed in the separate inventory for the Hunter region (Appendix B). This list is not comprehensive as it was not the focus of this study and therefore only a small subset of species are provided.

4.7.1. Cetaceans and pinnipeds

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of 17 published studies on cetaceans (no pinnipeds) overlapped with the Hunter OWF area (Figure 11; Tables 6-8). The majority of those studies were on humpback whales (*Megaptera novaeangliae,* n=4, listed migratory under the EPBC Act) and southern right whales (*Eubalaena australis,* n=4, listed endangered under the EPBC Act) with two studies on common dolphins (*Delphinus delphis*) and blue whales (*musculus* subspecies, listed endangered under the EPBC Act) and one study for each of killer whale (*Orcinus orca*, listed Migratory), false killer whale (*Pseudorca crassidens*), Indo-pacific bottlenose dolphin (*Tursiops aduncus*) and bottlenose dolphin (*Tursiops truncatus*). For most of the dolphin species and southern right whales, the overlap occurred along the half of the OWF area that was closest to shore, with overlap for blue and humpback whales extended further into the offshore parts of the OWF (Figure 11; Table 3-5).

Table 3. Baleen whale species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Hunter OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high . Hunter https://seamapaustralia.org/map/#48f1c097-5771-4901-a9dd-e9d090be285bBaleen cetacean Table Link.

Hunter OWF: Cetaceans (baleen)

			Areas as % of OWF		Observation counts	Seasonality	Number
Species	Family occurence	EPBC status	SNES	PUBS	OBIS-ALA	J F M A M J J A S O N D	PUBS
Southern Right Whale *Eubalaena australis*	Balaenidae -	Endangered	100	94	42		4
Antarctic Blue Whale *Balaenoptera musculus intermedia*	Balaenopteridae -	Endangered	100	78	0		1
Pygmy Blue Whale *Balaenoptera musculus brevicauda*	Balaenopteridae -	Endangered	100		0		0
Fin Whale *Balaenoptera physalus*	Balaenopteridae -	Vulnerable	92		0		0
Bryde's Whale *Balaenoptera edeni*	Balaenopteridae -	Migratory	100		1		0
Dwarf Minke Whale *Balaenoptera acutorostrata subsp.*	Balaenopteridae -	Migratory	100		17		0
Pygmy Right Whale *Caperea marginata*	Cetotheriidae -	Migratory	49		0		0
Humpback Whale *Megaptera novaeangliae*	Balaenopteridae -	Cetacean	100	100	899		4

Table 4. Toothed whale species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Hunter OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark brown indicates months of the year with peak occurrence, light brown indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. Note that for all the toothed whales there is limited data on seasonality, and they may be present year round. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Hunter toothed cetacean Table Link

Hunter OWF: Cetaceans (toothed)

			AREA AS % OF OWF		OBSERVATION COUNTS	SEASONALITY	NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	SNES	PUBS	OBIS-ALA	J F M A M J J A S O N D	PUBS
Killer Whale *Orcinus orca* i	Delphinidae -	Migratory	100	3	1		1
Sperm Whale *Physeter macrocephalus* i	Physeteridae -	Migratory	44		39		0
Common Bottlenose Dolphin *Tursiops truncatus* i	Delphinidae -	Cetacean	100	100	0		1
Common Dolphin *Delphinus delphis* i	Delphinidae -	Cetacean	100	94	150		2
False Killer Whale *Pseudorca crassidens* i	Delphinidae -	Cetacean	56	13	16		1
Indo-Pacific Bottlenose Dolphin *Tursiops aduncus* i	Delphinidae -	Cetacean	61	1	1059		1
Long-Finned Pilot Whale *Globicephala melas* i	Delphinidae -	Cetacean	44		4		0
Striped Dolphin *Stenella coeruleoalba* i	Delphinidae -	Cetacean	44		11		0
Dwarf Sperm Whale *Kogia sima* i	Kogiidae -	Cetacean	44		6		0
Pygmy Sperm Whale *Kogia breviceps* i	Kogiidae -	Cetacean	44		61		0
Gray's Beaked Whale *Mesoplodon grayi* i	Ziphiidae -	Cetacean	15		19		0
Strap-Toothed Beaked Whale *Mesoplodon layardii* i	Ziphiidae -	Cetacean	44		12		0

Table 5. Pinniped species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Hunter OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high and white indicating very low occurrence/ species absence from the OWF. Hunter pinniped Table Link

Hunter OWF: Pinniped

			AREA AS % OF OWF		OBSERVATION COUNTS	SEASONALITY	NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	SNES	PUBS	OBIS-ALA	J F M A M J J A S O N D	PUBS
Australian Sea Lion *Neophoca cinerea* i	Otariidae -	Endangered	0		11		0
Australian Fur-Seal *Arctocephalus pusillus doriferus* i	Otariidae -	Marine	61		1031		0
Long-Nosed Fur-Seal *Arctocephalus forsteri* i	Otariidae -	Marine	61		172		0

Existing freely available species observation data

Overlaying observations of the priority (and secondary priority) cetacean and pinniped species with the Hunter OWF region from ALA, and OBIS (Figure 12, 13), showed that Indo-pacific bottlenose dolphins Australian were the most common in the Hunter OWF area (1059) (Table 4), followed by fur seal observations (1031) (Table 5) and humpback whale (899) (Table 3). For all the remaining species the number of observations occurring in the Hunter OWF region were <150.

The spatial distribution of priority (and secondary priority) cetacean and pinniped species observations within the Hunter OWF region shows most of the species observations occurred along the shore, with observations of humpback whales, Indo-pacific bottlenose dolphin and Australian fur seal occurring further offshore (Figure 12, 13). Listed threatened species that have been observed in the Hunter OWF in OBIS and ALA include pygmy blue whales (*Balaenoptera musculus brevicauda*), southern right whales (*Eubalaena australis*) and the vulnerable listed fin whale (*Balaenoptera physalus*).

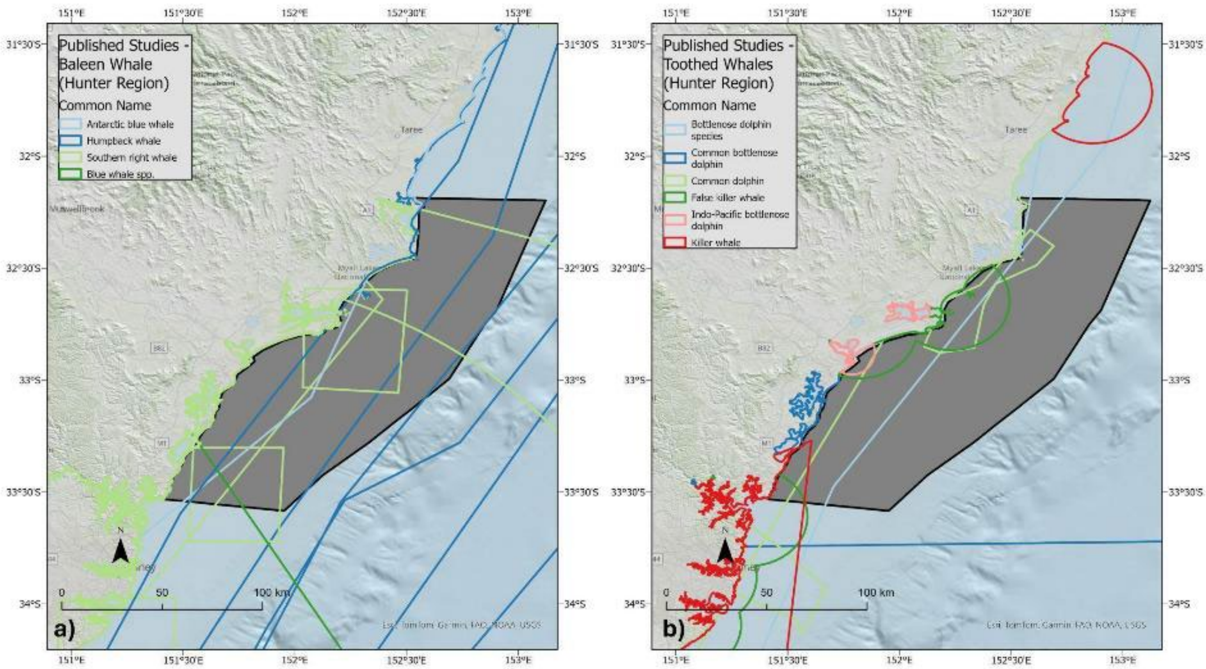

Figure 11: The Hunter OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where baleen whales (a) and toothed whales (b) occurred. The different species are represented by the different colours.

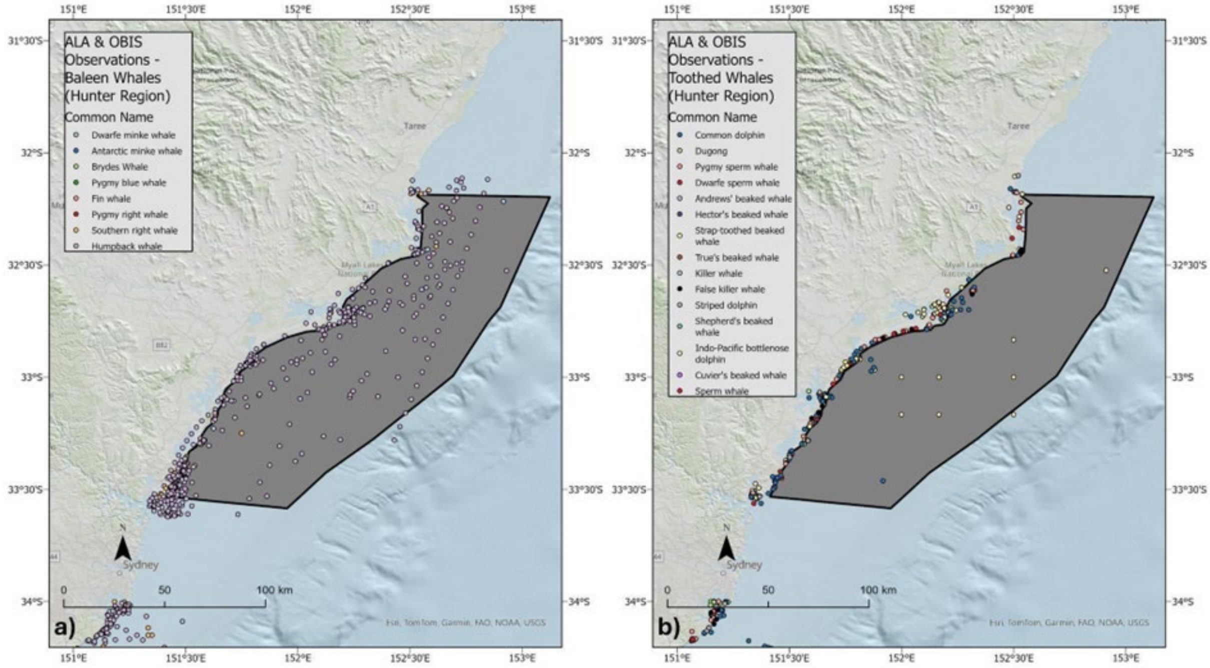

Figure 12: The Hunter OWF region (grey polygon) showing observations of baleen (a) and toothed (b) whales from the ALA and the OBIS across. The different species are represented by the different colours.

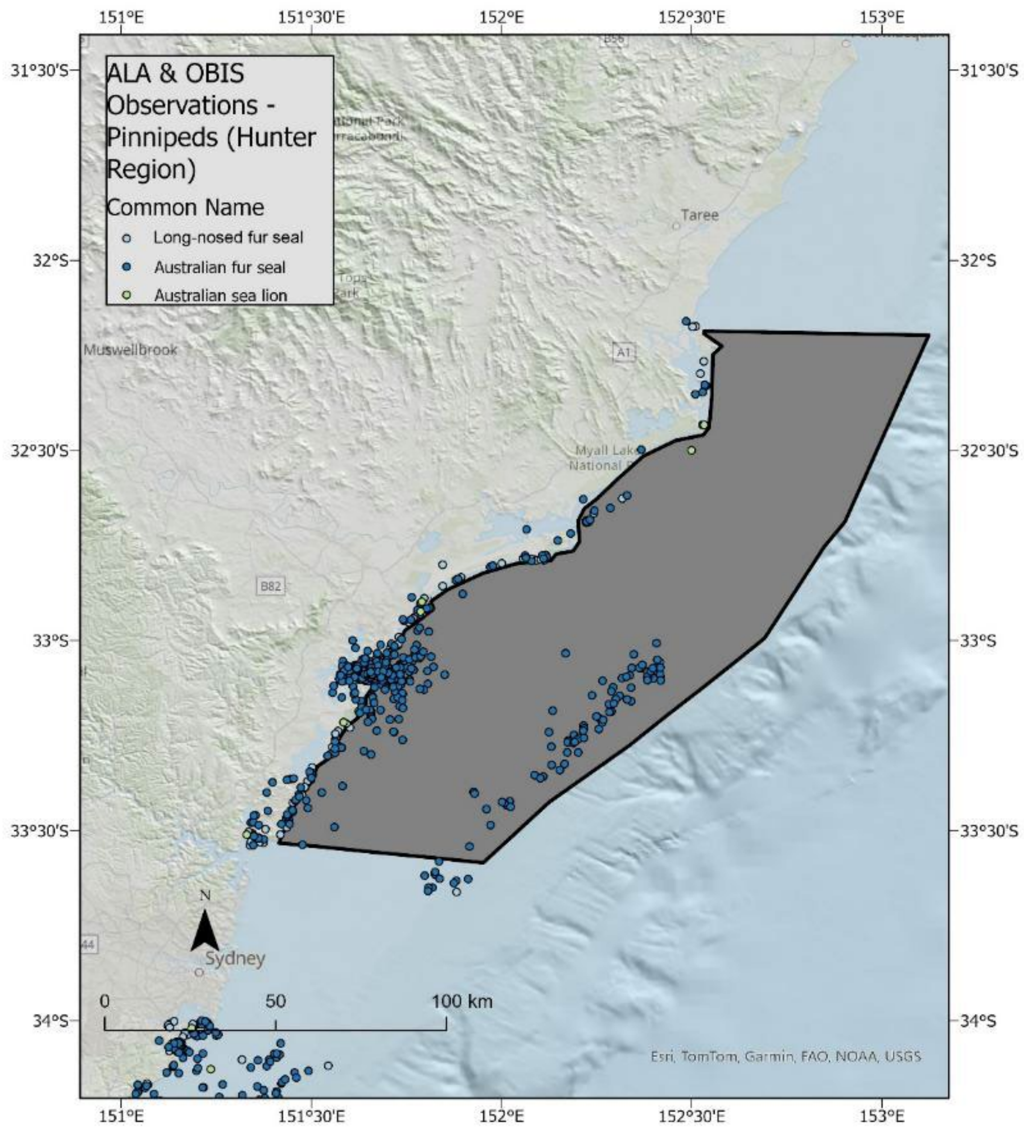

Figure 13. The Hunter OWF region (grey polygon) showing observations of pinnipeds from the ALA and the OBIS. The different species are represented by the different colours.

4.7.2. Birds

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of 14 published studies on bird species of interest overlapped with the Hunter OWF region (Figure 14). Most of those studies were on albatrosses (8) with two studies on waders (2) and one study for each of plovers, petrels, shearwaters, and parrots. For most of the sea bird species, the overlap occurred at the shore boundary of the OWF region, with overlap for albatross extending into the offshore parts of the OWF region (Figure 14) (overlap = 10,050 km^2). Although the polygon for swift parrots had high overlap with the OWF region (9,567 km^2), the actual locations that swift parrots were observed in the polygon were all on land (Saunders et al., 2017) (also see Figure 15). We found only low overlap of the study areas and occurrence of waders and plovers within the OWF region (643 km^2 and 5 km^2 respectively).

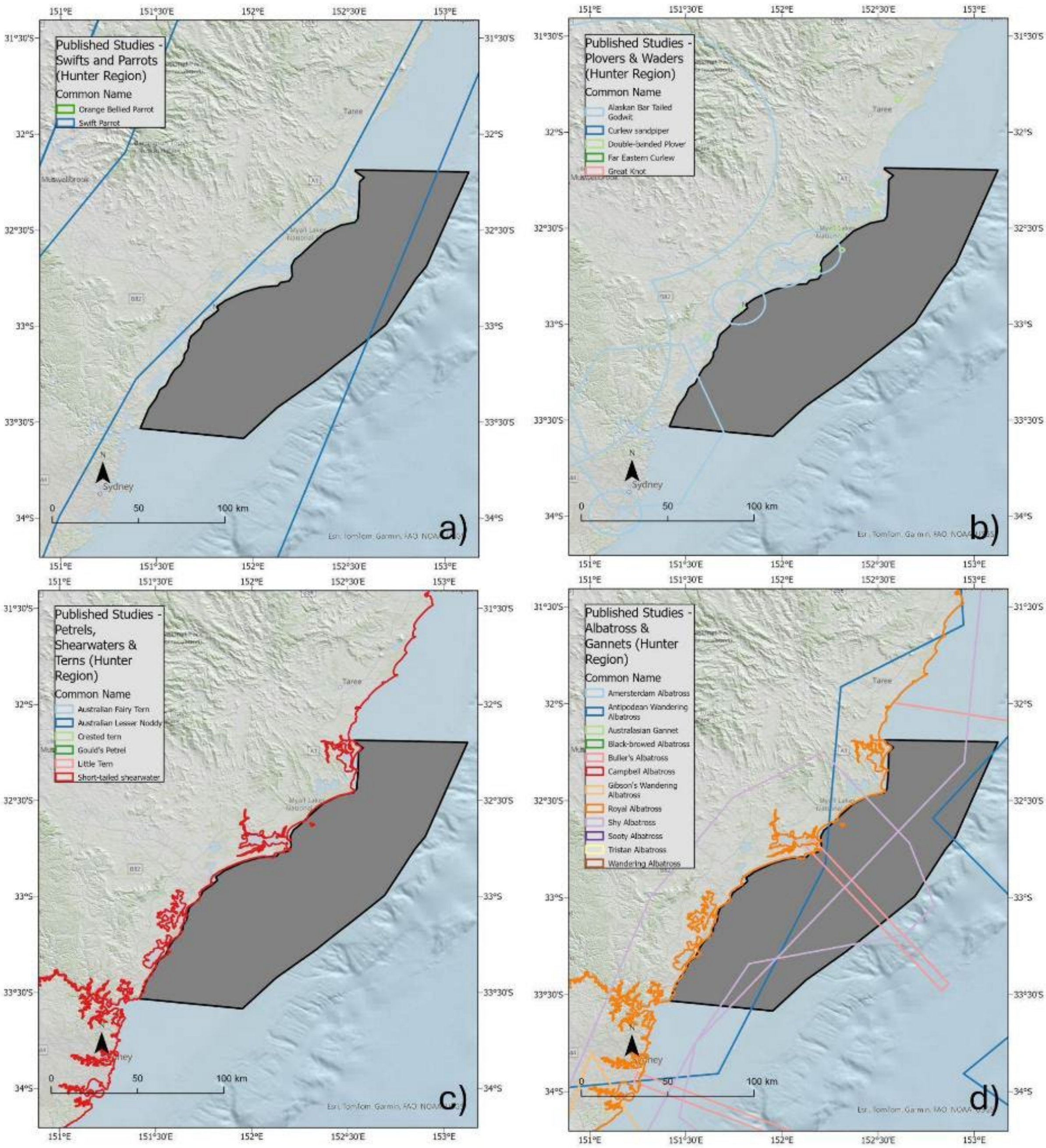

Figure 14. The Hunter OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where bird species occurred with separate maps for each species group (a-d). The different species are represented by the different colours.

Our inventory of studies overlapping with the Hunter OWF area included three listed threatened bird species; one study of the critically endangered Swift Parrot (*Lathamus discolor*), two studies on the endangered Shy Albatross (*Thalassarche cauta*) and one study on the endangered Gould's Petrel (*Pterodroma leucoptera*). The remaining species in the inventory are made up of species listed as vulnerable under the EPBC Act and other species identified of interest due to their migratory behaviour or potential interactions with wind farms in the OWF region (Table 6).

Table 6. Bird species for which we have compiled spatial data from published studies and freely available data repositories (BLA, OBIS and ALA) that overlap with the Hunter OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for each data repository used (BLA = Birdlife Aust, OBIS and ALA data combined). Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Hunter bird Table link

Hunter OWF: Bird

Species	Family / Occurrence	EPBC Status	Area as % of OWF: SNES	Area as % of OWF: PUBS	Observation counts: BLA	Observation counts: OBIS-ALA	Number: PUBS
Tristan Albatross *Diomedea dabbenena*	Diomedeidae Vagrant	Critically Endangered	0		0	0	0
Orange-Bellied Parrot *Neophema chrysogaster*	Psittacidae Rare	Critically Endangered	0		0	0	0
Swift Parrot *Lathamus discolor*	Psittacidae Rare	Critically Endangered	0	95	183	710	1
Curlew Sandpiper *Calidris ferruginea*	Scolopacidae Common	Critically Endangered	100		690	3721	0
Far Eastern Curlew *Numenius madagascariensis*	Scolopacidae Common	Critically Endangered	100		1726	4022	0
Great Knot *Calidris tenuirostris*	Scolopacidae Common	Critically Endangered	0		216	893	0
Lesser Sand Plover *Charadrius mongolus*	Charadriidae Rare	Endangered	0		53	385	0
Chatham Albatross *Thalassarche eremita*	Diomedeidae Vagrant	Endangered	100		0	0	0
Northern Royal Albatross *Diomedea sanfordi*	Diomedeidae Common	Endangered	100		0	0	0
Shy Albatross *Thalassarche cauta*	Diomedeidae Common	Endangered	100	84	73	233	2
Gould's Petrel *Pterodroma leucoptera leucoptera*	Procellariidae Rare	Endangered	0	100	84	19433	1
Southern Giant Petrel *Macronectes giganteus*	Procellariidae Rare	Endangered	100		26	58	0
Black-Tailed Godwit *Limosa limosa*	Scolopacidae Rare	Endangered	0		478	1618	0
Red Knot *Calidris canutus*	Scolopacidae Common	Endangered	100		476	2092	0
White-Throated Needletail *Hirundapus caudacutus*	Apodidae Common	Vulnerable	1		831	1561	0
Greater Sand Plover *Charadrius leschenaultii*	Charadriidae Rare	Vulnerable	1		11	58	0
Antipodean Wandering Albatross *Diomedea antipodensis antipodensis*	Diomedeidae Rare	Vulnerable	100	67	22	2	2
Black-Browed Albatross *Thalassarche melanophris*	Diomedeidae Common	Vulnerable	100		234	593	0
Buller's Albatross *Thalassarche bulleri*	Diomedeidae Rare	Vulnerable	100	100	35	62	2
Campbell Albatross *Thalassarche impavida*	Diomedeidae Vagrant	Vulnerable	100		37	1	0
Gibson's Wandering Albatross *Diomedea antipodensis gibsoni*	Diomedeidae Rare	Vulnerable	100	100	0	11	1
Indian Yellow-Nosed Albatross *Thalassarche carteri*	Diomedeidae Common	Vulnerable	100		172	3	0
Royal Albatross *Diomedea epomophora*	Diomedeidae Common	Vulnerable	100	100	1	6	1
Salvin's Albatross *Thalassarche salvini*	Diomedeidae Vagrant	Vulnerable	100		0	5	0
Sooty Albatross *Phoebetria fusca*	Diomedeidae Rare	Vulnerable	100		0	4	0
Wandering Albatross *Diomedea exulans*	Diomedeidae Rare	Vulnerable	100		73	184	0
White-Capped Albatross *Thalassarche steadi*	Diomedeidae Rare	Vulnerable	100		14	1	0
Northern Giant Petrel *Macronectes halli*	Procellariidae Vagrant	Vulnerable	100		39	71	0
Blue-Winged Parrot *Neophema chrysostoma*	Psittacidae Common	Vulnerable	1		0	0	0
Alaskan Bar-Tailed Godwit *Limosa lapponica*	Scolopacidae Common	Vulnerable	2	6	2256	5175	2
Little Penguin *Eudyptula minor*	Spheniscidae Common	Marine	0		91	541	0
Double-Banded Plover *Charadrius bicinctus*	Charadriidae Common	Migratory	0	0	330	3	1
Little Tern *Sternula albifrons*	Laridae Common	Migratory	1		830	2508	0
Short-Tailed Shearwater *Ardenna tenuirostris*	Procellariidae Common	Migratory	0	100	407	1179	1

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Existing freely available species observation data

Overlaying observations of the priority (and secondary priority) bird species with the Hunter OWF region from BirdLife Australia, ALA, and Ocean Biodiversity Information System (OBIS), showed that wader observations were the most common in the Hunter OWF area (21,267), followed by petrels (19,711 observations). For the remaining species the number of observations occurring in the OWF ranged from 2 (skuas) to 3,338 (terns) and several species having no recorded occurrence in these databases (Table 6).

The spatial distribution of bird observations within the Hunter OWF region shows that bird species of interest are found throughout the entire region, but as for the spatial data obtained from published papers, most of the species observations occurred along the shore outside of the ORF area but in potential activity areas (e.g., transit for maintenance, onshore infrastructure). Observations of petrel and albatross occurring offshore in the defined OWF region. The observation data also highlighted that most occurrences were in the lower two thirds of the OWF area (Figure 15). Observations of several species listed as critically endangered under the EPBC Act occurred in the OWF area including Curlew Sandpiper (*Calidris ferruginea*), Far Eastern Curlew (*Numenius madagascariensis*), Great Knot (*Calidris tenuirostris*), and Swift Parrot (*Lathamus discolor*). Endangered species that have been observed in the Hunter OWF include Red Knots (*Calidris canutus*), Lesser Sand Plover (*Charadrius mongolus*), Shy Albatross (*Thalassarche cauta*), and the Southern Giant Petrel (*Macronectes giganteus*).

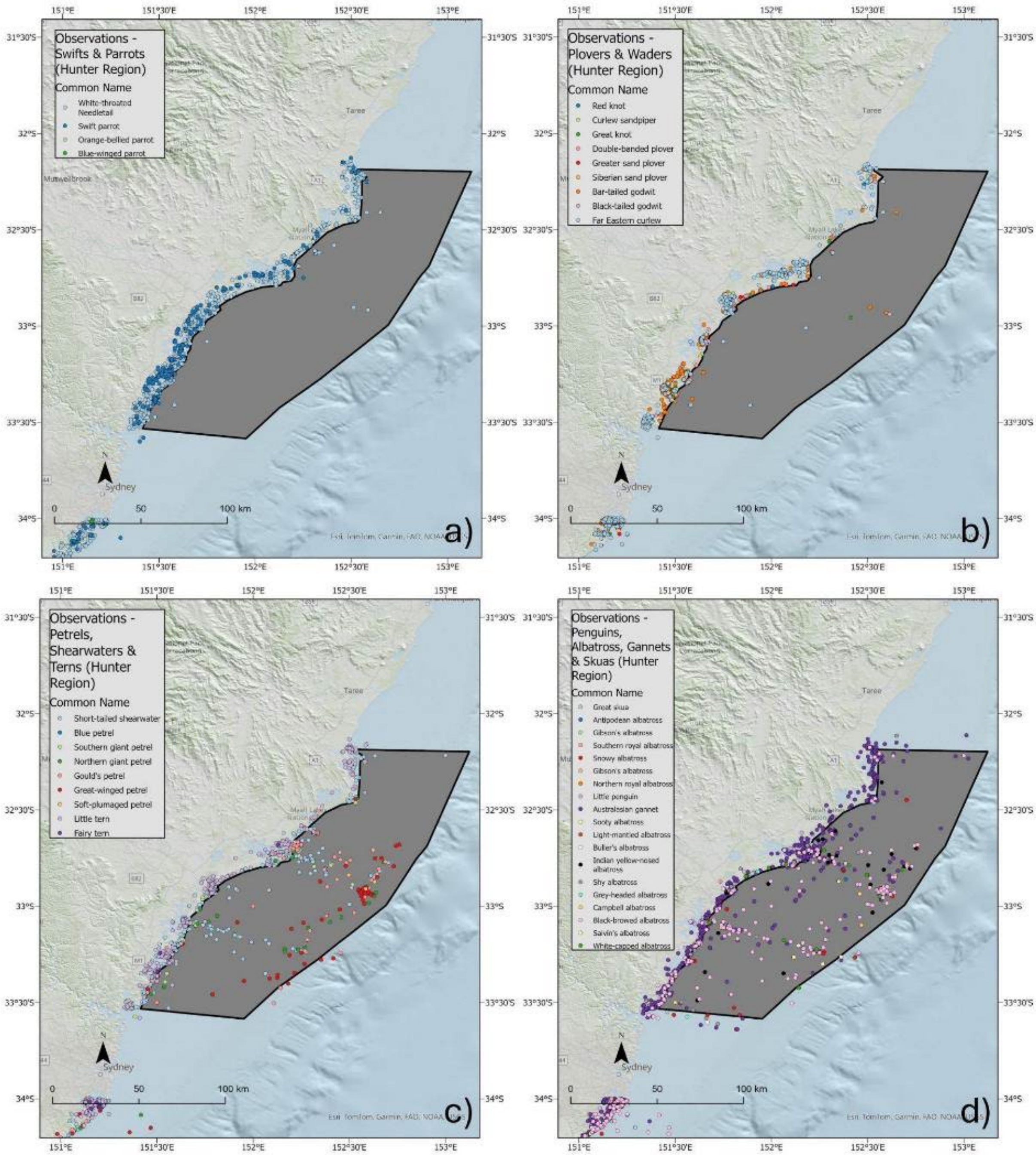


Figure 15: The Hunter OWF region (grey polygon) showing observations of bird species from BirdLife Australia, the ALA and the Ocean Biodiversity Information System for each bird grouping (a-d). The different species are represented by the different colours.

4.7.3. Sharks

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of 22 published studies on listed shark species overlapped with the Hunter OWF area (Figure 16). Of the 22 studies, 15 involved the white shark (*Carcharodon carcharias, listed vulnerable*), while the other seven were on the grey nurse shark (*Carcharias taurus,* critically endangered species on the east coast of Australia). The spatial coverage of white and grey nurse sharks studies spanned the entire Hunter OWF area (10,050 km^2) (Figure). Grey nurse sharks were considered to occur in the Hunter OWF region from March to December, whereas white sharks which were thought to be present between May and December (Table 7). Grey nurse sharks (GNS) tend to aggregate at specific sites along migration routes. There are currently 19 identified key aggregation sites along the eastern seaboard (Bradford pers. comm). These critical habitat sites have specialised regulations for fishing. Seven sites have already been given high levels of protection through inclusion in new and existing marine park sanctuary zones (NSW DPI 2002, 2012).

Further details on the biology, ecology and life history of white sharks are found (NSW DPI, 2005; Bruce et al., 2006; Bruce and Bradford, 2012; Bruce et al., 2013). Research on grey nurse sharks is presented within Otway et al. (2003), Otway and Ellis (2011), NSW DPI (2013) and Otway and Parker (2000). A recent study found that the eastern grey nurse shark (GNS) population was growing at a rate of 3-4% per annum (Bradford et al., 2018).

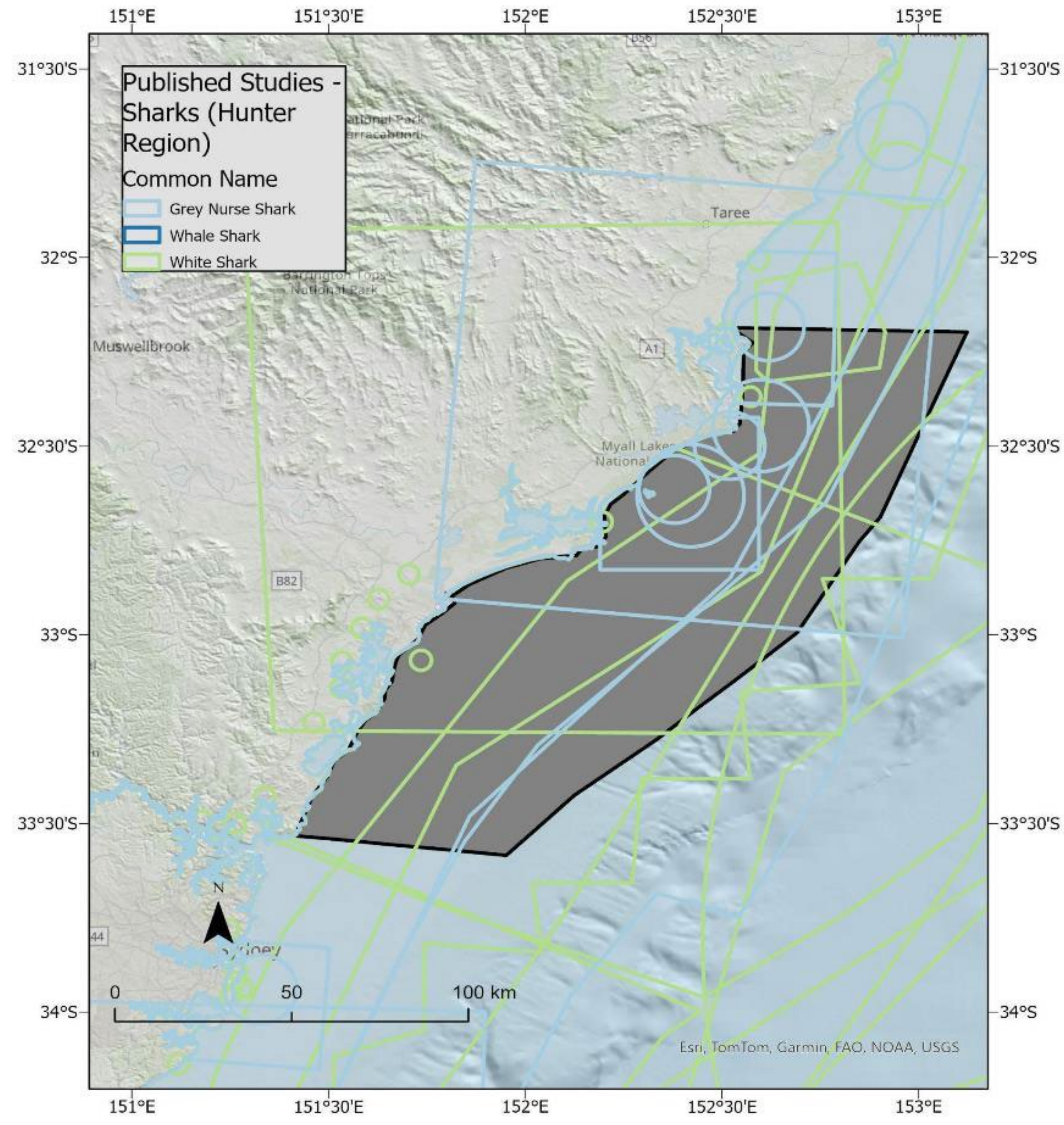


Figure 16. The Hunter OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where shark species occurred. The different species are represented by the different colours.

Existing freely available species observation data

Overlaying observations of the listed shark species from ALA and OBIS with the Hunter OWF showed white sharks to be more prominent (1820 observations) than grey nurse sharks (1147 observations; Table 7; Figure 17). The spatial distribution of shark observations within the Hunter OWF region shows that both species of shark are present across the latitudinal range of the OWF however, they most commonly occurred between the coastline and the edge of the OWF area and become less prevalent offshore. This is likely due to observations primarily occurring from onshore sightings and may not be representative of both shark species' distribution throughout the entire OWF area.

Table 7. Shark species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Hunter OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Hunter shark Table Link

Hunter OWF: Shark

			AREA AS % OF OWF		OBSERVATION COUNTS	SEASONALITY	NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	SNES	PUBS	OBIS ALA	J F M A M J J A S O N D	PUBS
Grey Nurse Shark *Carcharias taurus*	Odontaspididae -	Critically Endangered	94	100	1147		7
White Shark *Carcharodon carcharias*	Lamnidae -	Vulnerable	100	100	1820		14

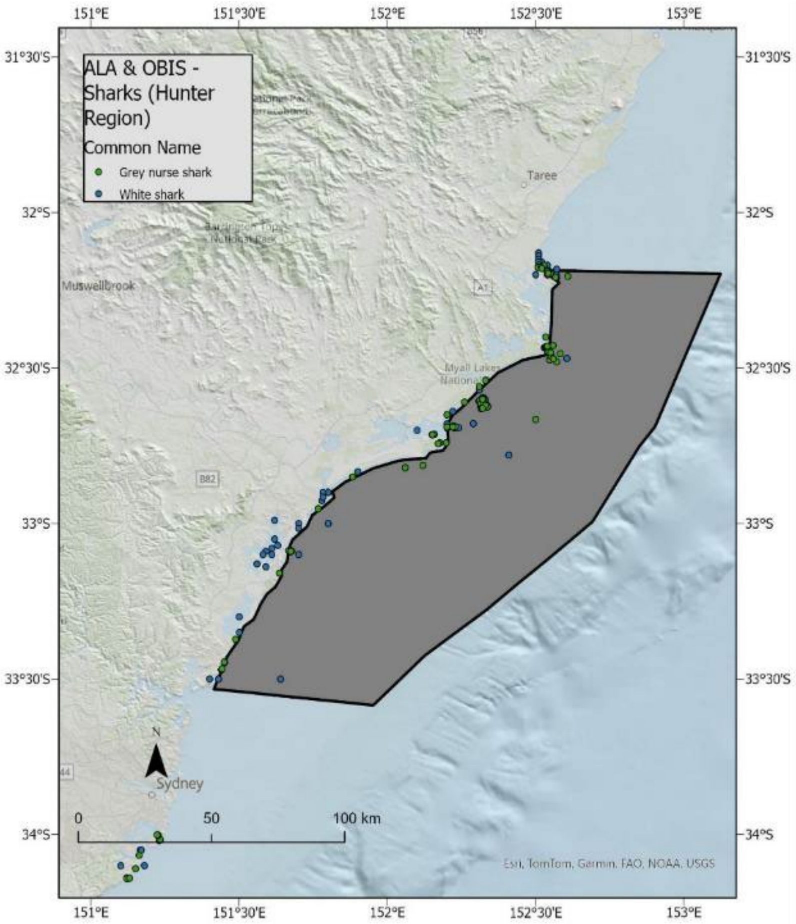


Figure 17: The Hunter OWF region (grey polygon) showing observations of sharks from OBIS and ALA. The different species are represented by the different colours.

4.7.4. Reptiles

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of, four published studies on listed reptile species overlapped with the Hunter OWF region (Figure 18). Three of the studies were on the leatherback turtle (*Dermochelys coriacea*), while the final was on the loggerhead turtle (*Caretta caretta*). Overlaying the study area polygons extracted from the turtle studies with the Hunter OWF region (10,050 km^2) amounted to overlap of approximately 80% (7938 km^2) for leatherback turtles and 100% for loggerhead turtles (Figure 18, Table 8). Overlaying the turtle Species of National Environmental Significance (SNES) distribution with the Hunter OWF region showed 100% overlap for five turtle species - loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), flatback (*Natator depressus*), and hawksbill (*Eretmochelys imbricata)* turtles. The leatherback and loggerhead turtles are considered endangered under the EPBC Act while the flatback, hawksbill, and green turtles are listed as vulnerable. Note that there were no published studies found for all the vulnerable species.

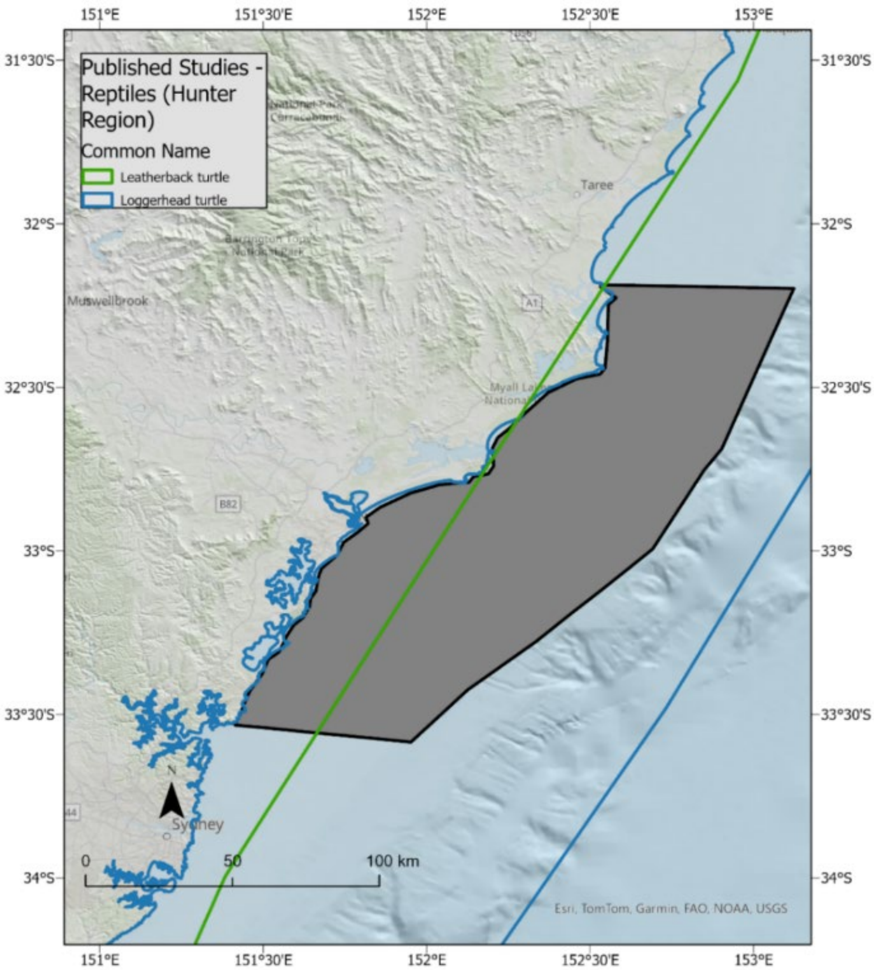


Figure 18. Polygons within the Hunter OWF region showing the spatial coverage of the study areas where turtle species occurred. The different species are represented by the different colours and the grey polygon shows the study region for the Hunter OWF.

Table 8. Turtle species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Hunter OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Hunter reptile Table link

Hunter OWF: Reptile

			AREA AS % OF OWF		OBSERVATION COUNTS	SEASONALITY												NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Loggerhead Turtle *Caretta caretta*	Cheloniidae -	Endangered	100	100	106													1
Leatherback Turtle *Dermochelys coriacea*	Dermochelyidae -	Endangered	100	79	81													3
Flatback Turtle *Natator depressus*	Cheloniidae -	Vulnerable	100		29													0
Green Turtle *Chelonia mydas*	Cheloniidae -	Vulnerable	100		864													0
Hawksbill Turtle *Eretmochelys imbricata*	Cheloniidae -	Vulnerable	100		39													0

Existing freely available species observation data

Overlaying observations of listed reptile species from ALA and OBIS with the Hunter OWF region showed the occurrence of five species of marine turtles with the highest number of observations for the green turtle (864), followed by the loggerhead turtle (106 observations) (Figure 19). The remainder of the occurrences ranged from nine observations (Flatback turtle) & hawksbill turtle (*Eretmochlys imbricata*) to 81 observations (leatherback turtle) (Table 8). Most observations occurred between the coastline and the landward OWF boundary which is likely due to shore and recreational boat-based sightings. Within the OWF, only observations of green turtles were recorded. These may be erroneous as this species usually feeds in shallow waters on seagrass and algae.

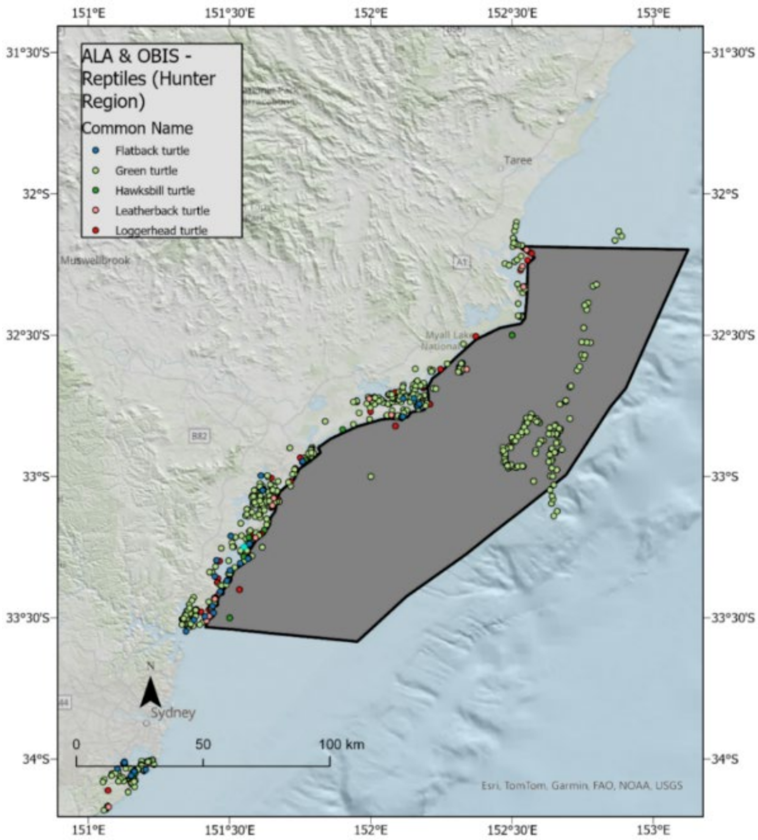


Figure 19. The Hunter OWF region (grey polygon) showing observations of turtles from the Atlas of Living Australia (ALA) and the Ocean Biodiversity Information System (OBIS). The different species are represented by the different colours.

4.8. Indigenous communities

The TOs adjacent to the Hunter Region (Newcastle area) are the Worimi people and the Awabakal people. Worimi country's boundaries are set by the four rivers: the Hunter River to the south, Manning River to the north, and the Allyn and Patterson rivers to the west, and the adjoining ocean and waterways. This area includes 18 clan groups or 'ngurras'. The Worimi nation has a strong connection to the land and sea as listed in '(Worimi Conservation Lands Plan of Management page 18 and Worimi Conservation Lands. The Awabakal country covers the north of Sydney, Newcastle, Lake Macquarie, and surrounding areas. At the time of writing this report there were no Native Title determinations or applications under the *Native Title (New South Wales) Act 1994* for these areas.

The Worimi ngurras ‘clans’ have a long history of fishing and shellfish collecting, this can be seen by the large number of cultural sites throughout the Worimi Conservation Lands. Connections to the sea can be seen through the extensive shell deposits ‘midden sites’ scattered throughout sandy beaches and dunes systems. A midden site is an occupation site that varies in size and was a place where Aboriginal people feasted on fish, shellfish, birds, animals. Midden sites are dominated with pippy shells but have also been found containing estuarine and rockshell shellfish. Other materials may be found throughout the midden such as plant materials, artifacts from tool making, cooking stones, charcoal, and bone materials. Seafood is also a staple food source of the Awabakal people’s diet including shellfish, cockles, mussels, pippies, oysters and fish (Miromaa ALTC, collected writings on the Awabakal people, p.44). A detailed summary of contemporary Aboriginal fisheries harvest in New South Wales shows there are more than 150 species of finfish and invertebrates harvested (Schnierer and Egan, 2016). It’s important to note these sites, they are culturally significant to Aboriginal people and help tell the history of the area and how the old people lived. It is also worth noting that even though the sites are not located within the OWF zone, these cultural sites may be impacted by cable routes or equipment that connect across the shoreline.

The Awabakal people have a strong connection to the sperm whale/ black whale with a strong cultural story attached to them (Miromaa ALTC, collected writing on the Awabakal people,p.8). This desktop investigation provides some examples of documented connections of Worimi and Awabakal people to coastal and marine environments, we expect they represent a small fraction of their deep and extensive connections with land, sea and sky country. Some of the main aquatic foods listed on (https://worimiconservationlands.com/ are – fish (makurr), oyster (ninang), pipi (bitjagang) and many others but the main delicacy was the Cobra (nyumarr) a worm found throughout the mangrove trees.

The Awabakal Local Aboriginal Land Council (ALALC) is the organisation representing the Awabakal people, its website states there are many sites of cultural significance registered within ALALC boundaries. There are many more unregistered sites of cultural significance within Awabakal boundaries. The Awabakal’s people have the role and responsibility to protect, care and manage the sites not only for the benefit of Awabakal members, but for all Australians to appreciate for generations to come. A publicly available positional statement from ALALC on offshore windfarms was not found at the time of writing this report.

The Worimi Local Aboriginal Land Council (WLALC) is the organisation representing the Worimi people, its vision and values are described on their website. The Worimi Conservation Lands Management Plan highlights respect and acknowledgement of the Worimi People and their Country as a primary precedent. There is also a strong emphasis on the protection and preservation of the land and cultural sites for the next generations to come, which will be achieved through educating the wider community on Worimi culture. A publicly available positional statement from WLALC on offshore windfarm development was not found at the time of writing this report.

There are numerous indications the Worimi and Awabakal peoples have interest and capacity to engage in discussions about key environmental factors for offshore wind farms and associated science. A 2023 desktop audit of coastal and catchment Aboriginal ranger groups was conducted as part of the implementation of the NSW Marine Estate Management Strategy 2018-28. There are several Aboriginal ranger groups established the areas adjacent to the Hunter OWF region, for example the Worimi people have developed capabilities and capacity to manage Worimi Conservation Lands.

5. Illawarra Offshore Wind Farm region – knowledge base

5.1. Bathymetry

The extent and structure of the continental shelf in the Illawarra region as characterised by broadscale single beam acoustic derived bathymetry shows considerable local variations in the distance to the 60 m depth contours, ranging from around 1.8 km south of Wollongong up to around 10 km to the north (Figure 20). This is consistent with the regional and local variation in the slope of the seabed of the inner-shelf regions. The depth at the State coastal waters boundary in the region also varies from around 60 m up to close to 100 m depth.

Multibeam data coverage for the Illawarra region is similar to the Hunter region to the north (Figure 20), with the western two-thirds of the declared area poorly covered by multibeam data. Data coverage on the continental slope is more extensive and continuous. In contrast, coverage on the continental shelf is limited to the eastern third of the declared area and to narrow swaths of data derived from vessel transits. High resolution multibeam coverage is available for several areas on the inner shelf in the region, mostly in depths <60 m (Jordan et al., 2010, Linklater et al., 2019). LiDAR data is also available as a combined gridded terrestrial (elevation) and subtidal marine (bathymetry) data at 5 x 5 m (horizontal resolution) Geotifs (State Government of NSW and NSW DCCEEW, 2019). These datasets provide detail on the interface between coastal headland/outcrop and littoral zone, including the distribution of unconsolidated sediment concealing bedrock on the inner continental shelf.

A focused hydrographic survey for the region between Port Kembla and Port Botany is scheduled for the first half of 2025 as part of the the HydroScheme Industry Partnership Program (HIPP) (https://www.hydro.gov.au/NHP/). The survey area (SI 1050) is defined as 621 NM^2, and extends across the continental shelf to depths of ~300 m.

5.2. Seabed geology

The configuration of the southeast NSW continental shelf is largely the result of rifting associated with the opening of the Tasman Sea during the late Mesozoic (Weissel and Hayes, 1977; Gaina et al., 1998). This rifting progressed south-to-north, modifying elements of the Lachlan Orogen which shaped both the Illawarra and Hunter regions. As such, the known structure and stratigraphy of the continental shelf of the two regions are largely similar (Thom et al., 2010; Figure 21).

The modern southeast NSW continental shelf is considered narrow and sediment-starved, with exposed bedrock (as extensions of headlands/promontories of the coastal plain) grading into the Tasman Sea Basin beneath a shelf sediment veneer (Thom and Roy, 1981). Shelf sediment, an amalgamated Cenozoic sediment wedge, onlaps bedrock close to the inner shelf and progressively conceals its structural variable architecture seaward. Limited published seismic data is available; however, a regionally identified ‘bedrock reflector’ beneath the inner shelf (characteristic of the southeast continental shelf of NSW; see Figure 22) persists beneath shelf sediments of the Illawarra Region (Thom et al., 2010). This suggests shallow bedrock is likely found beneath the inner and outer shelf with localised variability. Sub-horizontal reflectors that transition from conformable to unconformable, and typically thin beneath the outer shelf and upper slope are reported (Marshall, 1979), indicating typical shelf depositional processes.

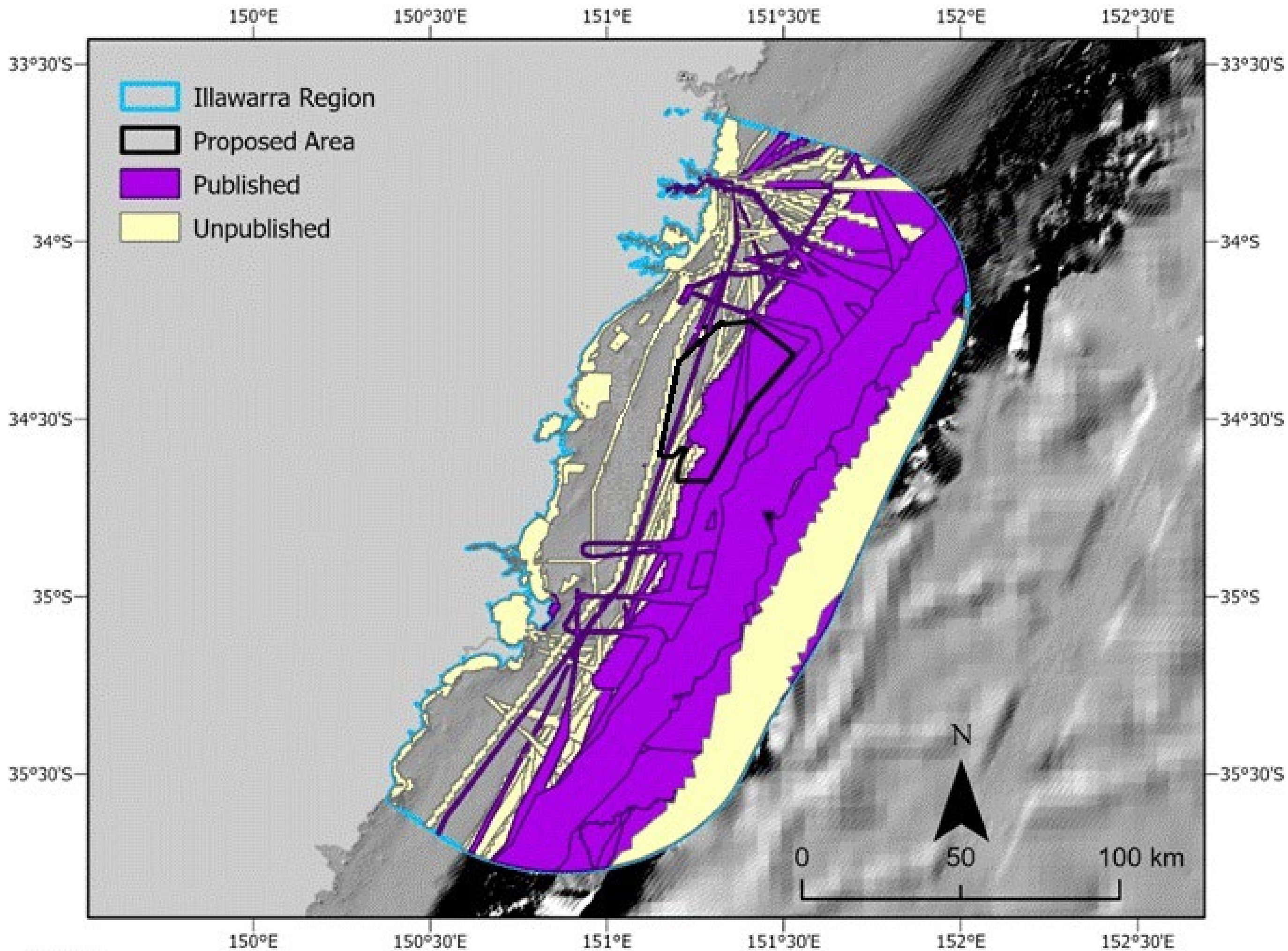


Figure 20. Bathymetry coverage for the Illawarra Region (defined by blue polygon) showing the spatial extent of bathymetry data (published and unpublished), including nearshore LiDAR data. Data extents are provided by third party contributors to the AusSeaBed Data Portal (listed in the Marine Baseline Data Inventory). Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

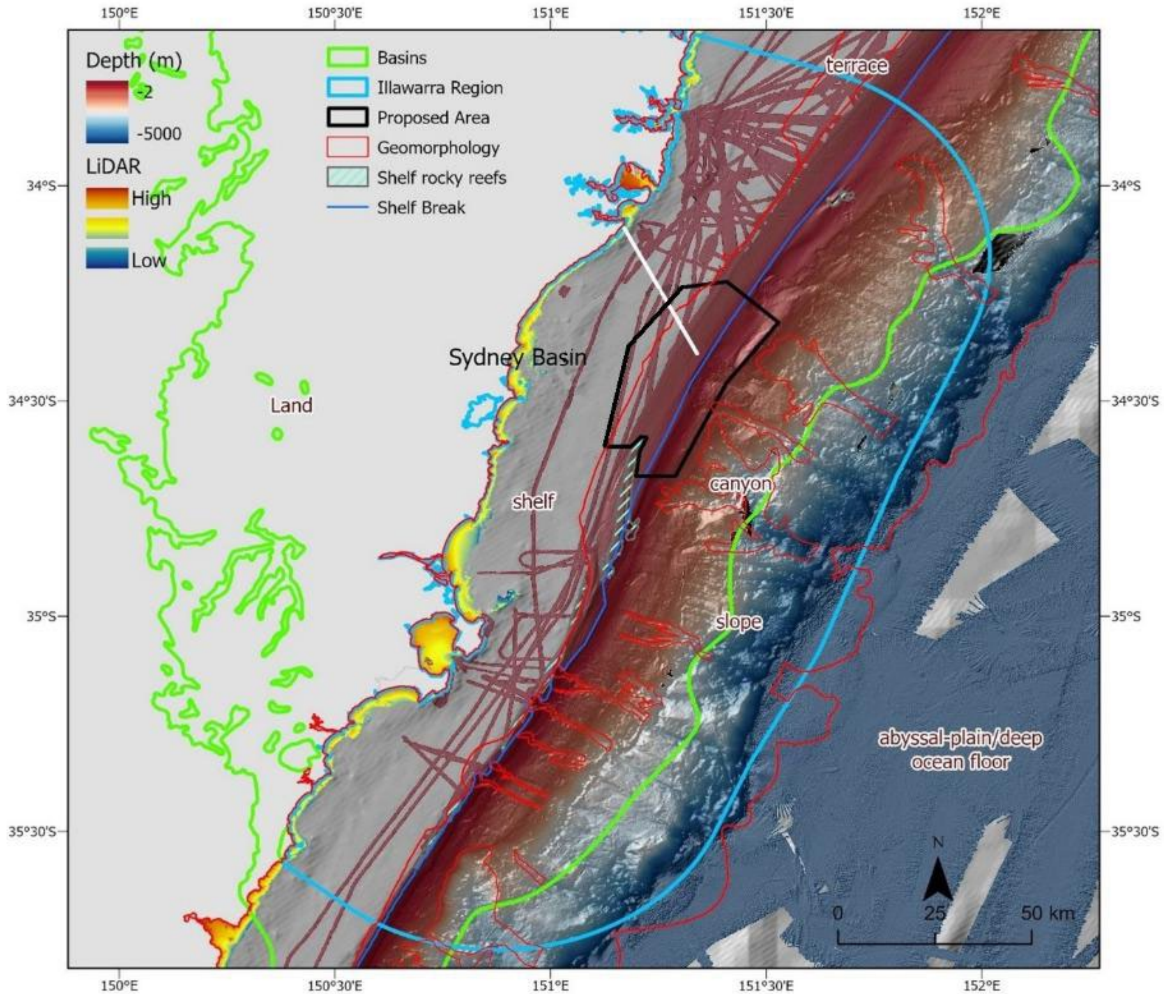


Figure 21: The Illawarra proposed area (black polygon) and the regional area (blue polygon), the shelf rocky reefs (key ecological feature), regional geology (green polygon) and geomorphology (red polygons; Heap and Harris, 2008), over the nearshore LiDAR 5 m and regional 50 m bathymetry grid (Parums and Spinoccia, 2019). The location of the cross-shelf seismic profile presented in Figure 22 is indicated by the white line. Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

The extensive bedrock platforms on the inner shelf are an abraded platform, and likely to result from wave action eroding the bedrock outcrops over several sea level cycles throughout the Paleozoic to Mesozoic (Linklater et al., 2019).

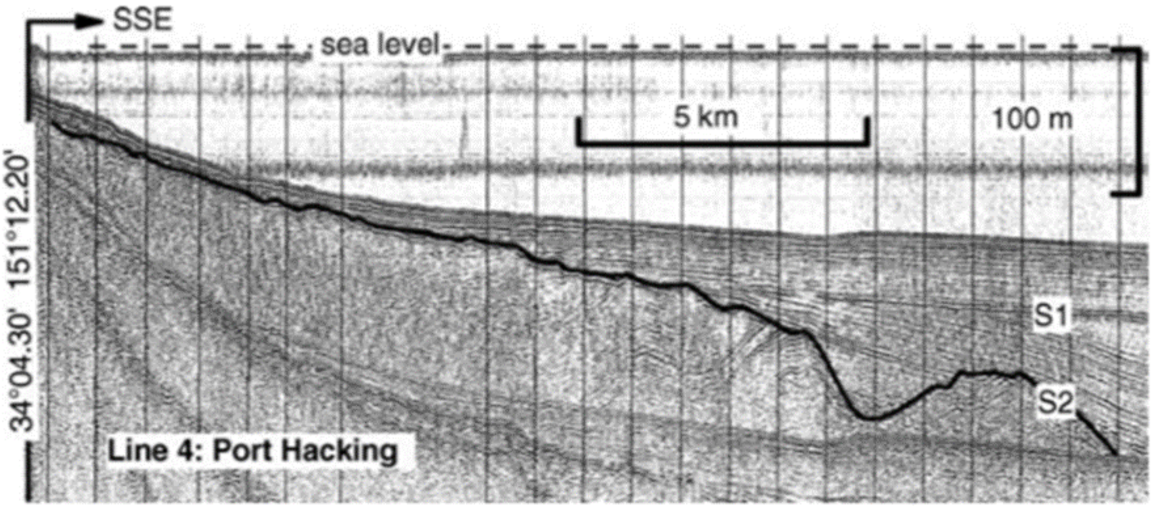


Figure 22. Seismic profile extending offshore to the southeast from Port Hacking in the northern portion of the Illawarra region. Data shows the southern continuation of shallow bedrock identified in the Hunter region immediately to the north also showing buried rock surface (S2, bold line) beneath modern sediment cover. Note – deeper reflectors are multiples of the seabed and buried rock surface. (Reproduced from Thom et al., 2010; see Figure 21 for location of seismic profile)

5.3. Seabed geomorphology

The Illawarra region spans, from west to east, the lower gradient outer continental shelf (< 2 degrees; 25 km wide) and the steeper continental slope (60 km wide; Heap and Harris, 2008). The southern margin of the declared area within the Illawarra abuts a narrow strip of outer shelf rocky reefs listed as Key Ecological Features (KEFs; 'Shelf Rocky Reef KEF'; DCCEEW, 2023b). On the continental slope, several submarine canyons are mapped, including four that are also recognised as KEFs ("Canyons on the eastern continental slope" KEF that are situated 1.5 – 5 km east of the Declared area; Parks Australia, 2023) (Figure 21).

Revised mapping of the canyons by Huang et al. (2014) shows that several of the canyons extend beyond their mapped KEF limits and into the declared area (Figure 21). Multibeam data also reveal large mass movements within the eastern portion of the area. These include NSW largest submarine slides (Bulli Slide and Shovel Slide; Power et al., 2015); these mass movements and the canyons have the potential for significant seafloor instability (Boyd et al., 2010; Power et al., 2015). It is likely that the steeper parts of the canyons (i.e. canyon heads), mass movement headwalls and the rocky reefs within the area provide important habitat for benthic communities (habitat-forming sponge communities, hard and soft corals etc.). At a local scale the seabed on the inner shelf offshore of Wollongong is dominated by relatively planar rocky reefs interspersed with mostly sandy sediments that form irregular plains in lower areas of seabed (Linklater et al., 2019).

5.4. Sedimentology

Surficial sediment within the Illawarra Region, enhanced by the south flowing EAC (Boyd et al., 2004), fines and thickens from north to south. Terrigenous sediment, sourced from the adjacent hinterland/coastal plain, dominates the littoral zone with a north directed longshore drift. Carbonate content and grainsize increase seaward. Inventory of surficial sediment samples from the continental shelf and slope within the region are sparse but are universally comprised of relatively coarse material (mostly sand to gravel size: Geoscience Australia, 2023; Figure 23). Nearshore sediment transport is towards the north under the influence of wave-generated currents (Roy and Thom, 1981; Boyd et al., 2010). However, the embayed configuration of the coastline limits the extent of sediment transport between sediment compartments.

The deeper shelf and slope region of the Illawarra region is more likely impacted by the southerly-flowing EAC (Boyd et al., 2010). Mapping and sediment analyses focused on the seafloor up to 10 km from the coast (Linklater et al., 2019; Kinsela et al., 2023) indicate that the shelf is characterised by bedrock platforms ("reef") and patches of sand to gravel size sediment that have partially infilled ancient bedrock valleys. Sand and gravel have also accumulated in localised patches in that area; both bedrock "reefs" and sediment patches may characterise the seabed within the unmapped portions of the area.

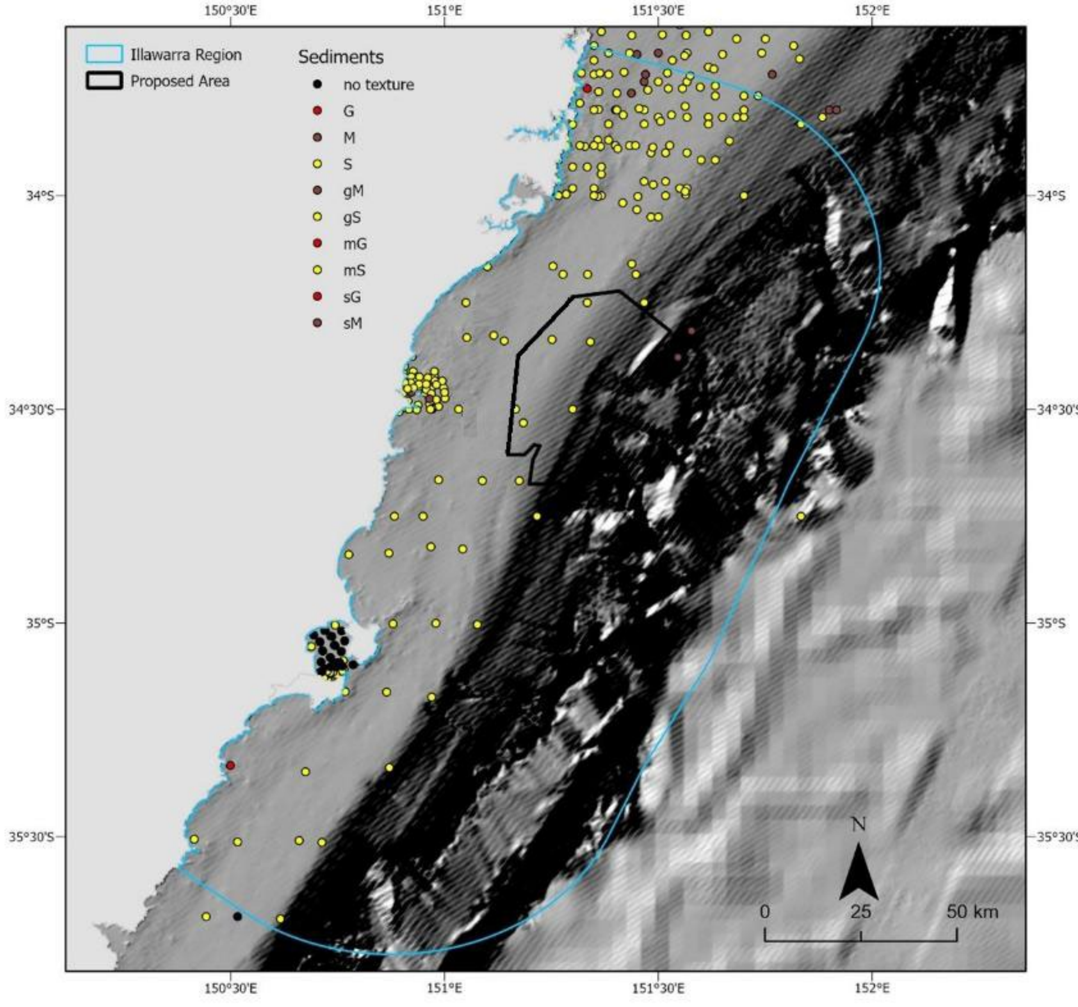


Figure 23. Map of seabed sediment samples for the Illawarra region held in the MARS database, showing sediment texture at sample sites. Sediment sample textures (primary, secondary): G, g – gravel; S, s – sand; M, m – mud (MARS: Geoscience Australia, 2024). Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

Overall, much of the shelf of the Illawarra region is dominated by clastic sediments on the inner-shelf grading to coarse dominated sediments on the outer shelf (Davies 1979). There is a distinct difference in sediment composition north and south of Jervis

Bay, with considerable cross-shelf and along-shelf variations evident in the north (Figure 23). Overall, some of this variability is a function of the difference in data density along the coast resulting in greater uncertainty in areas of low sample density. There are also distinct areas of coarser sediment on the inner shelf immediately north of Port Jackson, Wollongong, and Kiama and on the inner shelf and outer shelf north and east of the Port Stephens region (Figure 23).

5.5. Seabed habitats and benthic biodiversity

The inner shelf of the Illawarra region contains considerable area of rocky reef that are either outcropping or close to the surface, while the outer zone is the surface of a thick sediment wedge (Boyd et al., 2004; Jordan et al., 2010; Linklater et al., 2029)). Swath-mapping has revealed considerably more rocky reef throughout the inner shelf region than was defined previously from the broad-scale bathymetry. It is likely that much of the shallow reef in the region mapped using swath acoustics extends further offshore than currently defined. The ecology of the reefs and the structure of the biotic community is likely to be similar to that in the Hunter region (see Section 4.5).

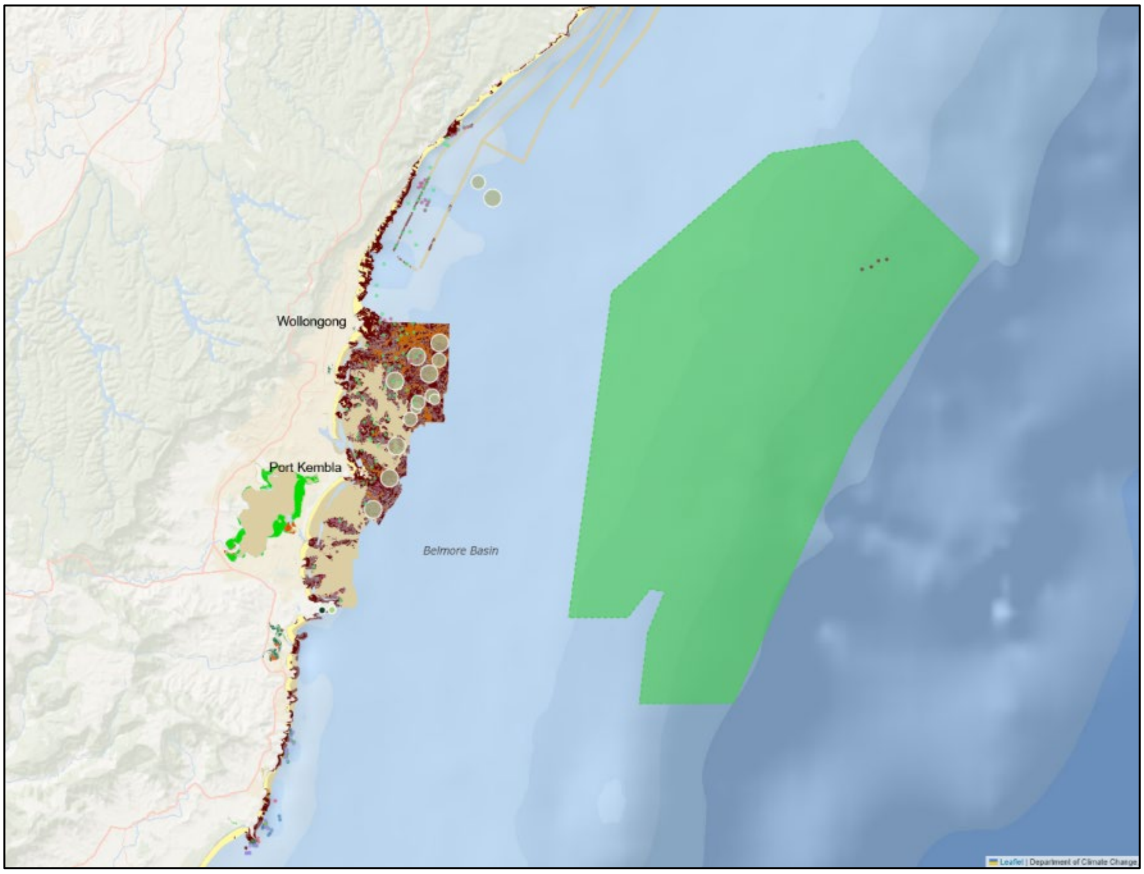


Figure 24: Available seabed ecological survey locations and habitat data for the Illawarra OWF region represented in the Seamap Australia marine spatial data portal, including survey locations using towed video, Autonomous Underwater Vehicles and Baited Remote Underwater Videos, represented as bubble plots. Details on habitat legend, deployment types and effort are available at:

https://seamapaustralia.org/map/#f069283a-7b05-4b95-bb83-2775740443f0

5.6. Oceanography

Oceanographic processes in the Illawarra OWF development region are similar to the Hunter Region. Tide range and maximum estimated currents are slightly reduced, and the outer shelf oceanography is still dominated by the EAC. The results of stratification analysis by Schaeffer et al. (2023) can be applied here also, with seasonal stratification fronts expected to cross the 50 m isobath during the year.

Wave energy in the OWF region is low to moderate (Hemer et al., 2018), but here the proximity of the OWF region to the coast increases the importance of assessing OWF impacts on coastal processes, although direct changes to coastal geomorphology are still expected to be low. The potential for infrastructure to generate turbid plumes may be important within the coastal side of the OWF and the potential for OWF to alter upwelling patterns should be assessed for any stratified (or seasonally stratified) section of the region.

5.7. Threatened and migratory marine species

All spatial layers from the fauna maps presented in text are available for viewing and download through the following map and table links. These are live documents that can be updated as new information is received.

Fauna Group		**OWF Area overlap**	**Tables of data**
	Cetaceans and pinnipeds	Map Link	Baleen, toothed, pinniped
	Birds	Map Link	Birds
	Sharks	Map Link	Sharks
	Reptiles (turtles)	Map Link	Reptiles

Note that information on finfish, invertebrates and other species of interest can be viewed in the separate inventory for the Illawarra region (Appendix B). This list is not comprehensive as it was not the focus of this study and therefore only a small subset of species are provided.

5.7.1. Cetaceans and pinnipeds

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of 17 published studies on cetaceans and 3 on pinnipeds overlapped with the Illawarra OWF area (Figure 25). The majority of those studies were on humpback whales (*Megaptera novaeangliae, n=4,* listed migratory under the EPBC Act) and southern right whales (*Eubalaena australis, n=4,* listed endangered under the EPBC Act) and with two studies on killer whales (*Orcinus orca*, listed migratory under the EPBC Act), blue whales (*musculus* subspecies, listed endangered under the EPBC Act) and Australian fur seal (*Arctocephalus pusillus doriferus*, listed marine under the EPBC Act) and one study for each of pygmy right whale (*Caperea marginata*), common dolphin (*Delphinus delphis*), false killer whale (*Pseudorca crassidens*), Indo-pacific bottlenose dolphin (*Tursiops aduncus*), *Tursiops spp* and long-nosed fur seal *(Arctocephalus forsteri)*. The overlap occurred across most of the OWF area for southern right whale, Antarctic blue whale, humpback whales, killer whales and common and bottlenose dolphin species (Figure 25, Table 9, and Table 10) and overlap of around two thirds for Australian fur seals (only one study found that showed very small overlap for long nosed fur seal) (Figure 27, Table 11).

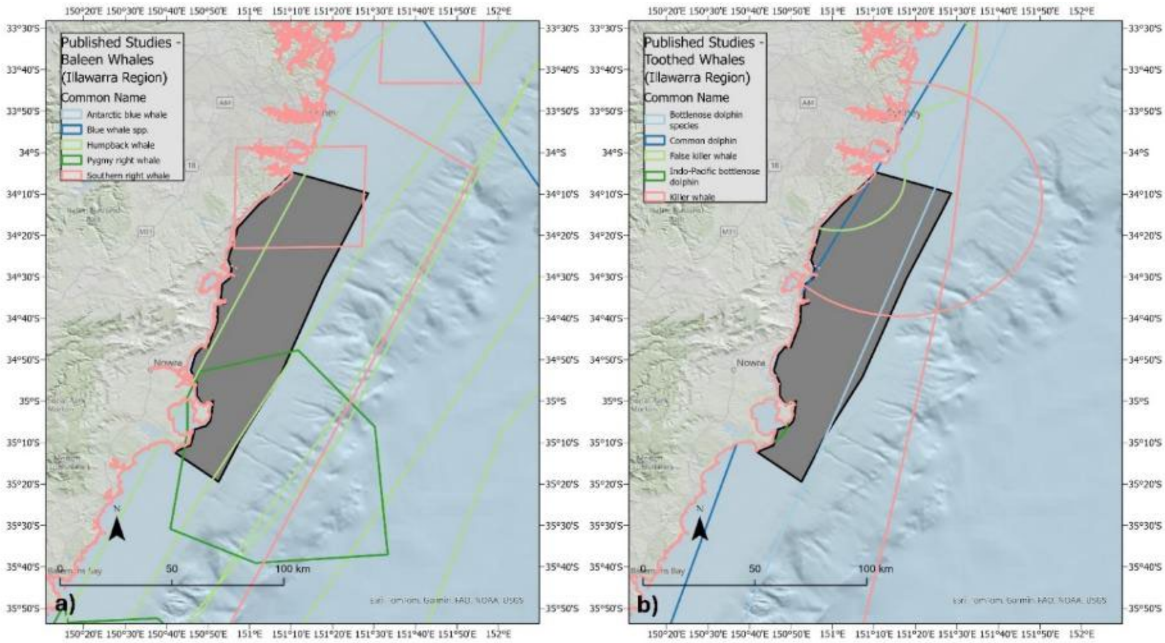


Figure 25. The Illawarra OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where baleen whales (a) and toothed whales (b) occurred. The different species are represented by the different colours.

Existing freely available species observation data

Overlaying observations of the priority (and secondary priority) cetacean species from ALA, and OBIS with the Illawarra OWF region (Figure 26), showed that baleen whales were observed over inshore and offshore (mostly humpback whales, n=434) (Table 9) areas and that toothed whales were more commonly observed inshore with little overlap with the Illawarra OWF area (Figure 26) and the toothed whale species with the highest numbers of observations were common dolphins (n=107), Gray's beaked whale (n=121) and Indo-pacific bottlenose dolphin (n=78) (Table 10).

For the pinniped species observations within the Illawarra OWF, the vast majority were Australian fur seals which had overlap across the majority of the OWF region (Figure 27) with 1145 observations (Table 11).

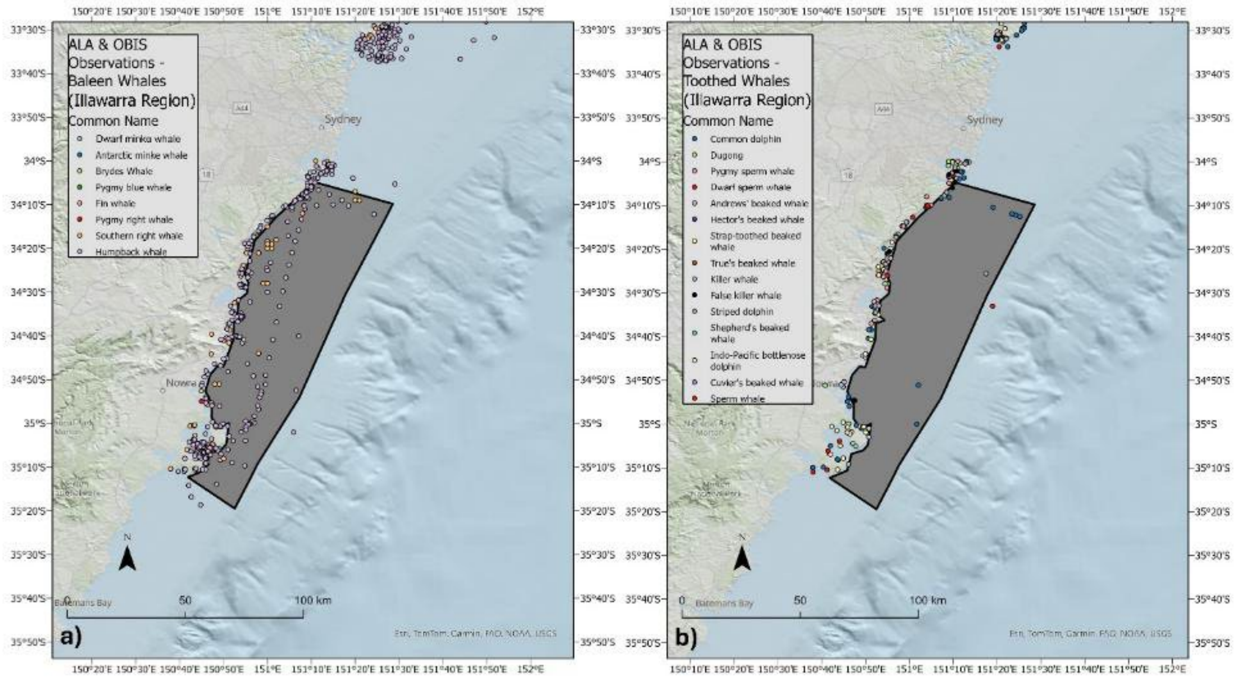


Figure 26. Observations of baleen (a) and toothed (b) whales from the Australian Living Atlas (ALA) and the Ocean Biodiversity Information System (OBIS) across the Illawarra OWF (grey polygon). The different species are represented by the different colours.

Table 9. Baleen whale species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Illawarra OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Illawarra baleen cetacean Table link

Illawarra OWF: Cetaceans (baleen)

			AREA AS % OF OWF		OBSERVATION COUNTS	SEASONALITY												NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Southern Right Whale *Eubalaena australis*	Balaenidae -	Endangered	100	100	70													4
Antarctic Blue Whale *Balaenoptera musculus intermedia*	Balaenopteridae -	Endangered	100	100	0													1
Pygmy Blue Whale *Balaenoptera musculus brevicauda*	Balaenopteridae -	Endangered	100		0													0
Fin Whale *Balaenoptera physalus*	Balaenopteridae -	Vulnerable	89		14													0
Bryde's Whale *Balaenoptera edeni*	Balaenopteridae -	Migratory	100		1													0
Dwarf Minke Whale *Balaenoptera acutorostrata subsp.*	Balaenopteridae -	Migratory	100		34													0
Humpback Whale *Megaptera novaeangliae*	Balaenopteridae -	Migratory	100	100	434													4
Pygmy Right Whale *Caperea marginata*	Cetotheriidae -	Migratory	99	26	5													1

Table 10: Toothed whale species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Illawarra OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. Note that for all the toothed whales there is limited data on seasonality, and they may be present year round. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Illawarra toothed cetacean Table link

Illawarra OWF: Cetaceans (toothed)

			Area as % of OWF		Observation counts	Seasonality												Number
Species	**Family Occurence**	**EPBC Status**	**SNES**	**PUBS**	**OBIS-ALA**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**PUBS**
Killer Whale *Orcinus orca*	**Delphinidae** -	Migratory	100	100	10													2
Sperm Whale *Physeter macrocephalus*	**Physeteridae** -	Migratory	52		35													0
Bottlenose Dolphin Species *Tursiops spp.*	**Delphinidae** -	Cetacean	100	89	0													1
Common Dolphin *Delphinus delphis*	**Delphinidae** -	Cetacean	100	95	107													1
False Killer Whale *Pseudorca crassidens*	**Delphinidae** -	Cetacean	24	10	15													1
Indo-Pacific Bottlenose Dolphin *Tursiops aduncus*	**Delphinidae** -	Cetacean	58	0	130													1
Long-Finned Pilot Whale *Globicephala melas*	**Delphinidae** -	Cetacean	52		27													0
Striped Dolphin *Stenella coeruleoalba*	**Delphinidae** -	Cetacean	0		30													0
Dwarf Sperm Whale *Kogia sima*	**Kogiidae** -	Cetacean	52		2													0
Pygmy Sperm Whale *Kogia breviceps*	**Kogiidae** -	Cetacean	52		27													0
Andrew's Beaked Whale *Mesoplodon bowdoini*	**Ziphiidae** -	Cetacean	52		6													0
Gray's Beaked Whale *Mesoplodon grayi*	**Ziphiidae** -	Cetacean	2		11													0
Strap-Toothed Beaked Whale *Mesoplodon layardii*	**Ziphiidae** -	Cetacean	52		11													0

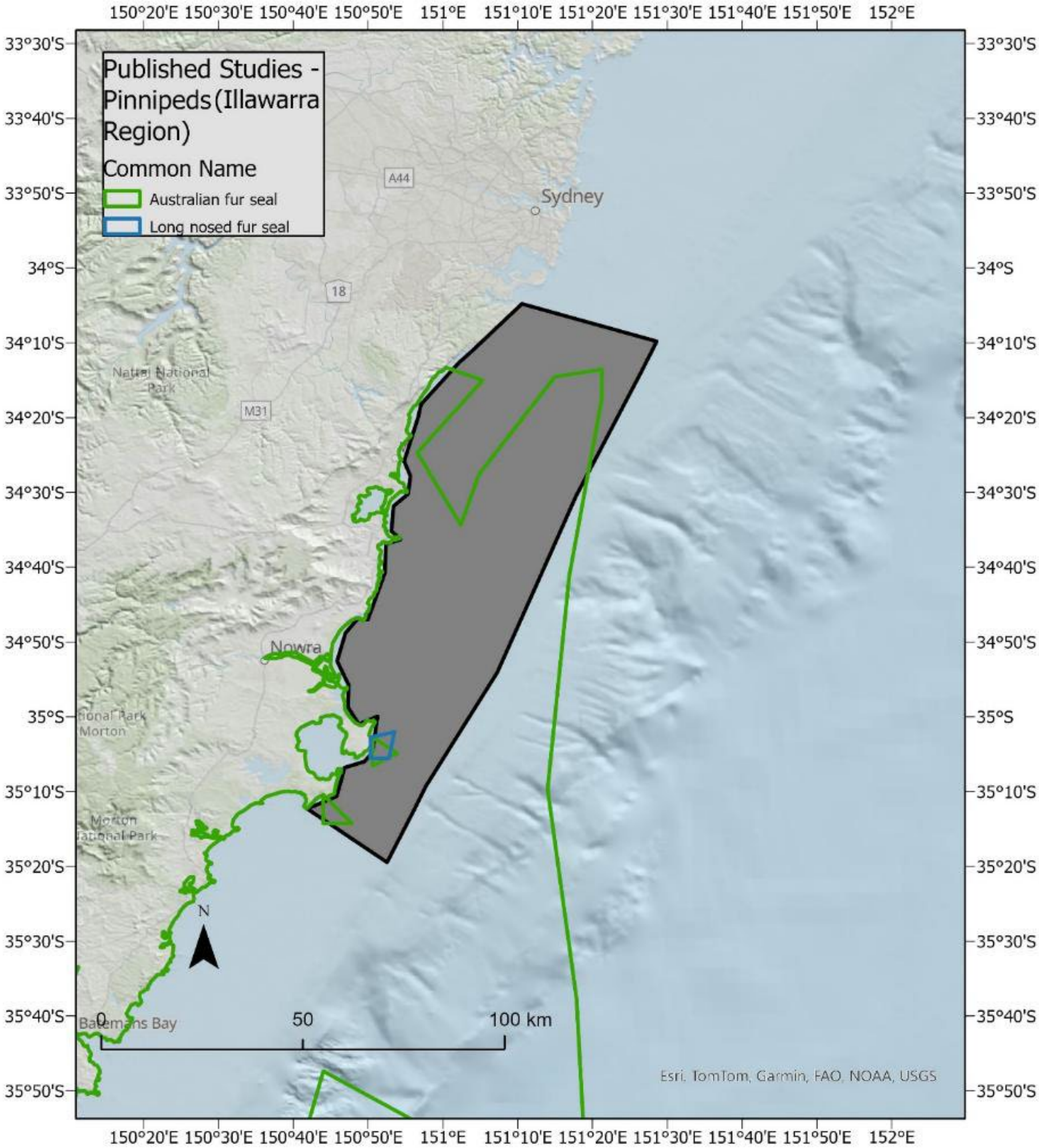


Figure 27. Polygons within the Illawarra OWF region showing the spatial coverage of the study areas from the publication inventory where pinnipeds occurred. The grey polygon shows the study region for the Illawarra OWF.

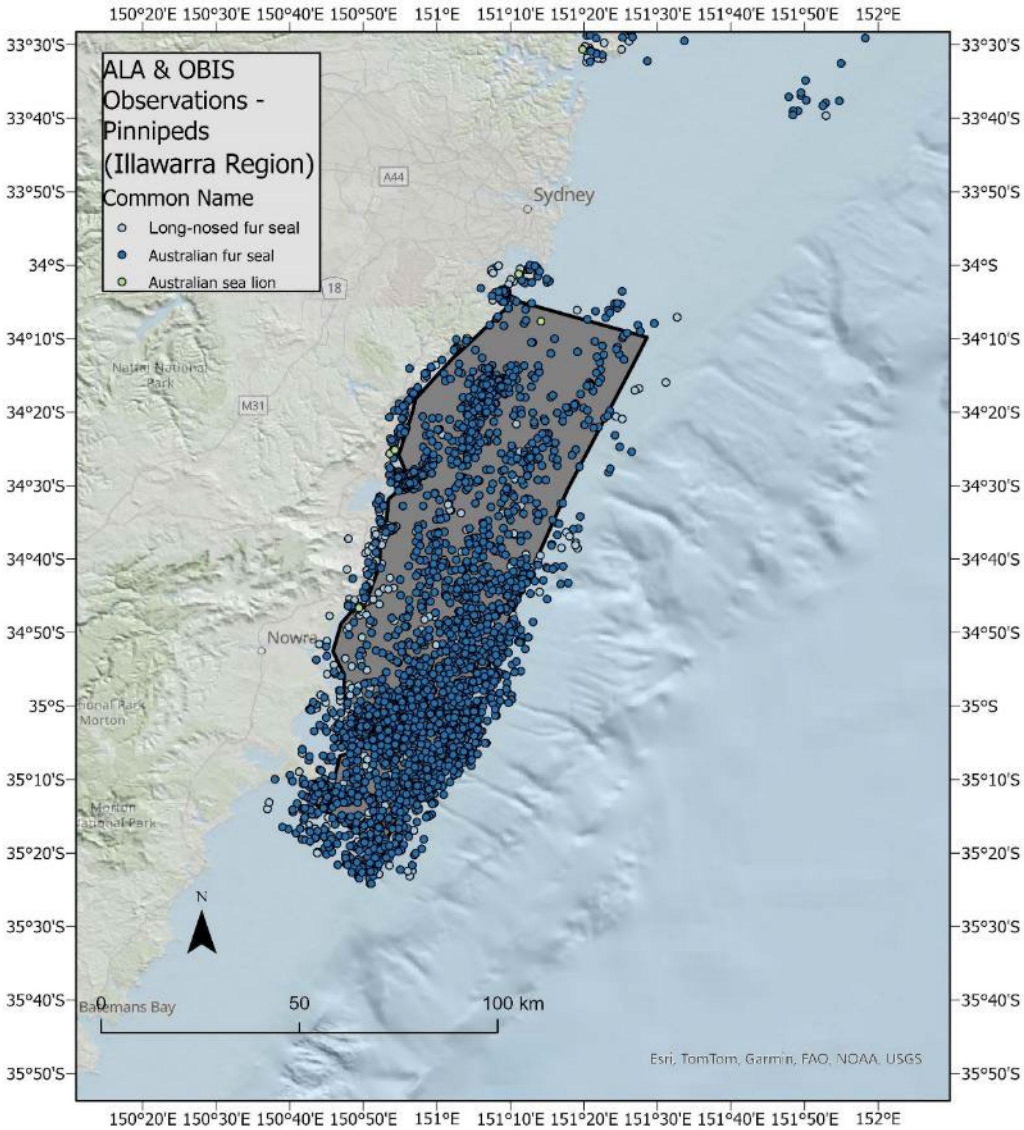


Figure 28. Observations of pinnipeds within the Illawarra wind energy zone (grey polygon). The different colours represent the different species.

Table 11. Pinniped species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Illawarra OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Illawarra pinniped Table link

Illawarra OWF: Pinniped

			AREA AS % OF OWF		OBSERVATION COUNTS	SEASONALITY												NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Australian Sea Lion *Neophoca cinerea*	Otariidae -	Endangered	0		11													0
Australian Fur-Seal *Arctocephalus pusillus doriferus*	Otariidae -	Marine	54	75	8198													2
Long Nosed Fur Seal *Arctocephalus forsteri*	Otariidae -	Marine	54	1	639													1

5.7.2. Birds

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of 16 published studies on bird species of interest overlapped with the Illawarra OWF area (Figure 29). The majority of those studies were on albatrosses (10) with two studies on waders (2) and one study each for terns, petrels, shearwaters, and parrots. Overlap between the study area polygons and the Illawarra OWF was highest for several of the albatross species, short-tailed shearwater and swift parrot. Regarding the latter, although the polygon for swift parrots had total overlap with the OWF area, the actual locations that swift parrots were observed in the polygon were all on land (Saunders et al., 2017). The study area polygons for the Australian bar-tailed godwit and the Australian fairy tern also had overlap with the OWF region but this was relatively low.

Species study areas that overlapped with the Illawarra OWF area included one critically endangered under the EPBC Act (swift parrot *Lathamus discolor*) and two endangered bird species under the EPBC Act (shy Albatross *Thalassarche cauta* and Gould's petrel *Pterodroma leucoptera*). The remaining species in the inventory are made up of species listed as vulnerable under the EPBC Act and other species identified as of interest due to their migratory behaviour or potential interactions with wind farms in the region (Table 12).

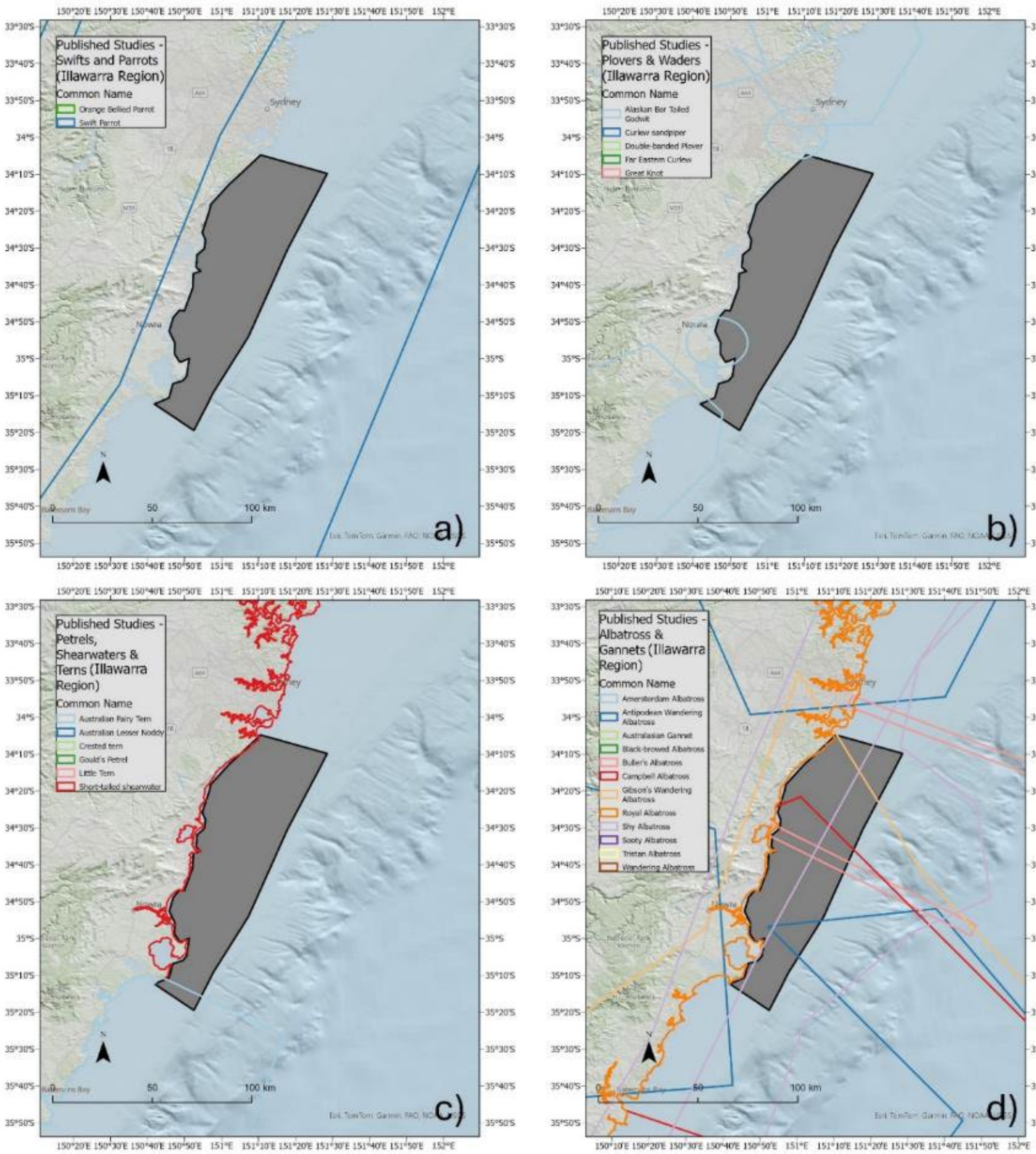


Figure 29. The Illawarra OWF region (grey polygon) showing the spatial coverage of the study areas where bird species occurred with separate maps for each species group (a-d). The different species are represented by the different colours.

Table 12. Bird species for which we have compiled spatial data from published studies and freely available data repositories (BLA, OBIS and ALA) that overlap with the Hunter OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Illawarra bird Table link

Illawarra OWF: Bird

			Area as % of OWF		Observation counts		Seasonality	Number
Species	Family / Occurence	EPBC Status	SNES	PUBS	BLA	OBIS-ALA	J F M A M J J A S O N D	PUBS
Tristan Albatross *Diomedea dabbenena*	Diomedeidae Vagrant	Critically Endangered	0		1	0		0
Orange-Bellied Parrot *Neophema chrysogaster*	Psittacidae Rare	Critically Endangered	1		0	9		0
Swift Parrot *Lathamus discolor*	Psittacidae Rare	Critically Endangered	1	100	14	174		1
Curlew Sandpiper *Calidris ferruginea*	Scolopacidae Common	Critically Endangered	100		105	835		0
Far Eastern Curlew *Numenius madagascariensis*	Scolopacidae Common	Critically Endangered	100		557	5147		0
Great Knot *Calidris tenuirostris*	Scolopacidae Common	Critically Endangered	0		50	826		0
Lesser Sand Plover *Charadrius mongolus*	Charadriidae Rare	Endangered	0		72	651		0
Chatham Albatross *Thalassarche eremita*	Diomedeidae Vagrant	Endangered	100		0	0		0
Northern Royal Albatross *Diomedea sanfordi*	Diomedeidae Common	Endangered	100		4	0		0
Shy Albatross *Thalassarche cauta*	Diomedeidae Common	Endangered	100	100	269	879		2
Gould's Petrel *Pterodroma leucoptera leucoptera*	Procellariidae Rare	Endangered	0	100	10	82		1
Southern Giant Petrel *Macronectes giganteus*	Procellariidae Rare	Endangered	100		65	229		0
Black-Tailed Godwit *Limosa limosa*	Scolopacidae Rare	Endangered	0		32	295		0
Red Knot *Calidris canutus*	Scolopacidae Common	Endangered	100		131	1513		0
White-Throated Needletail *Hirundapus caudacutus*	Apodidae Common	Vulnerable	1		110	793		0
Greater Sand Plover *Charadrius leschenaultii*	Charadriidae Rare	Vulnerable	1		21	159		0
Antipodean Wandering Albatross *Diomedea antipodensis antipodensis*	Diomedeidae Rare	Vulnerable	100	100	26	0		2
Black-Browed Albatross *Thalassarche melanophris*	Diomedeidae Common	Vulnerable	100		361	1665		0
Buller's Albatross *Thalassarche bulleri*	Diomedeidae Rare	Vulnerable	100	100	90	251		2
Campbell Albatross *Thalassarche impavida*	Diomedeidae Vagrant	Vulnerable	100	63	35	12		1
Gibson's Wandering Albatross *Diomedea antipodensis gibsoni*	Diomedeidae Rare	Vulnerable	100	100	0	9		2
Indian Yellow-Nosed Albatross *Thalassarche carteri*	Diomedeidae Common	Vulnerable	100		215	17		0
Royal Albatross *Diomedea epomophora*	Diomedeidae Common	Vulnerable	100	100	7	13		1
Salvin's Albatross *Thalassarche salvini*	Diomedeidae Vagrant	Vulnerable	100		1	5		0
Sooty Albatross *Phoebetria fusca*	Diomedeidae Rare	Vulnerable	100		3	11		0
Wandering Albatross *Diomedea exulans*	Diomedeidae Rare	Vulnerable	100		186	4409		0
White-Capped Albatross *Thalassarche steadi*	Diomedeidae Rare	Vulnerable	100		0	0		0
Fairy Tern *Sternula nereis*	Laridae Common	Vulnerable	0		21	0		0
Northern Giant Petrel *Macronectes halli*	Procellariidae Vagrant	Vulnerable	100		54	228		0
Blue-Winged Parrot *Neophema chrysostoma*	Psittacidae Common	Vulnerable	1		2	2		0
Alaskan Bar-Tailed Godwit *Limosa lapponica*	Scolopacidae Common	Vulnerable	2	6	848	6684		2
Little Penguin *Eudyptula minor*	Spheniscidae Common	Marine	0		77	13736		0
Little Tern *Sternula albifrons*	Laridae Common	Migratory	1		335	4960		0
Short-Tailed Shearwater *Ardenna tenuirostris*	Procellariidae Common	Migratory	0	100	212	1813		1

Existing freely available species observation data

Observations of birds within the Illawarra OWF region from BirdLife Australia, ALA, and OBIS, showed that waders were the most numerous (17,023 observations), followed by penguins (13,813 observations), then albatrosses (8,119 observations). The remaining groups observed ranged from 12 observations (skuas) to 5,295 observations (terns) (Table 12).

The spatial distribution of bird observations within the Illawarra OWF region shows that bird species of interest had higher densities along the shore and in the central section of the area, including offshore (Figure 30).

As noted in the Methods section, most of these observations are based on opportunistic sightings so they do not represent a systematic survey of the region and there are clear biases towards ship tracks, especially the region in the centre of the OWF area. Albatrosses have been observed throughout the OWF with the wandering albatross (*Diomedea exulans*) and black-browed albatross (*Thalassarche melanophris*) the most sighted in the region. The endangered Tristan albatross (*Diomedea dabbenena*), northern royal albatross (*Diomedea sanfordi*) and shy albatross (*Thalassarche cauta*) have also been observed in the region. The other critically endangered species under the EBPC Act that have been observed in and around the Illawarra OWF include the far eastern curlew (*Numenius madagascariensis*), curlew sandpiper (*Calidris ferruginea*), great knot (*Calidris tenuirostris*), swift parrot (*Lathamus discolor*), and orange-bellied parrot (*Neophema chrysogaster*). Additional species listed as endangered under the EPBC Act include red knots (*Calidris canutus*), lesser sand plover (*Charadrius mongolus*), southern giant-petrel (*Macronectes giganteus*), and Gould's petrel (*Pterodroma leucoptera leucoptera*).

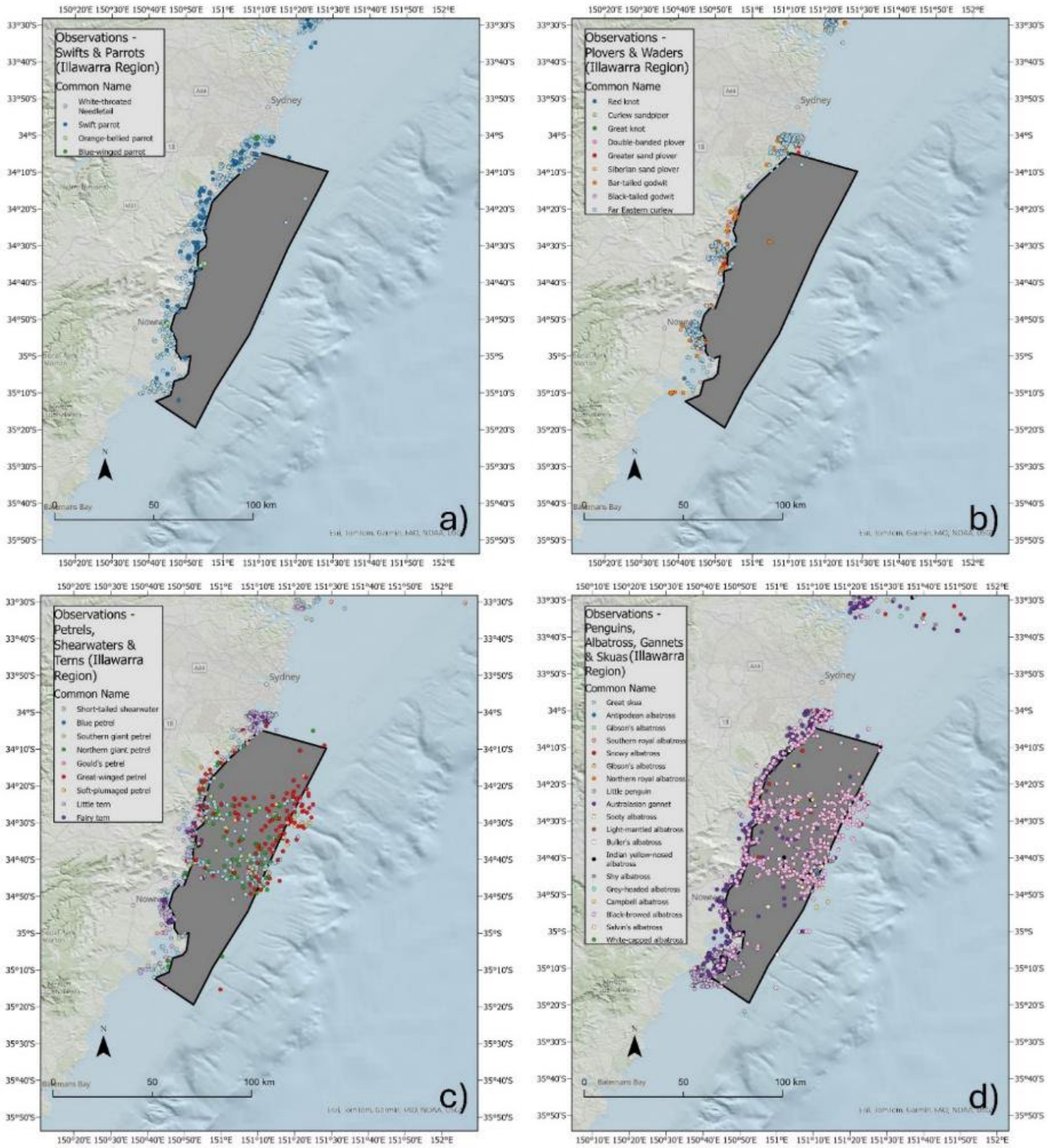


Figure 30. The Illawarra OWF region (grey polygon) showing observations of bird species from BirdLife Australia, the ALA, and the OBIS for each bird grouping (a-d). The different species are represented by the different colours.

5.7.3. Sharks

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of 19 paper/reports on shark species listed under the EPBC Act overlapped with the Illawarra OWF area (Figure 31). Of the nineteen studies, 13 were on white sharks (*Carcharodon carcharias,* vulnerable under the EPBC Act) and six were on the grey nurse shark (*Carcharias taurus,* critically endangered under the EPBC Act) which had 100% overlap with the Illawarra OWF area (3,955 km^2). Seasonality information collected for this species suggests that the grey nurse shark may be present in the Illawarra OWF area between March and December, while the white shark may be present between May and December (Table 13).

Table 13: Shark species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Illawarra OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Illawarra shark Table link

Illawarra OWF: Shark

			Area as % of OWF		Observation counts	Seasonality												Number
Species	Family occurence	EPBC status	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Grey Nurse Shark *Carcharias taurus*	Odontaspididae -	Critically Endangered	100	100	435													6
White Shark *Carcharodon carcharias*	Lamnidae -	Vulnerable	100	100	178													11

Existing freely available species observation data

Overlaying observations of the listed shark species from the ALA and OBIS with the Illawarra OWF region showed grey nurse shark observations to be more numerous (435) than those of the white shark (178 observations) (Figure 32). Both species were sighted throughout Northern and Southern regions of the OWF. There was a higher density of sightings for the grey nurse shark inshore of the OWF boundary in the south, while white sharks were more dispersed along the coastline. Sightings were less numerous further offshore, however, many of the offshore locations had several observations of both species but at different time points where observations were entered into the public data repositories from different sightings, so the map seems to show fewer observations.

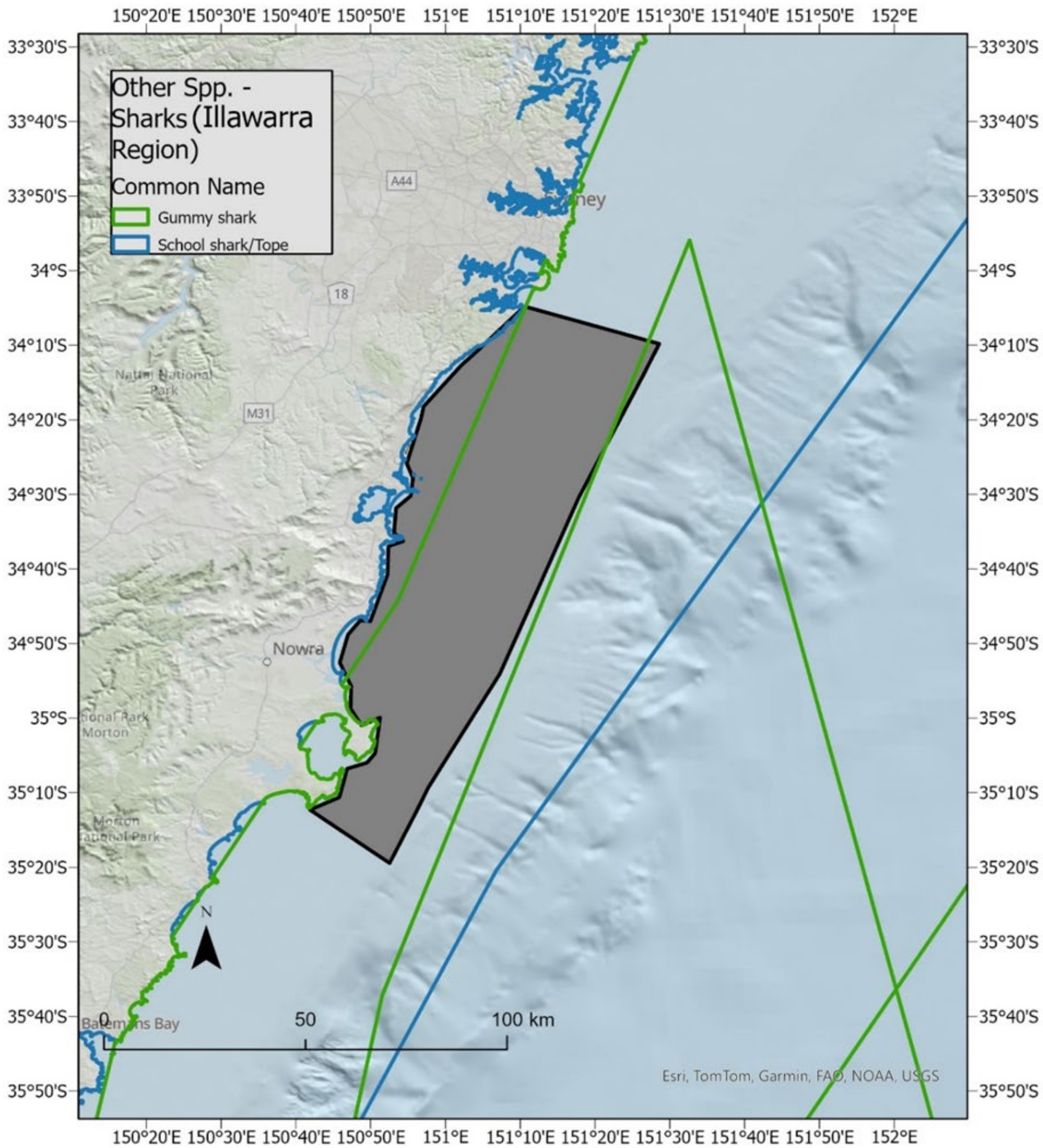


Figure 31. Polygons within the Illawarra OWF region showing the spatial coverage of the study areas where shark species occurred. The different species are represented by the different colours and the grey polygon shows the study region for the Illawarra OWF.

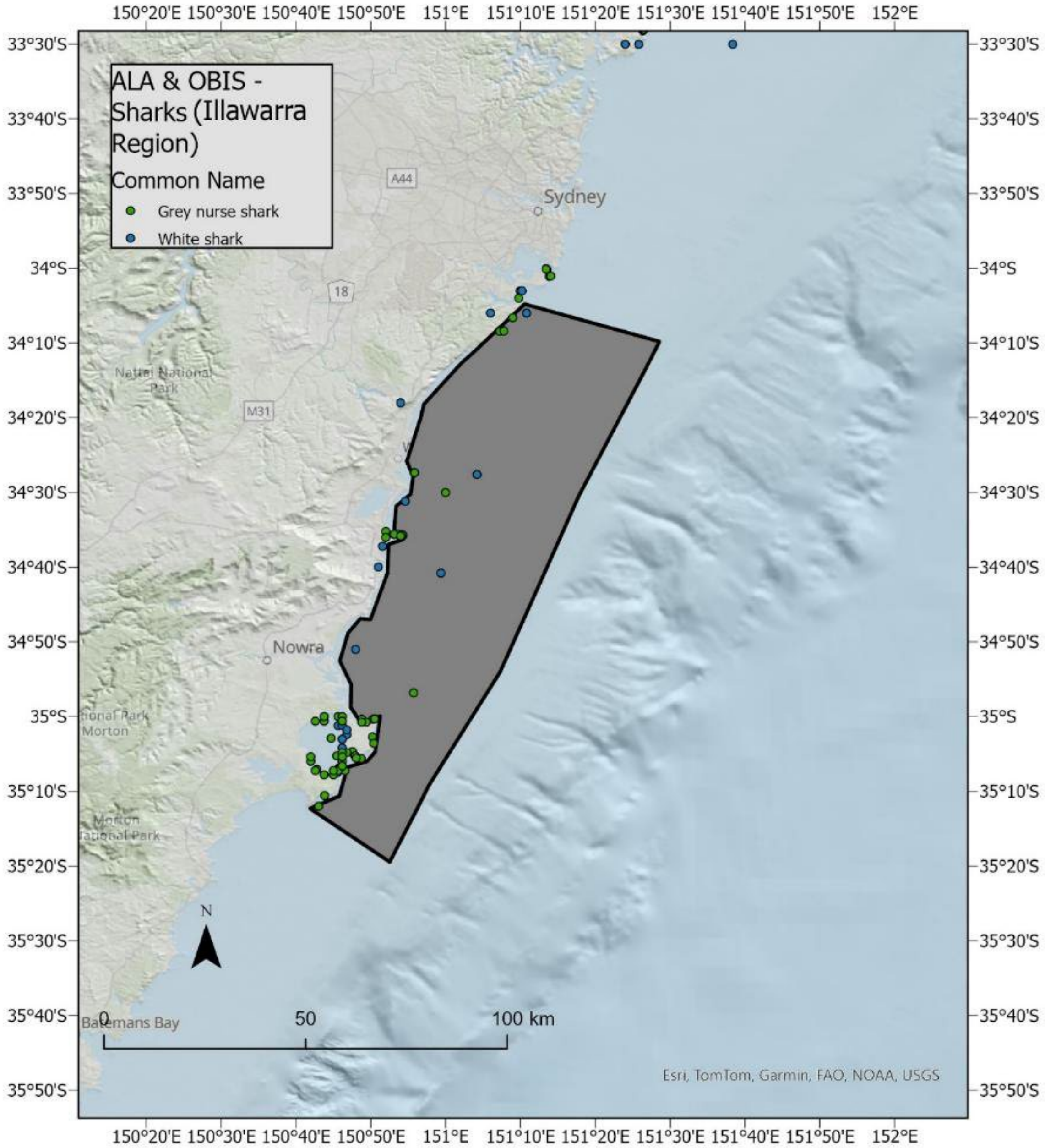


Figure 32. The Illawarra OWF region (grey polygon) showing observations of sharks from the ALA and the OBIS. The different species are represented by the different colours.

5.7.4. Reptiles

Published papers/reports inventory

Four published studies on listed reptile species that overlap with the OWF area were found and compiled in the inventory (Figure 33), which included three on leatherback turtle (*Dermochelys coriacea,* endangered under the EPBC Act) and one on loggerhead turtle (*Caretta caretta,* endangered under the EPBC Act). The study areas had high overlap with the Illawarra OWF area, with total overlap (3,955 km^2) for the loggerhead turtle and a slightly lower coverage (3,417 km^2) for the leatherback turtle. The SNES distribution map for loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), green (*Chelonia mydas,* vulnerable under the EPBC Act), flatback (*Natator* *depressus,* vulnerable under the EPBC Act), and hawksbill (*Eretmochelys imbricata,* vulnerable under the EPBC Act) turtles all overlapped the entire Illawarra OWF area.

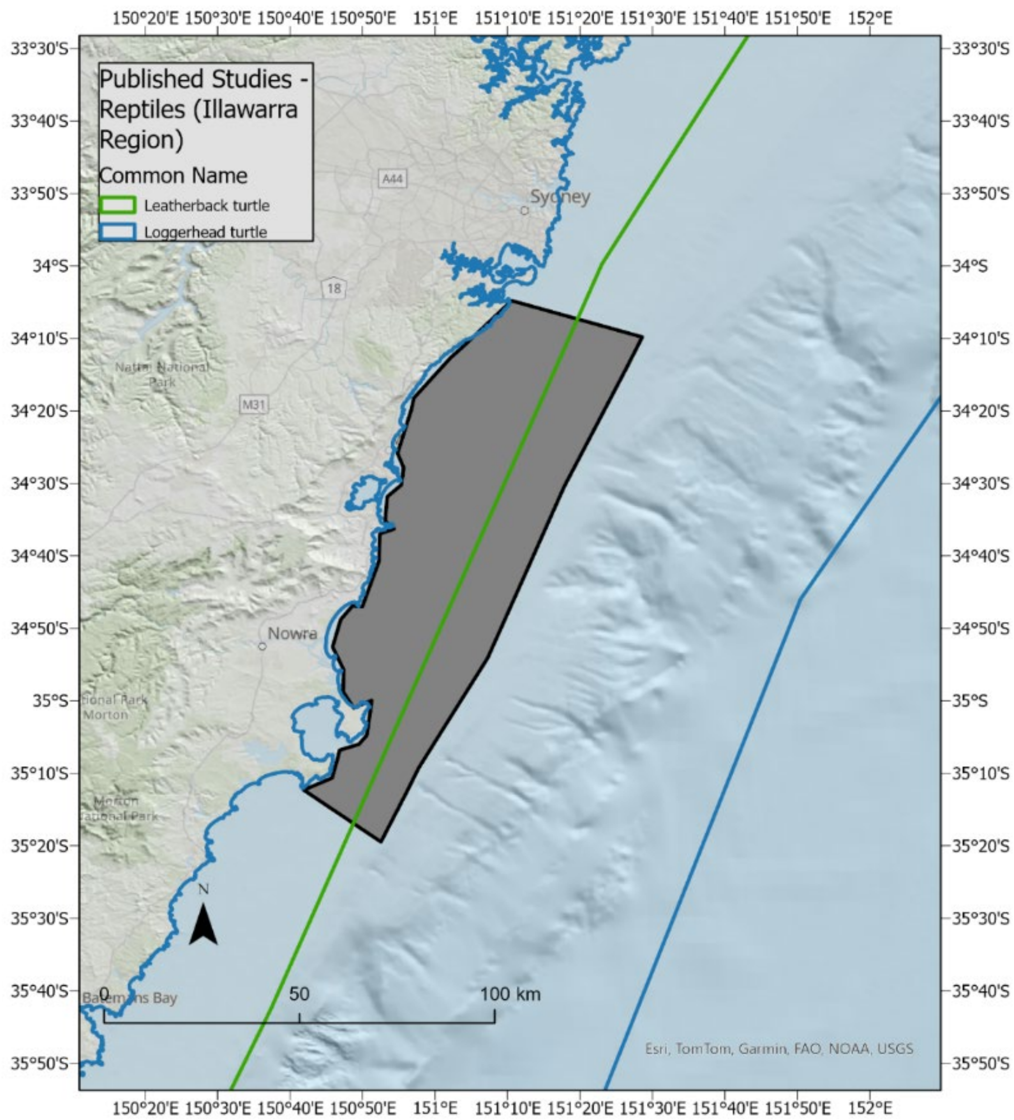


Figure 33. The Illawarra OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where listed reptile species occurred. The different species are represented by the different colours.

Existing freely available species observation data

Overlaying observations of listed reptiles from the ALA and OBIS with the Illawarra OWF region (Figure 34) showed the occurrence of five species of turtles with green turtle observations being the most numerous (310), followed by loggerhead (40 observations), leatherback (39 observations), hawksbill (26 observations) and flatback (21 observations) turtles (Table 14). Most of the sightings occurred between the coastline and the landward boundary of the OWF region. All species were present from north to south of the OWF region, but the vast majority occurred inshore of the OWF polygon with only a few green turtle sightings occurring offshore and within the OWF polygon (Figure). Therefore, although they may not be at risk within the OWF area there is the potential of interactions during transit to and from the sites within it.

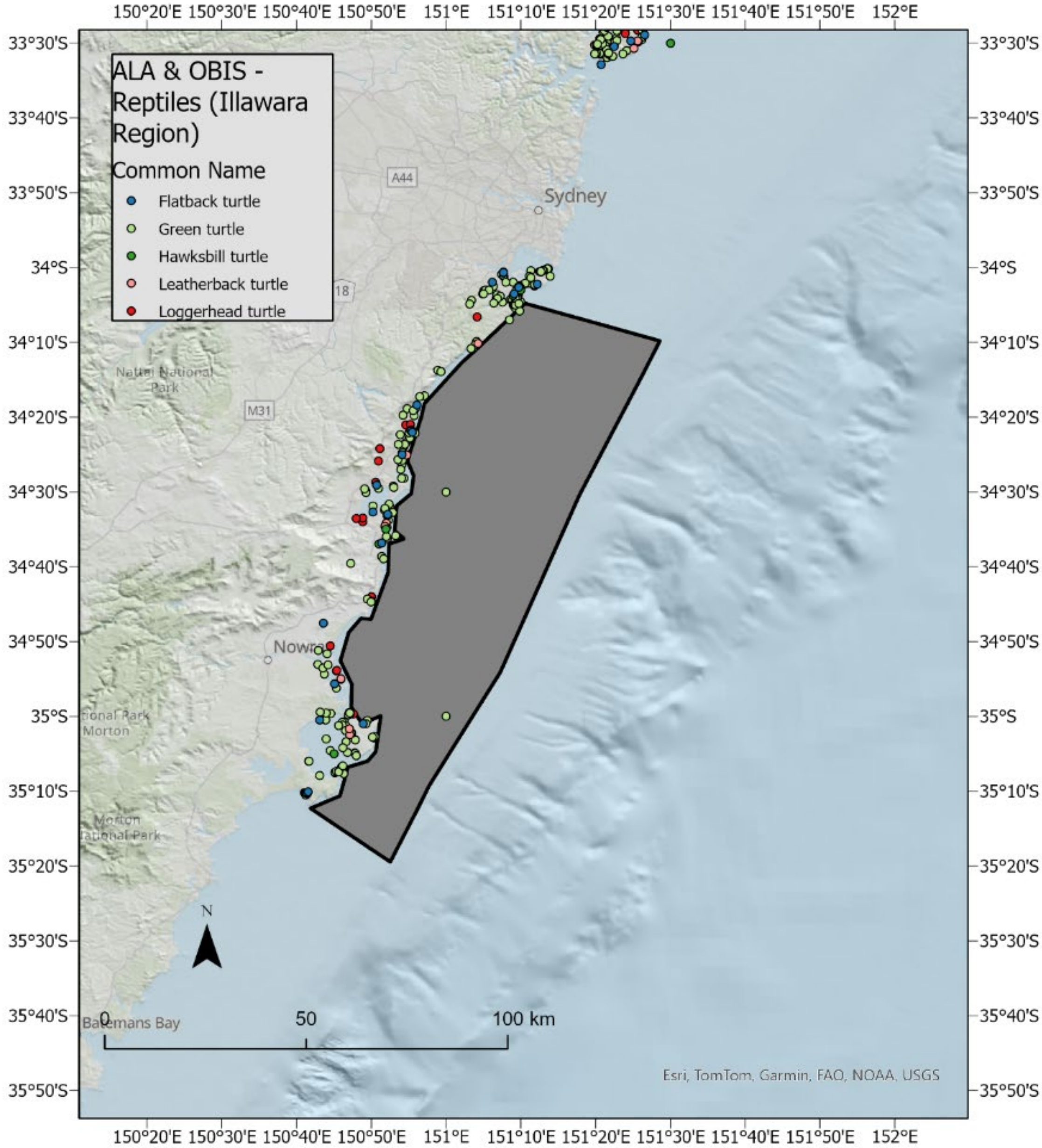


Figure 34. Observations of turtles from the ALA and the OBIS across the Illawarra OWF. The different species are represented by the different colours and the grey polygon shows the study region for the Illawarra OWF.

Table 14: Turtle species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Illawarra OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Illawarra reptile Table link.

Illawarra OWF: Reptile

			Area as % of OWF		Observation counts	Seasonality												Number
Species	Family occurence	EPBC status	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Loggerhead Turtle *Caretta caretta*	Cheloniidae -	Endangered	100	100	40													1
Leatherback Turtle *Dermochelys coriacea*	Dermochelyidae -	Endangered	100	86	39													3
Flatback Turtle *Natator depressus*	Cheloniidae -	Vulnerable	100		21													0
Green Turtle *Chelonia mydas*	Cheloniidae -	Vulnerable	100		310													0
Hawksbill Turtle *Eretmochelys imbricata*	Cheloniidae -	Vulnerable	100		26													0

5.8. Indigenous communities

The Traditional Owner groups within the Illawarra area are the Dharawal Elouri and the Wodi Wodi peoples of the Dharawal and Yuin Nations.

The Dharawal land covered south of Botany Bay and the Georges River, west to Appin, downs as far as Goulburn and the Wreck Bay near Nowra (Dharawal, the story of the Dharwal speaking people of southern Sydney). The Yuin nations covers a large area of NSW ranging from Cape Howe (VIC/NSW boarder) north to Nowra. It is important to note the South Coast People Native Title claim which covers 25 Aboriginal organisations based on the South Coast of NSW and 12 local Aboriginal Land Councils. The area covers approximately 1,680,800ha north from Voyager Point south to Nullica State Forest and out to sea 3 nautical miles.

The Dharawal and Yuin people have a strong connection to their land, sea and sky country. Their main protein source was fish – snapper, bream most popular along with mullet, flathead, groper, morwong, tarwhine and leatherjackets, there are midden sites listed throughout their landscapes ranging in sizes (Donaldson, Mike; Bursill, Les; and Jacobs, Mary: A history of Aboriginal Illawarra Volume 1: Before colonisation 2015.p.11.p.24). They would use plaited hair or twine from the cabbage tree palm as string, ground turban shell to create hooks and fish out of wooden canoes (Dharawal, the story of the Dharwal speaking people of southern Sydney). They would trade fish, shellfish, waterfowl and grubs to neighbouring groups in exchange for possum skill cloaks. (Before Colonisation 2015, p25). The Dharawal people maintain continuity of their cultural connections and practices on sea country (Edwards 2021). A detailed summary of contemporary Aboriginal fisheries harvest in New South Wales shows there are more than 150 species of finfish and invertebrates harvested (Schnierer and Egan 2016). They have a strong connection to the whale, and it is one of the main totems for the Tharawal people, giving them strength and comfort when faced with danger (Bursill et al, 2001). These are some examples of documented connections of Dharawal Elouri and the Wodi Wodi peoples to coastal and marine environments, we expect they represent a small fraction of their deep and extensive connections with land, sea and sky country.

There are numerous organisations that represent the broad interests the Dharawal Elouri and the Wodi Wodi peoples. The Illawarra Local Aboriginal Land Council (ILALC) is the organisation with inclusive representation of the Dharawal and Wodi Wodi people. A publicly available positional statement from the ILALC on offshore windfarm development was not found on the Internet at the time of writing this report.

There are numerous indications the Dharawal Elouri and the Wodi Wodi peoples have interest and capacity to engage in discussions about key environmental factors for offshore wind farms and associated science. A 2023 desk-top audit of coastal and catchment Aboriginal ranger groups was conducted as part of the implementation of the NSW Marine Estate Management Strategy 2018-28, it identified the following Aboriginal ranger groups adjacent the Illawarra Offshore Windfarm Area; Illawarra Environmental Management Team, Jerringa Rangers, Booderee Parks Australia Rangers and Wreck Bay Rangers, Bhewerre Rangers. There are also established environmental cultural tours run by Gumaraa tour group based in the Illawarra region and environmental educational programs such as Gadhungal Murring environmental and education program.

6. Bass Strait and Gippsland Offshore Wind Farm region – knowledge base

6.1. Bathymetry

Existing multibeam data coverage for the Bass Strait region is concentrated outside of the offshore wind declared areas, except for the northern most area offshore of Gippsland region (Figure 35). A regional 30 m resolution compilation bathymetry grid spans the entire Bass Strait region (Beaman, 2022). High resolution (2 m and 5 m) marine LiDAR data is also available for the mid- to eastern-Victorian to depths of 30 m (https://www.deeca.vic.gov.au/maps/home), including full coverage mapping in marine parks including Wilsons Promontory Marine National Park (Ierodiaconou and Young, 2022) and Bunurong Marine National Park (Ierodiaconou and Young, 2020). These datasets capture the interface between coastal headland/outcrop and littoral zone, including the distribution of unconsolidated sediment concealing bedrock on the inner continental shelf.

A number of specific areas within Bass Strait have recently had, or have planned, focused hydrographic surveys conducted as part of the HydroScheme Industry Partnership Program (HIPP) (https://www.hydro.gov.au/NHP/). Much of these are focused on areas in eastern Bass Strait surrounding the Furneaux and Kent Group of Islands, and within Beagle Marine Park. None of these overlap either the Gippsland or Bass Strait declaration areas.

6.2. Seabed geology

The Bass Strait continental shelf is generally low gradient (< 2°) and is characterised by a broad, shallow (< 83 m deep) marine basin that is centred over the 4 km thick Cretaceous-modern (geological) Bass Basin (Blevin, 2003; Figure 36). The basin is flanked by shallow plateaus (40-70 m water depth) and large islands to the south-east and south-west, and by deeper sills to the north-east (60 m deep) and north-west (75 m deep). These sills link the marine basin via broad submarine valleys to the sedimentary (geological) Gippsland (east) and towards the Sorell and Otway Basins (west). Numerous continental slope-confined submarine canyons characterise the continental slope in the east and west (Heap and Harris, 2008), and the Bass Canyon in the east is Australia's largest example of a shelf-incising canyon (Mitchell et al,, 2007). These canyons provide important habitat and act as conduits for erosive sediment laden bottom currents.

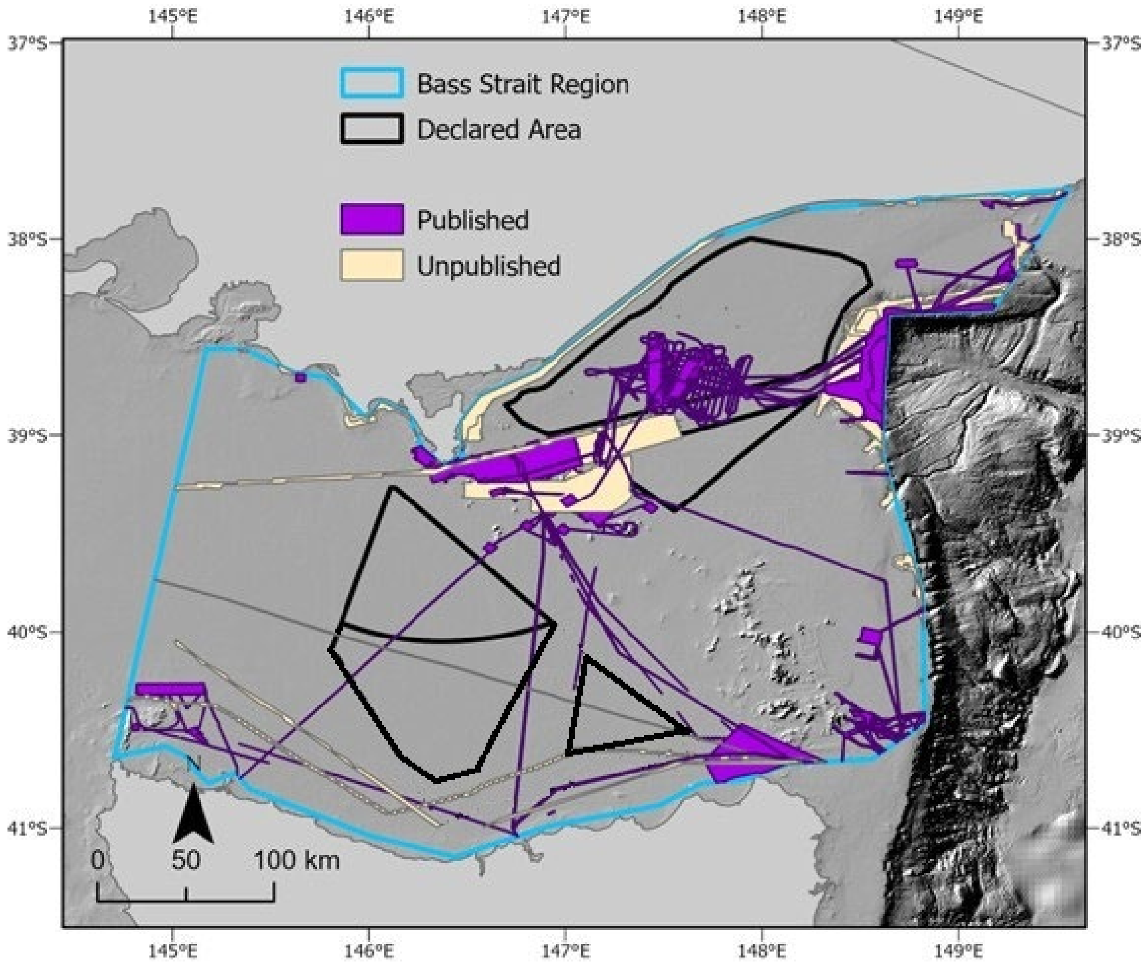


Figure 35. Bathymetry coverage for the Bass Strait region (defined by blue polygon) showing the spatial extent of bathymetry data (published and unpublished), including nearshore LiDAR data. Data extents are provided by third party contributors to the AusSeaBed Data Portal (listed in the Marine Baseline Data Inventory). Background hillshade derived from the 30 m bathymetry (Beaman, 2022).

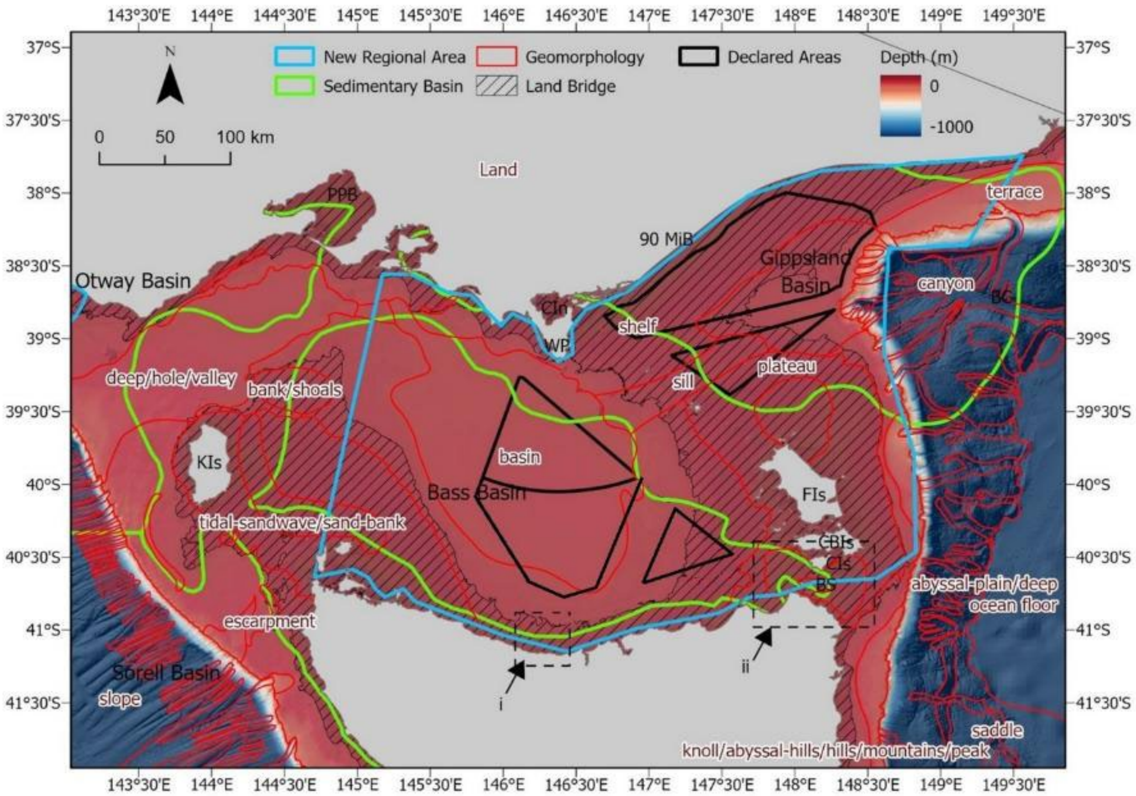


Figure 36. The Bass Strait declared area (black polygons) and the regional area (blue polygon), over the 30 regional bathymetry grid (Beaman, 2022). Seabed geomorphology, sedimentary basins, the – 67 m contour paleo-land bridge and locations for subsequent figures are indicated. Abbreviations: Flinders Island (FIs), Cape Barren Island (CBIs), Clarke Island (CIs), Banks Strait (BS), King Island (KIs), Wilsons Promontory (WP), Bass Canyon (BC), Port Phillip Bay (PPB), Corner Inlet (Cin) and 90 Mile Beach (90 MiB).

6.3. Seabed geomorphology

The regional 30 m bathymetry grid illustrates numerous ridges around the marine basin perimeter (Beaman, 2022). For example, 30 km south-east of Wilsons Promontory and 30 km NE of King Island, sets of relict coastal beach ridges (at 67 m depth) delineate the ancient shoreline of the former Bass Interior Seaway, when a land bridge connected mainland Australia (Victoria) to Tasmania via Flinders Island (Figure 37). Another prominent series of paleo-shorelines is visible around the eastern perimeter of the basin (75 m depth contour), and smaller examples are visible near Ulverston where they flank an incised valley offshore of the Mersey River and River Forth (46 m depth contour, Figure 36). The beach ridge paleo-shorelines of the Bass Strait typically form hard rocky reefs that, in addition to providing insights for paleo-environmental reconstruction, generally provide important habitat (see Arnould et al., 2015) and/or have archaeological potential. The collection of higher resolution bathymetry in the vicinity of these depth contours throughout the region may identify further examples of paleo-shorelines.

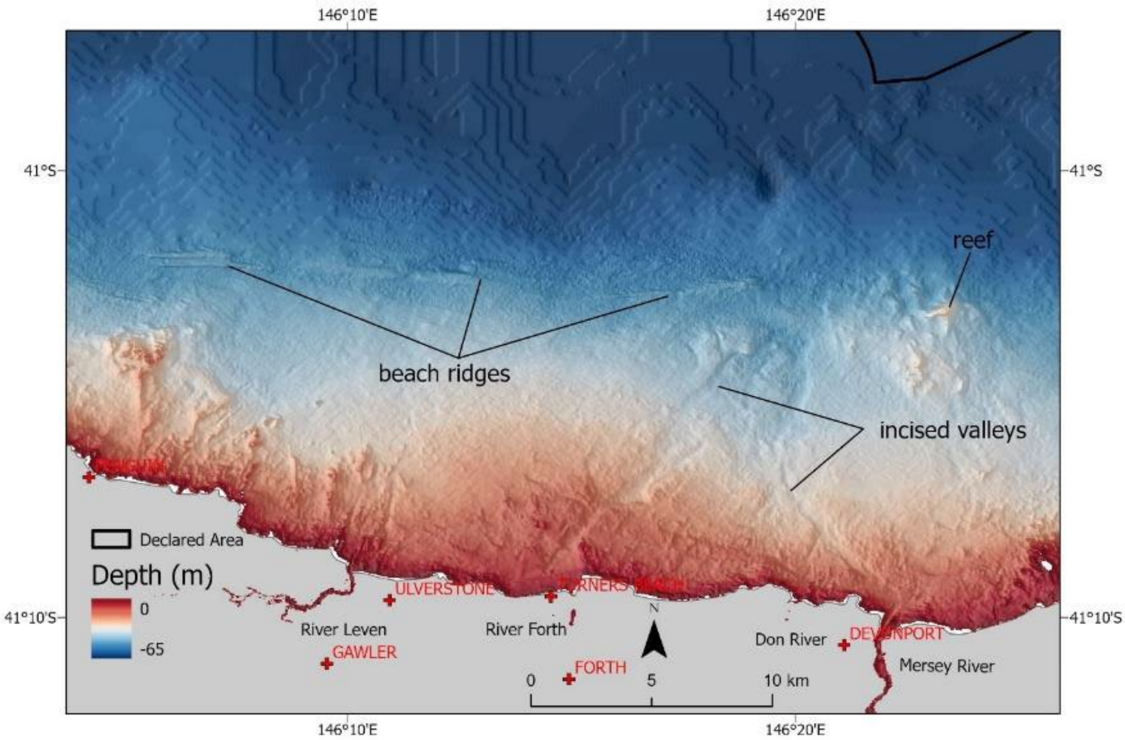


Figure 37. Beach ridges and incised valleys offshore northern 2022) Tasmania (Bass Strait 30 m bathymetry grid: Beaman, 2022).

6.4. Sedimentology

Seabed and coastal sediment within the Bass Strait are predominantly sand sized and composed of cool-water carbonate material (generally over 60%: Passlow et al., 2004; Figure 38). Along the coasts and in the deeper parts of the marine basin sediment is primarily transported by waves (storms); where ocean currents are forced through narrow straits (e.g. Banks Strait) and over shallow sills (e.g. between Wilsons Promontory and Flinders Island; between King Island and NW Tasmania) sediment is generally coarser and is predominantly transported by tidal currents (Figure 38 (*b*) from Passlow et al., 2004). Fields of large, mobile sedimentary dunes (up to 6 m high, 200 m wavelength: Auguste et al., 2022; Malkides et al., 1989) have formed in some of these higher energy settings (Heap and Harris, 2008; Figure 36). In the Banks Strait, where tidal currents reach up to 2.9 ms^{-1} (Penesis et al., 2020), deep holes have scoured (down to - 30 m below the surrounding seabed) and are situated adjacent to field of active dunes (Figure 38; cf. Dalrymple, 2023).

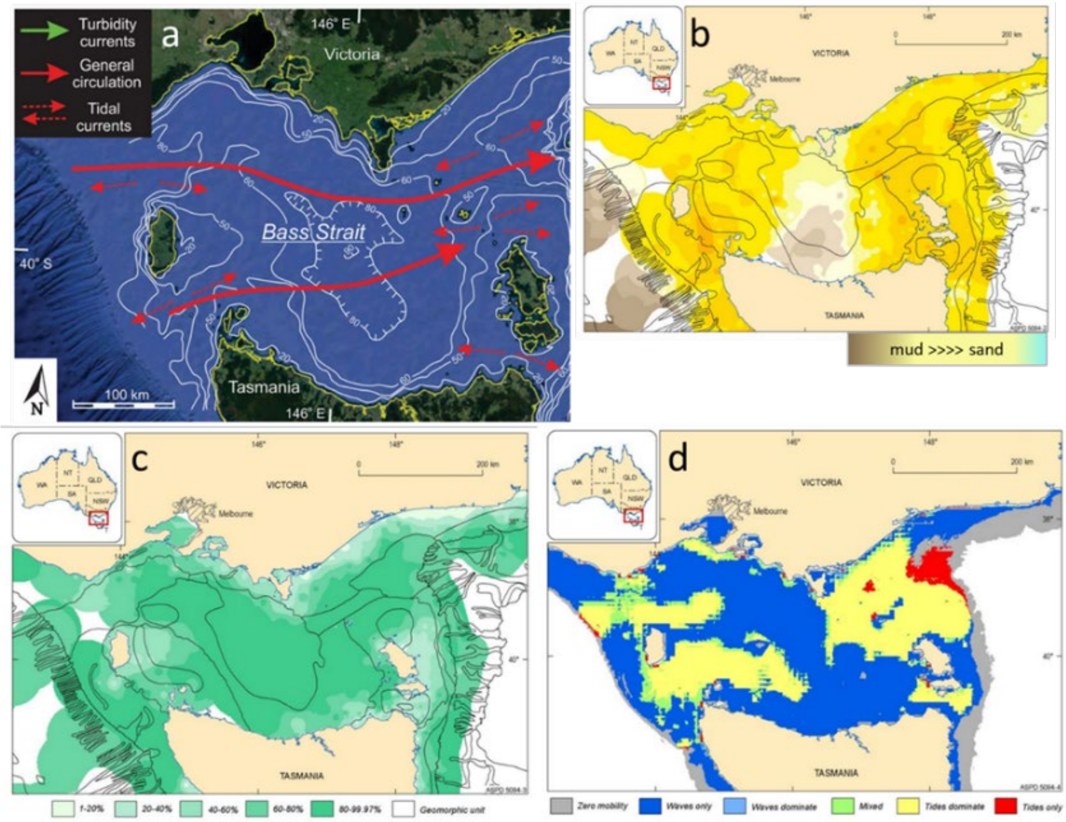


Figure 38. (a) ocean currents through the Bass Strait region (Dalrymple, 2023); (b) seabed sediment size; (c) seabed sediment carbonate composition; (d) relative contribution of waves and tides to seabed sediment transport (b-d modified from Passlow et al. 2004).

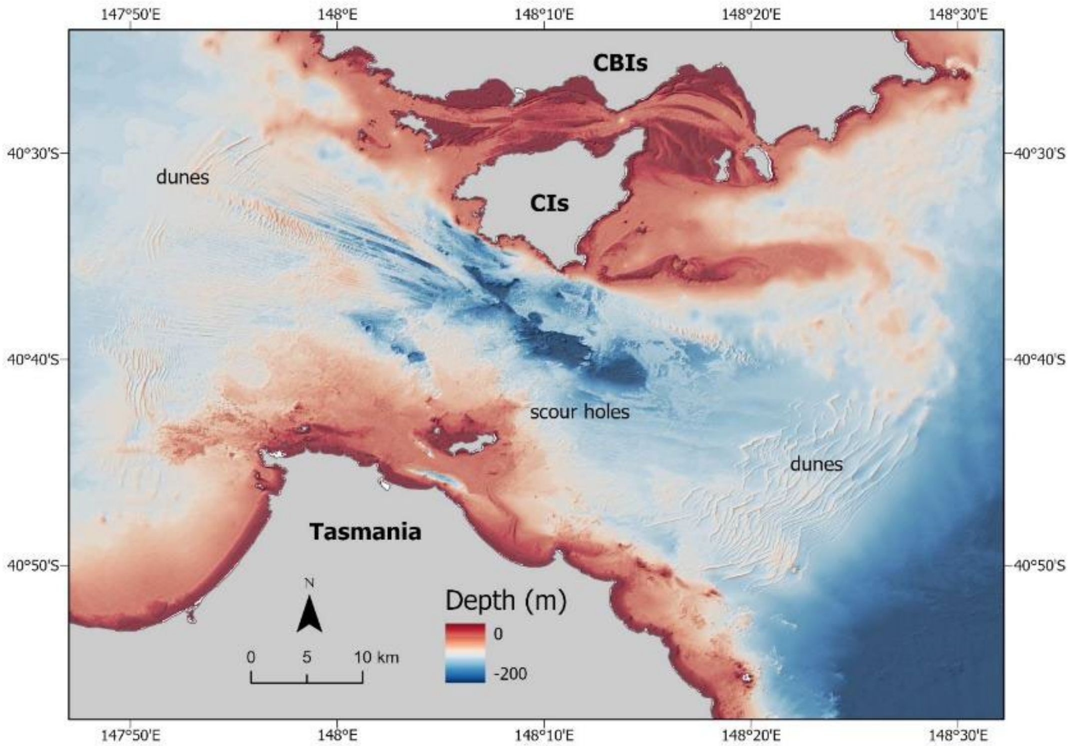


Figure 39: Deep scour holes and dunes in the Banks Strait. Cape Barren Island (CBIs); Clarke Island (CIs). Bass Strait 30 m bathymetry grid (Beaman, 2022).

In the Beagle Marine Park, high-energy sediment ribbons of disarticulate shells are aligned parallel to the dominant SW to NE current direction over the shallowest parts of the park (50-60 m water depth) and dominate the seabed between semi-lithified ancient beach ridges and dunes (now marine reefs). Much of the deeper western part of the marine park are characterised by continuous sediment cover and active bedforms, including 2D (straight crested) and 3D (wavy to sinuous crested) dunes (Barrett et al., 2020). These bedform fields are generally low profile and broadly oriented in the direction of tidal flow (SW to NE), but with dune heights less than one metre, such that the overall seabed is defined as planar. In contrast, the shallower eastern area of the marine park that has been surveyed are characterised by fields of linear evenly spaced ridges that extend several kilometres along a consistent SW to NE alignment. These features likely represent the seabed expression of the underlying sedimentary rock of the Bass Strait region, with a thin mantle of sand and gravel.

In Wilsons Promontory Marine National Park granitic outcrops descend steeply (up to 70º) to the seafloor to an average water depth of 40 m, with isolated areas near South East Point descending to around 90 m depth. Granitic outcrops occur offshore of the Promontory on Wattle Island and the Anser Group islands as well as below the sea surface as isolated outcrops. On the eastern sides of the islands large scour holes in the seafloor, up to 400 m wide, occur and descend to 90 m depth. Bedded sedimentary layers observed in seabed imagery likely represent tightly folded shales and sandstones of Ordovician age in which the Wilsons Promontory granites are intruded (Hill and Joyce, 1995). Unconsolidated sediment sheets are present to the west of the Promontory, just north of the Anser Group. These sheets are over 835 ha in area and are likely to be around 2 – 6 m thick, based on their height above the surrounding near-horizontal seafloor. Sediment mounds are at attached to all the islands in the marine park and have a sculptured formation like shadow dunes found on land. An isolated transverse ridge composed of sediment extends from South East Point to the SE for 4.5 km rising to a height of 22 m above the seabed with an average width of 100 m. All these sediment features appear to be active as they have steep (13–22°) slip faces present on their eastern sides (Kennedy et al., 2014).

Particularly cold and saline west to east directed flow through the Bass Strait exits to the east as the Bass Cascade Current (BCC), which interacts with the shallower and southerly directed East Australian Current and the northerly-directed Ekman Transport Flow to control sedimentation along the south-eastern continental margin (Wu et al. 2023). The BCC drives highly erosive, high velocity (> 1 m/s) dense shelf water cascades that are sufficiently energetic to entrain shelf sediment, shape the seafloor and shift infrastructure (Wu et al., 2023). The BCC also has an important role in shelf sediment source-to-sink transfer, as these currents develop into high-intensity, downslope traversing turbidity currents that flow down the continental slope via the canyon networks (Wu et al., 2023).

Sediment along the Victorian open coast is primarily derived from marine and coastal sources and is transported from west to east. Shallow LiDAR and multibeam sonar data along the coast, most of which is available online (see CoastKit Victoria - Victoria's Marine & Coastal Portal (mapshare.vic.gov.au), reveal that rocky headlands extend offshore and compartmentalise adjacent sandy beaches, which are more vulnerable to coastal movement (Pucino et al., 2021, McCarroll et al., 2024). Coastline movements vary from stable to slightly eroding along the central to western Victorian Bass Strait coast, to mixed erosional and progradational along the beaches adjacent to Wilsons Promontory, and predominantly retreating (eroding) along the 80 Mile Beach coast. Large flood- and ebb-tide deltas have formed at tidal inlets along this coast, and these have accumulated large volumes of longshore to offshore derived sediment (Provis and Mohal, 2011).

At Inverloch at the mouth of Anderson Inlet, one of Victoria's largest open barrier estuaries located at the head of Venus Bay, beach volumetric change show seasonality, with accretion dominating during Spring and Summer months, and erosion occurring during Autumn and Winter (Leach et al., 2023). Rivers discharging along the north coast of Tasmania also supply very little sediment to the Bass Strait (Davies and Hudson, 1987), and their nearshore marine and coastal sediment is primarily sourced from the shelf by wave energy (Passlow et al., 2004). The northern Tasmanian coastline is generally stable to prograding along the western half of the Bass Strait, and is primarily stable with pockets of both moderate progradation and retreat in the east.

6.5. Seabed habitats and benthic biodiversity

The Bass Strait region is characterised by predominantly low relief habitats with higher relief found around the islands and mainland coasts, except the 90 Mile Beach area, which is dominated by sediment.

Comprehensive coastal habitat mapping and fisheries assessments within Wilsons Promontory and Bunurong Marine National Parks have indicated the variability in habitats along the coastline (Young et al., 2022) (Figure 40). Wilsons Promontory is dominated by sublittoral mixed sediments and sublittoral sand and muddy sand over 90% of the park, while high energy open-coast circalittoral rock and infralittoral rock are found along the headlands and islands, extensions of granitic formations (Kennedy et al., 2014). There are also extensive *Ecklonia* and *Phyllospora* communities on the infralittoral rock, providing food and habitat for a wide variety of organisms residing within the marine park.

In deeper water hard ground reef supporting moderate to high densities of sessile invertebrates dominated by sponges, bryozoan, ascidians, and hydroids. Bunurong Marine National Park is dominated by high energy infralittoral rock at depths of 2 to 30 metres with sand and muddy sand in the very nearshore and in the southwest region of the park. This park is also defined by extensive rhodolith beds, covering 44% of the park, which provide additional complexity to the sediment regions (Porskamp et al., 2022). Fish diversity surveys within Wilsons Promontory found that there was higher species richness on the higher-relief reef habitats throughout the park compared to the lower-relief, sedimentary regions. This dataset was collected using BRUVs and identified a total of 76 taxa across 42 families in 52 BRUV deployments. The most abundant species identified from these surveys included rosy wrasse, Degen’s leatherjacket, blue-throat wrasse, and longfin pike. Shark species such as gummy sharks and Port Jackson sharks had the highest contributions to biomass within this area (Young et al., 2022).

Comprehensive surveys of benthic biota have occurred within the Beagle Marine Park in the central part of the region (Barrett et al., 2020). This study found that the relict dunes and adjacent sediment plain revealed four broad habitat categories, including: 1) low profile (2 – 5 m high) hard ground reef supporting moderate to high densities of sessile invertebrates (mixed sponge, bryozoan and hydroids); 2) scallop beds interspersed among unconsolidated coarse sand with shell fragments and extensive fields of sediment bedforms; 3) screw shell beds; and 4) aggregations of shell hash with broken bryozoan skeletons, and disarticulated and live scallops that provide an important substrata for a moderate cover of sessile filter feeding invertebrates. A highly diverse epifaunal assemblage was recorded from AUV imagery, with 205 biological morphospecies identified and seven substratum types.

Demersal fish were found to be abundant across the region of the Beagle Marine Park, with 61 species from 33 families recorded by stereo BRUV video (Barrett et al., 2020). The most speciose family were monacanthids, followed by labrids and triglids.

Commonly observed fish were Degens leatherjacket, butterfly, barber perch and common gurnard perches, Melbourne silverbelly, jackass morwong, rosy wrasse, cosmopolitan leatherjacket, sand flathead and draughtboard shark. These species were also among the most common observed on BRUVs in the vicinity of oil and gas structures offshore of Lakes Entrance in the Bass Strait in 2023 (unpubl. data – available by request through GlobalArchive).

Extensive Remotely Operated Vehicle surveys of oil and gas structures to east of the Bass Strait also show a prevalence of the jewel anemone (*Corynactis australis*) colonising structures that span the water column from the surface to near the seabed. Pipelines and the base of platform structures have high sponge coverage, in a range of morphologies from encrusting through to erect and massive varieties. The addition of rock scour and concrete mattresses promotes coverage of sponge biota and associated species, e.g. scorpionfish, butterfly perch.

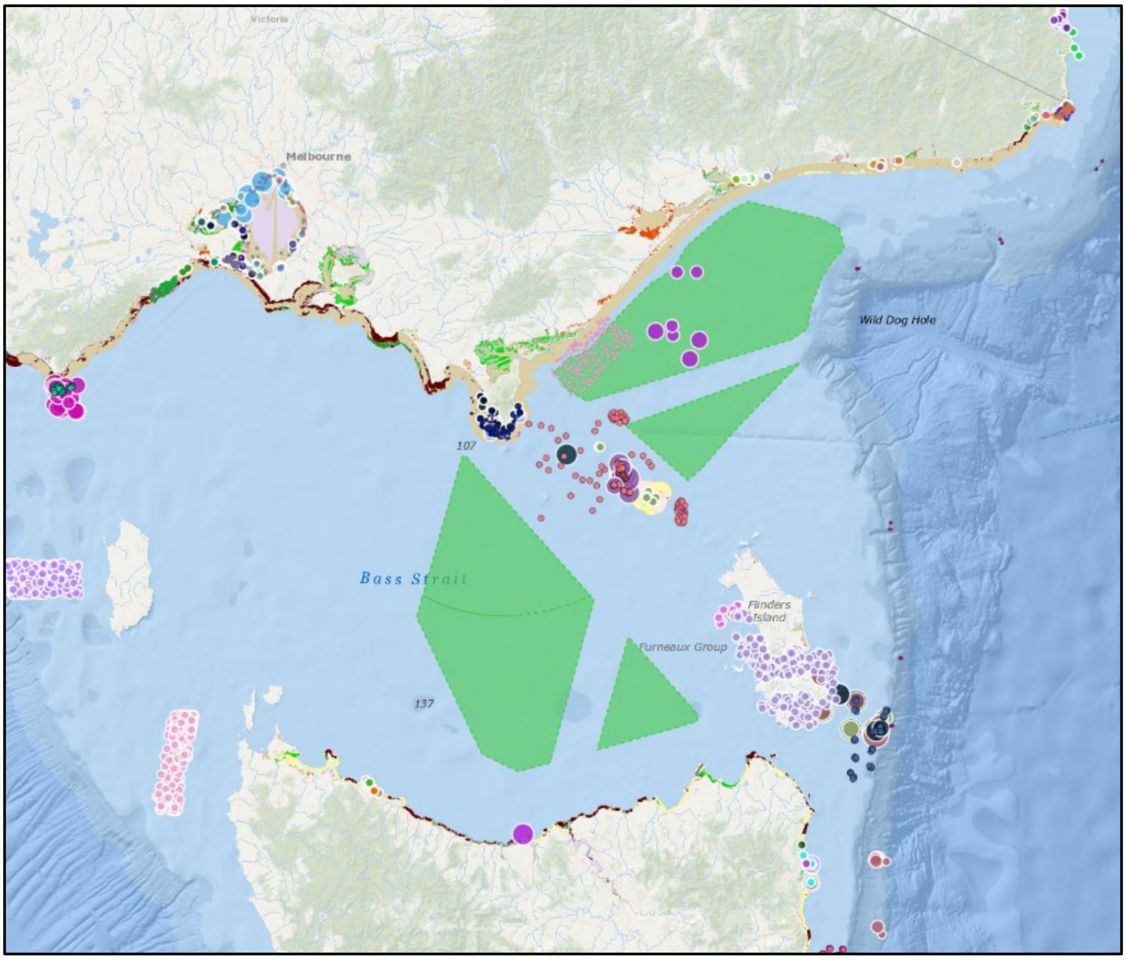


Figure 40: Available seabed ecological survey locations and habitat data for the Gippsland and Bass Strait OWF regions represented in the Seamap Australia marine spatial data portal, including survey locations using towed video, Autonomous Underwater Vehicles, panoramic drop camera and Baited Remote Underwater Videos, represented as bubble plots. [Declared area boundaries finalised after completion of maps in this report and are not amended here]. Details on habitat legend, deployment types and effort are available at: https://seamapaustralia.org/map/#4567c341-20e7-42e7-a458-6636cf121979

6.6. Oceanography

The Bass Strait and Gippsland OWF region is meso-tidal. Complex bathymetry around the shallow region generates strong spatially variable currents that can exceed 0.6 m s-1 (from TPXO8, Egbert & Svetlana, 2002). Periodic wind driven currents flow through the Strait to the east (Baines, 1989, Baines et al., 1990).

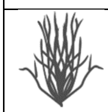
There are locally strong currents, with tidal flows reaching up to 2.5 m/s (Sandery and Kampf, 2005), particularly in the north-east of the Bass Strait between Flinders and Cape Barren islands (Baines et al., 1991; Wijeratne et al., 2012). Bass Strait waters are generally well-mixed in winter and spring, but weaker winds in summer can result in stratification in the central region (Baines and Fandry, 1983; Sandery and Kampf, 2005). Local wind stress drives much of the water flux through Bass Strait, with dominant easterly transport during winter (Baines et al., 1991; Jones, 1980); and cold fronts during autumn and winter resulting in storm surges (McInnes and Hubbert, 2003). Wind-driven currents through the strait are generally weaker during summer.

Seasonal stratification is expected to be important at the coastal edges of both the Bass Strait and Gippsland OWFs (based on preliminary CARS analysis – CSIRO Atlas of Regional Seas). Baines and Foundry (1983) interpolated ship-based measurements to show that stratification is present in both regions in summer, but not in winter, with fronts moving through the regions as the year progress. This suggested that periods of weak seasonal stratification exist across the entirety of both regions. Gibbs et al. (1986) found low nutrient levels within the Strait, as supplies from both the east and west sides were used rapidly.

Wave energy in the OWF regions are low to moderate due to interference at the western side of the Strait (Hemer et al., 2018). Infrastructure planned for close to the Gippsland coast should consider coastal processes. Strong wind energy resources in the region (Salvador, 2022) are suitable for the development of offshore wind farms which may alter nutrient fluxes and upwelling patterns.

6.7. Threatened and migratory marine species

All spatial layers from the fauna maps presented in text are available for viewing and download through the following map and table links. These links are live and can be updated as new information is received.

Fauna Group		**OWF Area overlap**	**Tables of data**
	Cetaceans and pinnipeds	Map Link	Baleen, toothed, pinniped
	Birds	Map Link	Birds
	Sharks	Map Link	Sharks
	Reptiles (turtles)	Map Link	Reptiles
	Macroalgae	Map Link	Macroalgae

6.7.1. Cetaceans and pinnipeds

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of 43 published studies on cetaceans (Figure 41, Figure 42) and seven for pinnipeds (Figure 43) overlapped with the Bass Strait OWF area. The majority of those studies were on killer whales (*Orcinus orca*, n=7, listed migratory under the EPBC Act), blue whales (*Balaenoptera musculus* subspecies, listed endangered under the EPBC Act, n=6), Australian fur seals (*Arctocephalus pusillus doriferus*, n=6, listed marine under the EBPC Act), humpback whale (*Megaptera novaeangliae, n=5,* listed migratory under the EPBC Act) and southern right whales (*Eubalaena australis, n=5,* listed endangered under the EPBC Act). There were three studies each on long-finned pilot whales (*Globicephala melas*, listed cetacean under the EPBC Act) and sperm whales (*Physeter macrocephalus*, listed migratory under the EPBC Act), two studies each fin whales (*Balaenoptera physalus*, listed as vulnerable under the EPBC Act), pygmy right whales (*Caperea marginata*, listed migratory under the EPBC Act), common dolphins (*Delphinus delphis*, listed cetacean under the EPBC Act) and dolphins (*Tursiops spp.*) and one study for each of pygmy (*Kogia breviceps*, listed cetacean under the EPBC Act) and dwarf (*Kogia sima*, listed cetacean under the EPBC Act) sperm whales, dusky dolphin (*Lagenorhynchus obscurus*, listed migratory under the EPBC Act), strap toothed whale (*Mesoplodon layardii*, listed cetacean under the EPBC Act), false killer whale (*Pseudorca crassidens*, listed cetacean under the EPBC Act), indo-pacific bottlenose dolphin (*Tursiops aduncus* , listed cetacean under the EPBC Act) and long-nosed fur seal (*Arctocephalus forsteri*, listed marine under the EPBC Act).

For the baleen whales, the highest overlap between the study area polygons and the Bass Strait OWF was for southern right and humpback whales (both 98%), followed by common dolphins (94%), Antarctic blue whales (63%), killer whales (61%), Tursiops spp (32%), pygmy right whale (27%), long finned pilot whale (26%), fin whale (14%) and dusky dolphin (7%) (Table 15, Table 16, Table 17 and Figure 41). For the pinniped, Australian fur seal studies had 98% overlap with the OWF areas and long-nosed fur seals had 43% overlap (Figure 44 and Table 17).

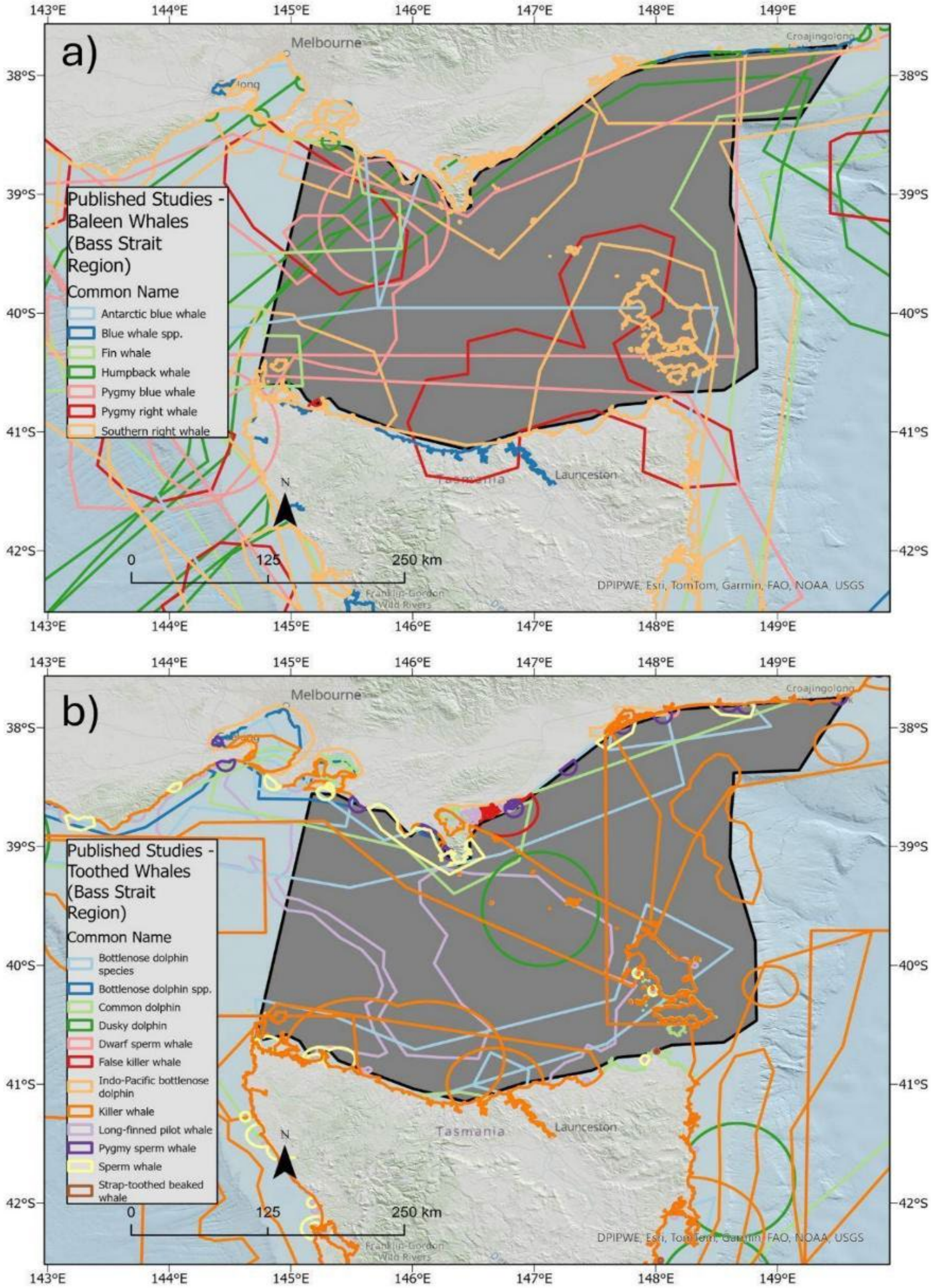


Figure 41. The Bass Strait OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where baleen whales (a) and toothed whales (b) occurred. The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

Table 15. Baleen whale species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Bass Strait OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Bass Strait baleen cetacean Table link

Bass Strait OWF: Cetaceans (baleen)

			Area as % of OWF			Observation counts	Seasonality												Number
Species	Family Occurence	EPBC Status	VBA	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Southern Right Whale *Eubalaena australis*	Balaenidae -	Endangered	73	98	98	285													5
Antarctic Blue Whale *Balaenoptera musculus intermedia*	Balaenopteridae -	Endangered	2	98	63	0													1
Pygmy Blue Whale *Balaenoptera musculus brevicauda*	Balaenopteridae -	Endangered	0	98	86	0													4
Fin Whale *Balaenoptera physalus*	Balaenopteridae -	Vulnerable	1	75	14	1													2
Dwarf Minke Whale *Balaenoptera acutorostrata subsp.*	Balaenopteridae -	Migratory	2	98		58													0
Pygmy Right Whale *Caperea marginata*	Cetotheriidae -	Migratory	0	98	27	107													2
Humpback Whale *Megaptera novaeangliae*	Balaenopteridae -	Cetacean	61	98	98	1855													5

Table 16. Toothed whale species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Bass Strait OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. Note that for all the toothed whales there is limited data on seasonality, and they may be present year round. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Bass Strait toothed cetacean Table link

Bass Strait OWF: Cetaceans (toothed)

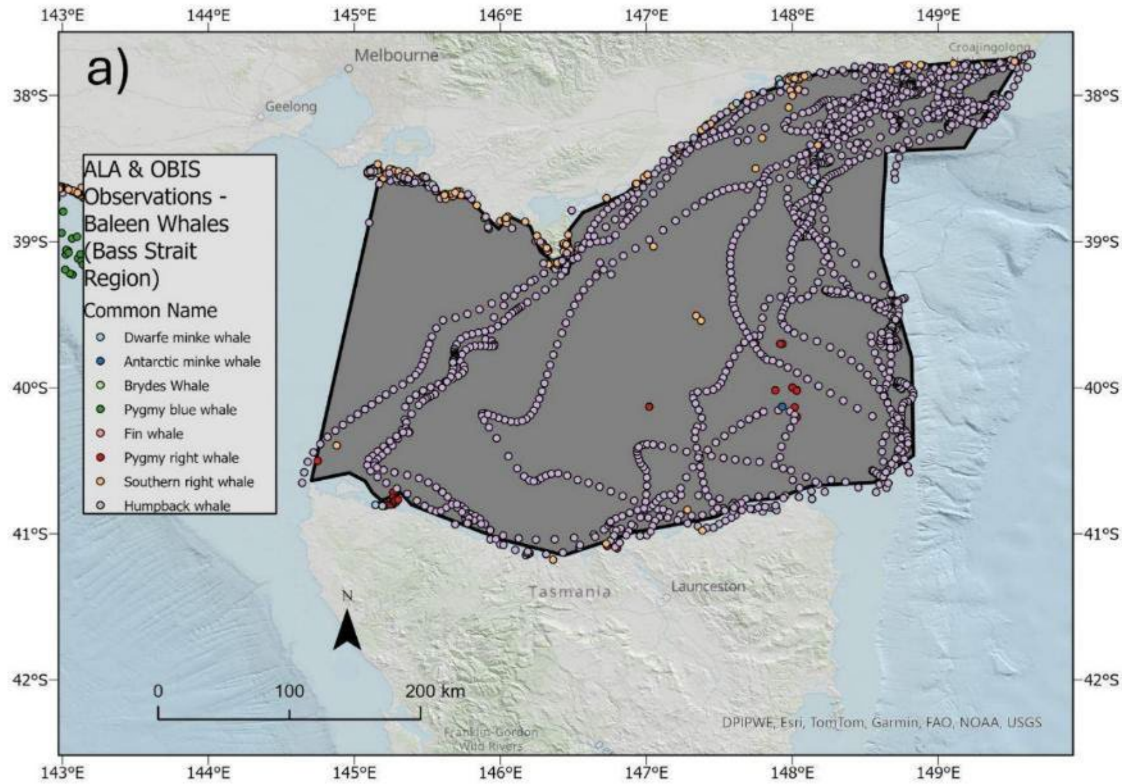
SPECIES	FAMILY OCCURENCE	EPBC STATUS	AREA AS % OF OWF: VBA	AREA AS % OF OWF: SNES	AREA AS % OF OWF: PUBS	OBSERVATION COUNTS: OBIS ALA	SEASONALITY: J F M A M J J A S O N D	NUMBER: PUBS
Dusky Dolphin *Lagenorhynchus obscurus*	Delphinidae -	Migratory	0	98	7	0		1
Killer Whale *Orcinus orca*	Delphinidae -	Migratory	19	93	61	72		7
Sperm Whale *Physeter macrocephalus*	Physeteridae -	Migratory	12	7	2	265		3
Bottlenose Dolphin Species *Tursiops spp*	Delphinidae -	Cetacean	0	98	32	0		2
Common Dolphin *Delphinus delphis*	Delphinidae -	Cetacean	34	98	94	190		2
False Killer Whale *Pseudorca crassidens*	Delphinidae -	Cetacean	1	57	1	22		1
Indo-Pacific Bottlenose Dolphin *Tursiops aduncus*	Delphinidae -	Cetacean	34	6	0	2		1
Long-Finned Pilot Whale *Globicephala melas*	Delphinidae -	Cetacean	4	7	26	213		3
Striped Dolphin *Stenella coeruleoalba*	Delphinidae -	Cetacean	0	0		2		0
Dwarf Sperm Whale *Kogia sima*	Kogiidae -	Cetacean	0	7	0	31		1
Pygmy Sperm Whale *Kogia breviceps*	Kogiidae -	Cetacean	7	7	1	69		1
Cuvier's Beaked Whale *Ziphius cavirostris*	Ziphiidae -	Cetacean	2	7		9		0
Gray's Beaked Whale *Mesoplodon grayi*	Ziphiidae -	Cetacean	2	1		26		0
Hector's Beaked Whale *Mesoplodon hectori*	Ziphiidae -	Cetacean	0	7		1		0
Shepherd's Beaked Whale *Tasmacetus shepherdi*	Ziphiidae -	Cetacean	0	0		26		0
Strap-Toothed Beaked Whale *Mesoplodon layardii*	Ziphiidae -	Cetacean	2	7	0	15		1

Table 17. Pinniped species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Bass Strait OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark brown indicates months of the year with peak occurrence, light brown indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Bass Strait pinniped Table link

Existing freely available species observation data

Overlaying observations of the priority (and secondary priority) cetacean and pinniped species from ALA, and OBIS with the Bass Strait OWF region (and), showed that observations of Australian fur seals were the most common in the Bass Strait OWF area (1938) followed by humpback whales (1855), southern right whales (285) and sperm whales (264) (Table 15, Table 16, Table 17). For all the remaining species the number of observations occurring in the OWF were <~200.

The spatial distribution of priority (and secondary priority) cetacean and pinniped species observations within the Bass Strait OWF region shows most of the species observations occurred nearshore, with the main species observed offshore including humpback whales and Australian fur seal (Figure 42 and Figure 45). Endangered species that have been observed in the Bass Strait OWF in OBIS and ALA include pygmy and Antarctic blue whales, southern right whales (*Eubalaena australis*) and the vulnerable listed fin whale (*Balaenoptera physalus*). In addition to OWF and OBIS data, tracking data from pygmy blue whales was made available (Moller et al., 2020), showing that at least one (of 13 instrumented individuals) pygmy blue whales tracked from the Bonney Upwelling region of South Australia used the Bass Strait OWF (Figure 43).



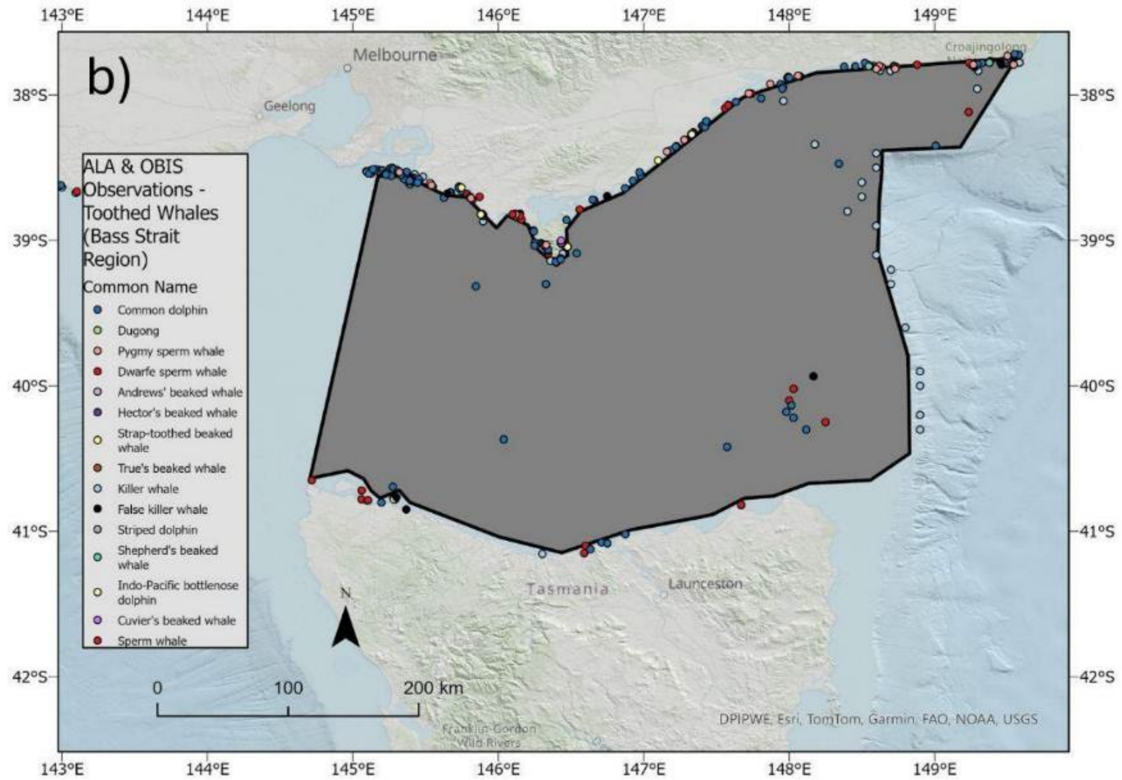


Figure 42. Observations of baleen (a) and toothed (b) whales from the ALA and the OBIS across the Bass Strait OWF. The different species are represented by the different colours and the grey polygon shows the study region for the Bass Strait OWF. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

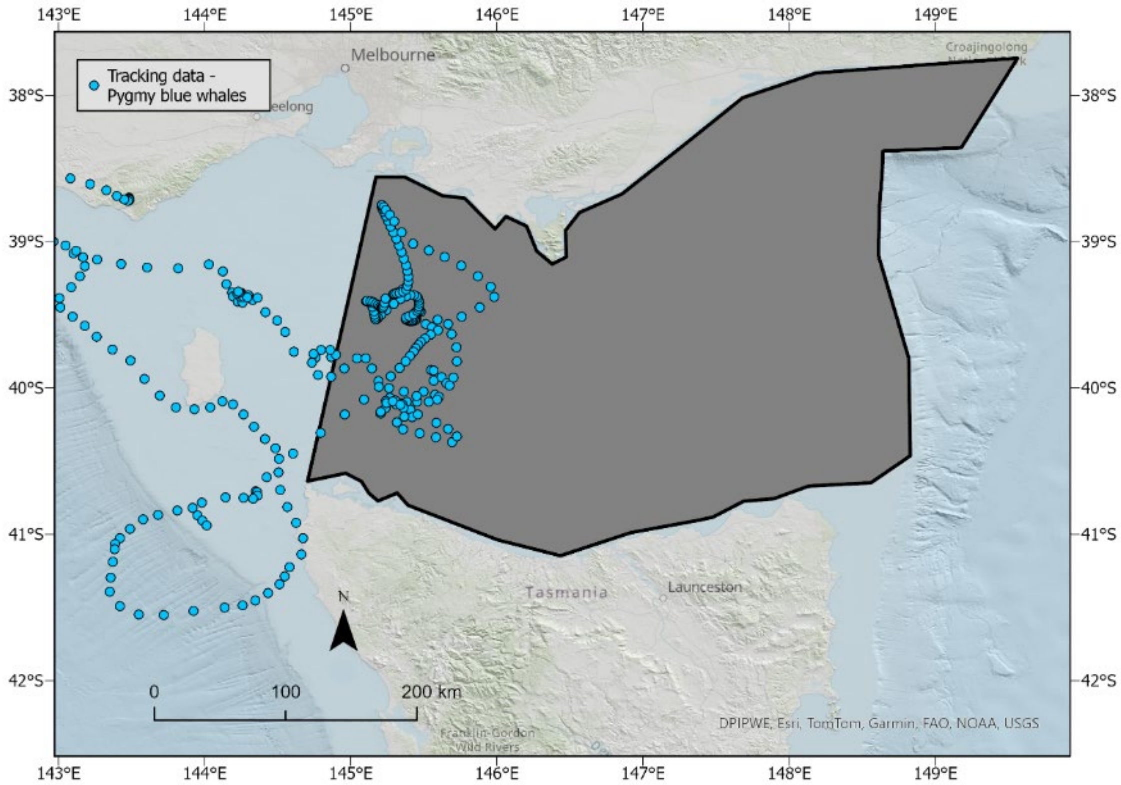


Figure 43.The Bass Strait OWF region (grey polygon) showing the spatial coverage of pygmy blue whale tracking data from Moller et al., 2020. Thirteen whales were tracked but only one whale's tracks (presented above) overlapped with the Bass Strait OWF. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

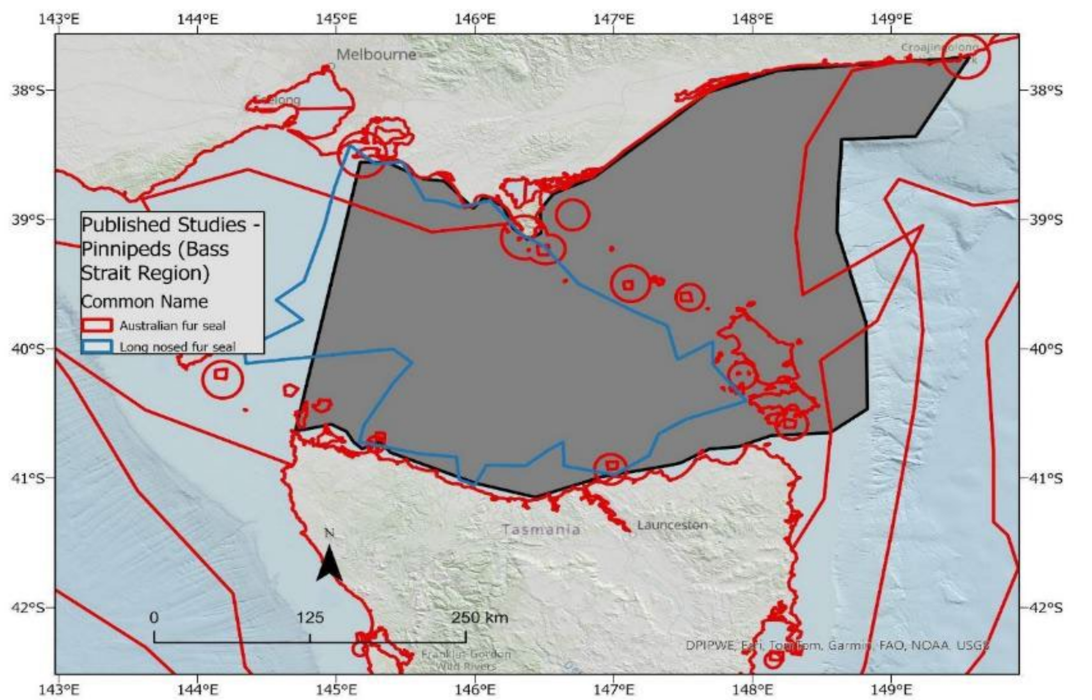


Figure 44. Polygons within the Bass Strait OWF region showing the spatial coverage of the study areas from the publication inventory where pinnipeds occurred. The different species are represented by the different colours and the grey polygon shows the study region for the Bass Strait OWF. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

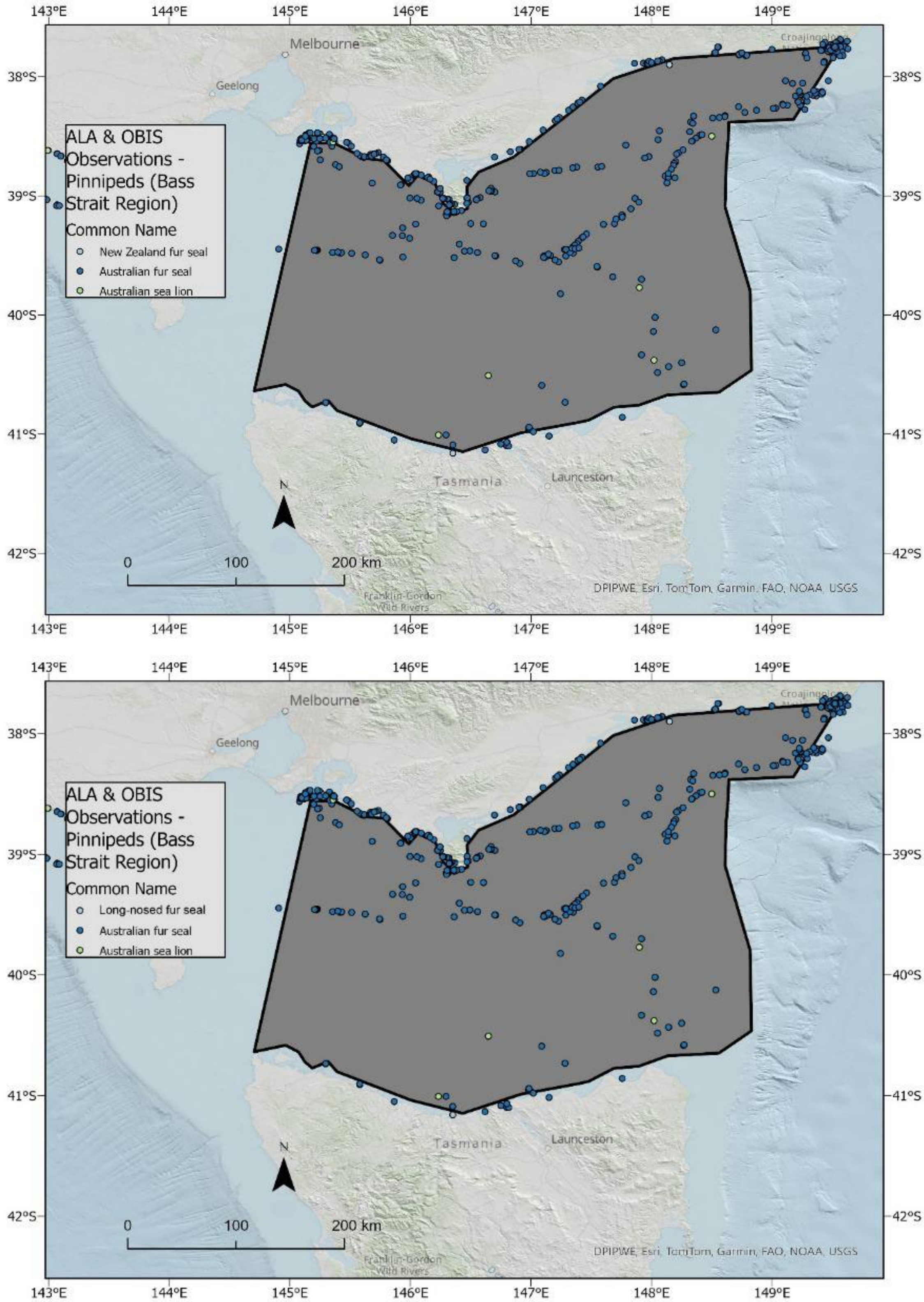


Figure 45. Observations of pinnipeds from the ALA and the OBIS across the Bass Strait OWF. The different species are represented by the different colours and the grey polygon shows the study region for the Bass Strait OWF. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

6.7.2. Birds

Published papers/reports inventory

Within the Bass Strait and Gippsland region, 32 published studies on bird species of interest that overlap with the OWF area were found and compiled in the inventory (Figure 46). The majority of those studies were on albatrosses (17), followed by waders (6), shearwaters (3), gannets (2), terns (2), parrots (1), and petrels (1). The study areas for the albatross species Shy (*Thalassarche cauta*, listed endangered under the EPBC Act), Bullers (*Thalassarche bulleri*, listed vulnerable under the EPBC Act), Campbell (*Thalassarche impavida*, listed Vulnerable) and southern royal (*Diomedea epomophora*, listed vulnerable under the EPBC Act) had 100% or near to 100% overlap with the OWF as did the far easter curlew (*Numenius madagascariensis*, critically endangered under the EPBC Act). Shearwaters also use a significant amount of the region with a coverage of 63,816 km^2. Gannets and parrots are also found within the region, but the studies show gannets across 2,739 km^2 and parrots covering 4,450 km^2 of the OWF area.

Several bird species listed as critically endangered and endangered under the EPBC Act occur in Bass Strait. The main ones are already listed above, but others include the critically endangered include the Curlew Sandpiper (*Calidris ferruginea*), Great Knot (*Calidris tenuirostris*), Swift Parrot (Lathamus discolor), and Tristan Albatross (*Diomedea dabbenena*). The Amsterdam Albatross (*Diomedea amsterdamensis*) and Gould’s Petrel (*Pterodroma leucoptera*) are listed as endangered. The remaining species in the inventory are made up of species listed as vulnerable and other species identified as of interest due to their migratory behaviour or potential interactions with wind farms in the region (Table 18).

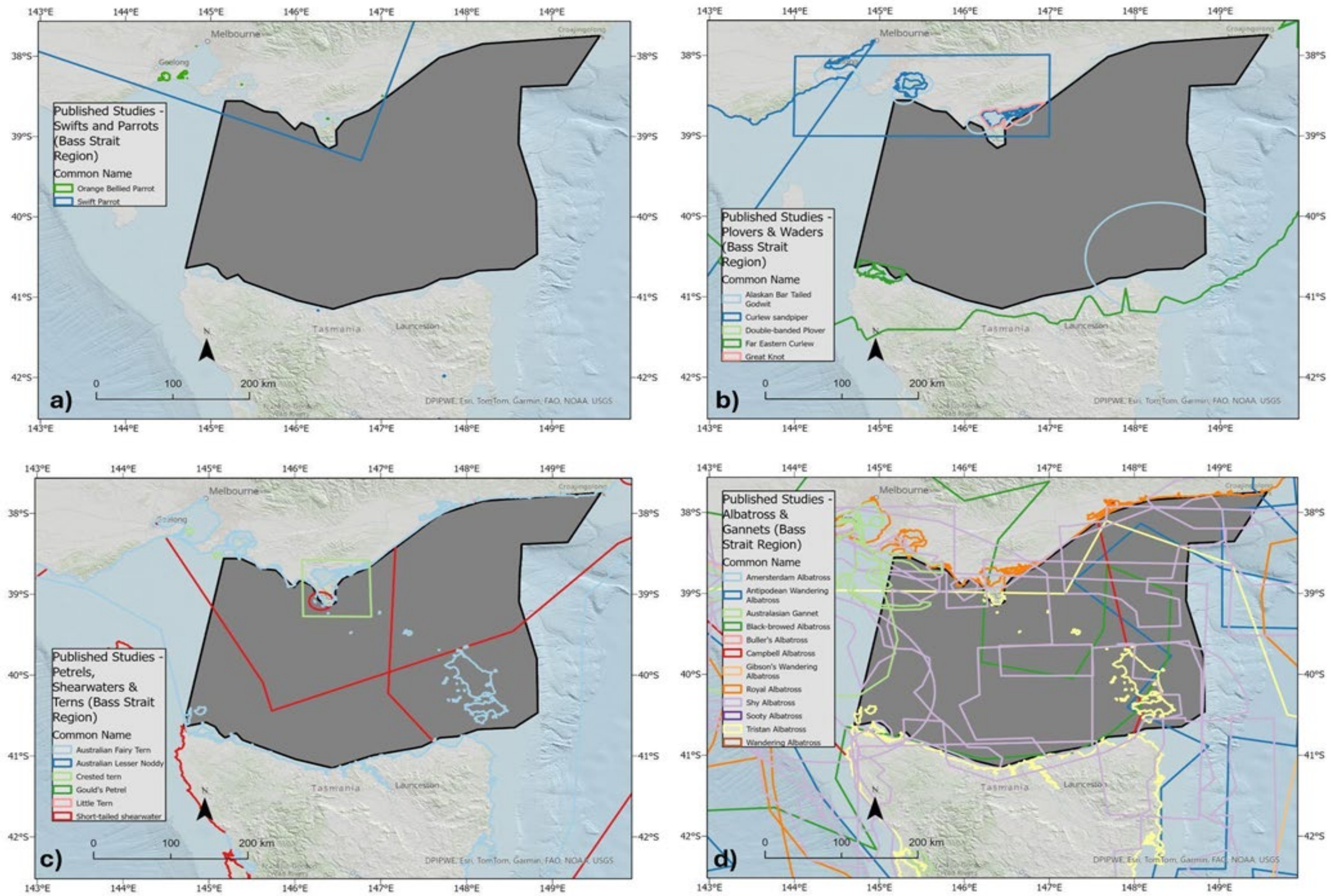


Figure 46. The Bass Strait OWF region (grey polygons) showing the spatial coverage of the study areas from the publication inventory where bird species (plotted in different colours) occurred, with separate maps for each species group (a-d). Data layers can be accessed here: Map Link. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

Table 18: Bird species for which we have compiled spatial data from published studies and freely available data repositories (BLA, (OBIS and ALA) that overlap with the Bass Strait and Gippsland OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for each data repository used (BLA = Birdlife Aust, OBIS and ALA data combined). Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Note that OBIS-ALA counts for little penguins are extremely high compared to the other species, making the counts for other species appear low. For clarity, view here: Bass Strait bird Table link

Bass Strait OWF: Bird

			AREA AS % OF OWF			OBSERVATION COUNTS		SEASONALITY	NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	VBA	SNES	PUBS	BLA	OBIS-ALA	J F M A M J J A S O N D	PUBS
Orange-Bellied Parrot *Neophema chrysogaster*	Psittacidae Rare	Critically Endangered	12	21		11	72		0
Swift Parrot *Lathamus discolor*	Psittacidae Rare	Critically Endangered	15	2	5	360	655		1
Curlew Sandpiper *Calidris ferruginea*	Scolopacidae Common	Critically Endangered	53	100	5	198	3717		1
Far Eastern Curlew *Numenius madagascariensis*	Scolopacidae Common	Critically Endangered	71	100	100	323	1970		2
Great Knot *Calidris tenuirostris*	Scolopacidae Common	Critically Endangered	17	0	0	25	404		1
Lesser Sand Plover *Charadrius mongolus*	Charadriidae Rare	Endangered	11	0		49	544		0
Chatham Albatross *Thalassarche eremita*	Diomedeidae Vagrant	Endangered	0	24		0	0		0
Grey-Headed Albatross *Thalassarche chrysostoma*	Diomedeidae Rare	Endangered	2	95		1	46		0
Northern Royal Albatross *Diomedea sanfordi*	Diomedeidae Common	Endangered	0	98		1	36		0
Shy Albatross *Thalassarche cauta*	Diomedeidae Common	Endangered	28	98	100	748	2328		7
Southern Giant Petrel *Macronectes giganteus*	Procellariidae Rare	Endangered	4	98		6	79		0
Red Knot *Calidris canutus*	Scolopacidae Common	Endangered	35	100		112	2380		0
White-Throated Needletail *Hirundapus caudacutus*	Apodidae Common	Vulnerable	85	3		262	1480		0
Greater Sand Plover *Charadrius leschenaultii*	Charadriidae Rare	Vulnerable	8	2		6	159		0
Antipodean Albatross *Diomedea antipodensis*	Diomedeidae Rare	Vulnerable	0	98		0	0		0
Black-Browed Albatross *Thalassarche melanophris*	Diomedeidae Common	Vulnerable	17	98	57	118	5912		1
Buller's Albatross *Thalassarche bulleri*	Diomedeidae Rare	Vulnerable	2	98	98	1	77		1
Campbell Albatross *Thalassarche impavida*	Diomedeidae Vagrant	Vulnerable	0	98	98	0	86		2
Gibson's Albatross *Diomedea gibsoni*	Diomedeidae Rare	Vulnerable	0	96		0	0		0
Indian Yellow-Nosed Albatross *Thalassarche carteri*	Diomedeidae Common	Vulnerable	7	98		18	81		0
Salvin's Albatross *Thalassarche salvini*	Diomedeidae Vagrant	Vulnerable	0	98		0	109		0
Sooty Albatross *Phoebetria fusca*	Diomedeidae Rare	Vulnerable	2	95		0	10		0
Southern Royal Albatross *Diomedea epomophora*	Diomedeidae Vagrant	Vulnerable	2	98	98	0	68		1
Wandering Albatross *Diomedea exulans*	Diomedeidae Rare	Vulnerable	9	98		4	229		0
White-Capped Albatross *Thalassarche steadi*	Diomedeidae Rare	Vulnerable	0	98		0	980		0
Fairy Tern *Sternula nereis*	Laridae Common	Vulnerable	62	0		378	1849		0
Blue Petrel *Halobaena caerulea*	Procellariidae Rare	Vulnerable	2	97		5	85		0
Northern Giant Petrel *Macronectes halli*	Procellariidae Vagrant	Vulnerable	6	98		6	356		0
Soft-Plumaged Petrel *Pterodroma mollis*	Procellariidae Rare	Vulnerable	0	24		1	7		0
Little Penguin *Eudyptula minor*	Spheniscidae Common	Marine	72	0	4	934	116507		5
Australasian Gannet *Morus serrator*	Sulidae Common	Marine	98	0	3	1645	5914		2
Little Tern *Sternula albifrons*	Laridae Common	Migratory	70	1		282	3007		0
Short-Tailed Shearwater *Ardenna tenuirostris*	Procellariidae Common	Migratory	100	0	70	1620	34842		3

Existing freely available species observation data

Observations of birds within the Bass Strait OWF region from BirdLife Australia, ALA, and OBIS showed that the most numerous observations were those of little penguins (*Eudyptula minor*, 117,441 observations), followed by albatrosses (10,853 observations combined). The remaining observations ranged from 10 observations (skuas) to 9,129 observations (waders) (Table 18).

The spatial distribution of bird observations within the Bass Strait OWF region shows that several bird species of interest are found in the region (Figure 47). For the parrots and needletails and plovers and waders, most of the observations occurred on or near shore. This is also the case for many of the other OWF regions and while it may seem that there is little overlap with OREs, these species are likely cross the offshore areas of OREs during infrequent long-distance movements such as during migration. It is difficult to observe these species during migration and such data can often only be obtained for telemetry studies which are not suitable for all species due to size and other constraints. Notably the critically endangered orange-bellied parrot and swift parrot, will potentially interact with Bass Strait and Southern Ocean OREs during their migrations. These predominantly occur in spring when they move from the mainland to Tasmania and autumn when they do the reverse migration.

Several seabird species occurred further offshore, most notably, little penguins (116,507 observations) including several albatross species, gannets, petrels and shearwaters (Figure 47). While little penguins may not have a particularly concerning conservation status (listed Marine), they appear to be wide spread in the Bass Strait OWF region (in addition to the Illawarra and Southern Ocean OREs), and so the potential interaction with wind farming may deserve particular attention to guarantee that their conservation status remains unchanged in the future. Several species of critically endangered (*Lathamus discolor*, *Neophema chrysogaster*, *Calidris ferruginea*, *Calidris tenuirostris*, and *Numenius madagascariensis*) and endangered (*Diomedea sanfordi*, *Thalassarche cauta*, *Thalassarche chrysostoma*, *Thalassarche eremita*, *Macronectes giganteus*, *Charadrius mongolus*, and *Calidris canutus*) birds under the EPBC Act have all been observed in the region.

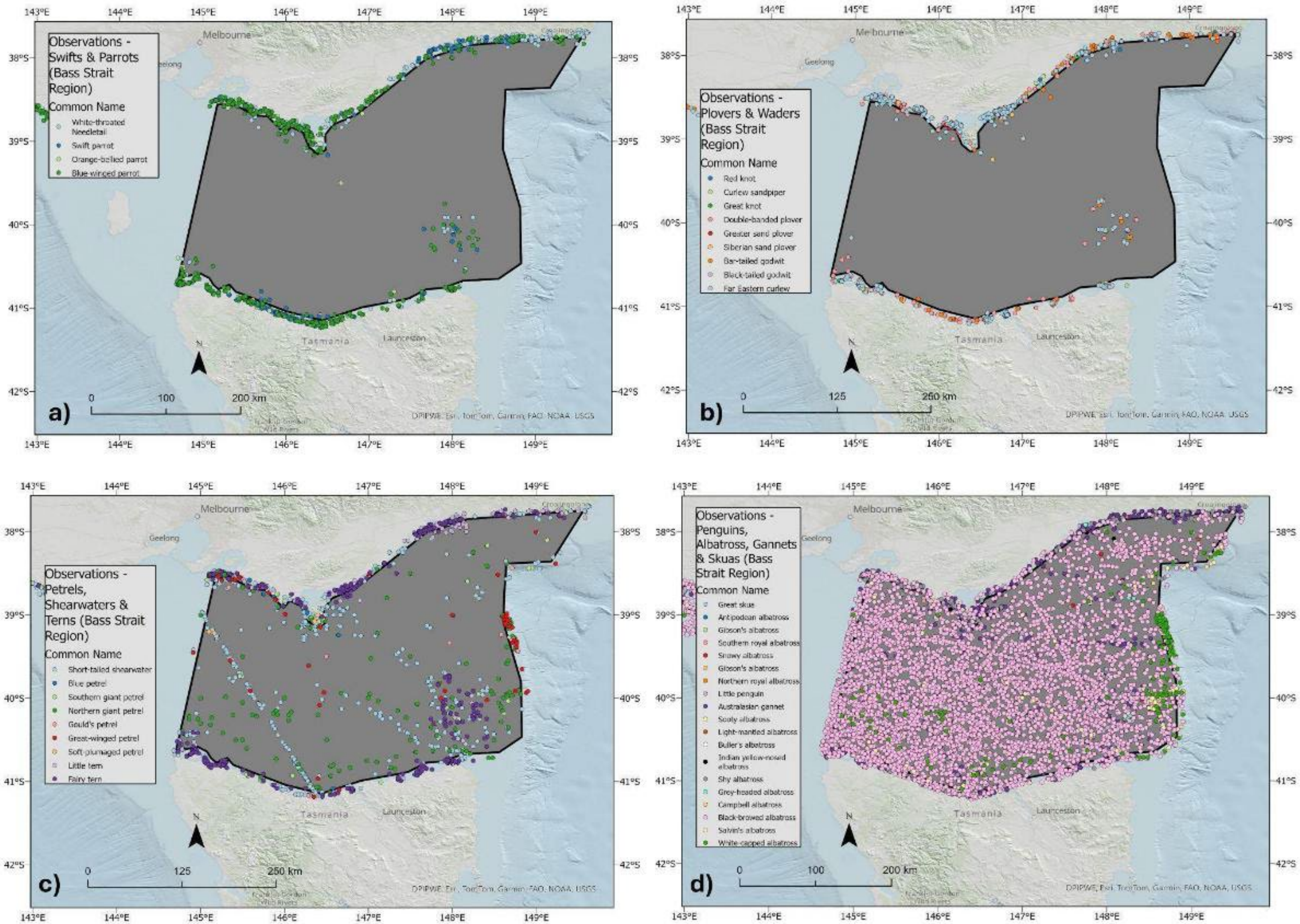


Figure 47. The Bass Strait OWF (grey polygon) showing observations of bird species (plotted in different colours) from BirdLife Australia, the ALA, and the OBIS for each bird grouping (a-d). [Declared area boundaries finalised after completion of maps in this report and are not amended here].

6.7.3. Sharks

Published papers/reports inventory

Within the Bass Strait region, ten published studies on shark species of interest that overlap with the OWF area were found and compiled (Figure 48). All ten studies were on the white shark (*Carcharodon carcharias*, listed vulnerable under the EPBC Act) with high overlap (Table 19) between the study areas where white sharks occurred and the OWF region suggesting that much of the Bass Strait region (91,530 km2) serves as potential habitat for white sharks (89,295 km^2). Occurrence of white sharks in the Bass Strait region was thought to be highest from January to July, with lower occurrence thereafter.

Table 19. Shark species for which we have compiled spatial data from published studies and freely available data repositories (BLA, OBIS and ALA) that overlap with the Bass Strait OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark brown indicates months of the year with peak occurrence, light brown indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Bass Strait shark Table link

Bass Strait OWF: Shark

			AREA AS % OF OWF			OBSERVATION COUNTS	SEASONALITY												NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	VBA	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Grey Nurse Shark *Carcharias taurus*	Odontaspididae -	Critically Endangered	0	1		1													0
White Shark *Carcharodon carcharias*	Lamnidae -	Vulnerable	0	98	98	111													10

Existing freely available species observation data

Observations of sharks within the Bass Strait OWF region from the ALA and OBIS showed two species of sharks to be present with the white shark (111 observations) being more numerous than those of the grey nurse shark (5 observations) (Figure 48). However, there was only limited spatial coverage of these observations in the OWF and highest density occurring to the East of Wilsons Promontory in Victoria and offshore.

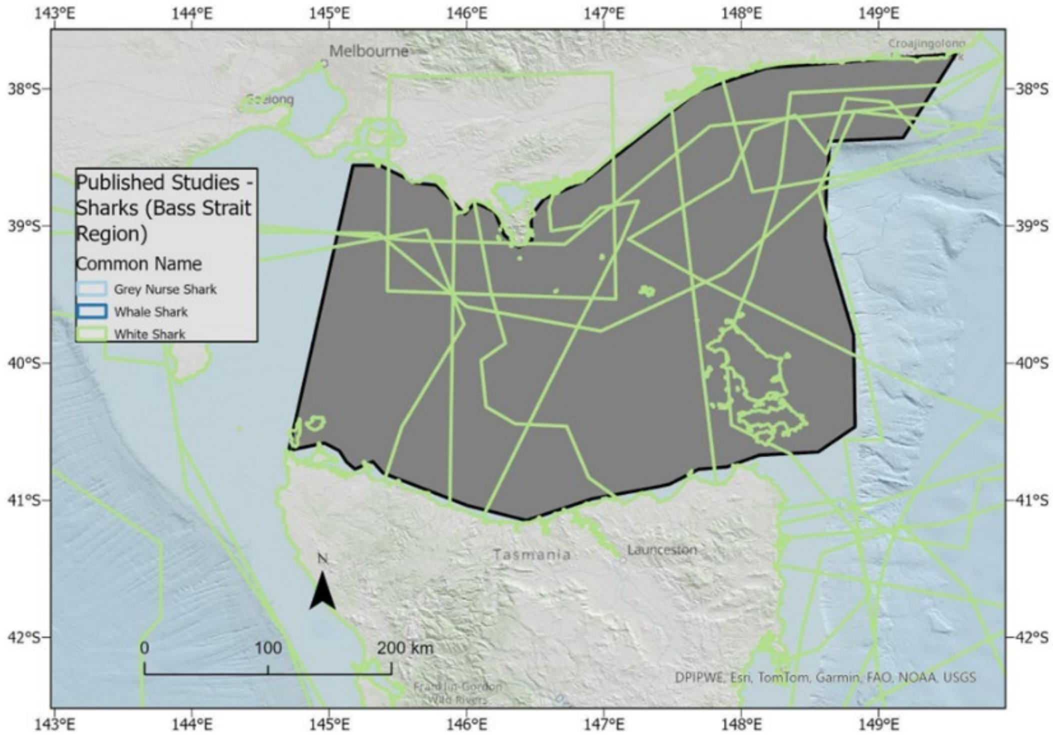


Figure 48. The Bass Strait OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where shark species occurred. The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

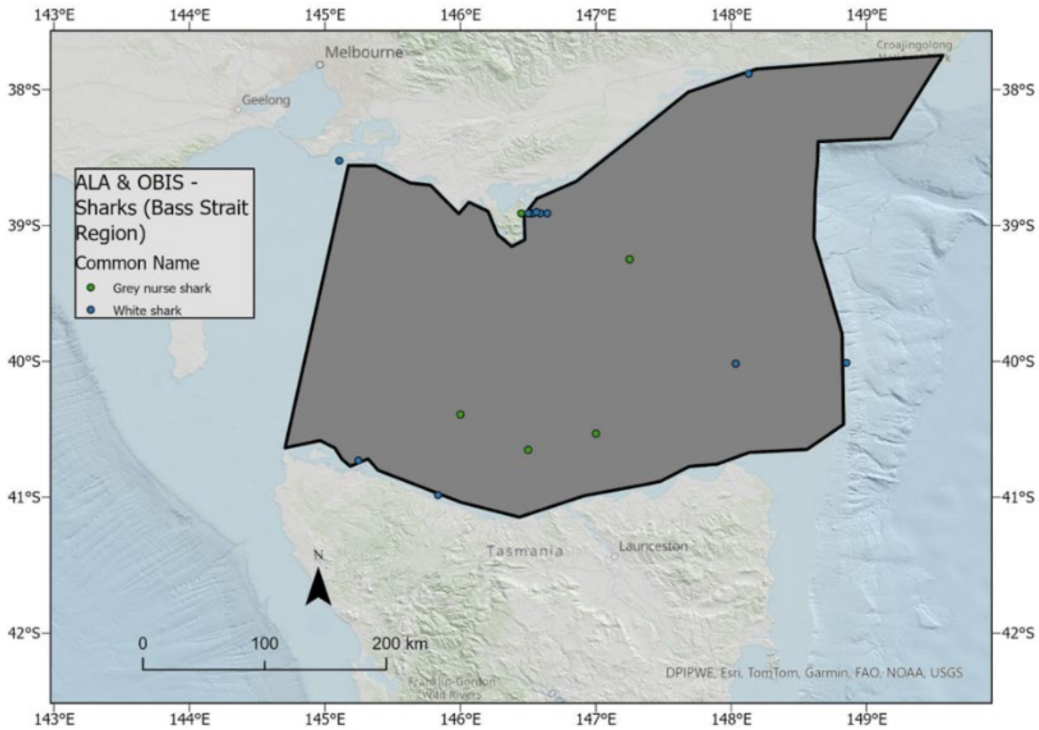


Figure 49. The Bass Strait OWF region (grey polygon) showing observations of shark species from the ALA and the OBIS. The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

6.7.4. Reptiles

Published papers/reports inventory

Within the Bass Strait region, four published studies on reptile species of interest that overlap with the OWF area were found and compiled. This included 3 studies of leatherback turtles (*Dermochelys coriacea,* listed endangered under the EPBC Act) and one on loggerhead turtles (*Caretta caretta,* listed endangered under the EPBC Act). The combined study areas where leatherback turtles were found had 65% overlap with the Bass Strait OWF area, while the study area of the loggerhead turtle had only negligible overlap with the OWF region. The SNES distribution map for loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*) and green (*Chelonia mydas,* listed vulnerable under the EPBC Act) turtles all had distributions that covered a majority of the Bass Strait OWF region (84%, 88%, 98%, respectively; Figure 50. The SNES distribution of the Hawksbill turtle (*Eretmochelys imbricata,* listed vulnerable under the EPBC Act) also intersected the OWF but had very minor coverage (3%).

Table 20. Turtle species for which we have compiled spatial data from published studies and freely available data repositories (BLA, OBIS and ALA) that overlap with the Bass Strait and Gippsland OWF area. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark brown indicates months of the year with peak occurrence, light brown indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Bass Strait reptile Table link

Bass Strait OWF: Reptile

			AREA AS % OF OWF			OBSERVATION COUNTS	SEASONALITY	NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	VBA	SNES	PUBS	OBIS-ALA	J F M A M J J A S O N D	PUBS
Loggerhead Turtle *Caretta caretta*	Chelonidae -	Endangered	2	84	0	15		1
Leatherback Turtle *Dermochelys coriacea*	Dermochelyidae -	Endangered	10	88	65	105		3
Green Turtle *Chelonia mydas*	Chelonidae -	Vulnerable	0	98		6		0
Hawksbill Turtle *Eretmochelys imbricata*	Cheloniidae -	Vulnerable	2	3		7		0

Existing freely available species observation data

Observations of listed reptiles within the Bass Strait OWF region from the ALA and OBIS showed four species of turtles to be present with observations of the leatherback turtle being the most numerous (105 observations), followed by the loggerhead turtle (15 observations), hawksbill turtle (7 observations) and the green turtle (6 observations) (Figure 50, Table 21). Most observations (especially for green turtles) occurred between the coastline and the landward OWF boundary which is likely due to shore and recreational boat-based sightings. There were only a few observations that occurred offshore. Satellite tracking of leatherback turtles indicates animals migrating along the east coast of Australia through NSW, Victoria and Tasmania. This species has an IUCN Red Listing of Critically Endangered. Leatherback turtles likely have seasonal residence in Bass Strait, potentially feeding on jellyfish. Pacific leatherbacks have shown population decline at nesting beaches, so there may only a few thousand adults remaining in the Pacific. The satellite tracking and direct observations together clearly show animals are widely distributed from near-shore waters out to the 200 nm limit of EEZ. The calculations in Hays et al. (2023) show large numbers of leatherbacks foraging in Bass Strait, so this area could be a globally important foraging hotspot for the species.

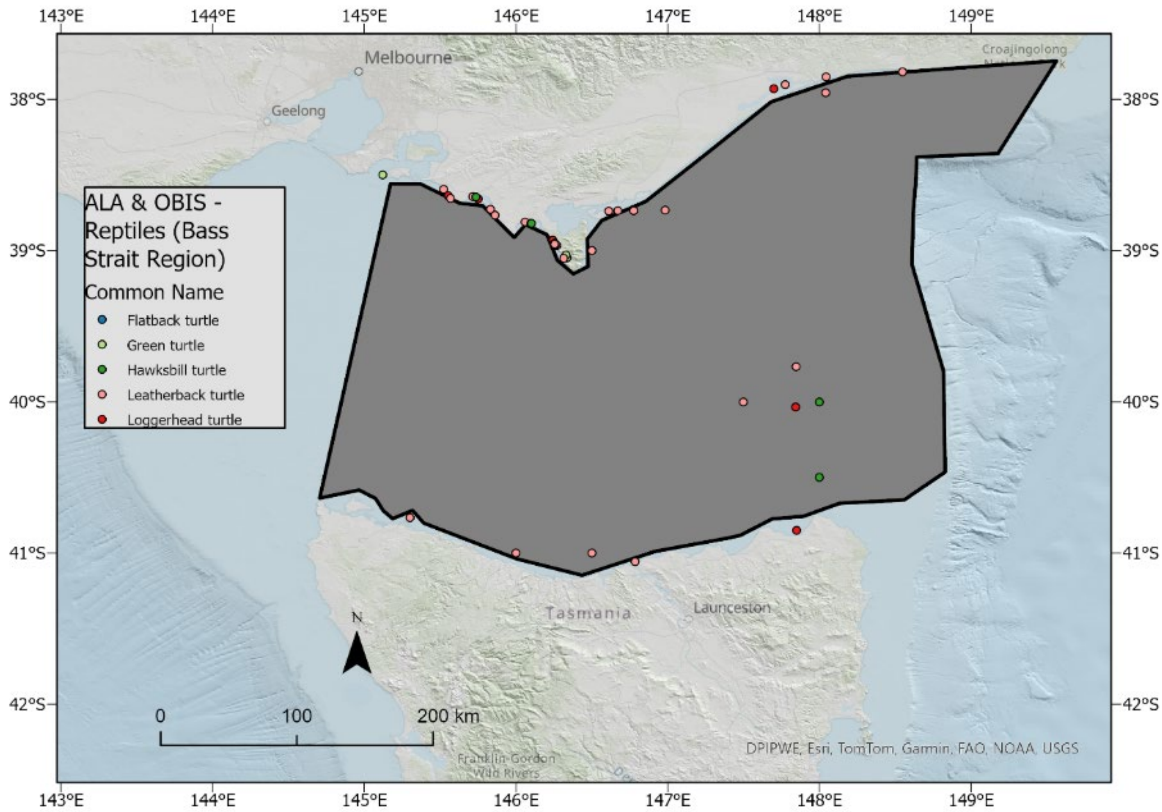


Figure 50. The Bass Strait OWF region (grey polygons) showing observations of reptiles from the ALA and the OBIS. The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

6.7.5. Other species

Information on finfish, invertebrates and other species of interest can be viewed in the inventory for the Bass Strait region. This list is not comprehensive as it was not the focus of this study and therefore only a small subset of species are provided. There were 484 observations of giant kelp within the Bass Strait OWF from the ALA (Table 21; Figure 51). A great number of these observations were in areas around the coastline of Tasmania, Victoria and islands that are located within the Bass Strait. Giant kelp observations occurred around much of the OWF boundary that paralleled with the coastline.

Within the Bass Strait region, three published studies on the macroalgae species of interest; giant kelp (*Macrocystis pyrifera),* that overlap with the OWF area were found and compiled (Figure 51, Figure 52). There was 56% overlap between the study areas where giant kelp was found (50,893 km^2) and the Bass Strait OWF region (91,530 km^2).

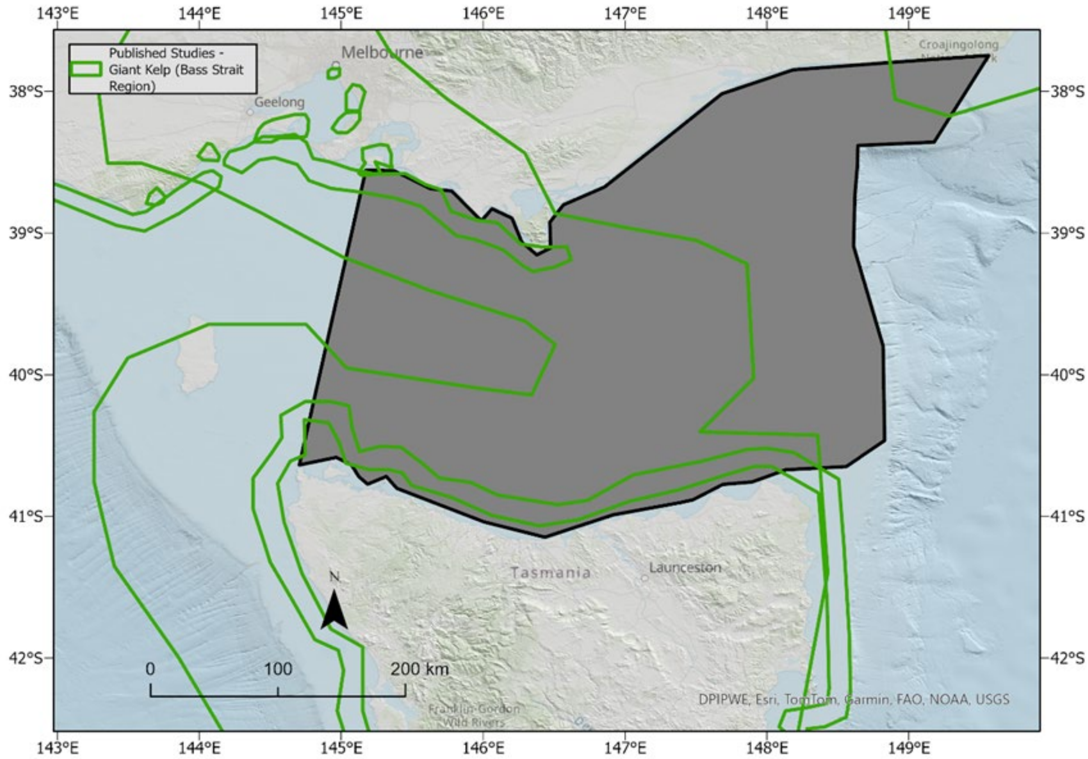


Figure 51. The Bass Strait OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where giant kelp occurred. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

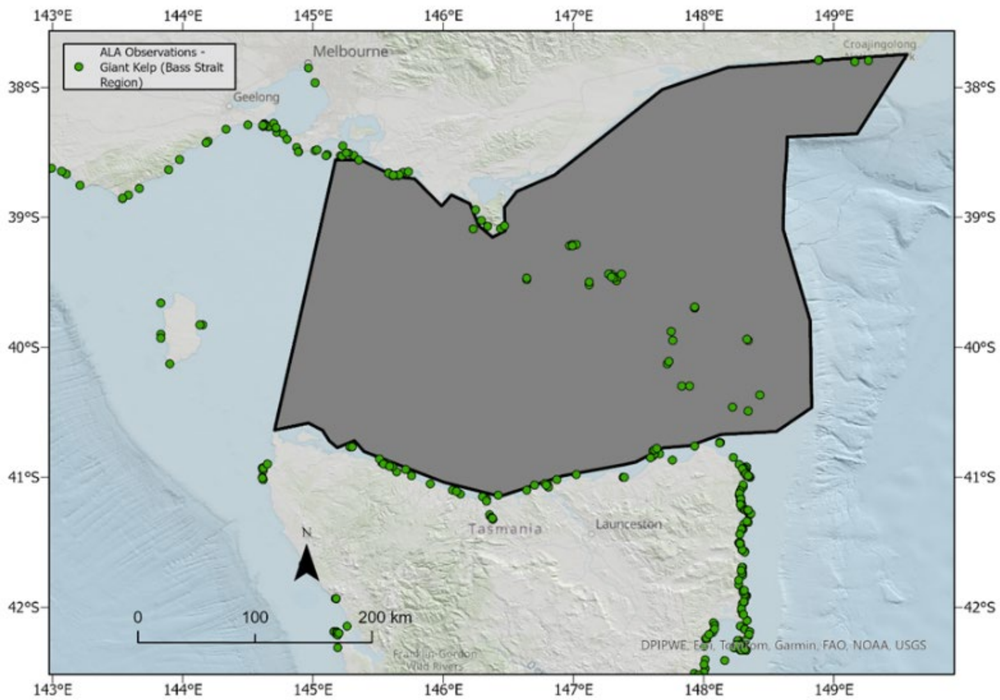


Figure 52. The Bass Strait OWF (grey polygons) showing observations of giant kelp from the ALA and the OBIS across the Bass Strait region. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

Table 21. Listed habitat (giant kelp) for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Bass Strait OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Bass Strait macroalgae Table link.

Bass Strait OWF: Macroalgae

			AREA AS % OF OWF			OBSERVATION COUNTS		SEASONALITY	NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	VBA	SNES	PUBS	BLA	OBIS-ALA	J F M A M J J A S O N D	PUBS
Giant Kelp *Macrocystis pyrifera*	Lessoniaceae -	Endangered	10	0	56	0	484		3

6.8. Indigenous communities

In this section we focus on the Aboriginal people within Victoria (Gippsland and Melbourne regions) and northern Tasmania. The land bridge between the Australian land mass and Tasmania (i.e. Bass Strait and Gippsland) falls well within the known timescale of habitation by Aboriginal people in the area, indicating strong historical connections between its First Nations people. There are many sacred sites listed throughout sea Country and a strong cultural heritage and spiritual connection to the seabeds that were once dry - an important note given offshore wind turbines will be bedded in or connected to the seafloor (Overview of the Proposed Area Bass Strait.docx (live.com).

Further connections between these areas and communities were highlighted by Hamacher et al. Linking oral stories of Tasmanian Aboriginal people (palawa) and the Kurnai people of Gippsland area recalling the stories of the land bridge and use as well as ancient coastline areas prior to sea level rise (2023, p.6). The coastline extending to the ancient coastlines of the land bridge / Bassian plain has been highlighted and recognised as an area containing many Aboriginal heritage sites that are “already located in intertidal and subtidal areas as a result of sea level rise associated with the last interglacial period...”(Page & Thorp, 2010, Chapter 5- p. 11).

6.8.1. Tasmania

In Tasmania there have been no successful Native Title applications under the *Native Title (Tasmania) Act 1994* (Tas) and there is no Native Title Representative Body in the state (AIATSIS, 2016., p. 4; NNTT Website) The ILUA’s and NT PBC website also returned no search results for Tasmania. The Office of the Register of Indigenous Organisations (ORIC) returned several results with overlaps in these organisations and state government collaborations, media results, IPAs and HCP’s. Tasmania’s Department of Premier and Cabinet through Aboriginal Heritage Tasmania (AHT) have responsibilities for administering the *Aboriginal Lands Act 1995*, the *Native Title (Tasmania) Act 1994* and the *Aboriginal Heritage Act 1975* through Minister for Aboriginal Affairs. AHT also administer and work with the Aboriginal Heritage Council and contribute to Healthy Country Planning in the sate (Aboriginal Heritage Tasmania n.d.; AIATSIS 2016).

The Tasmanian Aboriginal Centre Inc. (TAC) manage several IPAs around the proposed offshore renewables area which include Ramsar wetlands and ecologically significant coastal habitats in north-eastern Tasmanian waters. DCCEEW provided funding in May 2022 to link 5 existing IPAs together under a project called the Tayaritja Sea Country IPA and have since held community consultation workshops. Stated goals of the project include “the rehabilitation, restoration, monitoring and evaluation of ecologically significant marine ecosystems to protect threatened marine animals and mentions seabirds, megafauna and over 120 terrestrial and marine plant species" (Sea Country IPAs Program - Grant Opportunity - DCCEEW). Additionally, the project cites animal pests and weed management programs to ensure the maintenance of healthy coastal ecosystems.

The Tasmanian Aboriginal Centre website refers to a Sea Country IPA area surrounding Tayaritja/Bass Strait Islands aiming to support Palawa community's connection with Sea Country including understanding, protection and management through partnering with others. There is also a sea Country team including Aboriginal Sea Country Rangers (TAC 2023). The tayaritja Healthy Country Plan developed by the Tasmanian Aboriginal Centre Inc. for the Furneaux Islands covers Tasmanian Aboriginal Centre Managed Land through IPAs (TAC, n.d.). The plan includes that the Aboriginal community's connection to the Furneaux Islands extends back around 20 000 years and highlights the cultural connection to this area through various shell middens indicating thousands of years of connection to various places in this area as well as shelters and camps (TAC, n.d., p.50). The plan indicates there is focus on economic opportunity through utilising natural resources without exploiting them (TAC, n.d., p.53). Targets of relevance included things like yula (short-tailed shear water), Cape Barren Geese, cormorants and other birds, stringing shells, kelp and shellfish as sea Country cultural resources of significance (TAC n.d., p.36, 48).

State government collaborations and agreements have led to policy changes such as the Land and Sea Aboriginal Corporation Tasmania (LSACT) agreement with the Tasmanian state government allowing Tasmanian Aboriginal people to develop cultural and commercial fishery activities around significant cultural resource abalone. Recognition of cultural harvest as integral to cultural practice was highlighted as important for improving socio-economic outcomes for Tasmanian Aboriginal people (The Department of Premier and Cabinet, 2022)

The Tasmanian Regional Aboriginal Communities Alliance (TRACA) is an alliance between some of these ORIC registered organisations and their website states the group "was developed to provide a mechanism to engage and advise Government at all levels in regard to affairs affecting Aboriginal Tasmanians." The member organisations are all Aboriginal Community Controlled Organisations (ACCOs) and include seven organisations. The organisations adjacent to the OWF development area are Circular Head Aboriginal Corporation (CHAC), Six Rivers Aboriginal Corporation, Melythina Tiakana Warrana Aboriginal Corporation (MTWAC), and Flinders Island Aboriginal Association (FIAA) (Tasmanian Regional Aboriginal Communities Alliance, 2018). Results for these organisations varied in relation to whether they had websites, documented and/or publicly available documents that indicate environmental and cultural heritage values etc.

MTWAC have a strategic plan and 14 person Ranger group the Tebrakunna Rangers whose central responsibilities in Cultural Land and Heritage Management and are based in the NE corner of Tasmania (MTWAC n.d.). The MTWAC Strategic Plan 2018-2023 states members belong to Pairrebeene/Trawlwoolway people, direct descendants of the Coastal PlainsNation of northeast Tasmania.

Other Coastal Plains Nation clans include Peeberrangner, Leenerrerter, Pinterrairer, Pyemmairrenerpairrener, Leenethmairrener & Plennerremairemenner (MTWAC 2018, p. 5). The vision of the plan states the Pairrebeene/Trawlwoolway people's motivations for freedom and equity in to practice culture, care for traditional lands, water ways and sea Country. (MTWAC 2018, p.9). Priorities listed "Culture & Heritage" as one of five focuses including identifying, protecting, and managing unique cultural heritage (tangible and intangible) and sacred land and sea Country (MTWAC 2018, p. 9 &15). This included several commitments such as around continuing cultural practices, passing on knowledge, providing a voice to government on culture and heritage, seeking land return and access to sea Country and resources and supporting of opportunities to do this (MTWAC 2018, p.15).

Six Rivers Aboriginal Corporation care for the Tiagarra Cultural Centre at Mersey Bluff in Devonport with cultural heritage sites throughout the whole area adjacent to the OWF Development Area including rock engraving or petroglyphs. Six Rivers refers to members being palawa people who care for the area that has “deep cultural significance as a valued cultural heritage site”. The palawa people of Six Rivers Aboriginal Corporation state dedication to the area through protecting, preserving, understanding and educating others on these values and places as culturally significant (Six Rivers Aboriginal Corporation, 2021).

CHAC are a supportive body for the Aboriginal community of Circular Head aiming to represent the 9 tribes of the region. Culture and Heritage sections of their website mostly refer to focuses of reconnecting and continuing cultural practice between generations as well as educating and raising public awareness of Indigenous culture in the broader Circular Head Community (Circular Head Aboriginal Corporation, 2022).

Further environmental and cultural values and connections to the coast and sea Country for Tasmanian Aboriginal people and communities were found including sea Country being identified as womens Country in Tasmania with focus on seagrass where maireener shells grow used for stringing necklaces by Tasmanian Aboriginal women, kelp for making water carriers, shellfish such as abalone, crayfish, yula/ yolla- mutton bird or short tailed shear water (CMS 2023; Page & Thorp, 2010). Further coastal values identified were seals, swan eggs, fish traps, rock shelters and stone quarries dating back at least 40, 000 years (Page & Thorp, 2010, Chapter 5- p. 2-3). We were unable to find any information of public statements from Traditional Owner Groups in Tasmania in relation to OWF development for Bass Strait at this stage.

6.8.2. Gippsland Melbourne Region

The First Nations people of the area adjacent to the (declared) Gippsland OWF development region is the Gunaikurnai and the Boonwurrung/Bunurong peoples. The Gunaikurnai people (5 clans) hold Native Title over the approximate areas from Lakes Entrance to Wilson Promontory and have a strong governance structure - the Gunaikurnai Land & Waters Aboriginal Corporation (GLaWAC) which is the recognised Registered Aboriginal Party and represents the Gunaikurnai people under the Traditional Owners Settlement. They have an Indigenous Land Use Agreement (ILUA) alongside a joint management arrangement with the Victorian Government helping to manage 14 National Parks and Reserves which is driven by a separate entity, the Gunaikurnai Land Management Board.

The Gunaikurnai Whole of Country Plan is heavily focussed on culture and economic development stating general objectives, principles, and priorities to maintain and invigorate Gunaikurnai culture. The Gunaikurnai are in the process of developing a strong and skill rich Land and Sea Ranger Unit which has already engaged with scientists. Amongst the various documents collated, they do not see a difference between land and sea and regard the grey nurse shark (*Carcharias taurus*) alongside table fish such as flounder, flathead, mullet, garfish, perch and bream in high value and esteem. Similarly, mussels and abalone are also mentioned as indigenous food items. Other sea and skyscape concerns include migrating birds such as swifts, the blue wren, seabirds such as pelicans, cormorants and sea eagles as well as migrating marine mammals. There is additionally an IPA process currently progressing aimed at preserving cultural heritage places and values.

The Bunurong Land Council Aboriginal Corporation is the Registered Aboriginal Party that consists of 6 clans from the Morning Peninsula, Westernport, and a portion of the South-

West Gippsland. The Boonwurrung Land and Sea Council incorporate and have claim to the same area as the Bunurong, they have a native title claim in pending. Both Bunurong entities do not appear to have a Healthy Country Plan or list of environmental values from the online desktop search we conducted. However, both have strong connections to sea Country with seafood being a big part of their past and present diets, as evidenced from the shell middens of pippy shells and abalone found throughout the landscape (Bunurong Land Council).

7. Southern Ocean Offshore Wind Farm region – knowledge base

7.1. Bathymetry

Multibeam data coverage for the Southern Ocean OWF region is varied (Figure 53). Data coverage offshore of the continental shelf is extensive and continuous, allowing interpretation of seabed features. In contrast, data coverage on the shallower continental shelf is poor and limited to narrow swaths from vessel transits. Swaths of full coverage coastal LiDAR data complimented by multibeam bathymetry to 3 Nm are also available for the Victorian coastline allowing for detailed interpretation of seabed features in State waters (www.land.vic.gov.au).

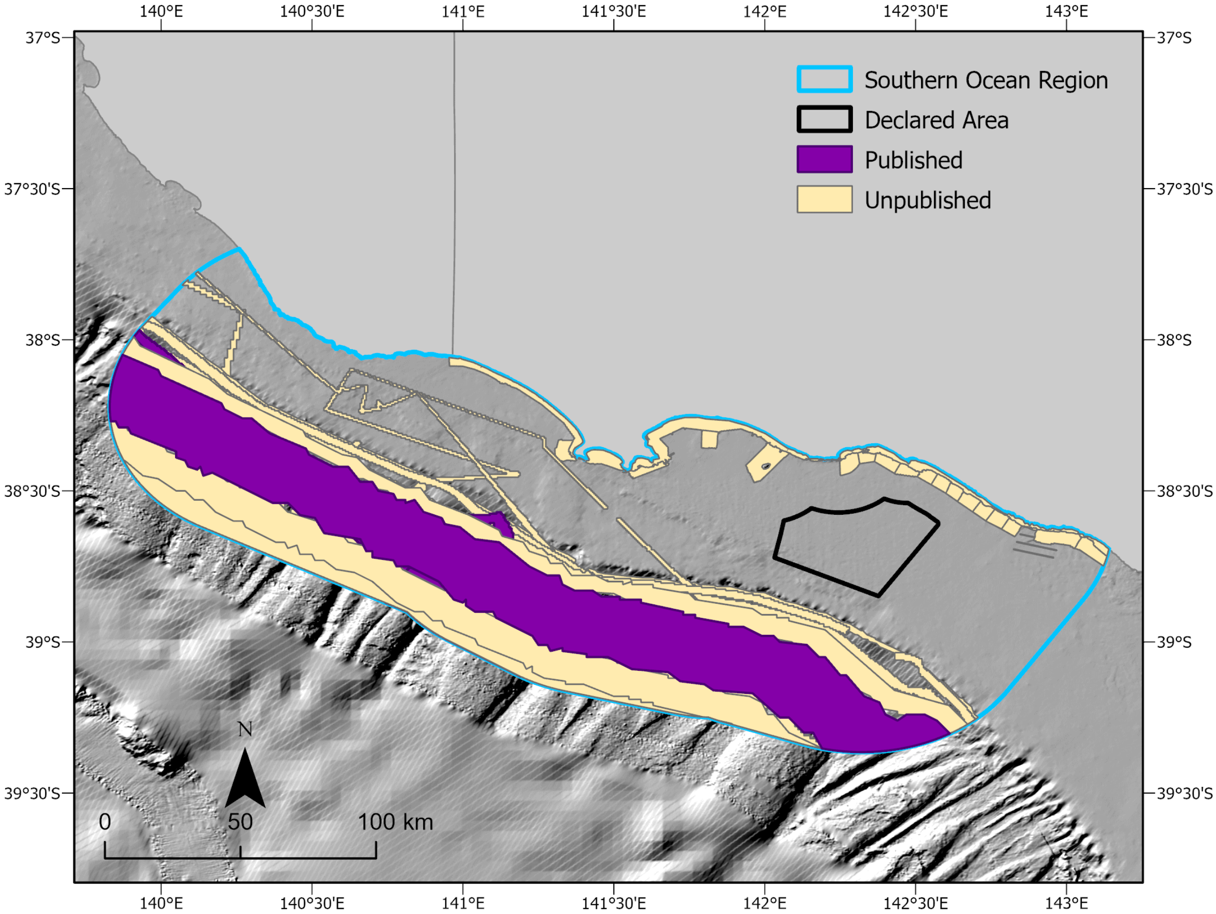


Figure 53. Bathymetry coverage for the Southern Ocean Region (defined by blue polygon) showing the spatial extent of bathymetry data (published and unpublished), including nearshore LiDAR data and multibeam bathymetry surveys to 3nm. Data extents are provided by third party contributors to the AusSeaBed Data Portal (listed in the Marine Baseline Data Inventory). Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

7.2. Seabed geology

The Southern Ocean OWF region is situated entirely within the sedimentary (geological) Otway Basin (Figure 54) and large, infilled, Late Miocene (2 – 10 million year old) canyons and ancient mass movements characterise the sub-surface geology of the area (Figure 55; Wu et al., 2022). The Otway Basin is the most recently active volcanic province on the

Australian continent (Holt et al., 2014). Though most buried volcanic/hydrothermal vents, lava flows and dykes were emplaced over 10 million years ago into offshore strata beneath the region (Niyazi et al., 2021), relatively recent volcanism occurred 4,300 years ago (e.g. Mt Gambier; Holt et al., 2014). The eruption frequency of this province has been estimated at once every 11,000 years; and there is potential for future volcanic events (Boyce, 2013).

7.3. Seabed geomorphology

The seafloor in the region is characterised by low gradient (<2 degrees), relatively shallow (< 200 m) continental shelf, and a series of named canyons and (unnamed) mass movements dissect the perimeter of the outer shelf and continental slope to water depths to over 3000 m (Figure 55 and Figure 53; Heap and Harris 2008). The steepest surfaces associated with canyons and mass movements, and the headwall of the Normanby Terrace on the shelf, likely provide important habitat for benthic communities (habitat-forming sponge communities, hard and soft corals etc.). Canyon and mass movement features at the seabed also have the potential for significant seafloor instability; submarine groundwater discharge may be occurring within these on the upper slope (Wu et al., 2022; DeDeckker and Nanson, 2023; Harishidayat et al., 2024). Submarine groundwater discharge may provide suitable conditions for dependant ecosystems but may also cause seabed instability (DeDeckker and Nanson, 2023).

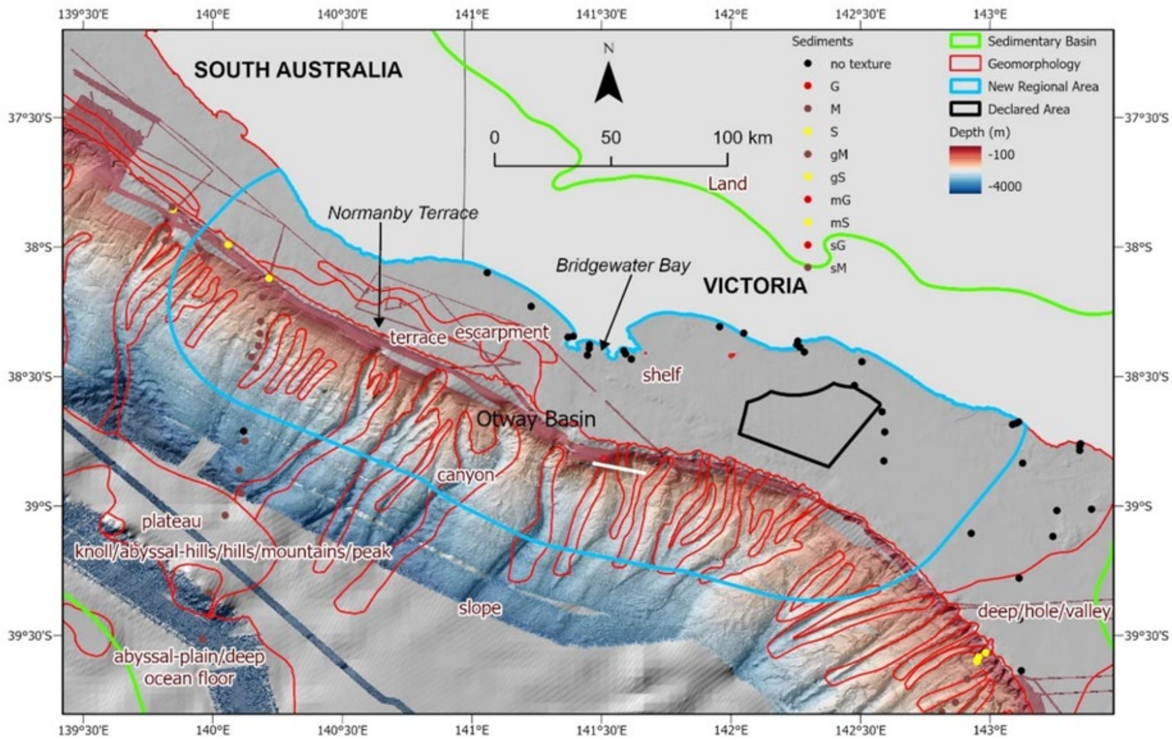


Figure 54. The Southern Ocean declared area (black polygon), and region (blue polygon), over the regional 50 m bathymetry grid (REF). Seabed geomorphology, the boundary of the Otway Sedimentary Basin (green) and locations referred to in the text are indicated. Bathymetry derived from the national 50 m grid (Parums and Spinoccia, 2019). Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

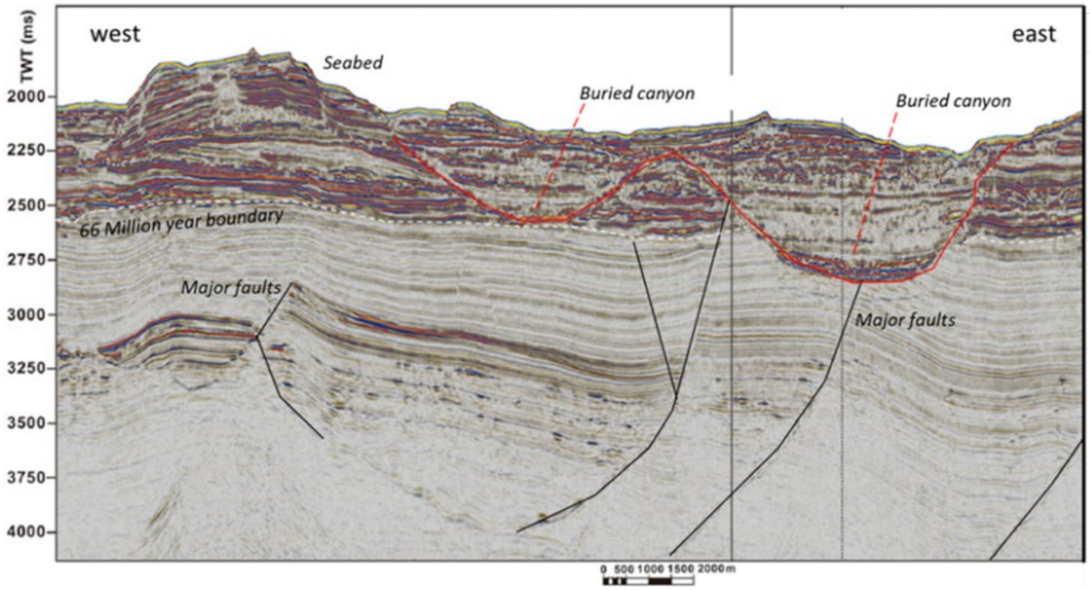


Figure 55. Buried canyons are common beneath the seabed on the continental shelf and slope. This seismic image is aligned approximately parallel with the shelf break and intersects the mid-southern region of the declared area.

7.4. Sedimentology

The shelf is predominantly sediment starved and erosional in places, with mixed sedimentary facies (James and Bone, 2011). Sediment samples in the region are sparsely distributed and only 15 of these provide information on grain size (Figure 56). Surficial sediments on the shelf are comprised of high energy, open ocean, cool-temperate sand-sized carbonates (James and Bone, 2011; Carvalho et al., 2022; MARS database; Figure 56). In deeper water the small number of available sediment samples are of mud to rarely sandy-mud size. Sediment transport is from east to west via the Flinders Current (James and Bone, 2011).

Shallow LiDAR data and multibeam bathymetry along the coast reveal that rocky headlands extend offshore and compartmentalise adjacent sandy beaches, which are more vulnerable to coastal movement. Recent coastline movements in the region are variable: a 30 km long section of coast in the Discovery Bay Coastal Park (near Bridgewater Bay: Figure 56) is prograding (building into the sea), however, the remainder of this coast (~300 km) is relatively stable or eroding at up to 2 m/year.

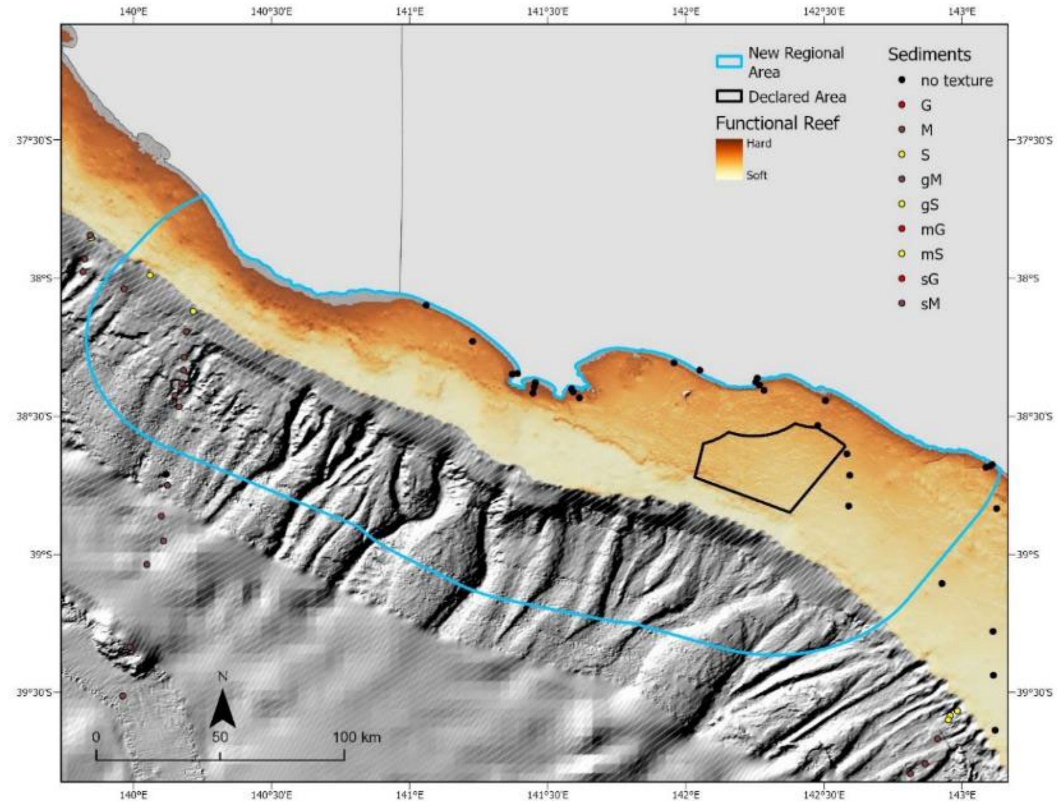


Figure 56. "Functional Reef" modelling (NESP 2.1) indicates predicted occurrence of reef forming habitats. Sediment sample textures (primary, secondary): G, g – gravel; S, s – sand; M, m – mud. Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

7.5. Seabed habitats and benthic biodiversity

The Southern Ocean region sits in the productive Bonney Upwelling zone off southern Australia. The shelf in this region is fairly large (~70 km wide) and consists of a diversity of substrates, including large areas of rocky reef or potential rocky reef. The extensive mapping completed within the nearshore waters areas of this region indicates that the seafloor is dominated by both high and low relief hard substrates interspersed with soft sediment. Additionally, a 50 m resolution bathymetry dataset indicates that these hard substrates continue offshore, potentially providing more mesophotic reef dominated habitats.

Comprehensive benthic habitat, fish diversity and southern rock lobster survey was completed inside and adjacent to the Discovery Bay Marine National Park, located inshore of the proposed Southern Ocean declaration area (Young et al., in review) (Figure 57). Transects using autonomous underwater vehicles (AUV) covering 21.7 km and ranging in depth from 16-75 m identified a diversity of benthic habitats. There was a clear variation in habitat types between depth zones, with macroalgae-dominated reefs in shallow areas, sponge and invertebrate dominated reefs in deeper areas, and the deeper, low relief areas dominated by unconsolidated substrates (see Che Hasan et al., 2012). Sponge dominant invertebrate assemblages were typical in depths >50 m, which may correspond to the habitats found in the Southern Ocean declaration area.

The region is known for its extensive low-profile reefs, often with a thin veneer of sand or mobile sand dunes, which suggests a generally sediment-starved system, with transport potential exceeding supply. The calcareous fraction of the bed sediments are biogenic and their abundance increases westward in the vicinity of the designated area, suggesting an origin on deep water bryozoan dominated reefs off Western Victoria (Carvalho et al., 2022). Video observations in the designated offshore wind zone consist of towed video records from locations commercially potted for fishery independent rock lobster assessments. The video sites between 80-120 m were predominantly low-profile patchy reef, with a few sites showing continuous high-profile reef. All these reefs were found to support sessile invertebrate communities (sponge dominated beds) (Ball et al., 2010).

Fish assessments from Discovery Bay using Baited Remote Underwater Video (BRUV) deployments identified a total of 88 taxa across 6,339 individuals. The most abundant taxa included small schooling species such as butterfly perch, scad, and redbait, along with jackass morwong and rosy wrasse. The taxa with the highest biomass included large sharks and rays such as eagle rays, gummy sharks, and smooth rays and the larger schooling fish such as snapper. The common and widespread taxa included rosy wrasse, jackass morwong, morid cods, blue-throat wrasse and butterfly perch.

The southern rock lobster surveys in this region also indicates that this area has very productive lobster habitat, with high abundances found both inside and outside the marine park, but with significantly more inside. Additionally, there were large numbers of legal-sized individuals. It is expected that the Southern Ocean OWF region contains a large amount of lobster habitat as this region is targeted by commercial fishers.

Although not inside the Southern Ocean OWF region, recent surveys in Apollo Marine Park, which is located just east of Cape Otway, may provide an indication of the types of species and habitats within the OWF area as surveys were conducted at greater distances offshore (Figure 57). The fish surveys observed 67 taxa, with teleosts comprising 42 taxa, chondrichthyans 18 taxa, and 7 invertebrate taxa, with chondrichthyans constituting nearly 30% of vertebrate taxa observed. Schooling species like scad, snapper, and velvet leatherjackets were among the most abundant, while large sharks and rays, along with larger schooling fish, dominated the observed biomass. Common gurnard perch, velvet leatherjacket, and snapper were the most widespread taxa observed on the majority of BRUV deployed.

Significant differences were observed in fish assemblages across different habitats and depth ranges. Species like common gurnard perch, snapper, and barracouta were more abundant in soft sediment habitats, while velvet leatherjackets, six-spine leatherjackets, and jackass morwong were prevalent in circalittoral reef areas. Additionally, some species showed preference for medium or deep habitats. Despite these differences, overall species richness, total abundance, and biomass did not vary greatly across habitat types and depth strata, except for higher species richness in circalittoral reef habitats compared to soft sediment.

Despite similar sampling efforts, a higher proportion of lobsters (59%) were captured outside the Apollo Marine Park than inside (41%), likely a function of available habitat. Previous work has also indicated that this region is likely to be productive blacklip and greenlip abalone fishing grounds in inshore regions. Surveys on populations and their associations with habitat has shown that the southwestern region of Victoria provides productive abalone fishing grounds (Young et al., 2020), and these fishing grounds are likely to extend offshore and include the greenlip abalone. However, this region has experienced multiple outbreaks of a virus that has dramatic effects on abalone populations (Jalali et al., 2015).

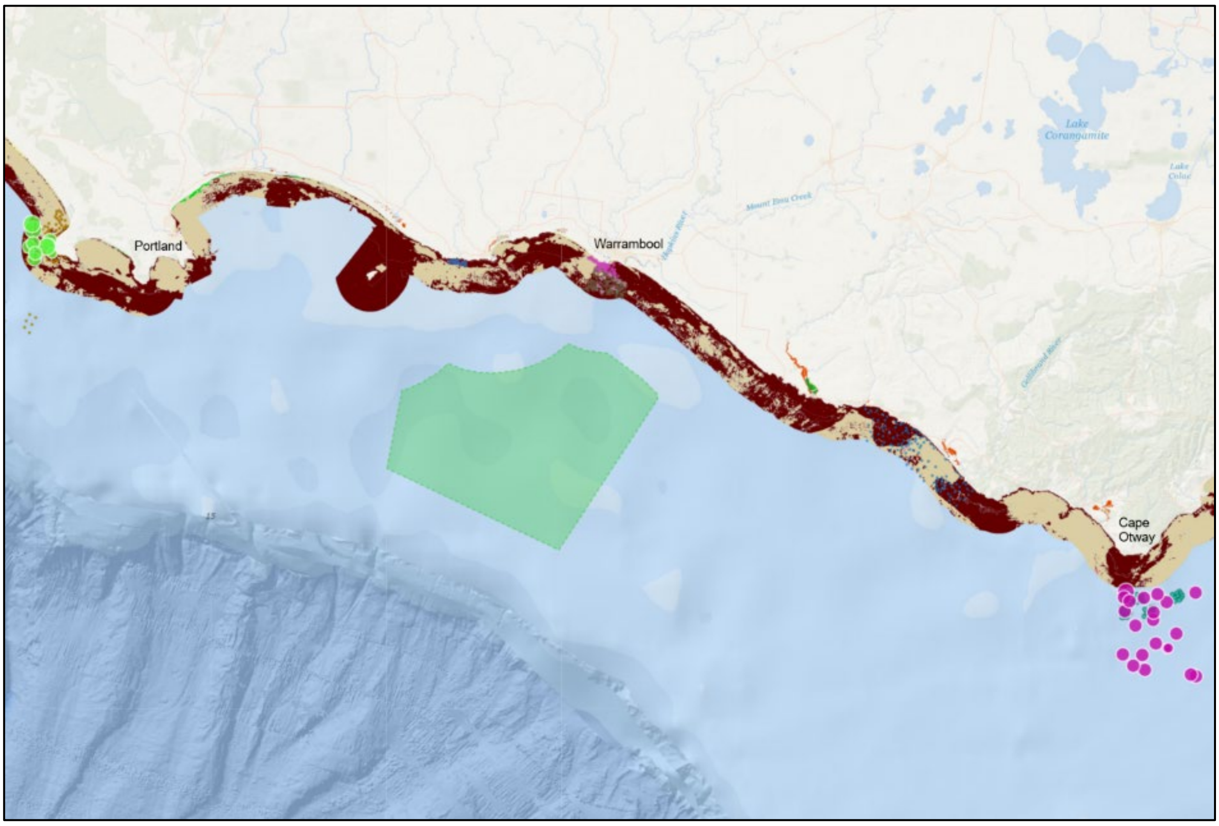


Figure 57: Available seabed ecological survey locations and habitat data for the Southern Ocean OWF region represented in the Seamap Australia marine spatial data portal, including surveys using towed video, Autonomous Underwater Vehicles and Baited Remote Underwater Videos. Details on deployment types and effort are available at:

https://seamapaustralia.org/map/#2cb29b60-9b99-452e-86a5-f061fde59a9d

7.6. Oceanography

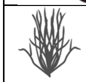
The Southern Ocean region is a micro-tidal open ocean area exposed to strong atmospheric and oceanographic processes. Peak tidal currents are estimated to be around 0.25 m s-1 in the OWF declared region (from TPXO8, Egbert and Svetlana, 2002). Periodic atmospheric cold fronts generate currents (coastally trapped waves) that flow west to east through the region (Baines, 1989). Along the southern shelf the circulation is predominantly the result of wind forcing. Observations strongly suggest that there is a wintertime eastward current over the continental shelf flowing from Cape Leeuwin to the southern tip of Tasmania. In the summer, the coastal wind reverses and changes to an upwelling favourable system producing westward flow at the coastal boundary (Butler et al., 2002).

Seasonal stratification is expected move through the OWF area (based on preliminary CARS analysis) with transitions from the stratified summer state to the well mixed winter state observed in the region (Levings & Gill, 2010). The region’s most distinctive oceanographic feature is the Bonney Upwelling. It is part of a regional upwelling system with an alongshore extent of ~800 km (Gill et al., 2011).

Wave energy in the OWF region is high due to the region's exposure to the Southern Ocean (Hemer et al., 2018; Liu et al., 2022), but the OWF declared area is likely far enough from the coast to limit impacts (Davi et al., 2022). The high waves in the region may also have impacts on local scour around foundations and related infrastructure, as well as installation, operation and maintenance. Strong wind energy resources in the region (Salvador, 2022) may alter seasonal nutrient fluxes and upwelling patterns.

7.7. Threatened and migratory marine species

All spatial layers from the fauna maps presented in text are available for viewing and download through the following map and table links. These are live documents that can be updated as new data is received.

Fauna Group		OWF Area overlap	Data tables
	Cetaceans and pinnipeds	Map Link	Baleen, toothed, pinniped
	Birds	Map Link	Birds
	Sharks	Map Link	Sharks
	Reptiles	Map Link	Reptiles
	Macroalgae	Map Link	Macroalgae

7.7.1. Cetaceans and pinnipeds

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of 43 published studies on cetaceans (Figure 58, Figure 59) and four for pinnipeds (Figure 60) overlapped with the Southern Ocean OWF area. The majority of those studies were on blue whales (*Balaenoptera musculus* subspecies, listed endangered under the EPBC Act, n=8), and southern right whales (*Eubalaena australis,* listed endangered under the EPBC Act, n=8). An additional study on pygmy blue whales (*Balaenoptera musculus brevicauda)* was published since development of the inventory that shows habitat use by the species in this region (Ferreira et al. 2024). Four studies were found for Australian fur seals (*Arctocephalus pusillus doriferus*, listed marine under the EPBC Act), killer whales (*Orcinus orca*, listed migratory under the EPBC Act) and Tursiops spp. Three studies were found for fin whales (*Balaenoptera physalus*, listed vulnerable under the EPBC Act), common dolphins (*Delphinus delphis*, listed cetacean under the EPBC Act) and bottlenose dolphins (*Tursiops truncatus*, listed cetacean under the EPBC Act). Two studies were found for sperm whales (*Physeter macrocephalus*, listed migratory under the EPBC Act) and Shepherd’s beaked whale (*Tasmacetus shepherdi*, listed cetacean under the EPBC act). Only one study was found for each of the remaining species (Table 22, Table 23, Table 24).

The highest overlap between the cetacean and pinniped study area polygons and the Southern Ocean OWF region was for southern right whale, Antarctic blue whale, pygmy blue whale, fin whale, bottlenose dolphin spp., common dolphin and Australian fur seals (all 100%), followed by, killer whales (90%), pygmy right whale (89%), common bottlenose dolphin (52%), dusky dolphin (51%) (Table 22, Table 23, Table 24).

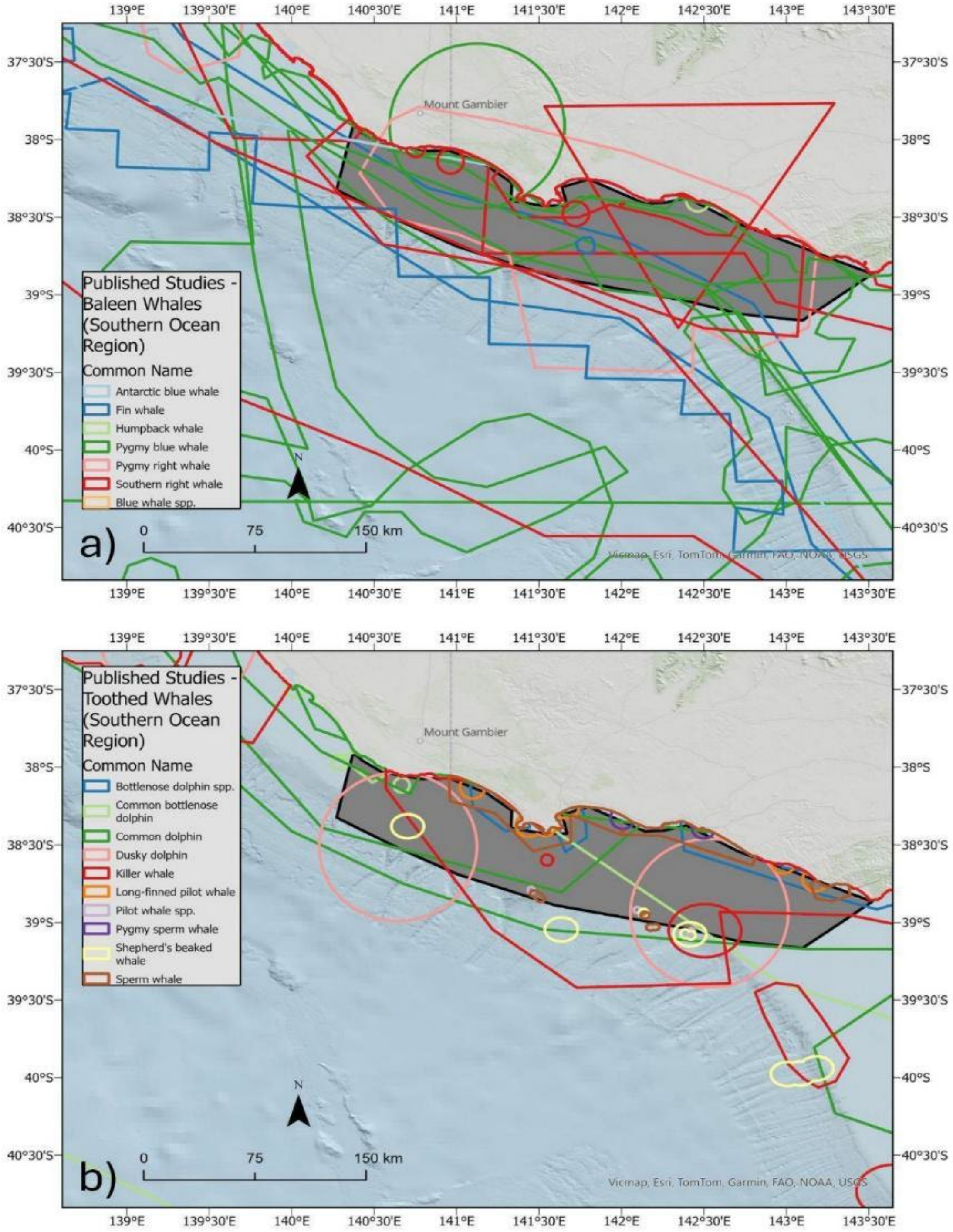


Figure 58. The Southern Ocean OWF region (grey polygons showing the spatial coverage of the study areas from the publication inventory where baleen whales (a) and toothed whales (b) of interest occurred. The different species are represented by the different colours.

Table 22. Baleen whale species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Southern Ocean OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Southern Ocean baleen cetacean Table link

Southern Ocean OWF: Cetaceans (baleen)

			AREA AS % OF OWT			OBSERVATION COUNTS	SEASONALITY	NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	VBA	SNES	PUBS	OBIS ALA	J F M A M J J A S O N D	PUBS
Southern Right Whale *Eubalaena australis*	Balaenidae -	Endangered	100	100	100	3621		8
Antarctic Blue Whale *Balaenoptera musculus intermedia*	Balaenopteridae -	Endangered	64	100	99	0		1
Pygmy Blue Whale *Balaenoptera musculus brevicauda*	Balaenopteridae -	Endangered	0	100	100	271		6
Fin Whale *Balaenoptera physalus*	Balaenopteridae -	Vulnerable	1	96	100	12		3
Sei Whale *Balaenoptera borealis*	Balaenopteridae -	Vulnerable	1	96		0		0
Bryde's Whale *Balaenoptera edeni*	Balaenopteridae -	Migratory	1	0		2		0
Dwarf Minke Whale *Balaenoptera acutorostrata subsp.*	Balaenopteridae -	Migratory	1	100		17		0
Humpback Whale *Megaptera novaeangliae*	Balaenopteridae -	Migratory	36	100	0	243		1
Pygmy Right Whale *Caperea marginata*	Cetotheriidae -	Migratory	4	100	89	114		1

Table 23. Toothed whale species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Southern Ocean OWF region. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Note that for all the toothed whales there is limited data on seasonality, and they may be present year round. Southern Ocean toothed cetacean Table link

uthern Ocean OWF: Cetaceans (toothed)

				AREA AS % OF OWF			OBSERVATION COUNTS	SEASONALITY												NUMBI
SPECIES		FAMILY OCCURENCE	EPBC STATUS	VBA	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Dusky Dolphin *agenorhynchus obscurus*	i	Delphinidae -	Migratory	0	100	51	0													1
Killer Whale *Orcinus orca*	i	Delphinidae -	Migratory	19	100	90	82													4
Sperm Whale *Physeter macrocephalus*	i	Physeteridae -	Migratory	13	42	11	168													2
tlenose Dolphin Species *Tursiops spp.*	i	Delphinidae -	Cetacean	0	0	100	0													4
Common Bottlenose Dolphin *Tursiops truncatus*	i	Delphinidae -	Cetacean	16	100	52	0													3
Common Dolphin *Delphinus delphis*	i	Delphinidae -	Cetacean	11	100	100	98													3
False Killer Whale *Pseudorca crassidens*	i	Delphinidae -	Cetacean	0	60		11													0
ıdo-Pacific Bottlenose Dolphin *Tursiops aduncus*	i	Delphinidae -	Cetacean	0	26		0													0
ng-Finned Pilot Whale *Globicephala melas*	i	Delphinidae -	Cetacean	9	42	2	128													1
Risso's Dolphin *Grampus griseus*	i	Delphinidae -	Cetacean	1	100		0													0
outhern Right Whale Dolphin *Lissodelphis peronii*	i	Delphinidae -	Cetacean	0	42		0													0
Striped Dolphin *Stenella coeruleoalba*	i	Delphinidae -	Cetacean	0	0		4													0
Dwarf Sperm Whale *Kogia sima*	i	Kogiidae -	Cetacean	1	42		0													0
ygmy Sperm Whale *Kogia breviceps*	i	Kogiidae -	Cetacean	3	42	0	26													1
ıdrew's Beaked Whale *Mesoplodon bowdoini*	i	Ziphiidae -	Cetacean	0	42		8													0
uvier's Beaked Whale *Ziphius cavirostris*	i	Ziphiidae -	Cetacean	1	42		8													0
ray's Beaked Whale *Mesoplodon grayi*	i	Ziphiidae -	Cetacean	1	13		16													0
pherd's Beaked Whale *Tasmacetus shepherdi*	i	Ziphiidae -	Cetacean	0	0	2	3													2
thern Bottlenose Whale *Hyperoodon planifrons*	i	Ziphiidae -	Cetacean	1	0		0													0
trap-Toothed Beaked Whale *Mesoplodon layardii*	i	Ziphiidae -	Cetacean	1	42		7													0
rue's Beaked Whale *Mesoplodon mirus*	i	Ziphiidae -	Cetacean	1	42		3													0

Table 24. Pinniped species of interest for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Southern Ocean OWF region. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts from OBIS and ALA combined. Seasonality was compiled from the literature and expert opinion where dark brown indicates months of the year with peak occurrence, light brown indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Southern Ocean pinniped Table link

Southern Ocean OWF: Pinniped

			Area as % of OWF			Observation counts	Seasonality												Number
Species	Family occurence	EPBC status	VBA	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Australian Sea Lion *Neophoca cinerea*	Otariidae -	Endangered		72		61													0
Australian Fur-Seal *Arctocephalus pusillus doriferus*	Otariidae -	Marine	31	61	100	546													4
Long-Nosed Fur-Seal *Arctocephalus forsteri*	Otariidae -	Marine	0	61		21													0

Existing freely available species observation data

Overlaying observations of the priority (and secondary priority) cetacean and pinniped species from ALA, and OBIS with the Southern Ocean OWF region (Figure 59, Figure 60and Figure 61), showed that observations of southern right whales (3621) were the most common in the Southern Ocean OWF area followed by pygmy blue whales (603) and Australian fur seals (359 (Table 22, Table 23, Table 24). For all the remaining species the number of observations occurring in the OWF were <~200.

The spatial distribution of priority (and secondary priority) cetacean and pinniped species observations within the Southern Ocean OWF region shows most of the species observations occurred nearshore, with the main species observed within the OWF region including pygmy blue whales and Australian fur seal (Figure 59 and Figure 61). Endangered species that have been observed in the Southern Ocean OWF in OBIS and ALA include pygmy and Antarctic blue whales, southern right whales (*Eubalaena australis*) and the vulnerable listed fin whale (*Balaenoptera physalus*) (Table 22).

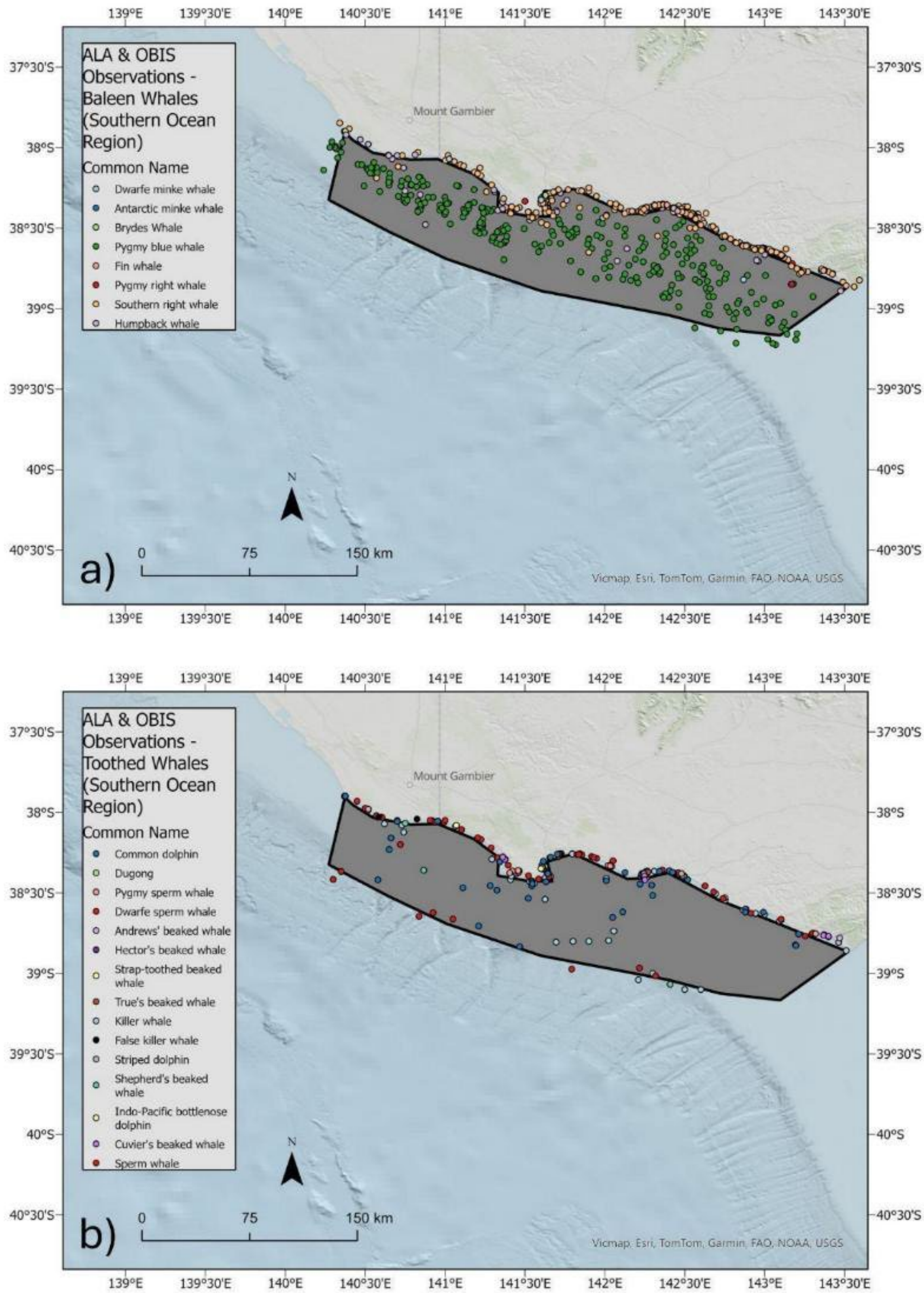


Figure 59. The Southern Ocean OWF region (grey polygon) showing observations of baleen (a) and toothed (b) whales of interest from the ALA and OBIS. The different species are represented by the different coloured points.

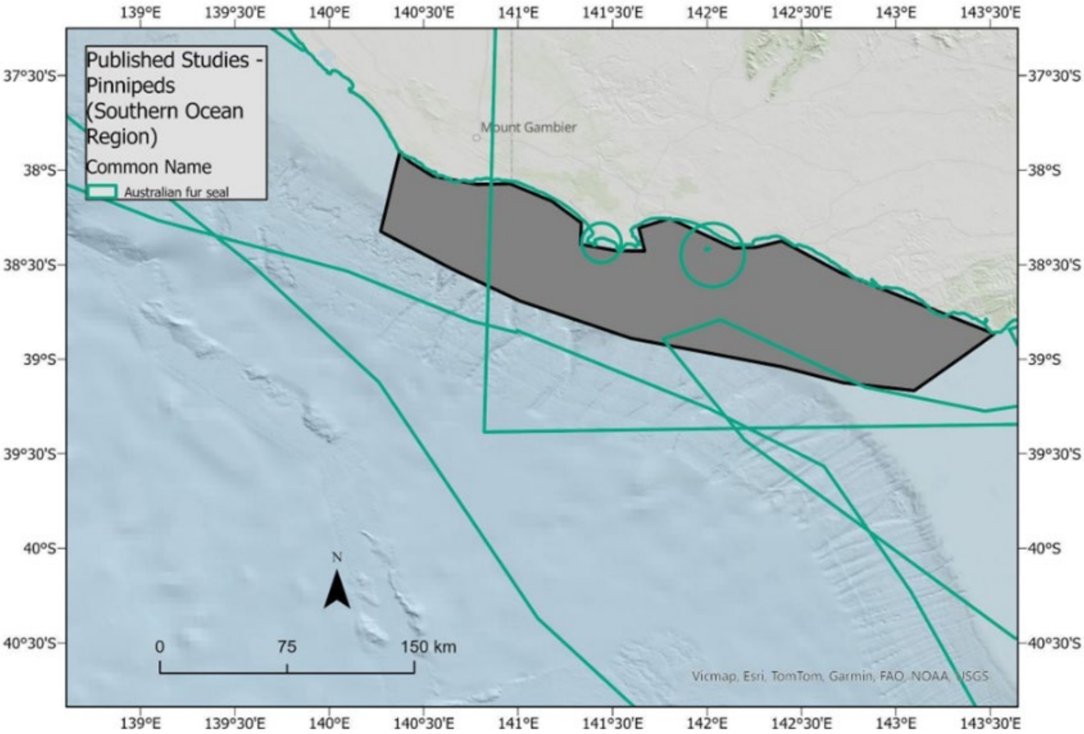


Figure 60. The Southern Ocean OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where pinnipeds occurred. The different species are represented by the different colours.

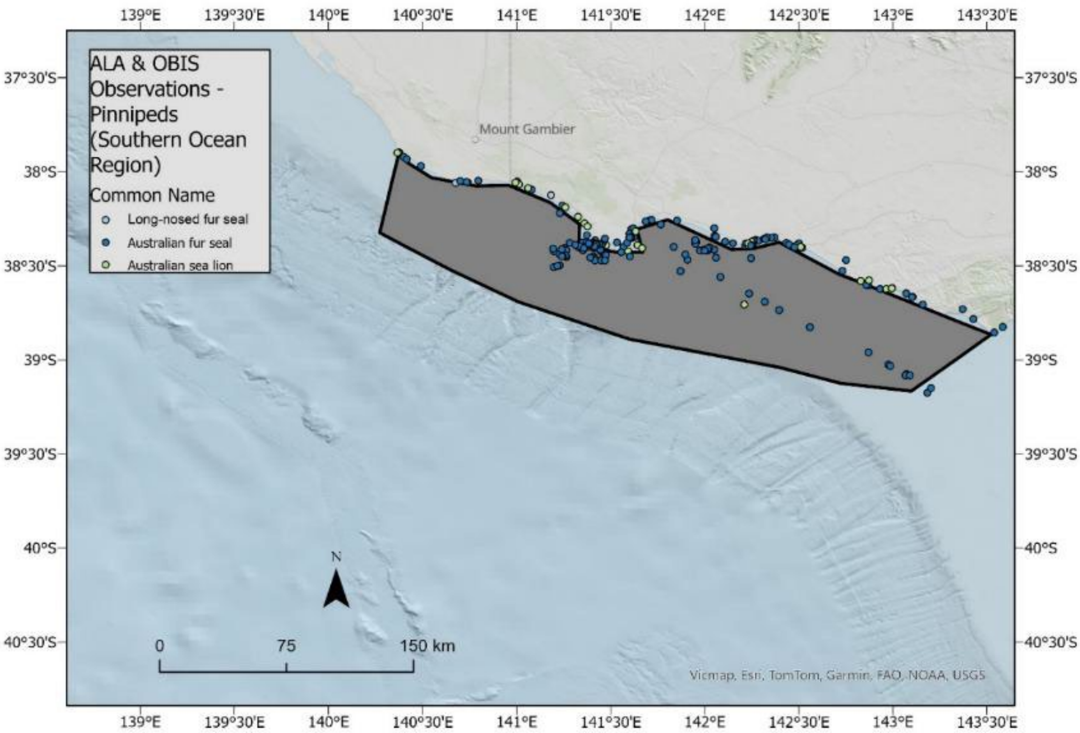


Figure 61. The Southern Ocean OWF (grey polygon) showing observations of pinnipeds from ALA and OBIS across. The different species are represented by the different colours.

7.7.2. Birds

Published papers/reports inventory

The Southern Ocean OWF region, 25 published studies on bird species of interest that overlap with the OWF area were found and compiled. The majority of those studies were on albatrosses (15) with three studies on gannets, three studies on waders, and one study each for terns and petrels. The entire Southern Ocean OWF region (15,748 km^2) has studies of albatrosses overlapping it with petrels and waders just short of full coverage. Gannets have been studied in the majority of the region with an aerial coverage of 14,608 km^2 while terns and shearwaters have studies that overlap 4,213 km^2 and 1,973 km^2 of the region, respectively (Figure 62).

Studies completed in the Southern Ocean OWF region included several critically endangered and endangered bird species listed under the EPBC Act. The critically endangered species include the Curlew Sandpiper (*Calidris ferruginea*), Far Eastern Curlew (*Numenius madagascariensis*), and Tristan Albatross (*Diomedea dabbenena*). The Amsterdam Albatross (*Diomedea amsterdamensis*), Gould's Petrel (*Pterodroma leucoptera*), and Shy Albatross (*Thalassarche cauta*) are all listed as endangered. The remaining species in the inventory are made up of species listed as vulnerable and other species identified as of interest due to their migratory behaviour or potential interactions with wind farms in the region (Table 25).

Table 25. Bird species for which we have compiled spatial data from published studies and freely available data repositories (BLA, OBIS and ALA) that overlap with the Southern Ocean OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for each data repository used (BLA = Birdlife Aust, OBIS and ALA data combined). Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Southern Ocean bird Table link

Southern Ocean OWF: Bird

			Area as % of OWF			Observation counts		Seasonality	Number
Species	Family Occurence	EPBC Status	VBA	SNES	PUBS	BLA	OBIS-ALA	J F M A M J J A S O N D	PUBS
Orange-Bellied Parrot *Neophema chrysogaster*	Psittacidae Rare	Critically Endangered	22	8		36	216		0
Swift Parrot *Lathamus discolor*	Psittacidae Rare	Critically Endangered	0	0		1	7		0
Curlew Sandpiper *Calidris ferruginea*	Scolopacidae Common	Critically Endangered	22	100	100	259	124		1
Far Eastern Curlew *Numenius madagascariensis*	Scolopacidae Common	Critically Endangered	8	100	31	42	207		1
Great Knot *Calidris tenuirostris*	Scolopacidae Common	Critically Endangered	3	0		17	90		0
Lesser Sand Plover *Charadrius mongolus*	Charadriidae Rare	Endangered	1	0		5	39		0
Chatham Albatross *Thalassarche eremita*	Diomedeidae Vagrant	Endangered	0	0		0	0		0
Grey-Headed Albatross *Thalassarche chrysostoma*	Diomedeidae Rare	Endangered	4	100		8	212		0
Northern Royal Albatross *Diomedea sanfordi*	Diomedeidae Common	Endangered	0	100		11	66		0
Shy Albatross *Thalassarche cauta*	Diomedeidae Common	Endangered	57	100	100	224	3372		6
Southern Giant Petrel *Macronectes giganteus*	Procellariidae Rare	Endangered	20	100		35	412		0
Red Knot *Calidris canutus*	Scolopacidae Common	Endangered	6	100		33	212		0
White-Throated Needletail *Hirundapus caudacutus*	Apodidae Common	Vulnerable	34	0		64	349		0
Greater Sand Plover *Charadrius leschenaultii*	Charadriidae Rare	Vulnerable	1	0		11	44		0
Antipodean Albatross *Diomedea antipodensis*	Diomedeidae Rare	Vulnerable	0	100		3	0		0
Black-Browed Albatross *Thalassarche melanophris*	Diomedeidae Common	Vulnerable	62	100	98	220	4860		1
Buller's Albatross *Thalassarche bulleri*	Diomedeidae Rare	Vulnerable	10	100	100	41	854		1
Campbell Albatross *Thalassarche impavida*	Diomedeidae Vagrant	Vulnerable	0	100	100	23	72		2
Gibson's Albatross *Diomedea gibsoni*	Diomedeidae Rare	Vulnerable	0	0		0	0		0
Indian Yellow-Nosed Albatross *Thalassarche carteri*	Diomedeidae Common	Vulnerable	36	100		137	435		0
Salvin's Albatross *Thalassarche salvini*	Diomedeidae Vagrant	Vulnerable	0	100		3	174		0
Sooty Albatross *Phoebetria fusca*	Diomedeidae Rare	Vulnerable	3	100		12	123		0
Southern Royal Albatross *Diomedea epomophora*	Diomedeidae Vagrant	Vulnerable	15	100	3	36	768		1
Wandering Albatross *Diomedea exulans*	Diomedeidae Rare	Vulnerable	27	100		78	6286		0
White-Capped Albatross *Thalassarche steadi*	Diomedeidae Rare	Vulnerable	1	100		0	169		0
Fairy Tern *Sternula nereis*	Laridae Common	Vulnerable	12	100		121	330		0
Blue Petrel *Halobaena caerulea*	Procellariidae Rare	Vulnerable	9	100		7	241		0
Northern Giant Petrel *Macronectes halli*	Procellariidae Vagrant	Vulnerable	14	100		50	816		0
Soft-Plumaged Petrel *Pterodroma mollis*	Procellariidae Rare	Vulnerable	3	100		6	122		0
Little Penguin *Eudyptula minor*	Spheniscidae Common	Marine	70	0	4	142	279355		1
Australasian Gannet *Morus serrator*	Sulidae Common	Marine	98	0	93	639	15325		3
Little Tern *Sternula albifrons*	Laridae Common	Migratory	9	0		63	212		0
Short-Tailed Shearwater *Ardenna tenuirostris*	Procellariidae Common	Migratory	62	0	13	1625	57385		2

Existing freely available species observation data

Observations of birds within the Southern Ocean OWF region from BirdLife Australia, Australian Living Atlas (ALA), and Ocean Biodiversity Information System (OBIS) showed that penguins were the most observed in the Southern Ocean region (279,497 observations), followed by terns (18,187 observations). The rest of the groups observed ranged from 1 observation (skuas) to 1,689 observations (petrels) (Figure 63).

The spatial distribution of bird observations within the Southern Ocean OWF region shows that parrot, plover and wader species of interest occurred predominantly on the coast, mostly inshore of the OWF area and that the seabirds occurred further offshore (Figure 63). Most of these observations are based on opportunistic information so they do not represent a systematic survey of the region. The highest numbers of observations occurred for several species of albatross, penguins, gannets, and waders. Several species of critically endangered (*Lathamus discolor*, *Neophema chrysogaster*, *Calidris ferruginea*, *Calidris tenuirostris*, and *Numenius madagascariensis*), endangered (*Thalassarche cauta*, *Macronectes giganteus*, *Calidris canutus, Thalassarche chrysostoma*, *Diomedea sanfordi*, and *Charadrius mongolus*), and vulnerable birds have all been observed in the region.

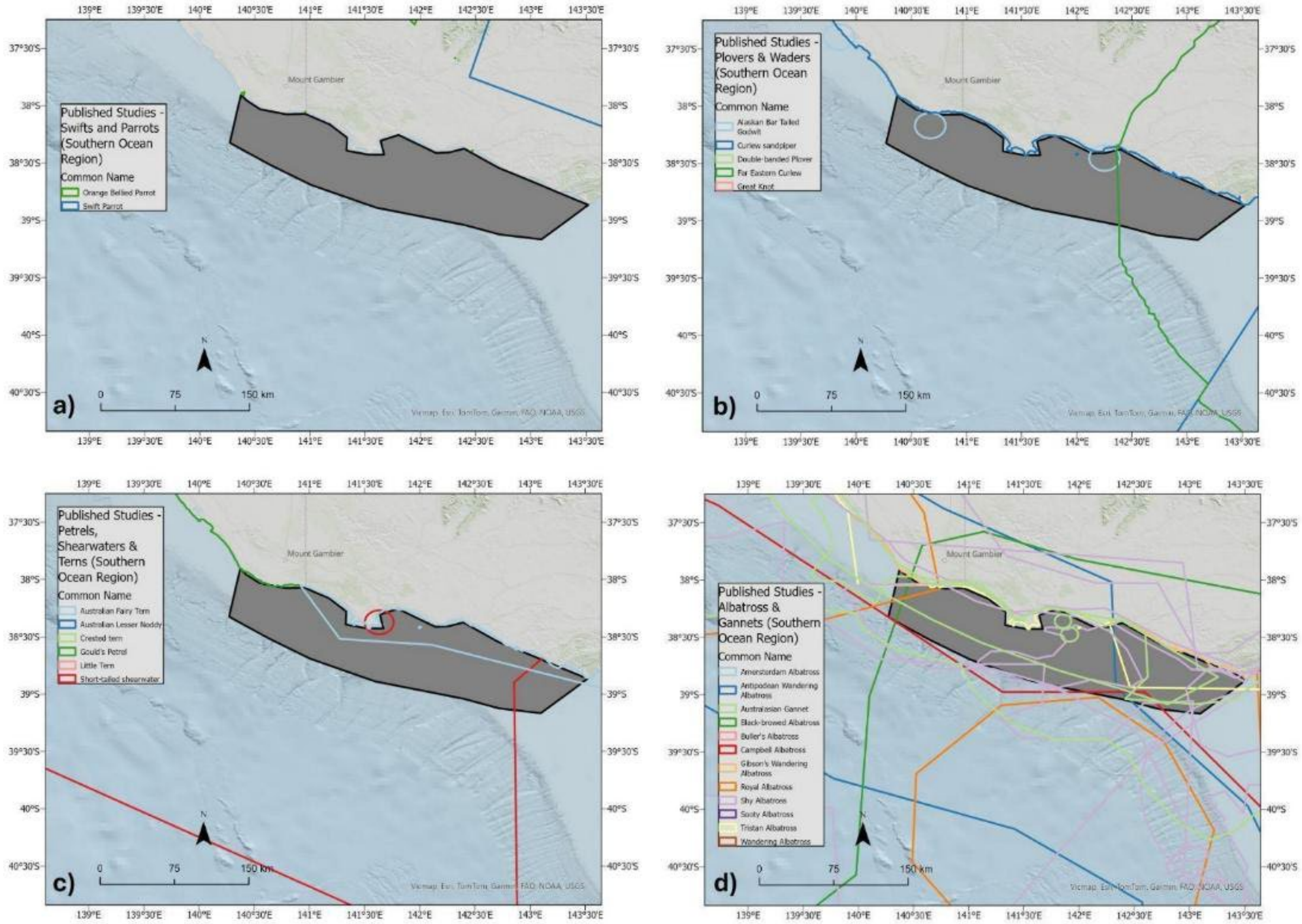


Figure 62. The Southern Ocean OWF region (grey polygon) showing the spatial coverage of the study areas where bird species of interest occurred with separate maps for each species group (a-d). The different species are represented by the different colours.

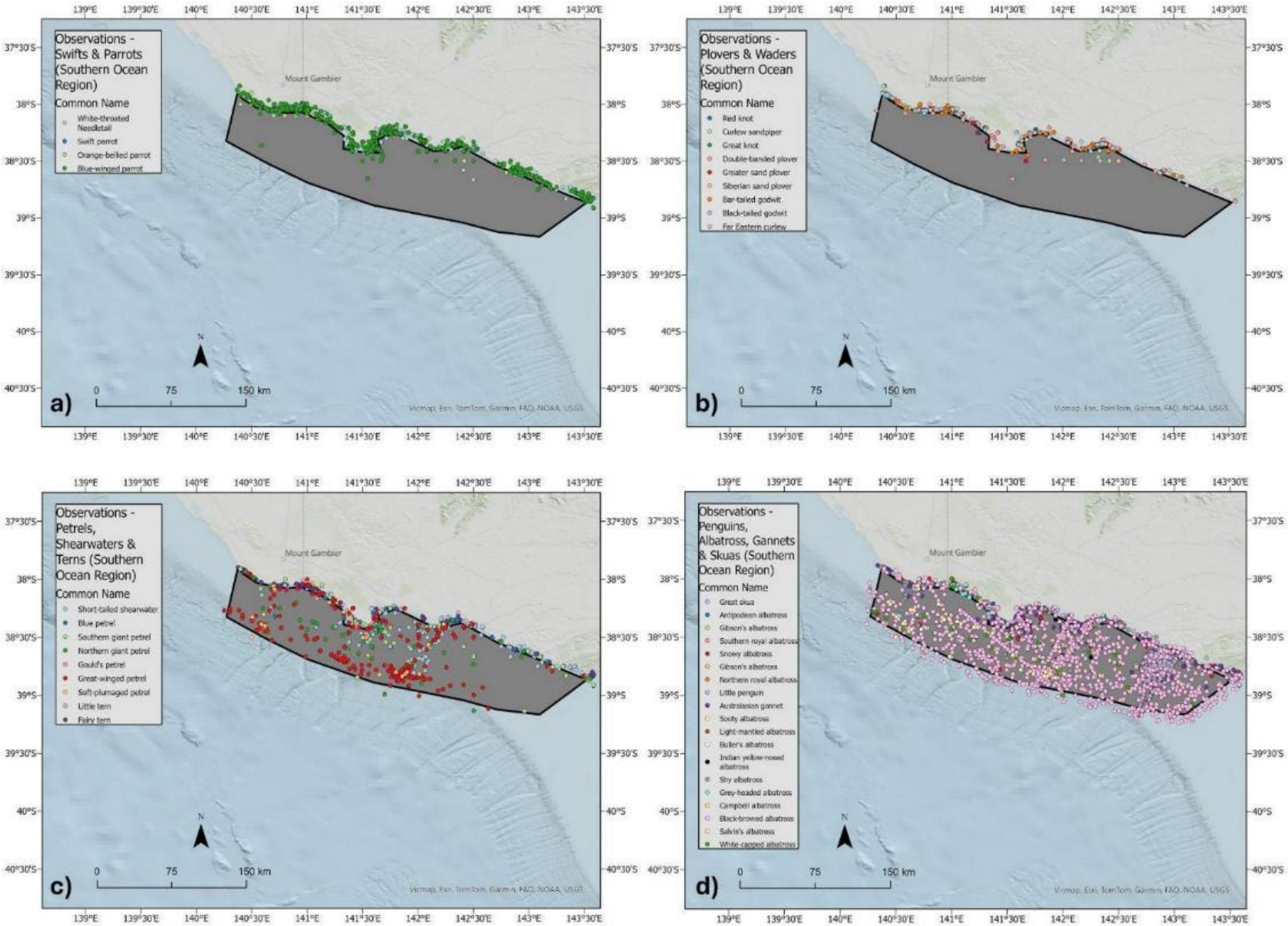


Figure 63. Observations of birds from BirdLife Australia, the Australian Living Atlas (ALA), and the Ocean Biodiversity Information System (OBIS) across the Southern Ocean OWF for each bird grouping (a-d). The different species are represented by the different colours and the grey polygon shows the study region for the Southern Ocean OWF.

7.7.3. Sharks

Published papers/reports inventory

Within the Southern Ocean region, three published studies on shark species of interest that overlap with the OWF area were found and compiled (Figure 64). All three studies were on the White shark (*Carcharodon carcharias*). Much of the Southern Ocean OWF (15,740 km^2) serves as potential habitat for White sharks (15,733 km^2). White sharks were found to have seasonal residency in the Southern Ocean OWF where they are prevalent from May to December. Contrastingly, the Victorian Biodiversity Atlas (VBA) suggested that the OWF does form any habitat for the White shark (0%).

Table 26. Shark species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the Southern Ocean OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Southern Ocean shark Table link

Southern Ocean OWF: Shark

			AREA AS % OF OWF			OBSERVATION COUNTS	SEASONALITY												NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	VBA	SNES	PUBS	OBIS ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
White Shark *Carcharodon carcharias* i	Lamnidae -	Vulnerable	0	100	100	5													5

Existing freely available species observation data

Observations of sharks within the Southern Ocean OWF region from the Australian Living Atlas (ALA) and Ocean Biodiversity Information Systems (OBIS) showed two species of sharks to be present with the white shark (5 observations) being more prevalent than the grey nurse shark (*Carcharias taurus)* (1 observation) (Figure 65). White sharks were sighted in the west of the OWF near inshore at Cape Bridgewater and one sighting offshore at the continental shelf. The single grey nurse shark was sighted offshore at Peterborough. The grey nurse shark is listed as critically endangered, while the white shark is listed as vulnerable.

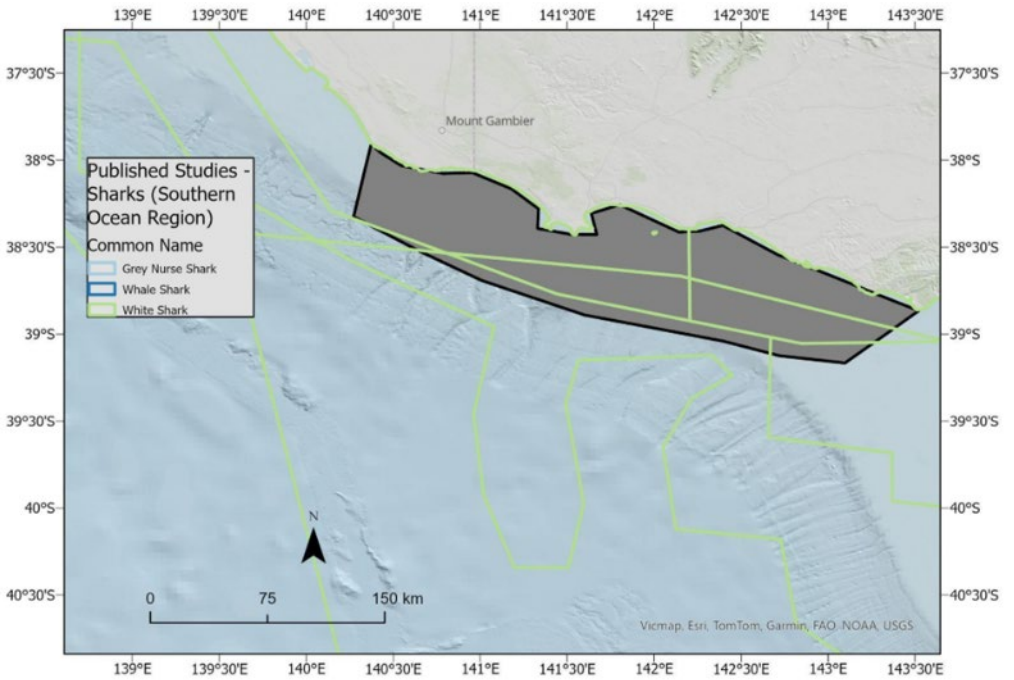


Figure 64. The Southern Ocean OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where listed sharks occurred. The different species are represented by the different colours.

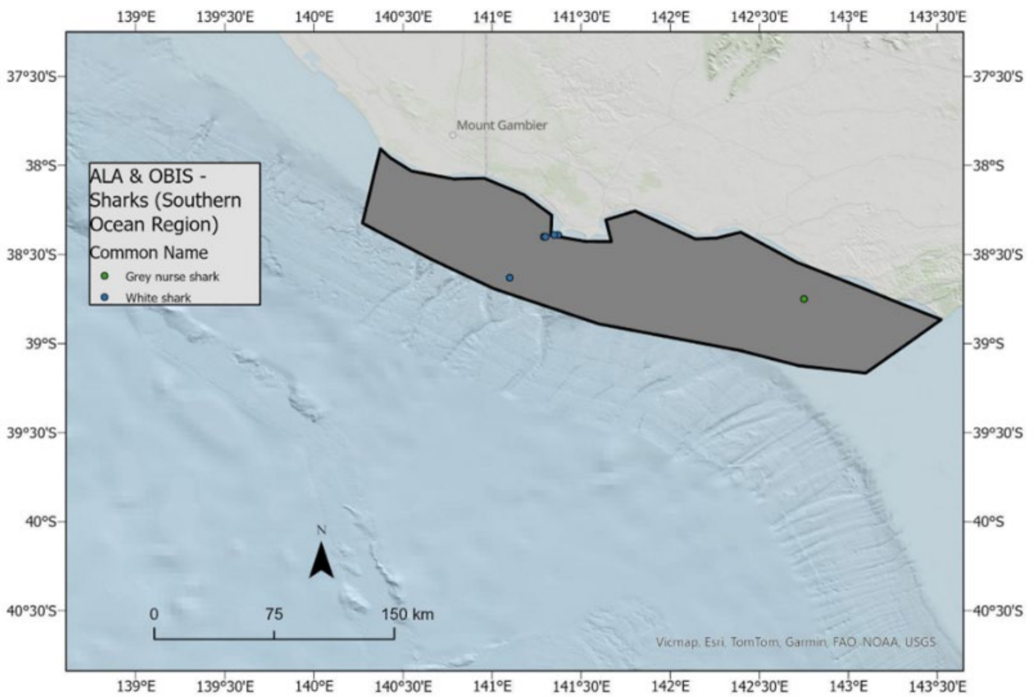


Figure 65. The Southern Ocean OWF (grey polygon) showing observations of listed sharks from the Atlas of Living Australia (ALA) and the Ocean Biodiversity Information System (OBIS) across. The different species are represented by the different colours.

7.7.4. Reptiles

Published papers/reports inventory

Overlapping the Species of National Environmental Significance (SNES) distribution maps for listed turtle species with the Southern Ocean OWF showed that the SNES distribution for loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), and green (*Chelonia mydas*) turtles had 100% coverage with the Southern Ocean OWF area (15,740 km^2). For the leatherback turtle, a high coverage was supported by the published studies which also found a distribution (13,220 km^2) that covered much of the OWF (Table 27). Alternatively, data from the Victorian Biodiversity Atlas (VBA) suggested that the OWF forms minor habitat for the loggerhead and green turtle (10%, 20%, respectively) and that 70% of the area was habitat for leatherback turtles. Loggerhead and leatherback turtles are listed as endangered and green turtles are considered as vulnerable.

Existing freely available species observation data

Observations of reptiles within the Southern Ocean OWF region from the Australian Living Atlas (ALA) and Ocean Biodiversity Information Systems (OBIS) showed three species of turtle occur there, with the leatherback turtle (72 observations) being the most prevalent, followed by the loggerhead turtle (8 observations), and the green turtle (3 observations) (Figure 66). Observations of loggerhead and leatherback turtles occurred along the nearshore areas across the extent of the OWF, while green turtles were only observed in the Eastern half of the OWF. Most observations occurred between the coastline and the landward OWF boundary which is likely due to shore and recreational boat-based sightings.

Table 27. Reptile species for which we have compiled spatial data published studies and freely available data repositories (OBIS and ALA) that overlap with the Southern Ocean OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Southern Ocean reptile Table link

Southern Ocean OWF: Reptile

			Area as % of OWF			Observation counts	Seasonality	Number
Species	Family occurence	EPBC status	VBA	SNES	PUBS	OBIS-ALA	J F M A M J J A S O N D	PUBS
Loggerhead Turtle *Caretta caretta*	Cheloniidae -	Endangered	1	100		8		0
Leatherback Turtle *Dermochelys coriacea*	Dermochelyidae -	Endangered	7	100	84	72		1
Green Turtle *Chelonia mydas*	Cheloniidae -	Vulnerable	2	100		3		0
Hawksbill Turtle *Eretmochelys imbricata*	Cheloniidae -	Vulnerable	0	0		0		0

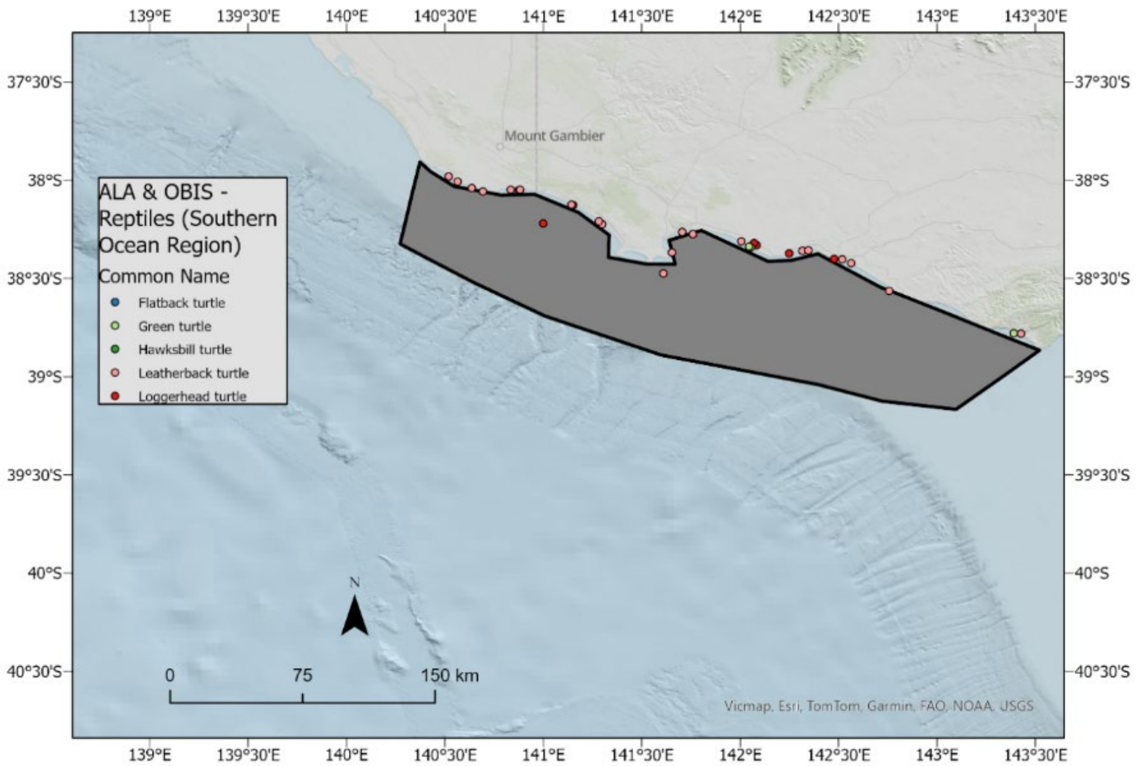


Figure 66. The Southern Ocean OWF region (grey polygon) showing observations of listed reptiles from the Atlas of Living Australia (ALA) and the Ocean Biodiversity Information System (OBIS) across. The different species are represented by the different colours.

7.7.5. Other species

Information on finfish, invertebrates and other species of interest can be viewed in the inventory for the Southern Ocean region. This list is not comprehensive as it was not the focus of this study and therefore only a small subset of species are provided. Within the Southern Ocean region, three published studies on the macroalgae species of interest, giant kelp (*Macrocystis pyrifera),* that overlap with the OWF area were found and compiled (Figure 68). Published studies suggest a giant kelp coverage (10,039 km^2) that spans over two-thirds of the Southern Ocean OWF (15,740 km^2).

There were 54 observations of giant kelp within the Southern Ocean OWF region from the Australian Living Atlas (ALA) and Ocean Biodiversity Information Systems (OBIS). Almost all observations were in coastal areas that were distributed along the entire extent of the OWF region (Table 28; Figure 67, 68).

Table 28. Listed habitat (giant kelp) for which we have compiled spatial data from published and freely available data repositories (OBIS and ALA) that overlap with the Southern Ocean OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Southern Ocean macroalgae Table link

Southern Ocean OWF: Macroalgae

SPECIES	FAMILY OCCURENCE	EPBC STATUS	AREA AS % OF OWF: VBA	SNES	PUBS	OBSERVATION COUNTS: BLA	OBIS ALA	SEASONALITY: J F M A M J J A S O N D	NUMBER: PUBS
Giant Kelp *Macrocystis pyrifera*	Lessoniaceae -	Endangered	1	0	64	0	54		3

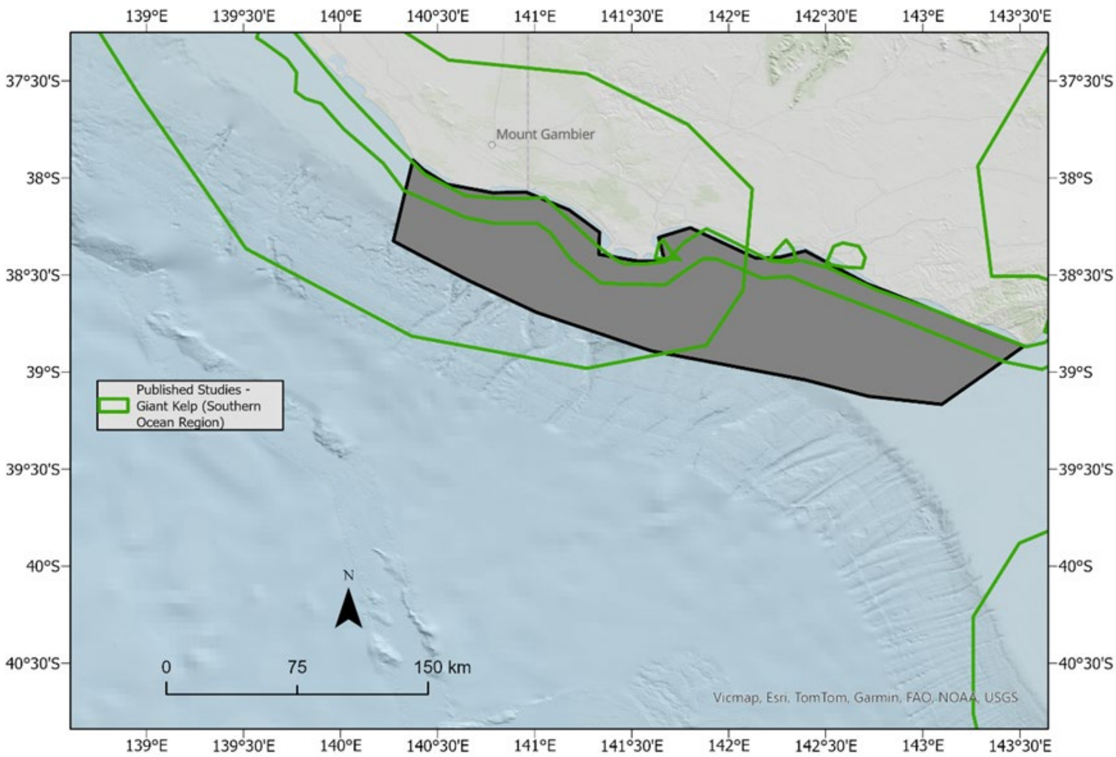


Figure 67. The Southern Ocean OWF region (prey polygon) showing the spatial coverage of the study areas where listed habitats (giant kelp) occurred.

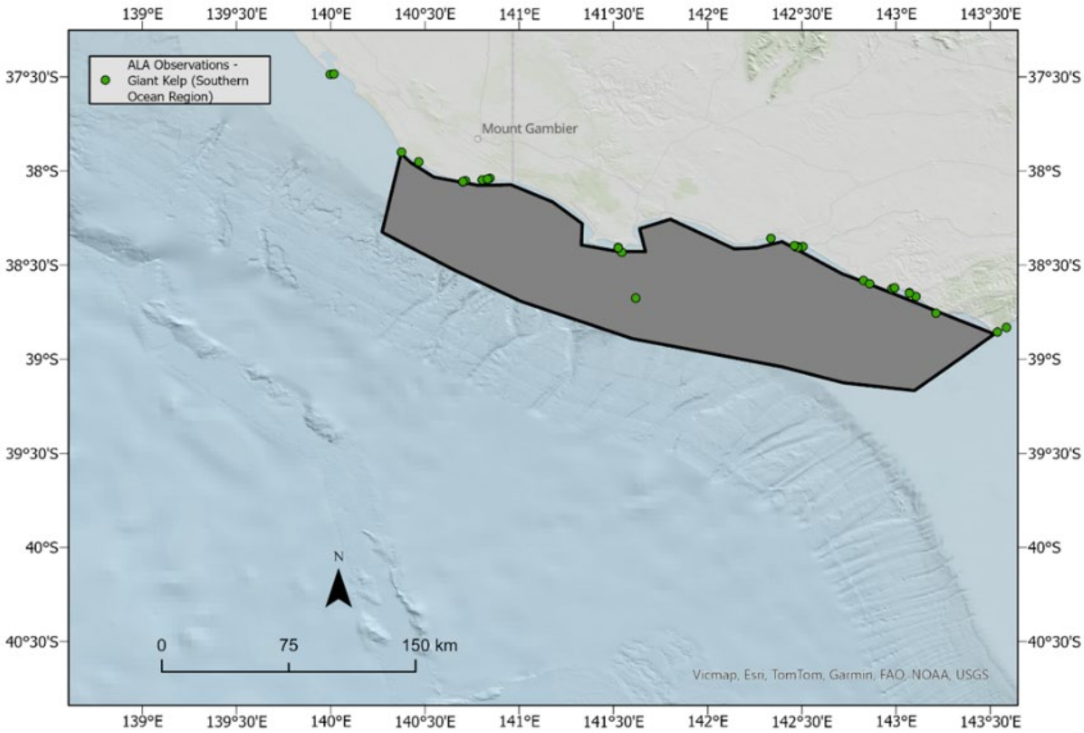


Figure 68. The Southern Ocean OWF (grey polygon) showing observations of listed habitat (giant kelp) from the Atlas of Living Australia (ALA).

7.8. Indigenous communities

The TO people adjacent to the (proposed) Southern Oceans area are the Gunditjmarra and Eastern Maar People. Gunditj Mirring Traditional Owners Aboriginal Corporation (who represent the Gunditjmarra People) represents 59 separate clans. In 2007 the Federal Court of Australia consented native title determination over 140,000 ha across Southwest Victoria to the Gunditjmarra people. The native title covers Glenelg River, to the north Wannon River, as well as four National Parks and five State Parks. In 2018 the Gunditj Mirring Traditional Owners Aboriginal Corporation combined its IPA listed areas under the Budj Bim IPA plan of management, this included an area of 2,700ha throughout the Bidj Bim cultural landscape.

In 2019 the Gunditj Mirring Traditional Owners Aboriginal Corporation was granted UNESCO World Heritage listing over the Budj Bim Landscape. It is sacred to the Gunditjmara people holding enormous cultural, archaeological, and environmental significance. The listing recognises one of Australia’s largest and oldest aquaculture systems where, for thousands of years, the Gunditjmarra People have been harvesting fish including the short-finned eels (Kooyang) which have complex life cycles. The eels are known to travel from southwest Victoria up to southeast of New Guinea in the Coral Sea to spawn (listed on Victorian Fisheries website). The Gunditjmarra People additionally have a strong connection to Deen Maar (Lady Julia Percy Island) through dreaming story connections.

The environmental and culturally significant values of Gunditjmarra sea Country include whales, dolphins, seals, as well as many bivalve, fish and bird species. The ancient connections their old people had to sea Country is clearly demonstrated through large midden sites scattered throughout their landscape. Today, they continue to keep their connections strong by harvesting parts of the whales/seals/dolphins that wash ashore and continue telling ancient and contemporary stories about sea Country to all visitors. Gunditj

Mirring has a large terrestrial focussed ranger group mostly working on restoring the World heritage Budj Bim lava flow. However, their connection to sea Country remains strong and they have an interest, willingness and capacity to engage in sea Country projects.

The Eastern Maar Aboriginal Corporation (EMAC) represents 7 different clan groups. In 2011 Eastern Maar was granted Native Title determination and jointly manage the 2700 ha in Southwest Victoria with Gunditj Mirring Traditional Owners Aboriginal Corporation. The two groups are also working collabroatively to establish an IPA across shared country.

In March 2023, a second positive Native Title Determination expanded EMAC's jurisdiction, covering an extended area acknowledging the Eastern Maar's ongoing connection and intrinsic relationship with their country in south-western Victoria, which included much of the coastline of the Great Ocean Road and part of the Great Otway National Park. Eastern Maar People have a connection to Sea Country from Portland through to Aireys Inlet. Throughout this landscape, there are many midden sites ranging from what appeared to be small camps to large occupation areas indicating that seafood played a major part of the Eastern Maar's diets.

Eastern Maar have similarly strong cultural and spiritual connections as the Gunditjmara with the short finned eel, and eel was a valued item of trade. Maintaining strong cultural connection to the land and sea through care and healing practices, the Eastern Maar have a proud and rich tradition of passing culture through storytelling.

EMAC have recently added a sea ranger crew to their ranger capacity and would be in a position to engage in science projects related to the offshore renewable industry within their sea Country. Indeed, the Eastern Maar have already partnered with science researchers in the recent past including allocation of a marine guardian to facilitate research efforts in Apollo Marine Park. Eastern Maar has a strong community presence and being involved with science projects would be of great benefit to science teams through two way sharing of knowledge.

EMAC is the formally recognised Registered Aboriginal Party (RAP) and the Registered Native Title Body Corporate (RNTBC) for which the Southern Ocean OWF area has been declared following the reduction of the proposed precinct area after public consultation. The have also provided a statement post the announcement. This highlights EMACs support for decarbonisation but not at the expense of marine life with particular reference to concerns for migratory pathways, feeding areas and nursery ground for koontapool (Whale) in the proposed area. EMAC also makes clear they would have liked to have seen the environmental studies conducted prior to declaration and call for a recalibration of the offshore wind strategy to ensure environmental integrity and cultural respect are prioritised alongside decarbonisation goals.

In 2020 the Great Ocean Road Coast and Parks Authority was formed to deliver better protection and management of the iconic coast and parks of Victoria's Great Ocean Road region extending from Warrnambool in the west and Torquay in the east. *The Great Ocean Road and Environs Protection Act 2020* recognises, protects and promotes the values, rights and interests of Eastern Maar and Wadawurrung Peoples. The Authority endeavours to support and equip Eastern Maar and Wadawurrung Peoples to play an active role in shaping the future of their traditional lands, waterways and seas. This includes acknowledging the intrinsic connection of TOs to Country through partnership and involvement in policy development, planning, and decision-making for the Great Ocean Road, its coastlines, landscapes and seascapes.

8. Bunbury Offshore Wind Farm region – knowledge base

8.1. Bathymetry

Bathymetry data for the broad south-west region includes acquisitions and compilations from a range of multibeam acoustic and LiDAR hydrographic surveys conducted over the past ~25 years (Figure 69). Data density is highest toward the mid to outer shelf in the region north of the declared area. The survey coverage is higher in the offshore part of the Bunbury OWF declared area, but consists principally of transit survey lines rather than structure survey areas. Inshore, and to the south of the declared area offshore of Cape Leeuwin, a focused hydrographic survey was conducted in 2022 as part of the HydroScheme Industry Partnership Program (HIPP) (https://www.hydro.gov.au/NHP/). The survey area (SI 1031) is defined as 422 NM^2, and extends across the continental shelf to depths of ~100 m.

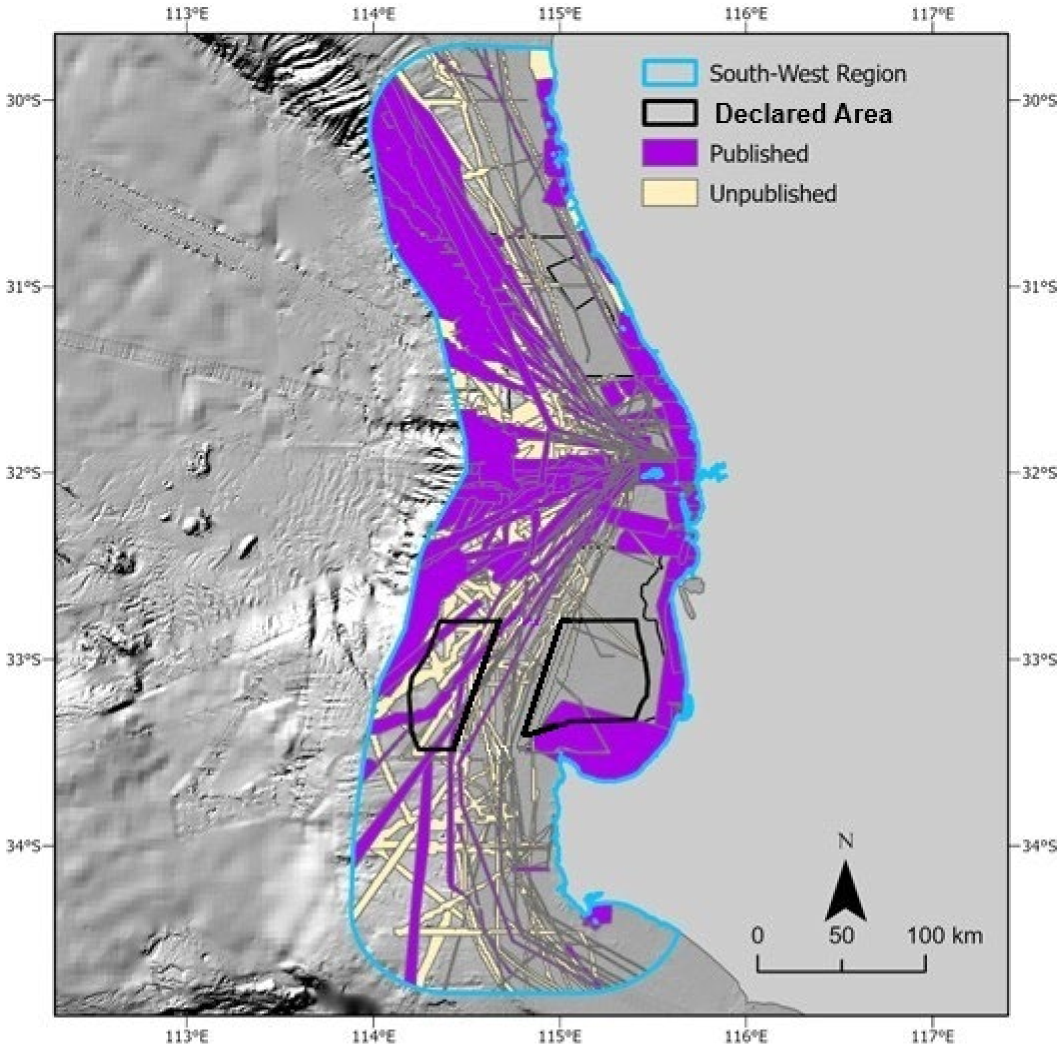


Figure 69. Bathymetry coverage for the south-west Australian Region (green) showing the spatial extent of bathymetry data (published and unpublished), including nearshore LiDAR data. Data extents are provided by third party contributors to the AusSeaBed Data Portal (listed in the Marine Baseline Data Inventory). Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

8.2. Seabed geology

The south-west OWF region extends across the sedimentary central- to southern-Perth and Mentelle Basins, and the geological basement high of the northern Yallingup Shelf that divides them (Figure 70). The Perth Basin has the most expansive overlap with the region. Its strata also extend onshore and its shallowest strata, which characterise much of the region (as well as that of the Mentelle Basin: Rahman et al., 2023), comprise hundreds of meters of open marine carbonate deposits (Crostella and Backhouse, 2000). Groundwater is present in some of these strata (e.g. the Leederville aquifer) and is harvested onshore for human use; modelling has indicated that extraction has modified the position of the saltwater to freshwater interface (Morgan et al., 2018) and managed aquifer recharge has resulted in vertical land motion (+20 mm / 3 years in the Perth to Swan River metropolitan area: Parker et al., 2021). Offshore activities that interact with submarine aquifers may have the potential to similarly impact onshore groundwater systems and need further investigation.

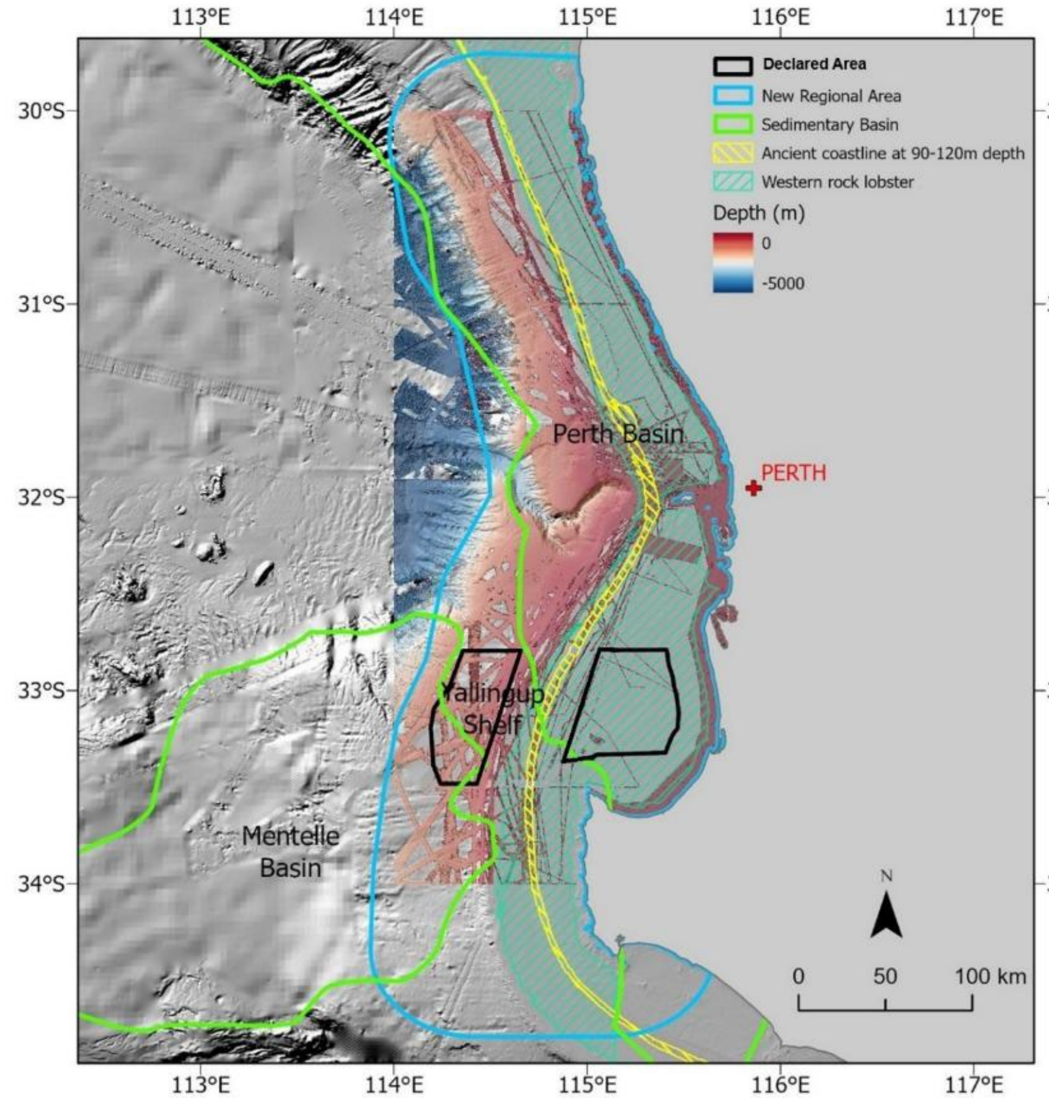


Figure 70. The south-west declared area (black polygon) and region (blue polygon), the Ancient Coastline and Western Rock Lobster (KEFs), and regional geology (green), over the regional 50 m (Parums and Spinoccia, 2019) and hillshade derived from the national 250 m (Beaman, 2022) bathymetry grids. The Yallingup Shelf occupies the area between the Mentelle and Perth Basin polygons (labelled within the vicinity of the declared area).

8.3. Seabed geomorphology

The south-west OWF region is primarily situated over the ~200 m deep and 40 – 100 km wide continental shelf, and the continental slope, which extends to over 4 km water depth (Figure 71). The shelf break between these is characterised by canyons, gullies, landslides and steep escarpments. Though the large, shelf-incising Perth Canyon is primarily a relict and geologically ancient feature (5 – 72 million years old: Nanson et al., 2022), the flanks and headwalls of all canyons in the region (including Busselton and Geographe Canyons in the south-west: Figure 71), the shelf break and parts of the upper slope are characterised by mass movements that may be vulnerable to sudden collapse (e.g. Heap et al., 2008: **see Project 3.3 Inventory**). Fields of pockmarks have also been identified at the seafloor in the central region (e.g. Heap et al., 2008; Figure 71); these indicate ongoing fluid or gas escape at the seabed. Such features are potentially unstable, and their broader distribution and character should be identified to assess the suitability of these areas for bottom fixed infrastructure.

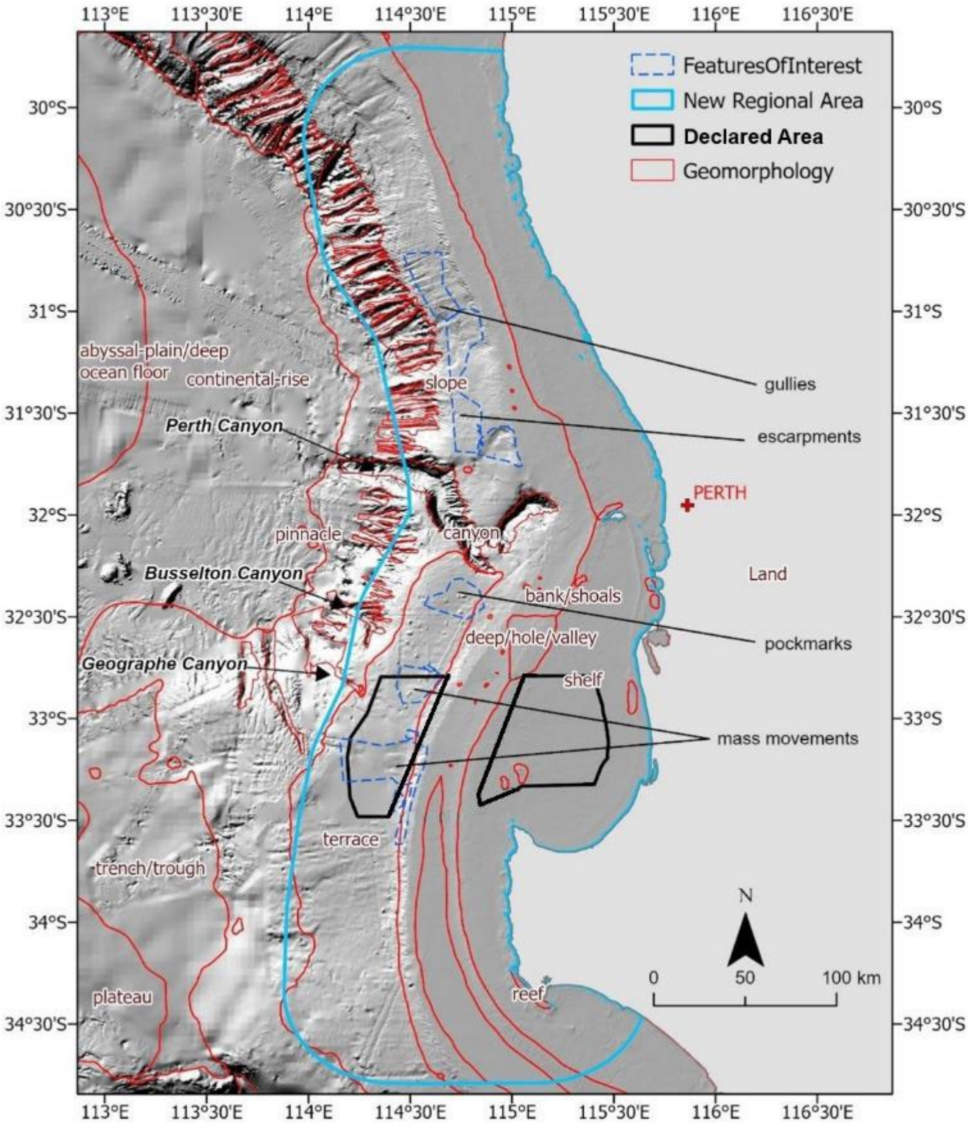


Figure 71. The regional geomorphology (red polygons; Heap and Harris, 2008) and areas containing additional features of interest (dashed blue polygons). Background hillshade derived from the 250 m bathymetry (Beaman, 2022).

Three KEFs intersect the declared areas; of these the "Ancient Coastline at 90 – 120 m Depth" dissects the region from north to south (Brooke et al., 2014). This feature is comprised of semi-lithified ancient beach ridges and dunes and may be associated with preserved archaeological and cultural material. The "Rock Lobster Habitat" KEF is also likely to include areas of hard ground and raised reef and may similarly provide important habitat. The "Ancient Coastline at 90–120 m Depth" KEF may also be an area where archaeological and cultural material is preserved; the potential cultural significance and habitats provided by these features require further investigation.

8.4. Sedimentology

In the south-west OWF region, sediment transport over the continental slope is from north to south via the Leeuwin Current, and over the shelf and along the coast is from south to north via the Leeuwin Undercurrent and swell driven flows (Collins, 1988; James et al., 1999). Sediment composition along this margin transitions from south to north from cool/temperate to sub-tropical carbonates (James et al., 1999).

Seabed sediment size in the region generally grades from sand and limited sandy gravel on the shelf (east), and around the Perth Canyon head (east), to mud on the slope and within the lower canyon reaches (west; Figure 72). In the southern area of the region gravel to sand size sediment also extend further offshore across the broader continental shelf; coarser sediment indicates stronger currents in these areas. The thicknesses of unconsolidated sediment within the region of interest range from thin cover (0 to 0.5 m) in water depths of 20 – 90 m on the shelf (Collins, 1988) that thicken across the upper continental slope (sub-bottom images indicate up to 75 m thick in the south; up to ~25 m thick nearer the Perth Canyon) (Figure 72). The stability of the southern accumulations has been modelled and linked to variations in slope, and triggers for their failure may include seismicity, gravity, ongoing sedimentation and failure of over steepened canyon walls (Heap et al., 2008; Project 3.3 OWF bathymetry-sediments inventory). Infrastructure activities on the shelf to upper slope may impact on the stability of seabed sediment and mass movement features.

Recent coastline movements vary alongshore Waves approaching the coast refract around numerous, shallow nearshore reefs (partially lithified Pleistocene barriers and dunes) and result in the development of a variety of sand spits that characterise this coastline (Sanderson and Elliot, 1996). The preferential on- and alongshore supply of sediment to the updrift (southern) flanks of these features results in their asymmetric net-growth, some of which are currently simultaneously prograding and eroding on separate flanks (e.g. Becher Point + 6 m pa updrift; -3 m pa downdrift: Nanson et al., 2021; Figure 72). Longer term patterns of growth and retreat have been linked to cyclic meteorological and oceanographic processes (decadal to millennial: Semeniuk et al., 1995). Offshore infrastructure has the potential to alter the local wave climate and potentially downstream coastal processes if close to the coast (David et al., 2022).

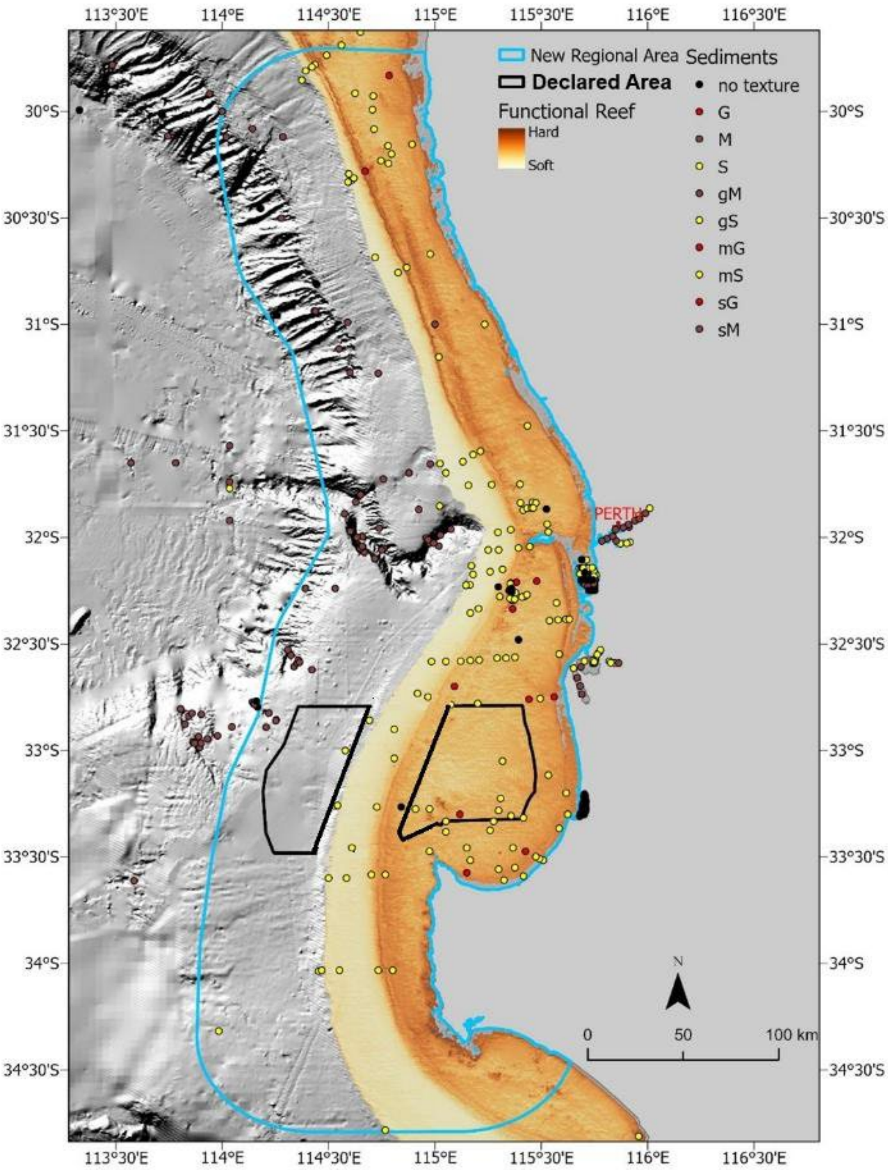


Figure 72. "Functional Reef" modelling (NESP 2.1) indicates predicted occurrence of reef forming habitats, and sediment sample textures (primary, secondary): G, g – gravel; S, s – sand; M, m – mud. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

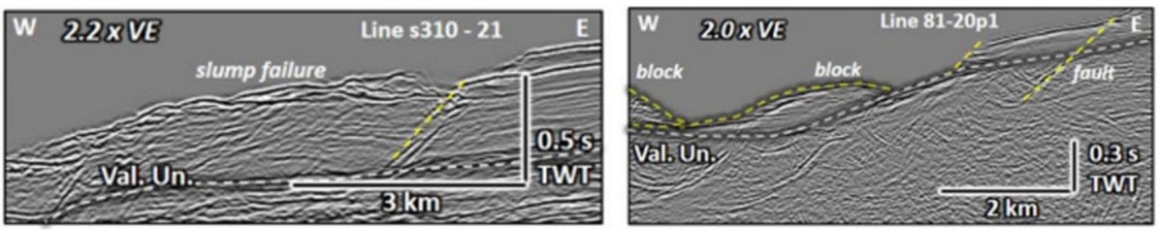


Figure 73. Seismic images illustrate vertical profiles through mass movements and failed blocks that characterise the perimeter of the Perth Canyon. Val. Un. is an ancient unconformity surface (dotted white line) over which many mass movements in the region fail; VE – vertical exaggeration; E – east, W – west; TWT – two-way time for sub-bottom signal in seconds, situated in water depths 700 – 1700 m; 0.5 s / 0.3 s TWT vertical scales are approximately 400 m / 250 m (modified from Nanson et al., 2022).

8.5. Seabed habitats and benthic biodiversity

The south-western bioregion, including the south-west region has a distinct geological and oceanographic history, with low productivity shelf waters and distinct algal, seagrass, sessile invertebrate and fish assemblages with high levels of endemism (Langlois et al., 2012).

The region is characterised by distinct and discrete paleo shoreline features which appear to play a strong role in structuring patterns in marine biodiversity across the modern continental shelf (Currey-Randall et al., 2021; Langlois et al., 2022). The recent bioregional mapping of functional reef and ecosystem components conducted in NESP Marine and Coastal Hub Project 2.1 revealed a distinctive pattern in ecosystem components across the continental shelf. However, no ground truthing samples of benthic or fish and shark assemblages have previously been collected within the Declared south-west offshore wind area, particularly those in greater depths within the defined declaration area.

Adjacent to the declared south-west offshore wind area lies the Geographe and South-west Corner Marine Parks in Commonwealth waters. Both these areas have been the subject of extensive benchmarking surveys (Lawrence et al. 2016; Langlois et al., 2022) and ongoing NESP projects (www.nespmarinecoastal.edu.au) to inform the assessment and management of the Australian Marine Parks. These previous surveys revealed that paleo shoreline and riverbed features formed during the falling and raising of sea levels before and during the last ice age are a distinct feature within both these marine parks and contribute to the abundance distribution of key species, including the vulnerable Grey Nurse Shark (*Carcharias taurus*) and unique endemic deepwater seagrass species that form extensive but spare distributions along the paleo shoreline features (Langlois et al., 2022). The deepest records of the endemic seagrass *Thalassodendron pachyrhizum* down to over 60 m in depth (Martin et al., 2023) where they occur interspersed with sessile invertebrate and algal assemblages.

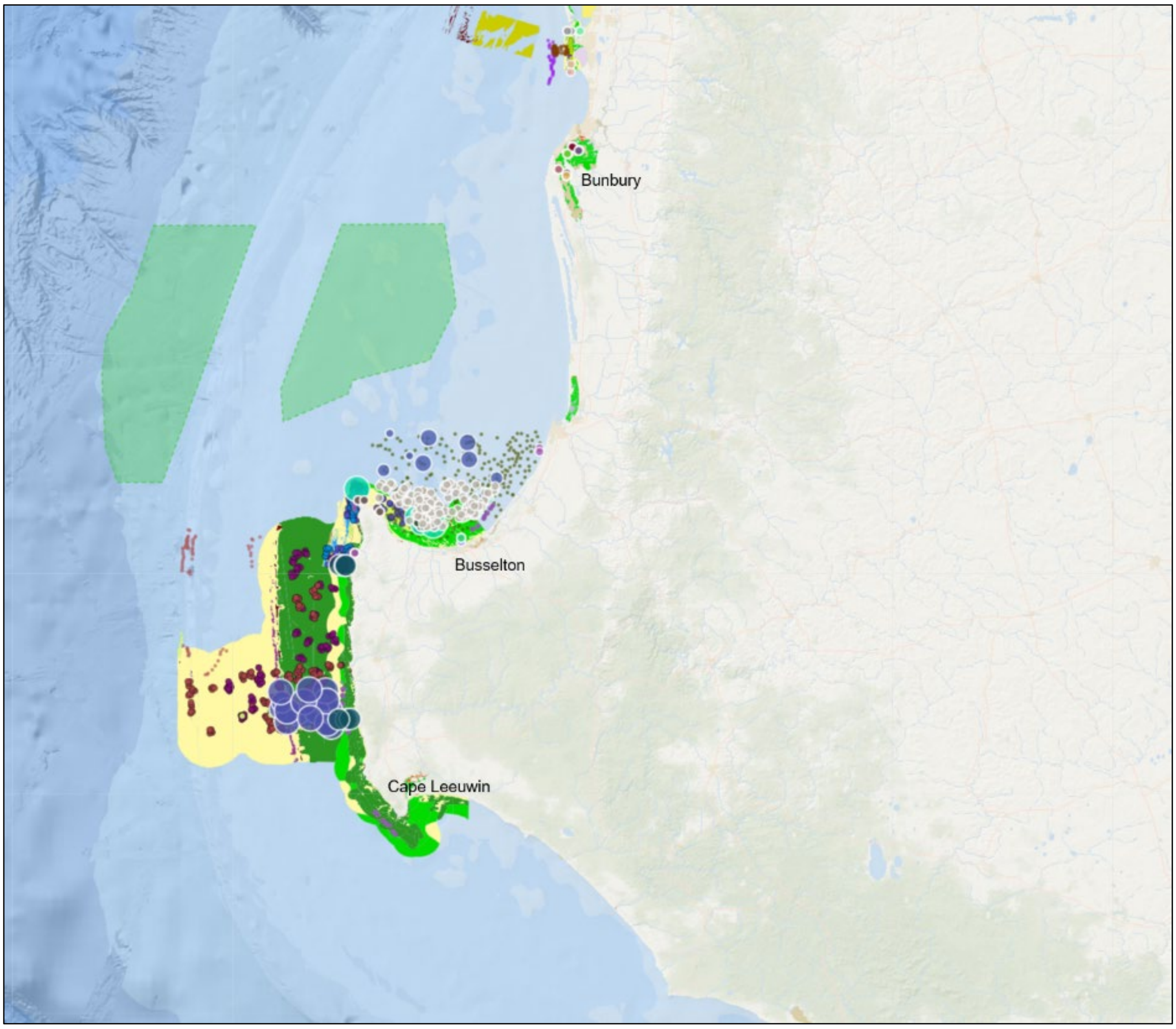


Figure 74: Available seabed ecological survey locations and habitat data for the south-west OWF region represented in the Seamap Australia marine spatial data portal, including surveys using towed video, panoramic drop camera, Autonomous Underwater Vehicles and Baited Remote Underwater Videos, represented as bubble plots. [Declared area boundaries finalised after completion of maps in this report and are not amended here]. Map legend details on deployment types and habitat maps are available at:

https://seamapaustralia.org/map/#2075aac3-9793-45cc-810d-c4e20bbe21b0

8.6. Oceanography

The south-west OWF development region a is micro-tidal region. Peak tidal currents are weak, estimated to be less than 0.1 m s-1 across the declared region (from TPXO8, Egbert and Svetlana, 2002). Despite the weak currents the nature of the seabed sediment and shallow water at the eastern edge of the region may be conducive to turbidity impacts. The Leeuwin current dominates the background flow, driving southerly advection of warm water through the region. Over summer wind stress and a weaker Leeuwin current can allow for upwelling and a northward flow named the Capes current, which passes through the region (Pearce and Pattiaratchi, 1998).

The stratification front is expected to remain near the shelf break year-round (based on preliminary CARS analysis) but seasonally variable currents may affect this. Wave energy in the OWF region is high due to the region's exposure to the Southern Ocean (Hemer et al., 2018), but the south-west declared area is expected to be far enough from the coast to limit significant impacts (David et al., 2022). Strong wind energy resources in the region (Salvador, 2022), including persistent wind events, may alter nutrient fluxes and upwelling patterns.

8.7. Threatened and migratory marine species

All spatial layers from the fauna maps presented in text are available for viewing and download through the following maps and table links. These are live documents that can be updated as more data becomes available.

Information on finfish, invertebrates and other species of interest can be viewed in the inventory for the south-west region. This list is not comprehensive as it was not the focus of this study and therefore only a small subset of species are provided in the inventory.

Fauna Group		**OWF Area overlap**	**Data tables**
	Cetaceans and pinnipeds	Map Link	Baleen, toothed pinnipeds
	Birds	Map Link	Birds
	Sharks	Map Link	Sharks
	Reptiles	Map Link	Reptiles

8.7.1. Cetaceans and pinnipeds

Published papers/reports inventory

From our literature search and compilation (inventory), the study areas of 45 published studies on cetaceans (Figure 75) and four for pinnipeds (Figure 78) overlapped with the south-west OWF region. Most of those studies were on pygmy blue whales (*Balaenoptera musculus brevicauda*, listed endangered under the EPBC Act, n=8), and southern right whales (*Eubalaena australis,* listed endangered under the EPBC Act, n=8). An additional study on pygmy blue whales was published since development of the inventory that shows habitat use by the species in this region (Ferreira et al., 2024). Five studies were found for Indo-pacific bottlenose dolphin (*Tursiops aduncus*, listed cetacean under the EPBC Act), four studies were found for humpback whales (*Megaptera novaeangliae*, listed migratory under the EPBC Act), three for killer whales (*Orcinus orca*, listed migratory under the EPBC Act), two for sperm whales (*Physeter macrocephalus*, listed Migratory), false killer whale (*Pseudorca crassidens*, listed Cetacean) and Australian sea lion (*Neophoca cinerea*, listed endangered under the EPBC Act). Only one study was found for each of the remaining species (Table 29, 30, 31). The highest overlap between the cetacean and pinniped study area polygons and the south-west OWF (Figure 75 and Figure 78) was for humpback whales and pygmy blue whales (both 100%), followed by southern right whales (66%), pygmy right whale (61%), fin whale (56%), Antarctic blue whale (40%), bottlenose dolphin spp. (49%), killer whales (35%) and sperm whales (30%) (Table 30, Table 31, Table 32). The remaining species overlap between the species study areas and the south-west OWF was <10%. The high overlap suggests this area is provides important habitat for these species.

Table 29. Baleen whale species and species of secondary importance for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA combined) that overlap with the south-west OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. South-west baleen cetacean Table link

WA OWF: Cetaceans (baleen)

			Area as % of OWF		Observation counts	Seasonality												Number
Species	Family Occurence	EPBC Status	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
Southern Right Whale *Eubalaena australis* i	Balaenidae -	Endangered	100	66	18													8
Antarctic Blue Whale *Balaenoptera musculus intermedia* i	Balaenopteridae -	Endangered	100	40	0													1
Pygmy Blue Whale *Balaenoptera musculus brevicauda* i	Balaenopteridae -	Endangered	100	98	10													8
Fin Whale *Balaenoptera physalus* i	Balaenopteridae -	Vulnerable	51	56	2													1
Antarctic Minke Whale *Balaenoptera bonaerensis* i	Balaenopteridae -	Migratory	2		0													0
Bryde's Whale *Balaenoptera edeni* i	Balaenopteridae -	Migratory	100	4	0													1
Dwarf Minke Whale *Balaenoptera acutorostrata subsp.* i	Balaenopteridae -	Migratory	100	2	21													1
Humpback Whale *Megaptera novaeangliae* i	Balaenopteridae -	Migratory	100	100	1244													4
Pygmy Right Whale *Caperea marginata* i	Cetotheriidae -	Migratory	56	61	12													1

Table 29. Toothed whale species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA combined) that overlap with the south-west OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. Note that for the toothed whales information on seasonality is absent and the species are presumed present all year round. South-west toothed cetacean Table link

WA OWF: Cetaceans (toothed)

			AREA AS % OF OWF		OBSERVATION COUNTS	SEASONALITY	NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	SNES	PUBS	OBIS-ALA	J F M A M J J A S O N D	PUBS
Indo-Pacific Bottlenose Dolphin *Turstops aduncus*	Delphinidae -	Migratory	68	1	42		5
Killer Whale *Orcinus orca*	Delphinidae -	Migratory	100	35	4		3
Sperm Whale *Physeter macrocephalus*	Physeteridae -	Migratory	34	30	5		2
Bottlenose Dolphin Species *Tursiops spp.*	Delphinidae -	Cetacean	100	49	0		1
Common Dolphin *Delphinus delphis*	Delphinidae -	Cetacean	100		2		0
False Killer Whale *Pseudorca crassidens*	Delphinidae -	Cetacean	48	2	30		2
Long-Finned Pilot Whale *Globicephala melas*	Delphinidae -	Cetacean	34		3		0
Striped Dolphin *Stenella coeruleoalba*	Delphinidae -	Cetacean	34	1	15		1
Pygmy Sperm Whale *Kogia breviceps*	Kogiidae -	Cetacean	34		3		0
Andrew's Beaked Whale *Mesoplodon bowdoini*	Ziphiidae -	Cetacean	34	0	2		1
Arnoux's Beaked Whale *Berardius arnuxii*	Ziphiidae -	Cetacean	4		0		0
Blainville's Beaked Whale *Mesoplodon densirostris*	Ziphiidae -	Cetacean	24	5	0		1
Cuvier's Beaked Whale *Ziphius cavirostris*	Ziphiidae -	Cetacean	34		2		0
Gray's Beaked Whale *Mesoplodon grayi*	Ziphiidae -	Cetacean	12	1	62		1
Shepherd's Beaked Whale *Tasmacetus shepherdi*	Ziphiidae -	Cetacean	0	1	0		1
Strap-Toothed Beaked Whale *Mesoplodon layardii*	Ziphiidae -	Cetacean	34		1		0
True's Beaked Whale *Mesoplodon mirus*	Ziphiidae -	Cetacean	34	3	0		1

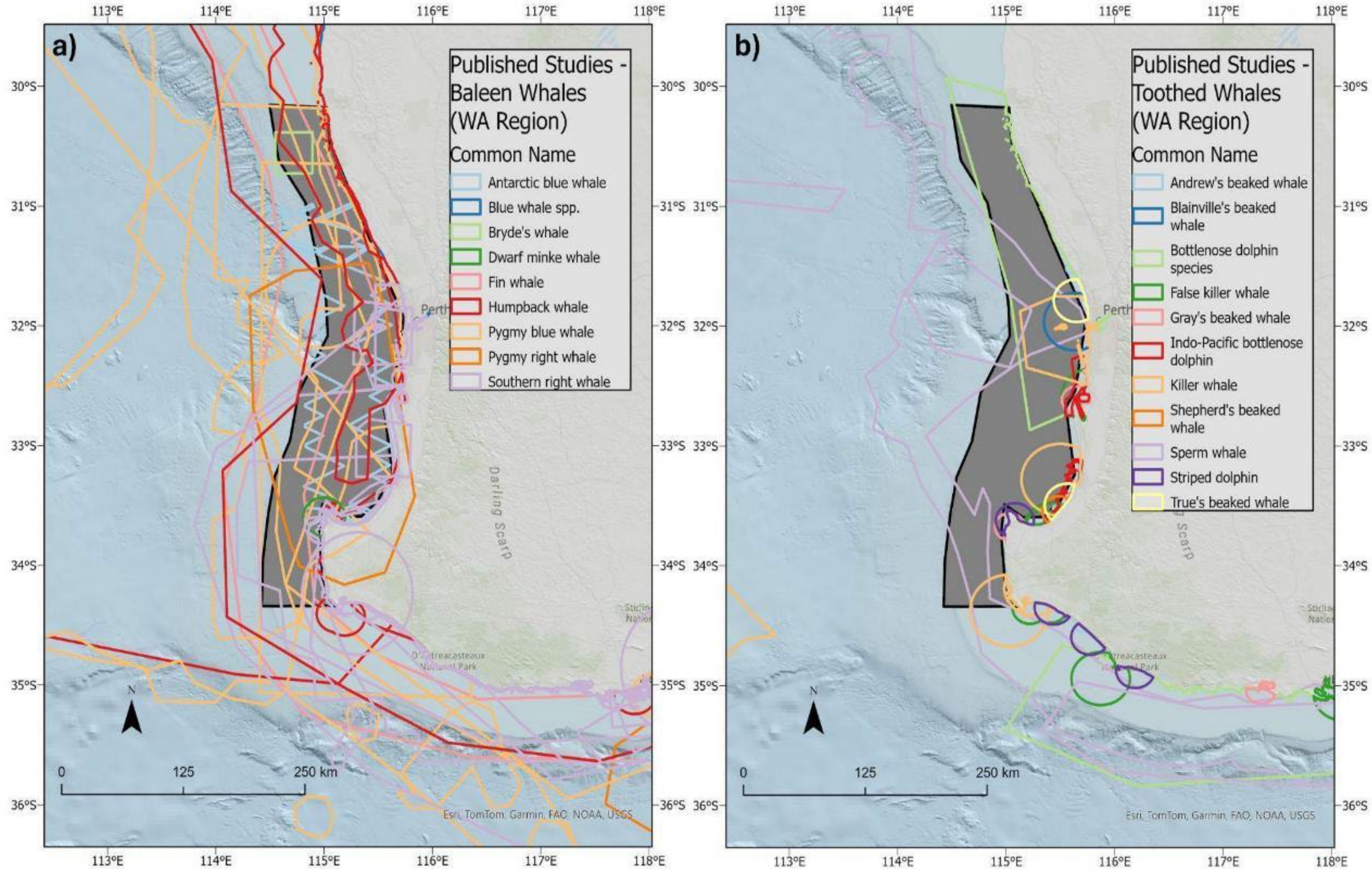


Figure 75: The south-west OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where baleen (a) and toothed (b) whales occurred. The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

Existing freely available species observation data

Overlaying observations of the priority (and secondary priority) cetacean and pinniped species from ALA, and OBIS with the south-west OWF region (Figure 75 and Figure 76), showed that observations of humpback whales (1244) were the most common followed by Australian sea lion (140) and for all the remaining species the number of observations occurring in the OWF were <~100 (Table 30, Table 31, Table 32).

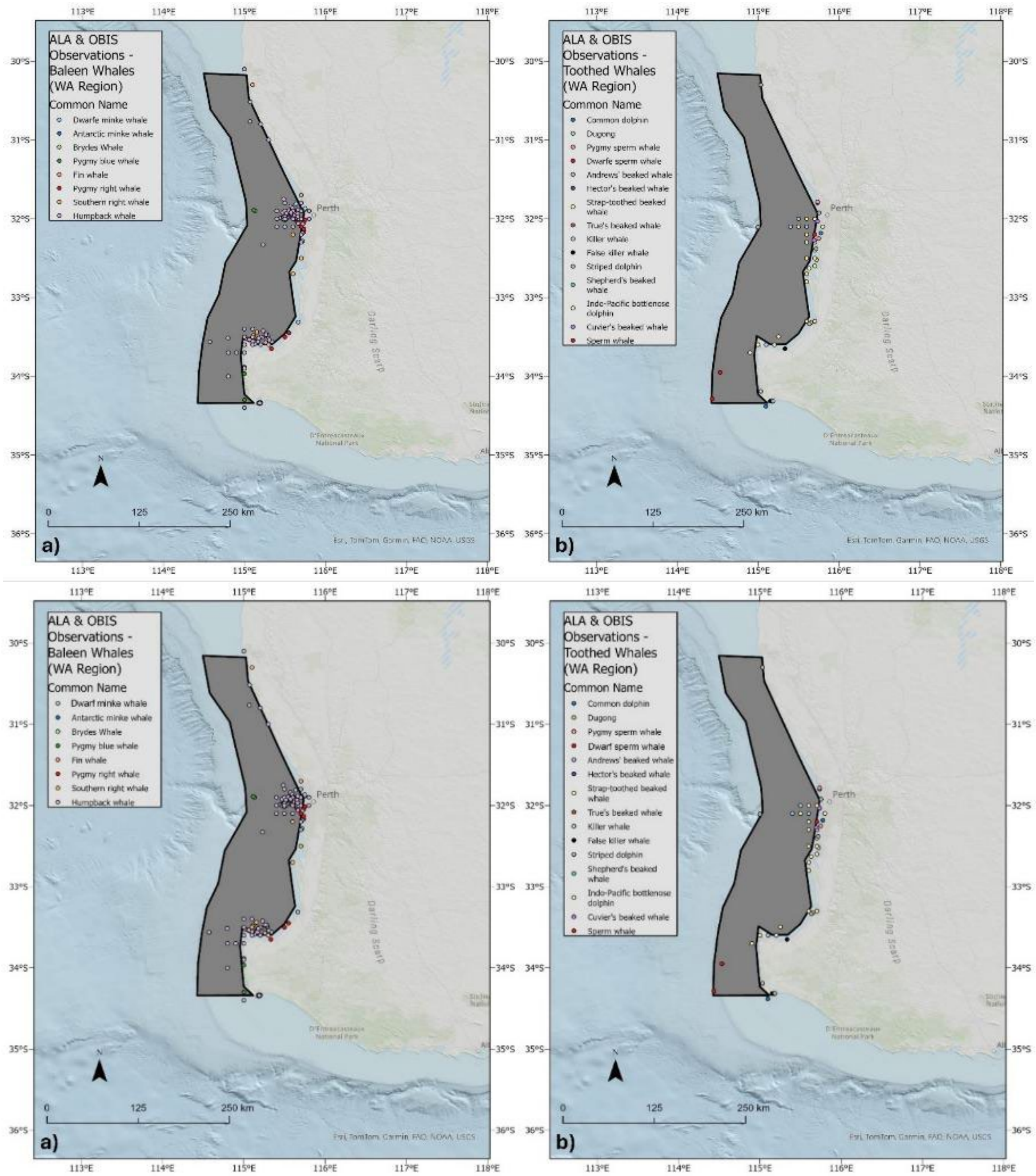


Figure 76: The south-west OWF (grey polygon) showing observations of baleen (a) and toothed (b) whales from the Atlas of Living Australia (ALA) and the Ocean Biodiversity Information System (OBIS) across. The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

The spatial distribution of priority (and secondary priority) cetacean and pinniped species observations within the south-west OWF region shows most of the species observations occurred off Perth and in the southern part of Geographe Bay (Figure 76). Endangered species that have been observed in the south-west OWF in OBIS and ALA include pygmy (Figure 77) and Antarctic blue whales, southern right whales (*Eubalaena australis*) and the vulnerable listed fin whale (*Balaenoptera physalus*) (Table 30). In addition to OBIS data, tracking data from pygmy blue whales was made available (Thums et al., 2022), showing that pygmy blue whales tracked from Perth Canyon used the south-west OWF, but predominantly used the more offshore parts of the OWF area (Figure 77).

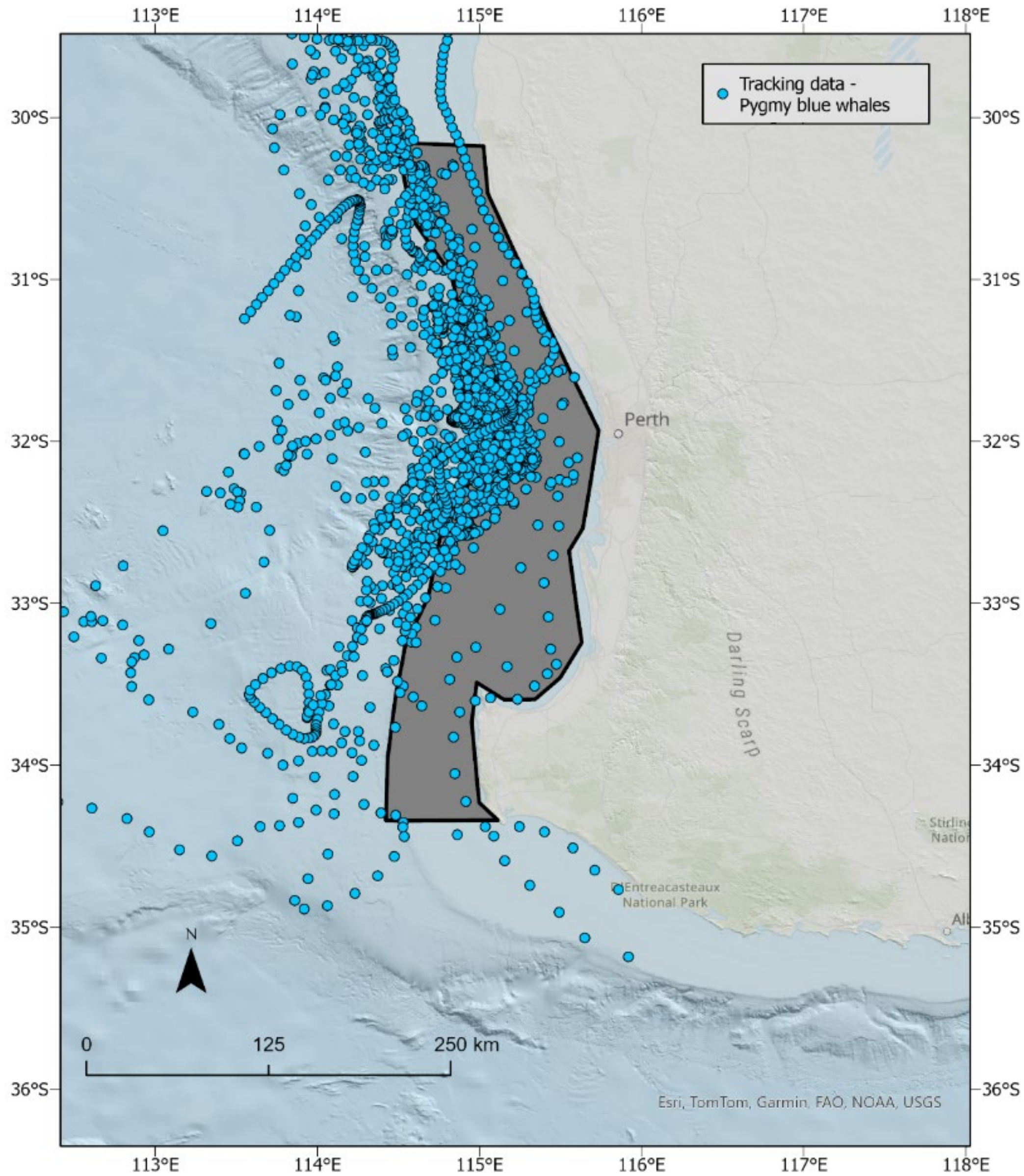


Figure 77: Pygmy blue whale tracking data for south-west, Western Australia showing overlap with proposed OWF area from Thums et al., 2022. Additional information on this species in this region is provided in Ferreira et al. 2024. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

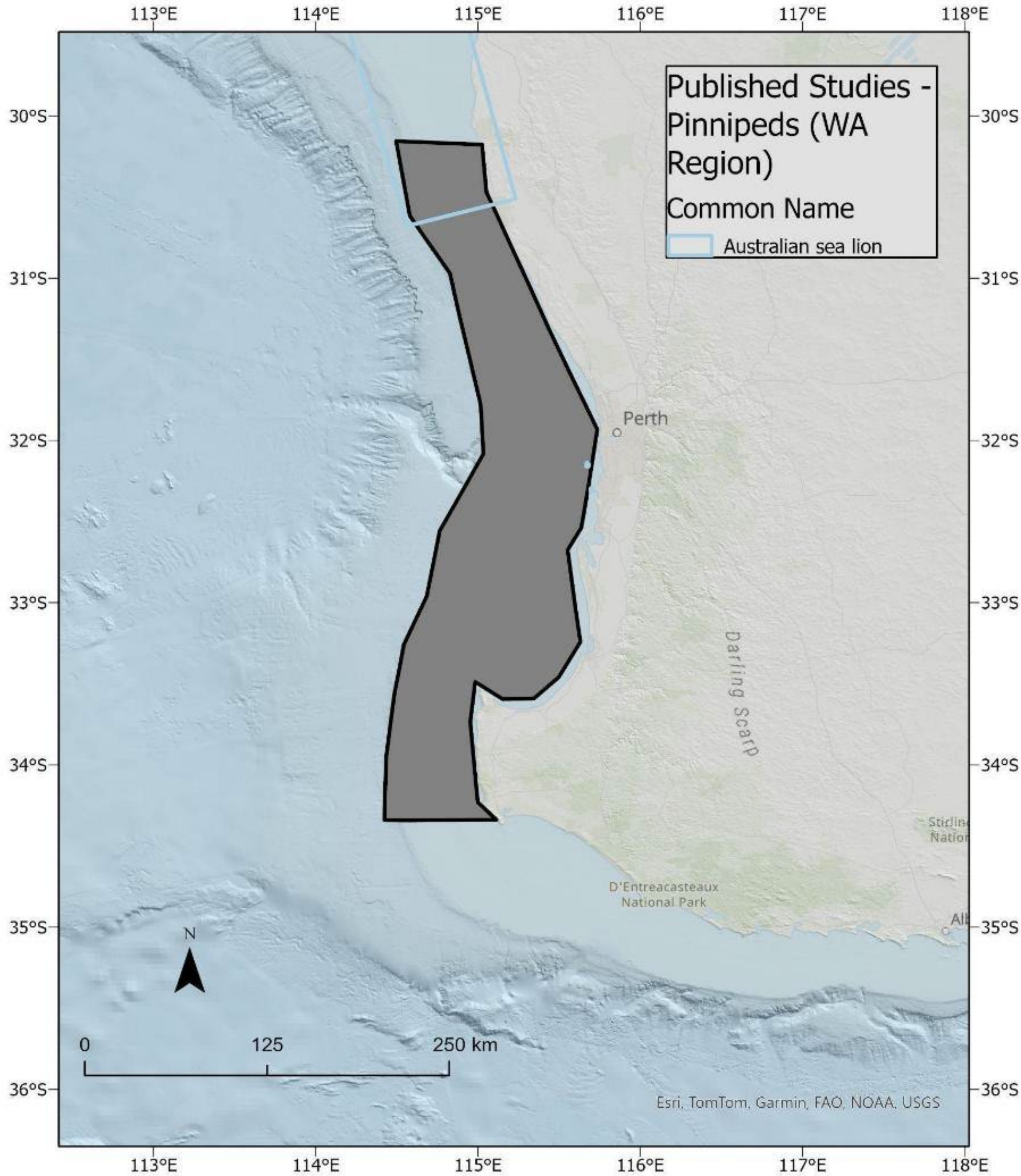


Figure 78: The south-west OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where pinnipeds occurred. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

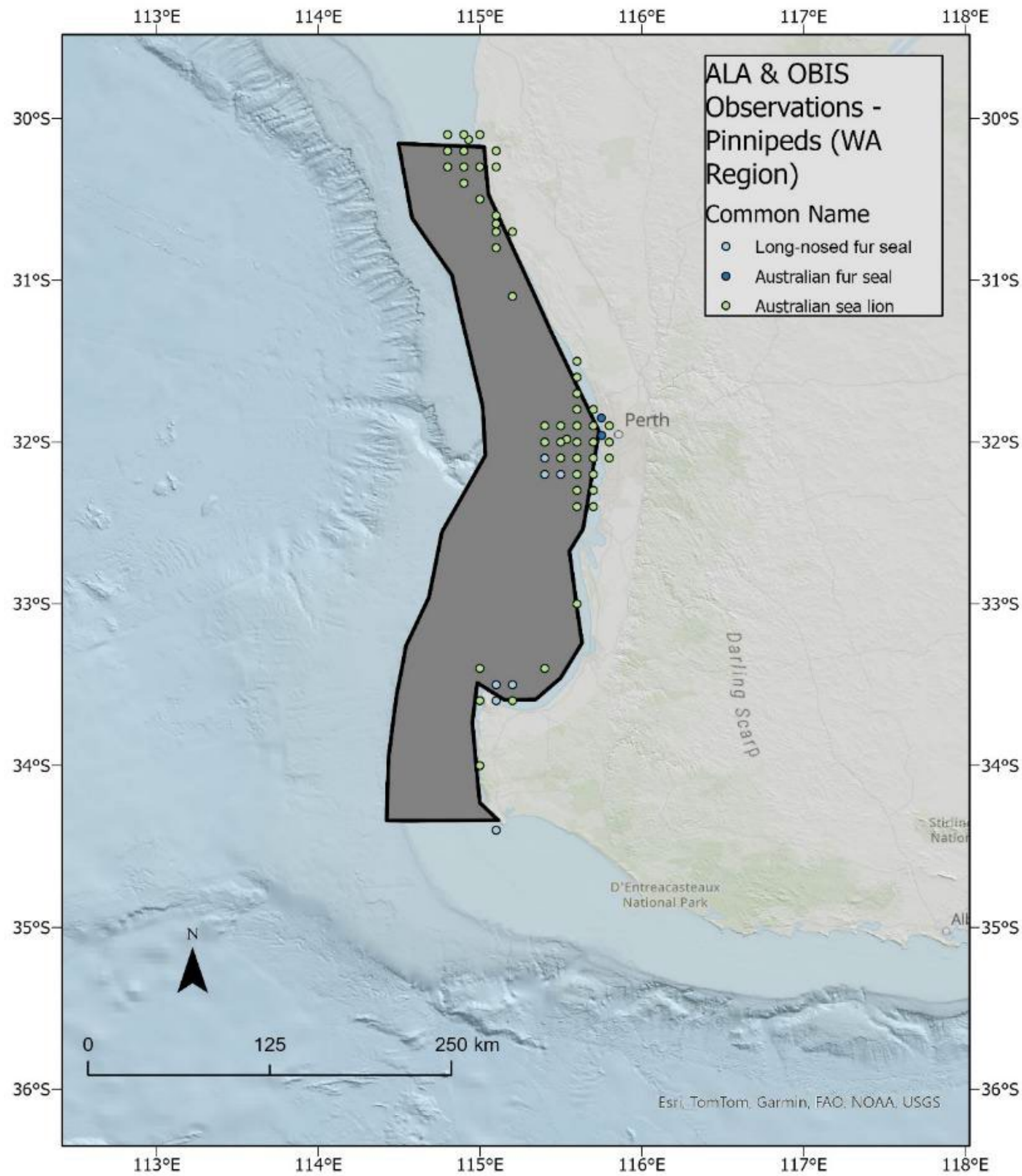


Figure 79: The south-west OWF region (grey polygon) showing the spatial coverage of observations from ALA/OBIS where pinnipeds occurred. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

Table 30. Pinniped species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA combined) that overlap with the south-west OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high.

WA ORE: Pinniped

			AREA AS % OF ORE		OBSERVATION COUNTS	SEASONALITY											
SPECIES	FAMILY OCCURENCE	EPBC STATUS	SNES	PUBL.	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D
Australian Sea Lion *Neophoca cinerea*	Otariidae -	Endangered	100	8	118												
Australian Fur-Seal *Arctocephalus pusillus doriferus*	Otariidae -	Marine															
Long-Nosed Fur-Seal *Arctocephalus forsteri*	Otariidae -	Marine	68		76												

8.7.2. Birds

Published papers/reports inventory

Within the south-west region, 17 published studies on bird species of interest that overlap with the OWF area were found and compiled (Figure 80). Most of those studies were on albatrosses (9) with six studies on terns, and one study each for noddies, penguins, and shearwaters. The entire south-western region (29,171 km^2) has studies of noddies overlapping it with albatrosses and terns just short of full coverage. Studies of shearwaters covers just short of 10 km^2 while penguin studies overlap with 3,755 km^2 of the OWF.

Studies completed in the south-west OWF included three listed threatened bird species under the EPBC Act; the critically endangered tristan albatross (*Diomedea dabbenena*) and the endangered shy albatross (*Thalassarche cauta*) and Amsterdam albatross (*Diomedea amsterdamensis*). The remaining species in the inventory are made up of species listed as vulnerable and other species identified as of interest due to their migratory behaviour or potential interactions with wind farms in the region (Table 33). Although the Tristan albatross is listed critically endangered, it is considered a vagrant in the south-west OWF region.

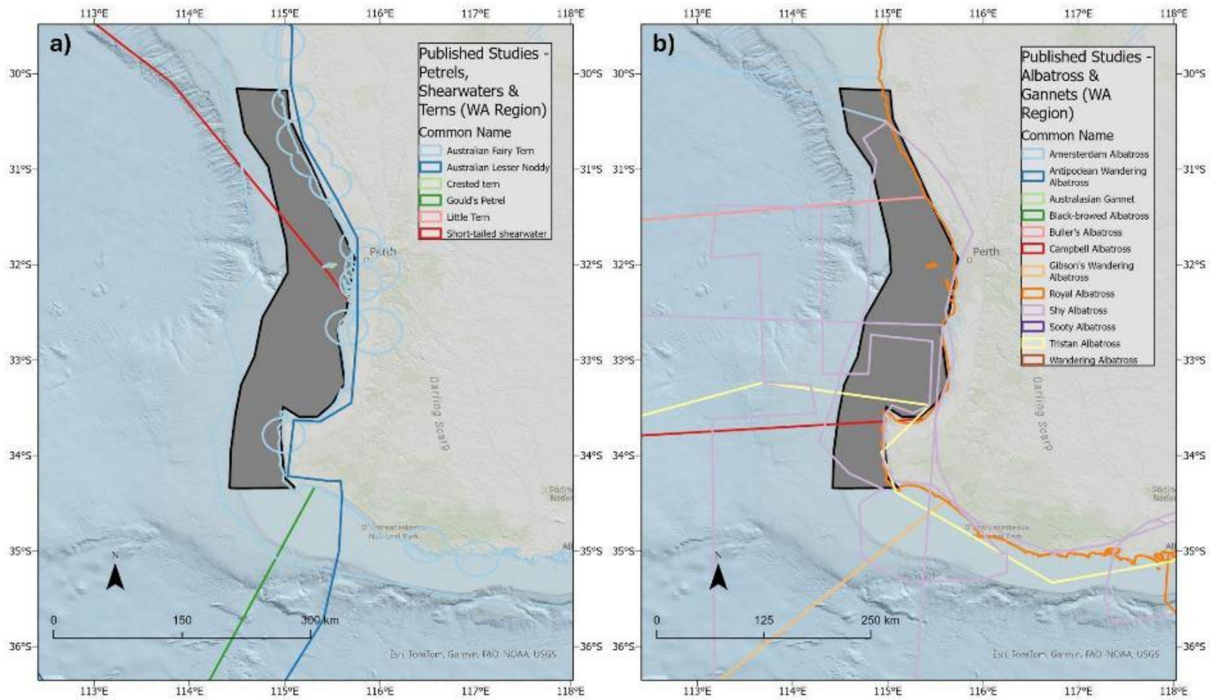


Figure 80: The south-west OWF region (grey polygon) showing the spatial coverage of the study areas where bird species occurred with separate maps for each species group (a-b). The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

Existing freely available species observation data

Observations of birds within the south-west OWF region from BirdLife Australia, ALA, and OBIS showed that waders were the most observed in the Western Australian region (6,237 observations), followed by terns (3,285 observations). The rest of the groups observed ranged from 1 observation (skuas) to 1,919 observations (petrels) (Table 33).

The spatial distribution of bird observations within the south-west OWF region shows that bird species of interest have been recorded along the nearshore edge of the OWF area and heading out from the Port of Fremantle (Figure 81). Most of these observations are based on opportunistic information so they do not represent a systematic survey of the region and are mainly in areas where boat traffic and human populations are greatest. However, a wide variety of species use and transit through the area. Several species of critically endangered (*Diomedea dabbenena*, *Numenius madagascariensis, Calidris ferruginea*, and *Calidris tenuirostris*), endangered (*Calidris canutus, Thalassarche cauta*, *Macronectes giganteus*, *Charadrius mongolus, Pterodroma leucoptera leucoptera,* and *Diomedea amsterdamensis*), and vulnerable birds under the EPBC Act have all been observed in the region.

Table 31. Priority bird species and bird species of secondary importance for which we have compiled spatial data from published studies and freely available data repositories (BLA, OBIS and ALA) that overlap with the south-west OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for each data repository used (BLA = Birdlife Aust, OBIS and ALA data combined). Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. South-west bird Table link

WA OWF: Bird

Species	Family Occurence	EPBC Status	Area as % of OWF: SNES	Area as % of OWF: PUBS	Observation counts: BLA	Observation counts: OBIS-ALA	Number: PUBS
Tristan Albatross *Diomedea dabbenena*	Diomedeidae Vagrant	Critically Endangered	62	20	0	0	1
Curlew Sandpiper *Calidris ferruginea*	Scolopacidae Common	Critically Endangered	90		300	966	0
Far Eastern Curlew *Numenius madagascariensis*	Scolopacidae Common	Critically Endangered	100		146	515	0
Great Knot *Calidris tenuirostris*	Scolopacidae Common	Critically Endangered	0		197	1474	0
Lesser Sand Plover *Charadrius mongolus*	Charadriidae Common	Endangered	0		38	47	0
Amsterdam Albatross *Diomedea amsterdamensis*	Diomedeidae Vagrant	Endangered	100	97	0	0	2
Northern Royal Albatross *Diomedea sanfordi*	Diomedeidae Vagrant	Endangered	64		0	0	0
Shy Albatross *Thalassarche cauta*	Diomedeidae Common	Endangered	100	90	47	270	3
Southern Giant Petrel *Macronectes giganteus*	Procellariidae Rare	Endangered	100		43	172	0
Black-Tailed Godwit *Limosa limosa*	Scolopacidae Rare	Endangered	0		28	246	0
Red Knot *Calidris canutus*	Scolopacidae Common	Endangered	100		101	522	0
Greater Sand Plover *Charadrius leschenaultii*	Charadriidae Common	Vulnerable	1		123	231	0
Black-Browed Albatross *Thalassarche melanophris*	Diomedeidae Vagrant	Vulnerable	100		41	247	0
Campbell Albatross *Thalassarche impavida*	Diomedeidae Vagrant	Vulnerable	100	13	0	0	1
Indian Yellow-Nosed Albatross *Thalassarche carteri*	Diomedeidae Common	Vulnerable	100		148	27	0
Royal Albatross *Diomedea epomophora*	Diomedeidae Vagrant	Vulnerable	100	97	0	8	1
Sooty Albatross *Phoebetria fusca*	Diomedeidae Rare	Vulnerable	99		1	10	0
Wandering Albatross *Diomedea exulans*	Diomedeidae Rare	Vulnerable	100		5	44	0
White-Capped Albatross *Thalassarche steadi*	Diomedeidae Rare	Vulnerable	100		0	0	0
Fairy Tern *Sternula nereis nereis*	Laridae Common	Vulnerable	0	99	921	2535	5
Blue Petrel *Halobaena caerulea*	Procellariidae Rare	Vulnerable	84		3	17	0
Northern Giant Petrel *Macronectes halli*	Procellariidae Vagrant	Vulnerable	100		3	269	0
Soft-Plumaged Petrel *Pterodroma mollis*	Procellariidae Rare	Vulnerable	99		68	431	0
Great-Winged Petrel *Pterodroma macroptera*	Procellariidae Rare	Marine	49		58	855	0
Little Penguin *Eudyptula minor*	Spheniscidae Common	Marine	0	13	64	388	2
Short-Tailed Shearwater *Ardenna tenuirostris*	Procellariidae Common	Migratory	0	33	1	10	1
Bar-Tailed Godwit *Limosa lapponica*	Scolopacidae Common	Migratory	2		311	1431	0

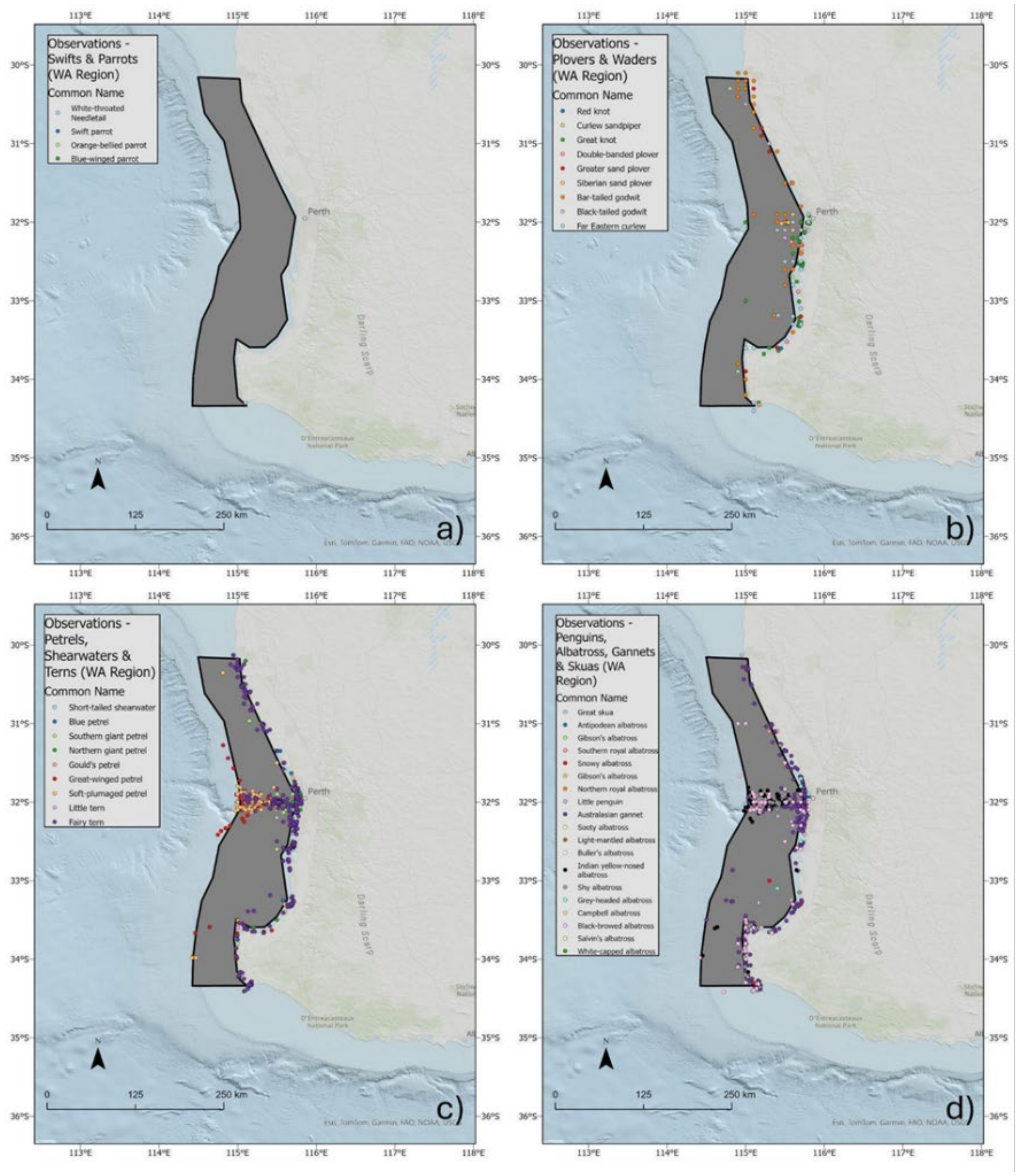


Figure 81: The south-west OWF (grey polygon) showing observations of birds from BirdLife Australia, the ALA, and the OBIS across for each bird grouping (a-d). The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

8.7.3. Sharks

Published papers/reports inventory

Within the south-west OWF region, six published studies on shark species of interest that overlap with the OWF area were found and compiled (Figure 82). Of the six studies, five were on the white shark (*Carcharodon carcharias*) and one was on the whale shark (*Rhincodon typus*). Overlap of the published study areas of sharks suggest that most of the south-west OWF region (29,170 km^2) is habitat for white sharks (28,636 km^2) and over half of the OWF (16,379 km^2) for whale sharks. White sharks were found to reside in the south-west OWF region between December and March. No spatial coverage of grey nurse sharks (*Carcharias taurus*) could be found in published studies; however, they are believed to reside in the south-west OWF region between March and June. The grey nurse shark is listed as critically endangered, while both white and whale sharks are listed as vulnerable under the EPBC Act.

Existing freely available species observation data

Observations of sharks within the WA region OWF region from the ALA and OBIS showed two species of sharks to be present with the grey nurse shark (49 observations) being more prevalent than the white shark (5 observations) (Table 34 and Figure 83). Grey nurse shark observations occurred throughout the entire south-west OWF region and in high density in waters around Perth. White sharks were exclusively sighted in waters near Perth.

Table 33. Shark species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the south-west OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. https://vhost2009.hosted-sites.deakin.edu.au/ORE/WA_Shark.html

WA OWF: Shark

			Area as % of OWF		Observation counts	Seasonality												Number
Species	Family occurence	EPBC status	SNES	PUBS	OBIS-ALA	J	F	M	A	M	J	J	A	S	O	N	D	PUBS
White Shark *Carcharodon carcharias* i	Lamnidae -	Vulnerable	100	98	5													5
Grey Nurse Shark *Carcharias taurus* i	Odontaspididae -	Vulnerable	91		49													0
Whale Shark *Rhincodon typus* i	Rhinchodontidae -	Vulnerable	91	56	0													1

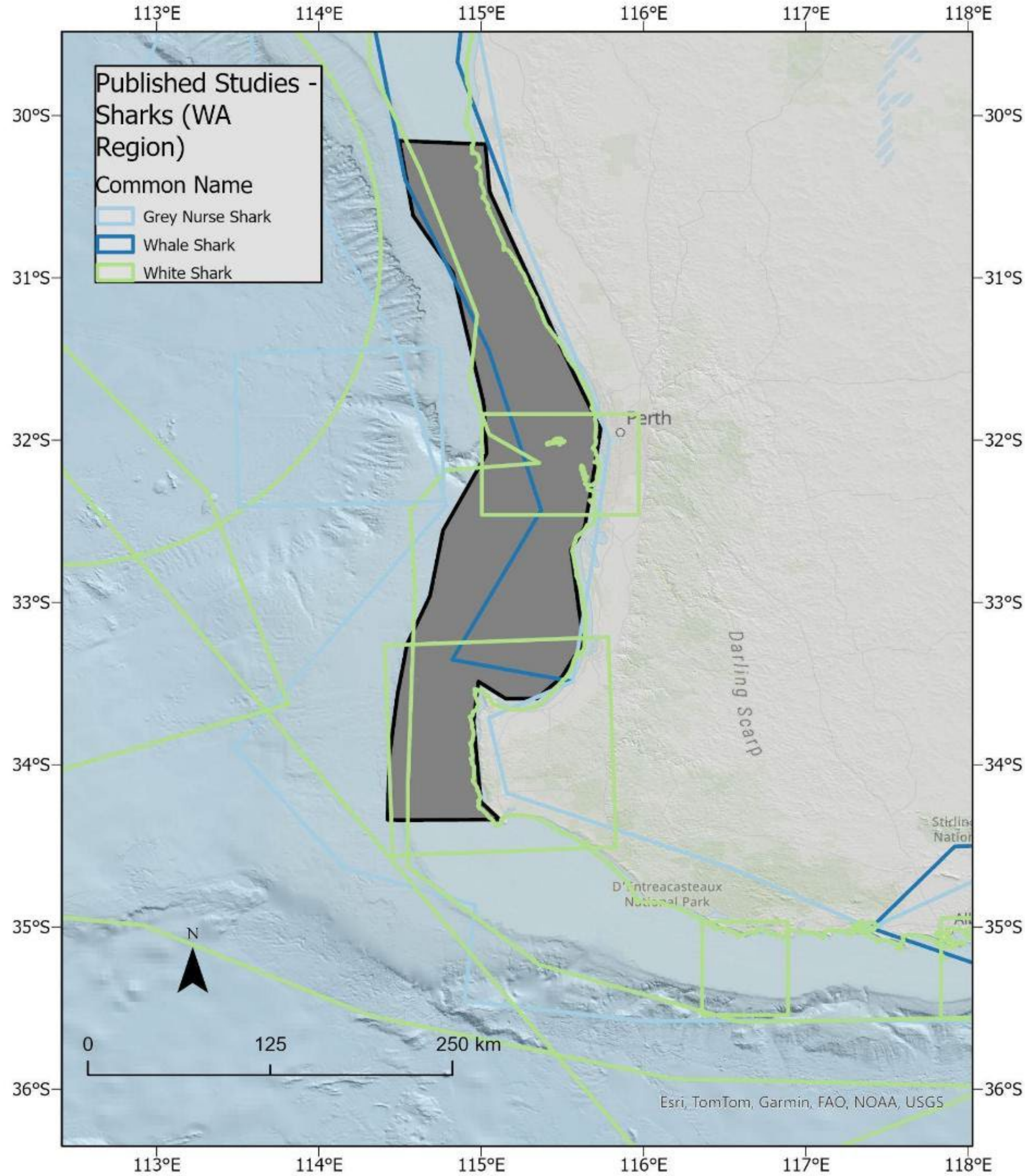


Figure 82: The south-west OWF region (grey polygon) showing the spatial coverage of the study areas from the publication inventory where listed sharks occurred. The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

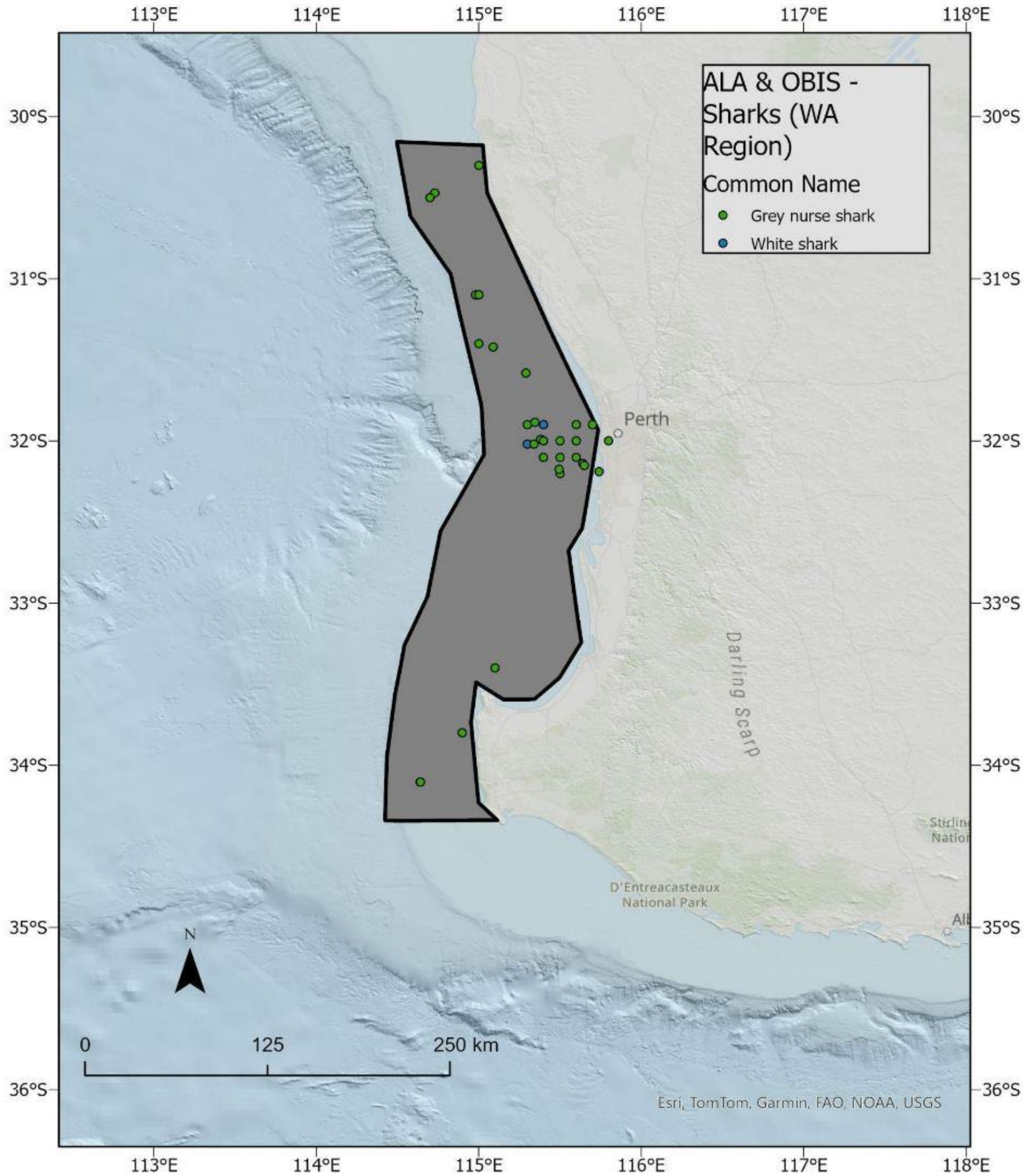


Figure 83: The south-west OWF region (prey polygon) showing observations of listed sharks from the ALA and the OBIS across. The different species are represented by the different colours. [Declared area boundaries finalised after completion of maps in this report and are not amended here].

8.7.4. Reptiles

Published papers/reports inventory

No published studies were found for listed reptile species that overlapped the south-west OWF region (Table 35), however the SNES distributions for loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), and flatback (*Natator depressus*) turtles all had total overlap with the entire south-west OWF region (29,170 km^2). The leatherback and loggerhead turtles are considered endangered while the flatback and green turtles are listed as vulnerable under the EPBC Act.

Table 32. Reptile species for which we have compiled spatial data from published studies and freely available data repositories (OBIS and ALA) that overlap with the south-west OWF. Shown is the area of overlap between each source and the OWF. Shown is the area of overlap between each source and the OWF. Also shown is the overlap of the OWF with known species distributions (SNES) and observation counts for OBIS and ALA data combined. Seasonality was compiled from the literature and expert opinion where dark green indicates months of the year with peak occurrence, light green indicates months in which the species is present but in lower numbers, grey indicates months in which the species is absent and white fields depict missing data/unknown. The last column shows the number of publications found for each species and colour refers to our assessment of relative species data overlap with red = low, orange = medium, green = high. https://vhost2009.hosted-sites.deakin.edu.au/ORE/WA_Reptile.html

WA OWF: Reptile

			AREA AS % OF OWF		OBSERVATION COUNTS	SEASONALITY	NUMBER
SPECIES	FAMILY OCCURENCE	EPBC STATUS	SNES	PUBS	OBIS-ALA	J F M A M J J A S O N D	PUBS
Loggerhead Turtle *Caretta caretta*	Cheloniidae -	Endangered	100		77		0
Leatherback Turtle *Dermochelys coriacea*	Dermochelyidae -	Endangered	100		42		0
Flatback Turtle *Natator depressus*	Cheloniidae -	Vulnerable	100		3		0
Green Turtle *Chelonia mydas*	Cheloniidae -	Vulnerable	100		8		0

Existing freely available species observation data

Observations of listed reptiles within the south-west OWF region from the ALA and OBIS showed four species of turtle to be occur, with the loggerhead turtle (77 observations) being the most prevalent, followed by the leatherback (42 observations), green (8 observations), and flatback (3 observations) turtles (Table 35). All observations occurred in the southern half of the OWF region with the greatest density around the inshore waters of Perth (Figure 84).

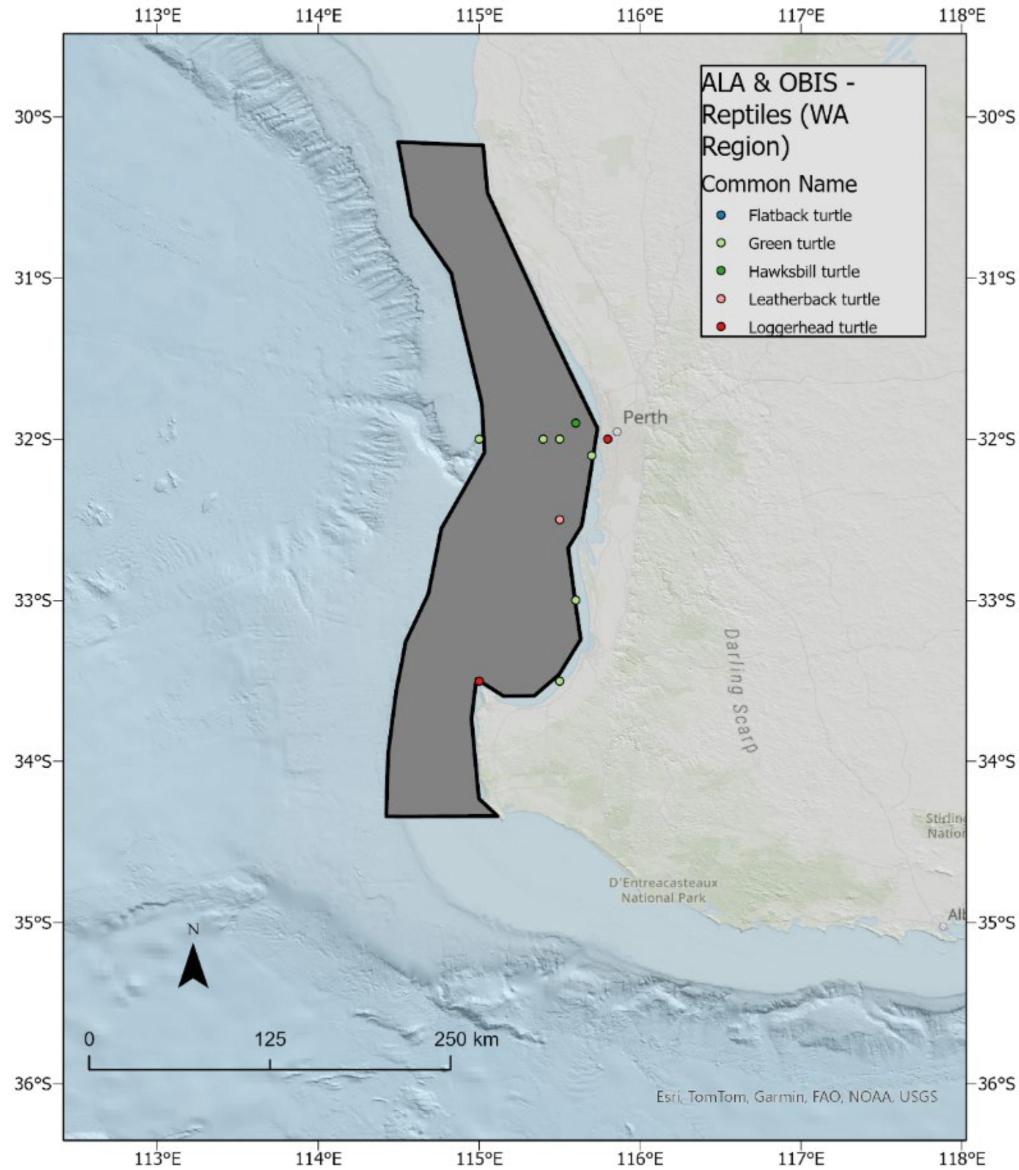


Figure 84. The south-west OWF region (grey polygon) showing observations of turtles from the ALA and OBIS across. The different species are represented by the different colours.

8.8. Indigenous communities

The Indigenous communities for this area are made up of 4 distinct Noongar groups: the Wadandi, Bibulmun/Piblemen, Binjareb/Pinarup, Wilman and Ganeang Peoples. ILUA's within the region cover sea Country areas up to 3 nautical miles offshore. However, traditionally areas of significance and interest are likely to go considerably further offshore.

The Gnaala Karla Booja Aboriginal Corporation (GKBAC) is the regional corporation entity representing the Binjareb/Pinjarup, Wilman and Ganeang dialect groups for the region covering 30,424 sq km. Towards the east of the Gnaala Karla Booja region is the Balladong region and to the south-east is the Wagyl Kaip region. The Gnaala Karla Booja region encompasses the towns of Capel, Donnybrook, Balingup, Wickepin, Narrogin, Williams, Mundijong, Kwinana, Brookton, Pingelly, Wagin, Harvey, Collie, Pinjarra, Mandurah and Boddington.

The Karri Karrak Aboriginal Corporation (KKAC) is the regional corporation entity for the 10,085 sq km south-west Boojarah region. This region includes both the Wadandi and Bibulmun/Piblemen Noongar dialect groups and encompasses today's towns of Busselton, Capel, Margaret River, Witchcliffe, Augusta, Windy Harbour, Northcliffe, Pemberton, Manjimup, Bridgetown and Nannup. Publicly available positional statements from GKBAC or KKAC on offshore windfarm development was not found on the Internet at the time of writing this report.

Indigenous communities represented by the GKBAC and KKAC have a strong connection to their land, sea and sky country. Cultural values for the Wadandi region have been published in the report, "The Cultural Seascape of Wadandi Boodja" (Davies et al. 2022), which, in collaboration with the Wadandi Traditional Owners, was used to direct and plan seafloor and biodiversity surveys across the region. Figure 83 and Table 32 provide a summary of these cultural values.

There are numerous indications the TOs represented by the GKBAC and KKAC have interest and capacity to engage in discussions about key environmental factors for offshore wind farms and associated science. The Karri Karrak Aboriginal Corporation, through the Undalup Association, is collaborating on NESP Marine and Coastal Hub to guide the science, monitoring and management of the Geographe Marine Park and South-west Corner Marine Park. This work complements the Undalup Associations Western Australian Government Aboriginal Ranger Program that funded "Ni Kidji Gnangkaa Boodja – Listening to Mother Country" project, which also collaborates with the KKAC and GKBAC.

Table 33: Cultural values of the Wadandi Cultural Seascape. *Reproduced from Davies et al., (2022) 'The Cultural Seascape of Wadandi Boodja'.

Cultural value	Description
Cowara Kwala (Purple Crown Lorikeet Songline)	The Cowara comes from inland where he breeds and comes to the coast following the gabbi kwala (freshwater songlines) during the summer for feeding. The arrival of the Cowara signals the arrival of Ngaralaang (Herring) in the ocean.
Gortjguttuk Kwala **(Pink Snapper Songline)**	The *Gortjguttuk Kwala* (Pink Snapper Songline) starts in the *Waatu Waugal* water (Geographe Bay). They come out in the Bay in Makuru time (June/July) when it is cold and wet. They come out in the *Waarten Waugul* water (West Coast) in *Birak* time (Dec/Jan) when it is hot and dry. The *Gortjguttuk* follow the scallop line in the Bay and when they get around Cape Naturaliste, they start head-butting the shellfish, this is why they have bigger foreheads in *Waarten Waugul* water.
Ngingaraa Kaala **(Lava flow)**	The *Ngingaraa Kaala* (Lava flow) shows us the path the lava took back when the Country shook. When the Country shook, the old people left their camp at *Yoondaddup* (Lake Jasper) and went down to *Bolghinup* (Black Rock) and fell asleep. When they went back the whole place had changed. All the hills had pushed out of the ground. This is when people left that area and spread out across the Country and sung the songs of their creation.
Wooditj Kaarbin Kwala	*Wooditj Kaarbin Kwala* (Old Man Groper Songline). *Wooditj* was a powerful medicine man and could do almost anything with his magic wand. He fell in love

Cultural value	Description
(Old Man Groper Songline).	with *Milyan*, a beautiful young woman who was betrothed to somebody else. The love-struck couple ran away together but *Milyan's* father *Ngungargoot* chased them. Wooditj used his magic wand to create a powerful river (The Margaret River) between the lovers and *Ngungargoot.* The old man couldn't cross the river but he continued to follow the runaways on the opposite bank. When they got to the mouth of the river the young couple were hungry and decided to spear some *Kaarbin* (Groper) that were plentiful on the reefs there. After a while, the rushing river slowed down and *Ngungargoot* could reach the couple, he almost seized Milyan but Wooditj struck him with his wand and turned him into a *Kaarbin* which disappeared onto the reef which is now known as Ngungargoot (Cow rock). *Milyan* was very sad at the loss of her father and *Wooditj* wished the old man would return to them, immediately he was restored as a man and accepted the marriage of Milyan and Wooditj.
Ngari Up (Place of the Salmon)	*Ngari Up* is the place of the *Ngari* (Salmon). The beginning of *Bunuru* time (Feb/Mar) is marked by the *Ngoolaak* (white tailed cockatoo) who sing in the *Ngari*. The cockatoos sing in a certain song and move in a certain direction to show us when to fish for *Ngari*.
Gabbi Up (Freshwater Place)	There are many important freshwater places along the Wadandi coast. In some places you can drink freshwater that comes up in the saltwater. These freshwater places show us where the water might flow out to the ancient coastline, these places would have been very important for our ancestors. The freshwater flows are important for the fish and animals that live in the saltwater. The *Gabbi Waugul* (Freshwater Serpent) drives the flow of freshwater into the sea. The *Gabbi Waugal* is in a constant battle with the *Waatern Waugal* and *Waatu Waugal* (Saltwater Serpents). When the saltwater serpent wins, it pushes seas up into the rivers and when the freshwater serpent wins the freshwater flows out to sea. This endless battle shows us the patterns of change in Wadandi Country, both daily with the tide and over long periods of time. For a long time, the saltwater serpent has been winning, which has caused the sea levels to rise.
Mammung biddi-wah **(Whales path)**	Wadandi Boodja is an important place for *Mammung* (whales). When *Gullyung* (*Acacia Cyclops or Wattle)* flowers, the *mammung* are starting their migration. The *Gullyung* grows a bean at the time that calves are being born up in Bardi Country in the Kimberley and the seed opens up as the *mammung* come down past Wadandi Country, this seed represents the great eye of the whale. The *mammung biddi-wah* (whale path) is sometimes far offshore but they often follow a path close to shore. They come to the *Gabbi-up* places where the freshwater seeps out into the saltwater and when they beach themselves they are offering themselves back to the land where they come from. Before they entered the water, the *mammung* were more like hippos and liked to live in the shallow marshland in *Yoganup* at the foothills of *yalyal* (Whitcher Escarpment) behind what is now known as *Undalup* (Busselton). The *Yogan* (Thylacine/ wild dog) would scare the mammung into the sea. The *mammung* would come back in from *Waatu* (Geographe Bay) to land with seagrass in his mouth. Eventually the *mammung* decided the saltwater was a better place to live and so he stayed. The *Kwillan* (Dolphin) felt left behind, he saw the *mammung* in the sea and decided to follow him.

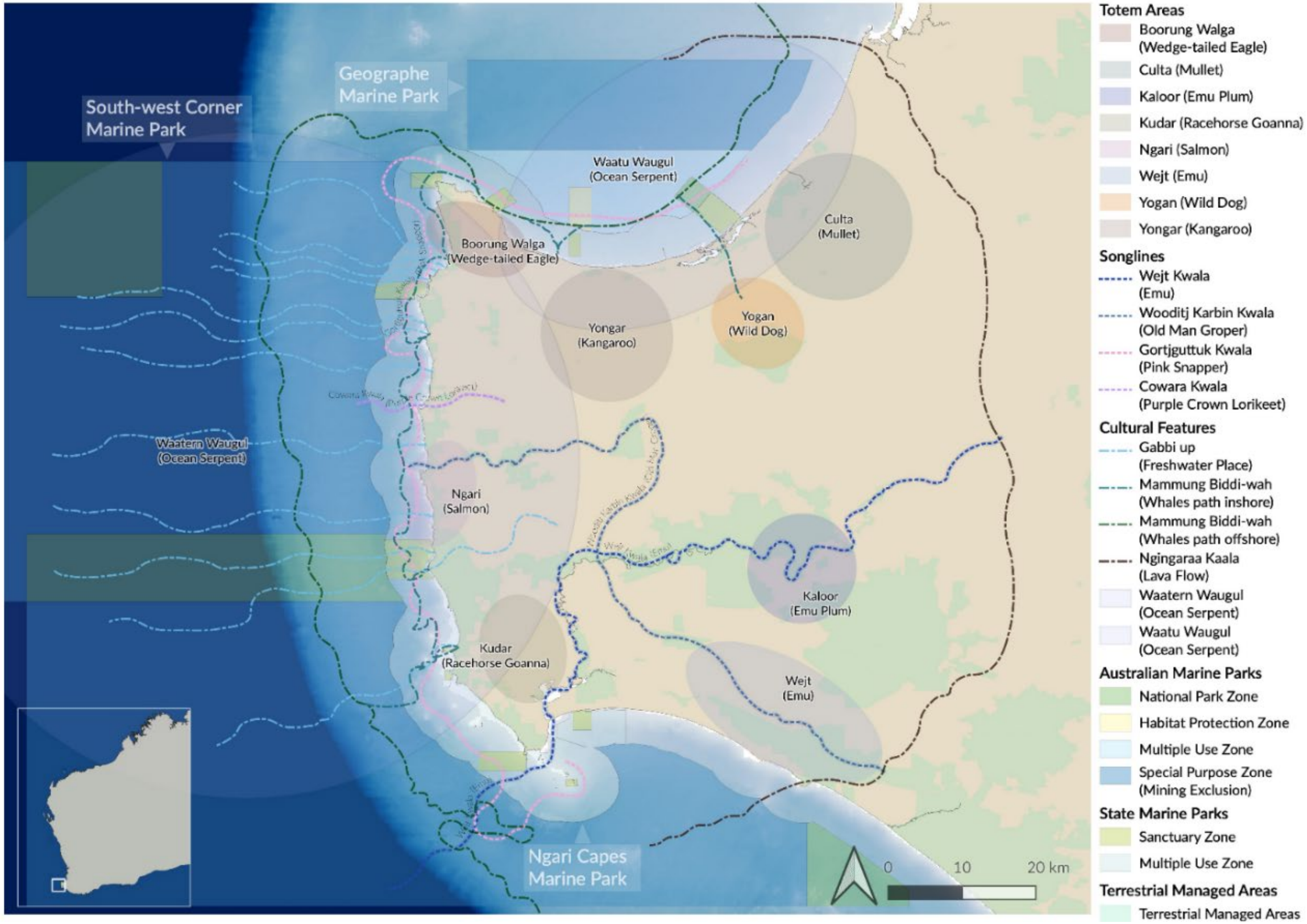


Figure 85: Map of the Wadandi Cultural Seascape. Reproduced from Davies et al. (2022) 'The Cultural Seascape of Wadandi Boodja'.

9. Monitoring needs and associated best practices

Rigorously designed and executed data collection for informing projected environmental impacts and mitigation, establishing baselines and on-going monitoring are critical for effectively managing environmental impacts of OWF developments. A range of guidelines exist for monitoring and best practices for OWF developments, particularly with a European focus. Examples of these include:

- Stephenson (2021) presents a review of monitoring needs and best practices for the offshore wind energy sector in the Baltic Sea and North Sea. This includes comparison of the jurisdiction-specific guidelines below.
- BSH (2013) outlines German standards of investigations expected for Environmental Impact Assessments, including across the operational phase. This standard details survey schedules, methods and analytical approaches expected to adequately monitor environmental impacts of offshore renewables, building on previous standards and experience.
- DCCAE (2018a) and DCCAE (2018b) outline Irish standards and best practice for baselines and monitoring of the environmental impacts of offshore renewables. It includes description of environmental indicators, survey methodology (with associated best practices), and survey schedules.
- Matthiopoulos et al. (2022) focuses specifically on recommending best practice methodological and quantitative guidelines for combining seabird study data collected from different platforms. Such guidance recognises that often several survey methods are used, often at different temporal and spatial resolutions.

The accompanying database of monitoring best practice guidelines (Project 3.3 OWF best practice inventory) provides a resource to help identify best practices for monitoring. It includes a comprehensive list of references to best practice guidelines, that is current as at December 2024. Summaries of best practice standards by topic and method are provided in Appendix A. Whilst no similar set of specific guidelines exist in Australia, guidance on marine monitoring standards and best practice have been progressed by the research community, principally through the previous NESP Marine Biodiversity Hub, and built on by the NESP Marine and Coastal Hub, with contributions from 136 researchers across 53 agencies.

Adopting an Ocean Best Practice (OBP) approach reduces the bias and variance in sample data and increases confidence in the provision of advice (Przeslawski et al., 2019). A suite of Australian OBP field manuals is available that outline standardised protocols and analytical approaches, with the majority directly applicable to environmental assessment and monitoring of offshore renewable energy projects (Przeslawski et al., 2019).

The following NESP field manuals are available online (https://marine-sampling-field-manual.github.io/):

- Survey design
- Multibeam echosounder
- Autonomous Underwater Vehicles (AUVs)
- Benthic Baited Remote Underwater Video
- Pelagic Baited Remote Underwater Video
- Towed imagery
- Sleds and trawls
- Grabs and box corers

- Remotely Operated Vehicles
- Wide-field stereo-video drop camera
- Knowledge, Attitudes, Practice surveys of recreational users
- Microplastics

Other NESP community standardised approaches include:

- OBP-developed seabed geomorphology classification and mapping scheme (Dove et al., 2020; Nanson et al., 2023)
- Sub-bottom profile guidelines (McNeil et al., 2023).

National guidelines are also available for some species groups, and include:

- National guidelines for cetaceans, marine turtles and the dugong (DCCEEW 2024)
- Survey guidelines for Australia's threated birds (Magrath et al., 2010)

These field manuals outline a well-supported standard operating protocol to support robust and consistent data collection, quality control, and data storage and sharing in support of FAIR data principles (Findable, Accessible, Interoperable, Reusable). For example, stereo video fish annotation field manuals (benthic BRUVs, pelagic BRUVs and wide-field stereo drop camera) have associated tools for quality control (CheckEM) and data storage and accessibility (https://globalarchive.org/) (Langlois et al., 2020), with workflows documented within NESP MaC Project 2.2. Similarly, Geoscience Australia's standardised geomorphology classification scheme (Dove et al., 2020; Nanson et al., 2023) is essential for generating nationally consistent local and regional geomorphology maps. Opportunities exist to continue to build these data workflows in ways that can be integrated into environmental monitoring of offshore renewable energy projects within Australia.

While the suite of Australian field manuals is growing, there also remains gaps of relevance for OWF projects and key environmental factors. In particular, standardised protocols are limited for monitoring, quality control and data storage when monitoring seabirds and marine mammals. Some national scale guidance for these aspects of environmental monitoring can be derived from various programs. For example, Magrath et al., (2010) outline suggested monitoring strategies for Australia's threatened birds and link to well used standards for monitoring. Similarly, DCCEEW (2024) provide guidelines for monitoring cetaceans, marine turtles and dugong. Nevertheless, national standardised sampling protocols and data management and delivery for seabirds and marine mammals requires further development and investment to work towards FAIR data.

Similarly, there is relatively little experience within Australia for some of the most promising emerging technologies for monitoring offshore wind. This includes the use of digital aerial surveys which have shown promise for monitoring seabirds and marine mammals around offshore renewable sites in Europe (BSH, 2013; DCCAE, 2018a). Similarly, there is little Australian experience with radar technology that can be used to both monitor bird usage of wind farm areas as well as mitigate collisions by triggering wind farm shutdowns (Bailey et al., 2014).

A key strength of the Australian field manuals and expertise is in the use of non-destructive sampling methods for monitoring fish and habitats (e.g., stereo-BRUVs, stereo-ROVs and BOSS). International guidelines for monitoring fish around offshore renewable projects often rely on destructive methods such as otter or beam trawls (Stephenson, 2021). Australian researchers have pioneered and helped standardise approaches to monitoring fish using non-destructive sampling approaches (Harvey et al., 2021; Langlois et al., 2020) that are readily applicable to offshore renewable energy projects. These techniques have been applied to studying fish associated with offshore infrastructure (e.g., offshore oil and gas infrastructure (McLean et al., 2018)) and have proven particularly adept at sampling close to infrastructure (Bond et al., 2018a, b; Bond et al., 2022).

9.1. Monitoring needs

The monitoring needs for OWF projects includes multiple phases, topics, and spatial scales each with unique sets of methodological challenges. Rather than tackling each phase, topic and scale independently, a comprehensive framework to guide decisions about what to monitor, how and where should be used. For example, a combination of the Drivers-Pressures-State-Impact-Response (DPSIR) framework with the adaptive management framework supports a comprehensive higher-level strategic framework to guide decisions. Guidance on the application of these frameworks to solar and wind energy developments are provided in Bennun et al. (2021). They distinguish between risk surveys in early project planning (similar to a pre-feasibility scoping study under the EPBC Act) aimed at identifying values most at risk from the project; impact and mitigation surveys (similar to baseline studies under the EPBC Act) during the project design stage targeted to help develop mitigation approaches for values at risk; and monitoring surveys that are designed to detect impacts on values. We discuss each of these monitoring needs in more detail below.

9.2. Surveys to inform risks

Surveys often aim to understand a broad level the risk that a proposed project poses to a particular environmental value. Such surveys can often be informed by a broader desktop prioritisation identifying key environmental values that interact with the project area. For example, Reid et al. (2023) conducted a desktop ecological risk assessment, based on life-history and behavioural attributes of 272 bird taxa, to identify and rank the risk posed by offshore windfarms to Australian bird species. Surveys would aim to contextualise these risks in relation to a particular OWF development area by confirming which species utilise the area. For example, aerial surveys can be used to characterise the bird species utilising the project area, hydrophones can be used to detect cetacean species utilising the project area, and Baited Remote Underwater stereo-Video (stereo-BRUVs) can be used to characterise the fish, sharks and ray assemblages utilising the project area.

Surveys can be used to quantify at a broad level the likely risk that the project poses to a particular species and can inform avoidance-mitigation strategies that could be used (e.g., modifying planned locations of structures to avoid critical areas within the project footprint). It is for this reason that risk surveys occur early in project planning.

Careful consideration of the strengths and weaknesses of different risk survey monitoring approaches need to be considered. For example, for surveying bird species, boat-based observations can provide better taxonomic resolution whereas aerial surveys can cover a broader area (Stephenson, 2021). Similarly, aerial surveys of cetaceans are likely to under-detect darker coloured species including the southern right whale (*Eubalaena australis*) (DCCEEW, 2024).

Tailored advice to guide method selection is available from several resources. Stephenson (2021) provide broad-scale advice on different monitoring methods in relation to offshore wind projects based on experiences in the Baltic and North Sea. This includes advice on the pros and cons of methods for birds and bats, marine mammals and fish and seabed communities. Magrath et al. (2010) provide guidance on appropriate monitoring methods for Australia’s threatened bird species considering their unique distributions and behaviours. Similarly, DCCEEW (2024) provide advice on methods for surveying cetaceans, marine turtles and dugongs. Similar guidance based on the strengths and weaknesses of different methods for monitoring Australian fish, sharks and rays, as well as bathymetry, seabed habitats and benthic biota are available through NESP field manuals (https://marine-sampling-field-manual.github.io/).

9.3. Impact and mitigation surveys

Impact and mitigation surveys focus on key natural values and aim to more precisely quantify the potential impact of the OWF project and identify appropriate mitigation techniques (Bennun et al., 2021). These surveys require a more in-depth understanding of how a particular species is using the project area, particularly in relation to potential impact mechanisms. For example, for migrating cetaceans that may be impacted by noise during the construction phase of an offshore renewables project, impact and mitigation surveys may seek to characterise the precise migration pathways impacted, understand if the project area is utilised in a specific way (e.g., if it is a feeding ground), and characterise the timing of the migration. This information can then be used to inform construction planning to avoid peak migration timing, or specific areas.

The detailed information required for impact and mitigation surveys will often necessitate a different choice of monitoring method relative to surveys to inform risks. For mobile species, gaining a functional understanding of how a species is using an area will require more extensive sampling (e.g., several surveys per season) as well as approaches that allow more precise tracking of individual animals (e.g., telemetry). Similarly for immobile species, higher resolution mapping of spatial distribution within the project site may be required.

9.4. Monitoring surveys

Monitoring surveys are designed to detect any impacts of the project on a natural value. This is both required to confirm that pre-construction projected project impacts are accurate, as well as support adaptive management should unexpected project impacts occur. To detect project impacts, Before-After-Control-Impact (BACI) or Before-After-Gradient (BAG) experimental design are frequently utilised to separate natural variability from the project impact (Methratta, 2021). Whilst both BACI and BAG designs are theoretically justifiable, the identification of appropriate control sites has been identified as a challenge for some offshore wind projects, and as a result some jurisdictional guidance has called preferred BAG designs that remove ambiguities around the appropriateness of controls (Stephensen, 2021).

The establishment of monitoring baselines pre-construction is a critical pre-requisite for attributing changes to project impacts. Importantly, these baselines will often need to involve multiple survey points for several seasons before construction. For example, advice for monitoring marine mammals in offshore renewable project areas in Germany and Ireland call for 2-3 years of monthly pre-establishment baselines (BSH, 2013; DCCAE, 2018a; DCCAE, 2018b). This is to ensure that the pre-construction seasonal and inter-annual variation is captured and can be adequately compared to the post-construction seasonal and inter-annual variation to attribute impacts of the project.

Appropriate statistical considerations also need to be considered in impact surveys. Power analysis should be conducted to ensure that impact monitoring plans have sufficient statistical power to detect likely changes. For example, Franco et al. (2015) show that sampling effort in monitoring of offshore wind farms in the United Kingdom were insufficient to detect even substantial (>50% loss) in benthic abundance and biomass and as such are arguably not fit for purpose. Power analysis can help avoid this situation by providing advice on the level of replication required to detect change given the variability in the natural value being assessed.

An important consideration in designing impact surveys is having a targeted approach towards specific metrics. An important lesson from experiences in the North Sea is that careful metric selection is critical and must consider the ability of a monitoring program to detect change. For example, studies have established that noise from pile driving impacts marine mammals can lead to spatial displacement, but none have been able to link this to empirical changes in population size (Teilmann et al., 2012). Often detecting the existence and extent of an impact pathway and inferring using modelling impacts on an overall population is more feasible than directly monitoring for changes in population size (Bailey et al., 2014). Further detailed information on impact pathways can help direct effective monitoring, and a matrix of key impact pathways (stressors)/sources of OWF impact and receptor groups/specific protected matters in Australia is presented in DCCEEW (2023a).

9.5. Non-biological monitoring needs

The above discussion of monitoring needs is largely targeted towards monitoring species or communities. As part of a comprehensive monitoring strategy, there is a need to expand the scope of monitoring for OWF projects.

A robust understanding of the seabed bathymetry, geology and sedimentology is required to inform engineering decisions of the project. Seabed geomorphology also exerts a first-order control on seabed stability and the distribution of marine ecosystems (Harris and Baker, 2012; Spalding, 2016; Micallef et al., 2017), and geomorphology maps are used to synthesise this foundational information to guide sustainable development within the marine environment. As outlined in this report, much information exists on these aspects, but in some cases, information is likely too coarse or imprecise to inform specific engineering decisions. Monitoring of seabed sedimentology and geomorphology in both the development areas and their downdrift regions will be necessary to assess the impact of OWF activities.

Understanding of the seabed type and oceanography surrounding offshore renewable energy projects is important for consideration both in terms of engineering challenges, but also changes in oceanography in the project area may act as a pressure on natural values. As such, initial characterisation as well as monitoring of changes in oceanography is important for understanding impacts on natural values, and designing mitigation solutions. Similarly, monitoring of other pressures such as underwater noise levels and levels of light and sound pollution are important for identifying linkages with species impacts and informing mitigation approaches.

An additional dimension to monitoring needs for offshore renewable energy projects is monitoring of impacts on the ecosystem services people derive from the area. OWF have the potential to affect ecosystem services, and final benefits for people through multiple pathways. For example, where exclusion areas exist for recreational activities, it will be important to understand the magnitude of the impact and any behavioural change that may be induced (e.g., displaced fishing effort to adjacent areas).

10. Potential impacts of offshore wind farms in Australia

10.1. A summary of impact literature and inventory

The Project 3.3 OWF Impacts Inventory consists of a list of over 500 searchable peer-reviewed publications and grey literature relating to 16 impacts (Figure 86). The methods used in producing this resource based can be found in Appendix A. Some of the information available on the impacts of OWF from around the world is transferable to Australia's unique environment: however, the Australia's continental shelf seabed material and our unique suite of fauna mean that this is not always the case. We present two further topics of growing interest: ecotoxicology, for which there is little available information for OWFs; and cumulative effects assessments/cumulative risk assessments, for which there is a growing appreciation of the need to better understand how interactions between stressors can affect the receptors. In addition, three example case studies for which the project team had subject matter experts, are presented to highlight the advantages and limitations of applying this international information to the Australian context (noise, seafloor and oceanography). The contents of the Project 3.3 OWF Impacts inventory are not meant to be an exhaustive list of all the research effort across all impacts, because the methods used to produce the impact inventory were driven by the availability of experts, rather than a systematic review of all impacts. A systematic review would have required that the same effort be spent on each impact, by at least one subject-matter expert per impact type and potentially each receptor group. In addition, the relevance to Australia of the information gathered is not a trivial task.

As such, the composition of article topics within the inventory are biased towards the effort and subject matter expertise of the project team. The inventory should not, therefore, be interpreted as representative of the full breadth of current knowledge on the impacts of OWF or the only data transferable to operations in Australian environments. A research gap analysis was out of scope, but three sub-sections highlight the limitations of using existing published information without tailoring it to the Australian context are available below (Section 11). Each line entry in the inventory was assigned to a set of categories, which can be translated into high-level information about the contents of the inventory, but this should not be equated to a gap analysis (see Appendix C for summary figures).

Impacts	**Australian context**
Entanglement	
Cultural heritage	
Visual disturbance	
Species introduction	
Ecosystem services	
Vessel displacement	
Pollutants (dust, light, waste)	Limitations highlights, section 15
Electromagnetic fields	
Noise	Limitations highlights, section 15
Vessel strike/avoidance	
Electrocution	
Trophic cascades	
Hydrology/hydrodynamics	Limitations highlights, section 15
Habitat loss	
Collision	
Barrier	

Figure 86: Impacts categorised in the Project 3.3 OWF Impacts Inventory highlighting three impact where the limitations of using international information without considering the Australian context are exemplified.

The impact categories adopted in the Project 3.3 OWF Impacts inventory reflect the categories defined in DCCEEW (2023a), and those published by IUCN. The only impact type present in the inventory but not reflected in the DCCEEW or IUCN categories are 'TO communities' and 'entanglement'. Entanglement relates to the advent of floating wind turbines, which requires that dynamic cables be installed to drive the energy from the floating turbine to the cable array on the seafloor. Primary entanglement risk is low, given the large diameter and weight of the cables that reduces likelihood of the cables 'looping' into a form that could entangle fauna (SEER, 2022). Secondary entanglement, (i.e. where marine fauna gets entangled with marine debris that has become entangled in/around the cable) is yet to be evaluated (SEER, 2022). Six publications in the database have this impact category focus, all of them relating to the risk to marine mammals.

Most of the entries in the Project 3.3 OWF Impacts inventory are research articles and reports (A-Figure 17). Most studies are about characterising or identifying the impact, rather than mitigating its effects (A-Figure 18). Most of the publications in the inventory are relevant to the construction or operation phase of an offshore wind farm, with very few publications on the exploration and decommissioning phase of OWF structures (A-Figure 19).

10.2. Cumulative effects and cumulative risks assessments

Whilst evaluating cumulative impacts is considered an essential part of understanding the environmental impacts of OWF (Bennun et al., 2021), the task of estimating cumulative effects is challenging. It is made more difficult by the fact that few guiding documents to date provide information on a standardised way to determine these cumulative impacts.

Receptors, i.e. any marine flora or fauna subjected to anthropogenic activities, are rarely exposed to a single stressor. Cumulative effects assessments (CEA), also termed cumulative pressures and impact assessments (CPIA, Korpinen and Andersen, 2017) on ecosystems have been required by many jurisdictions in Europe, US, UK and Canada (Therivel, 2007) since the 1970s, and survey of 2000 scientists identified cumulative effects as the top global marine research priority (Rudd, 2014). Some prominent examples of government and non-government efforts to develop frameworks for CEAs can be seen in the US (e.g., Bureau of Ocean Energy Management), UK (e.g. UK Centre for Ecology and Hydrology), and elsewhere in Europe (e.g., Noordzeeloket), with knowledge hubs as repositories set up across jurisdictions, such as Tethys (https://tethys.pnnl.gov/knowledge-base-wind-energy).

In the last 15 years, CEAs have been receiving increasing attention to help identify marine conservation priorities and assist management actions (Halpern et al., 2008; Micheli et al., 2013; Tulloch et al., 2015; Menegon et al., 2018). Yet they still suffer significantly from the use of several base assumptions that are associated with the relative weighting, uniformness, or linearity of habitat, stressor and receptor distribution, response and interaction (Halpern et al., 2013), many of which current scientific knowledge cannot easily address (Tyack et al., 2023). Given the acknowledged importance of cumulative stressors, yet paucity of information on management application in the marine environment, particularly for OWF, we provide a brief overview of the subject here and highlight selected key publications in this reports database (Project 3.3 OWF Impacts inventory).

Scientific research has considered the impacts of multiple stressors for several decades (Carson, 1962), however, while environmental management and modelling has focussed on the effects, human and animal health research has focussed on the risks (Tyack et al., 2023). These are approaches that differ significantly, which is problematic for adopting methods between disciplines (Tyack et al., 2023). In toxicology, the EFSA Scientific Committee et al. (2019) attempted to provide guidance on harmonising methodologies for health and ecological risk assessment to address these differences, however, this appears to have had little visibility in marine environmental management world. One exception to this is the management of water quality, which has been inclusive of cumulative risk within its own field, for some years (see Gladstone Healthy Harbour Partnership, 2023, or the Australian and New Zealand Water Quality Management Strategy and Framework as recent Australian examples).

In general, since the first major marine study by Halpern et al. (2008), CEAs have several associated assumptions that require addressing (Halpern and Fujita, 2013), including 1) stress layers of equal importance; 2) uniform distribution of stressor within an study cell or ‘pixel’; 3) binary measure of habitat presence within each pixel; 4) stressors are normalised; 5) linear dose-response relationships; 6) a consistent ecosystem response; 7) accurate weighting of vulnerability; 8) additive effect of multiple stressors; and 9) linear response of ecosystem to multiple stressors.

To date, most of the applied models have assumed a linear response to the individual stressors and additive responses when they are combined, leading to the use of the term ‘cumulative effects’. However, dose-response relationships are typically non-linear, and interactions are predominantly synergistic (the total response is greater than the sum of the individual parts), or antagonistic (the total response is less than the sum of the individual parts) in some form (see Cedergreen, 2014, for example definitions of interactions from toxicology research). Non-linear responses for stressors and weighting factors to prioritise stressors are increasingly factored into models (see Table 1 in Stelzenmuller et al., 2018, for examples of where this has been conducted). However, weightings are often based on expert judgement and therefore highly uncertain. Few studies have attempted to assess the interactions between stressors, and these are almost all qualitative assessments, providing categorical, rather than continuous levels of assessment, which leaves little capacity for uncertainty analysis (Tyack et al., 2023).

Even cumulative risk models can only estimate the interactions between stressors, without necessarily knowing which is a priority. To improve uncertainty around interactions and nonlinearity of stress responses, and therefore increase confidence in impact assessments, Tyack et al. (2023) proposed a flow process to integrate assessment of cumulative risk from multiple stressors with targeted dose response multi-stressor experiments (see Tyack et al., 2023, Figure 3), and a stepwise plan to applying this framework to a particular environment (see Tyack et al., 2023, Box 2).

Moving from single-stressor dose-response curves to multi-stressor response ‘surfaces’, to address nonlinearity of dose-response within interactions has been conducted in the chemical field (e.g., Macoustra et al., 2021; Koppel et al., 2018), and could be used more broadly as a model. By examining mechanistic pathways to prioritise stressors and interpret potential ways in which they may interact, it may be possible to identify key health indicators of accumulated effects to detect changes in vital rates that drive population status. This could be achieved through direct experimentation or through probabilistic methods (e.g. Fisher et al., 2019; Landis et al., 2024; Moe et al., 2024). However, a note of caution comes with the complexity of moving from laboratory to real-world conditions and the need to successfully develop dose response experiments with sufficient replication to be statistically robust (Parsons et al., 2023).

One example of modelling cumulative risk from multiple stressors associated with OWF developments was conducted for marine mammals in the US (Southall et al., 2021). Although heavily weighted towards the impacts of noise produced during construction and operation, this study provides an interesting case study for Australia, given it encompasses several key marine mammal species that are similar or related to those found in our waters (baleen whales, mid- and high-frequency hearing odontocetes and pinniped species). Southall et al. (2021) expanded techniques used to model risk of exposure to acute noise from seismic surveys (Ellison et al., 2015; Southall et al., 2018) to include vulnerability to disease, exposure to whale-watching tours and other potential stressors. This created a high resolution (5x5 km for northern right whales and 10x10 km for all other species) spatial grid for which monthly risk was assessed for the construction period of the wind farm. If combined with the proposal by Tyack et al. (2023) for on-going monitoring of key activities and targeted experiments to identify effects of prioritised stressors, this provides a good framework to manage negative population consequences of the wind farm.

A number of research programs are underway in Europe and US focused on understanding the impacts of offshore renewables across the physical and ecological components of development regions in order to improve predictions on ecosystem-level cumulative effects (e.g. Marchand et al., 2022; PELAgIO - https://ecowind.uk/projects/pelagio/). There is also increasing consideration of the key considerations and challenges relevant to assessing the cumulative effects of offshore renewable development and other activities on ecosystems (e.g. Willsteed et al., 2017).

In Australia, mapping the presence of key stressors (or proxies of them) has been conducted for the northwest shelf to provide a coarse map of where key stressors (e.g., vessel presence, light, anthropogenic activity, a proxy for noise) overlap with each other as well as the distribution of selected threatened species; Ferreira et al., 2023). The study then used these combinations to identify areas where monitoring of the effects of multiple stressors may be required.

An approach to quantify cumulative risk to ecosystems in the Bass Strait in the context of proposed OWF developments in the region will be further developed and applied through NESP project 4.7 (https://www.nespmarinecoastal.edu.au/project/4-7/). A methodology for probabilistic, cumulative, risk assessment for resident and static environmental values has already been developed by CSIRO and applied to new coal seam gas and coal mine operations (Hosack et al., 2017). Cumulative probabilistic risk assessment for migratory species, however, is significantly more difficult and will require innovative risk assessment approaches. This project will use two different modelling strategies – a species-specific and a whole-of-ecosystem approach – employed in a complimentary fashion.

Whilst modelling may present partial solutions to the challenges of assessing cumulative effects/risks, a more comprehensive approach will depend upon integrated monitoring approaches. Fully integrated environmental monitoring may be impractical; however, a number of developing solutions are available in the Australian context. Parks Australia through management of the Australian Marine Parks are establishing national monitoring programs of key ecological features (KEFs) and values within their parks. These marine parks are often adjacent to, and in similar environments to proposed and declared offshore wind zones. These are applying standard operating protocols for monitoring key biodiversity features and an adaptive evaluation framework for monitoring condition and trends of KEFs.

Integrating monitoring of offshore wind farms with Parks Australia's monitoring of the Australian Marine Parks represents a path for an improved understanding of cumulative impacts. Ensuring data are generated, stored, and analysed using consistent protocols and FAIR data principles, will enable at least some consideration of cumulative impacts. Storage and management of the volumes of data (and metadata) at this scale will require significant preparation and support. A useful example of this type of exercise can be seen in the U.S.'s National Centre for Environmental Information (NCEI) and its effort to collate active and passive ocean acoustics sampling.

11. Case studies for developing a knowledge resource base

Developing a holistic, unbiased resource base or gap analysis regarding the effects of OWFs in Australia and the baseline knowledge is a significant task outside the scope of this report. Ideally, a complete inventory would include information on the potential variation in the intensity and characteristics of each stressor and the variation in the response of selected receptors to each stressor, which would be replicated for each impact and potentially each step within the different impact pathways. Such a task requires significant effort and contribution from a wide range of subject experts. Failure to carry out this level of detail creates bias and may to lead to misinterpretation due to incomplete information.

While developing the Project 3.3 OWF Impacts inventory it became clear that what to include and what to leave out can only be determined according to a set of pre-defined rules for inclusion. For example, indirect effects, baseline environmental conditions, transferable information, grey literature, receptor biophysical and behavioural data to support or predict responses, are often omitted from these types of reference databases, and yet are intrinsic to understanding the effects of OWF. Each of these factors require expert consideration in the respective stressor and impact group to identify and prioritise literature for the inventory that is pertinent to OWF in Australia. This expertise is vital to avoid overpopulating the impacts inventory with less-relevant articles returned by a systemised search with simple, yet broad key words.

The Project 3.3 OWF Impacts inventory is therefore likely to have some level of bias. An illustration of this is provided through three case studies: 1) baseline information on the impact of noise highlights the need to consider supporting information to understand effects; 2) the uniqueness of the Australian seafloor and marine fauna combination highlights the need to understand what is transferable in an Australian context; and 3) differences in the relevant oceanographic processes and conditions in Australia compared to where most existing OWF have been developed, for example in the currently proposed OWF areas in Australia tidal currents are considerably weaker than in the North Sea where oceanographic impacts of OWFs have been the most studied. In comparison with that of the entire topic of effects of OWF, that includes 18 impact types, many of which elicit different responses from a multitude of species, habitats and human receptors.

Two additional aspects of potential importance, but with little available literature or standards are the toxicology associated with OWF and quantifying the cumulative effects of OWF. As such, we have provided short summaries for these two topics.

11.1. Case Study 1: Baseline information on the impacts of noise

Noise is one of the most pervasive and impactful pollutants emitted during offshore construction (Tougaard, et al., 2008) and, to a less-evident extent, operation of offshore infrastructure (Todd et al., 2020*),* but is influenced by the particular technologies deployed. In recent years, significant effort has gone into mitigating noise propagating from standard construction activities (e.g. bubble curtains around pile-driving activities) and novel installation methods (e.g., suction bucket installation of structures). The application of some of these methods in Australian conditions and the reduction in noise levels achieved by their use in these potentially unique environments requires study.

Noise from anthropogenic sources can be intermittent, impulsive, continuous, high, low intensity, or simultaneous combinations thereof (Todd, 2016). Increased use of the marine environment for a range of activities, (e.g., commercial shipping and fishing, recreational boating, installation of offshore infrastructure OWF, geophysical exploration for oil and gas, and, less frequently, military exercises) has meant that at some locations, particularly coastal waters of developed countries and near shipping lanes, underwater noise levels are estimated to be at least ten times higher today than a few decades ago (Duarte et al., 2021, Miksis-olds et al., 2016; Halpern et al., 2008).

There are many facets to predicting effects of noise on marine fauna, and not all are related directly to exposure level and response. For example, a list of publications reporting on long-term ambient noise levels around Australia either at a specific location (e.g. Jolliffe et al. 2023, Erbe et al., 2016, McCauley et al., 2016, McCordic et al., 2021) or modelling acoustic propagation in marine environments Australia-wide (e.g. Koessler et al., 2017; Erbe et al., 2021a, 2021b; Gaboury et al., 2008; McPherson and Quijano, 2017) may be invaluable to assisting in characterising baseline levels, while identifying communication rates and source levels are key to understanding distances and signal-to-noise ratios over which animals communicate.

Reports of species' frequency-dependent hearing sensitivities are vital to identify what components of anthropogenic noise they can detect and may respond to and how to model their exposure (Erbe et al., 2014). Additionally, this information informs stakeholders on vulnerability of these species to potential impacts of OWF developments. Further, while there may appear to be little information directly related to a stressor from OWF activities, transfer of information from similar activities or topics, such as, oil and gas activities, for example (e.g., Cato et al., 2012, 2013), may assist in better understanding potential responses (though caution should be taken noting many responses are species and context-specific). For example, responses to impulsive pile-driving sounds may not be identified for some species, yet studies of responses to seismic survey signals that are also impulsive sounds can inform on threshold levels to better design mitigation strategies (e.g. Cato et al., 2012, 2013*)*.

Quantifying the effects of noise on marine fauna is non-trivial and responses are often context- and species-specific. Therefore, summarising this topic in a handful of reviews requires significant effort. Effects of noise on marine fauna depends greatly on source characteristics (e.g. source level/type of noise), weather conditions, ambient levels (e.g. affected by nearby vessels), local sound-propagation conditions, and receiver characteristics (frequency-dependent hearing sensitivity). There are multiple reviews of this topic (e.g., Richardson et al., 1995; Nowacek et al., 2007b; Wright et al., 2007; Andersen et al., 2012; Johnston et al., 2012; Nabi et al., 2018; NMFS, 2018b; Southall *et al.*, 2019a, Erbe, 2013, Erbe and Thomas, 2022, Popper et al., 2014, 2022) that highlight that increased background noise and certain sound sources can impact marine fauna in several ways, and these effects can be driven by one or more of the acoustic pressure, particle motion or ground motion that is generated from different activities.

At extreme exposure levels the effects of noise, particularly impulsive sounds, can include injury (temporary or permanent hearing loss) and in the worst cases, result in direct mortality (Popper et al. 2014; Carroll et al. 2017; Southall et al. 2019). There have been no reports of mortality as a direct result of the noise associated with installation and operation of OWF infrastructure that we are aware of for marine mammals, and there are multiple technologies applied and under development to reduce the impulsive noise and vibration produced by pile-driving, both in water and through sediment. The population consequences of noise produced by pile-driving is less studied and even less so for newer technologies or synergistic effects of multiple stressors. More common effects are altered behaviours (including displacement from feeding/breeding/migration habitat), increased stress (both acute and chronic), masking of communication and indirect effects such as displacement of prey species (Branstetter et al., 2013; Mikkelsen et al., 2017; Hastie et al., 2019; Stöber and Thomsen, 2019).

This last point is extremely hard to quantify. For example, anthropogenic noise from operational phases of OWF (e.g. vibration to the seabed, low-frequency hum, etc.) can also affect marine fauna indirectly through impact to both adult and juvenile/larval stages of prey, such as fish and invertebrates (e.g. Packard et al., 1990; Simpson et al., 2010; Radford et al., 2011; Holles et al., 2013; de Jong et al., 2018; Wale et al., 2019). To date, many studies to understand these effects are limited to either binary tests for effects or lack variation in quantified exposure levels to understand what levels and mechanisms drive the behavioural and physical changes, so in many cases, further work is needed to build a dose response curve. Finally, in extreme circumstances, low-frequency noise may induce morphological and ultrastructural changes in plants, such as those observed in seagrass (*Posidonia oceanica*) rhizome statocysts, which sense gravity and process sound vibration (Solé et al., 2021), i.e. effects of noise are not simply limited to zoo taxa.

The breadth of information to provide an assessment of the impacts of noise is therefore considerable, and to expand this knowledge base to incorporate supporting information such as soundscape baselines, source signatures, responses to other related sounds, species hearing sensitivities etc. to fully understand how to apply information from international experiences to an Australian context, is even more so. A review of the Australian noise guidelines for marine mammals, reptiles and avians has been sought by DCCEW and is currently underway, anticipated for public comment in late 2024. However, at the time of writing, this resource is not available for review or evaluation and does not address the impacts of noise on fishes (teleosts and elasmobranchs) or invertebrates. Further, while such reviews (and likely those of other topics) may outline the need for supporting information, they are unlikely to provide an inventory of available data.

11.2. Case study 2: The uniqueness of Australia’s coastal seafloor

Engineering requirements for the foundations of offshore wind turbines are well-developed for fixed (e.g. Byrne and Houlsby, 2003; Kallehave et al., 2015; Wu et al., 2019) and, to a lesser extent, floating wind turbines (e.g. Gaudin et al., 2017; Roddier et al., 2010). However, these designs have been based on modelling and experience in European and US waters and are not readily applicable directly for Australia’s continental shelf seafloor, much of which comprises thick layers of calcarenite substrate, covered by a thin veneer (sometimes less than a metre deep) of sand (Koessler et al., 2017; Erbe et al., 2021b). Feasibility licences allow prospective proponents to conduct geophysical and geotechnical surveys within their licence areas to map finescale seafloor bathymetry and seabed material that inform specific foundation design and confirm feasibility. However, although such geotechnical and environmental considerations are a known requirement for establishing OWF in Australian waters (Hammer et al., 2010), the performance of novel foundation and installation technologies and, at some sites, even pile-driving of monopiles of the sizes potentially required for turbines in our environments remains a significant knowledge gap. Detailed site-specific surveys will be required during the feasibility licence phase to inform specific designs and technologies.

During installation and operation phases of OWF, adaptations in foundation engineering to install in Australian waters may alter characteristics of impacts produced compared to elsewhere, which in turn affects mitigation and management needs. Two examples of this are: 1) noise produced while pile-driving and, 2) sediment scour/deposition over time. Although there are several studies of source signatures of noise emitted by impacted piling in Australia’s seafloor (Gaboury et al., 2008; Salgado Kent et al., 2009; Duncan et al., 2010; McPherson and Quijano, 2017), these are unlikely to translate to driving piles of a size required for fixed wind turbines (potentially up to 14 m diameter) into hard substrate habitats. Indeed, further site-specific knowledge will be required to inform how such sized monopiles can be installed in our calcareous sediments, whether via impacting piling, suction buckets (Hammar et al., 2010; Bienen et al., 2021), or more novel methods, such as 'vibro' installation (Bienen et al., 2021), and other novel foundation and installation technologies may need to be tested in Australian waters.

In addition to geotechnical installation considerations, mitigation methods used elsewhere to reduce impacts, such as noise (e.g. see Todd et al., 2015), may not be appropriate for our local suite of fauna. In Europe, for example, bubble curtains are employed successfully to reduce 'high-frequency' noise that impacts fauna sensitive to that frequency band, such as odontocetes (Bohne et al., 2019; Wehner and Landro, 2020; Dähne et al., 2017); however, some of the highest priority threatened migratory species in Australia are baleen whales that are sensitive to low-frequency sounds, for which bubble curtains are less effective (Lee et al., 2012). These animals are found around offshore windfarms in the US, and the effects of pile-driving noise are increasingly studied, but in these regions, sediments (and therefore noise profiles), mean that mitigation measures associated with activities such as pile-driving, may need to differ from Australia. Thus, there is currently a paucity of information on potential impacts of piling used that may be used install offshore wind turbines in Australian conditions, and a lack of directly transferable information from elsewhere. This also highlights the issue that impact avoidance and reduction measures are also important steps that could be achieved through siting, planning and design, as outlined in DCCEEW (2023a).

Finally, though scour of the seafloor and sediment deposition around offshore wind turbines outside Australia have been modelled and measured (e.g. Mayall, 2019; Guan et al., 2022; Tang et al., 2022; Wei et al., 2024; Qu et al., 2024; Whitehall et al., 2011). However, there are limited reports modelling and monitoring studies of scour around offshore structures in Australian waters (Welzel et al., 2019). There is an opportunity to further develop nature-based solutions for scouring protection from other experiences to mitigate impacts on local benthic, demersal, and pelagic communities (Lengkeer et al., 2017; Tang et al., 2020), such as the development of artificial reefs, to enhance ecological function of offshore wind turbine foundations (Glarou et al., 2020; see also Section 13). Similar to any activity associated with OWF developments, the opportunity to develop nature-based solutions needs to be examined for their own potential impacts.

This summary highlights the need to better understand the implications of Australia-specific engineering requirements and how they will change the stressor-related characteristics of the installation and the opportunity to re-design foundations to better manage any impacts and provide ecosystem benefits.

11.3. Case study 3: Oceanographic changes

OWF infrastructure has the potential to alter the physical characteristics of the local environment, with flow-on effects to biological ecosystems due to habitat modification. The existing literature is sparse and most of it has come from studies elsewhere, particularly Europe, and primarily related to offshore wind. Potential oceanographic changes are likely to be highly site specific and therefore environmental monitoring and best practice site evaluation will be a key component of offshore energy development.

11.3.1. Anthropogenic mixing

A primary cause for concern with the development of OWF infrastructure is the additional mixing generated by the submerged component of renewable energy infrastructure, such as wind turbine monopiles (Dorrell et al., 2022; Christiansen et al., 2023; Schultze et al., 2020; Carpenter et al., 2016). Structures that penetrate the thermocline (e.g., offshore wind monopiles and floating structures) could lead to changes in the existing stratification, particularly in seasonally stratified or weakly stratified areas, by inducing additional mixing as turbulence is generated by currents flowing around structural or mooring elements. The primary impact of this is expected to be changes to existing nutrient pathways and primary productivity processes. The mixing of stratified waters by offshore infrastructure is poorly understood and the time and space-dependent impacts can be difficult to measure, but it is an active area of research that is briefly summarised here. Given the potential impacts on stratification and mixing it is important to understand the water column structure and how stratification varies seasonally prior to any OWF development.

Observations of anthropogenic mixing of stratified waters are limited. Fossil fuel-related infrastructure is typically sparse, limiting previous concerns on regional changes to ocean properties. OWF programs, particularly OWF, are designed in ‘dense’ arrays typically at spacings where tidal advection can result in the interaction of structure wakes. This has triggered further study of how these arrays of structures may influence the surrounding ecosystem, both via in-situ observations (Vanhellemont and Ruddick, 2014; Baeye and Fettweis, 2015; Floeter et al., 2017; Schultze et al., 2020; Floeter et al., 2022; Huang, 2022) and numerical modelling studies (Rennau et al., 2012; Carpenter et al., 2016; Cazenave et al., 2016; Christiansen et al., 2023).

Processes that generate mixing at the thermocline can be an order of magnitude more efficient at mixing out stratification than those that do not, e.g., baroclinic bulk mixing vs. barotropic bulk mixing (Dorrell et al., 2022). A simplified analysis by Dorrell et al. (2022) using typical structure spacing and conservative assumptions suggested that turbulent dissipation rates at the thermocline would be 140% higher inside an OWF averaged over the entire development footprint. Dorrell et al. (2022) concluded that OWF would clearly affect first order turbulent kinetic energy transport in the wind farm area. This may result in fundamental changes to hydrodynamic and ecological processes within (and in the lee of) arrays of installed structures, such as an OWF [Figure 1, taken from Dorrell et al., 2022].

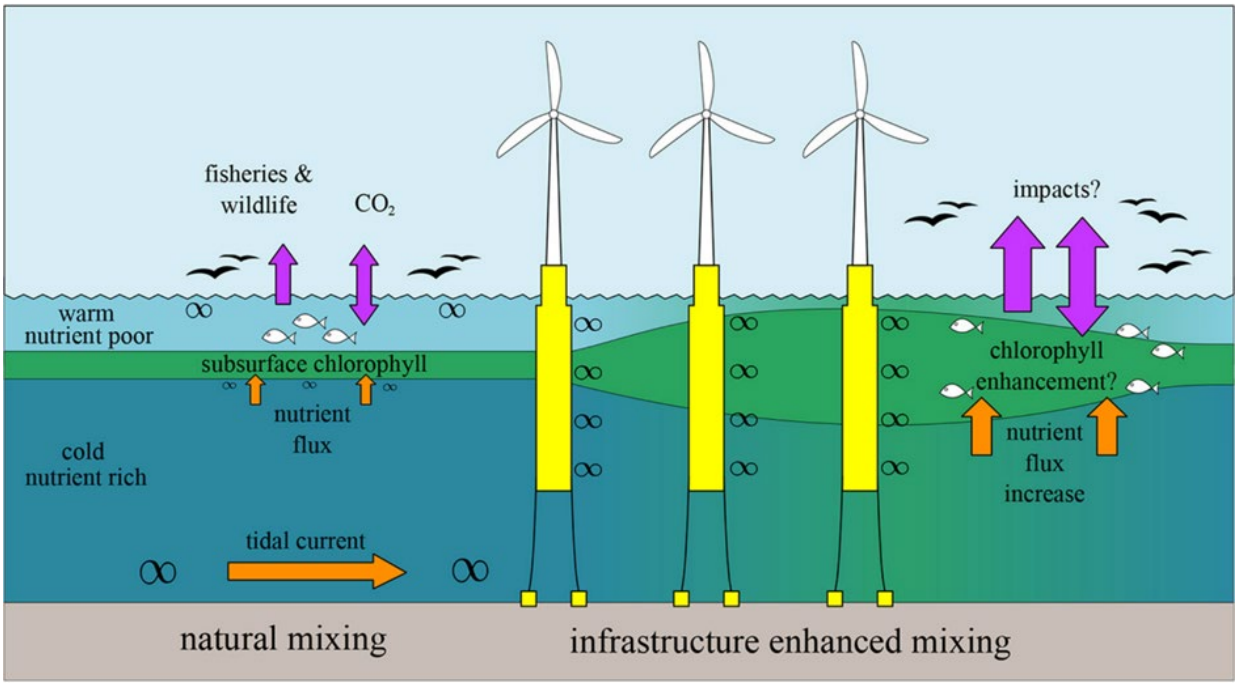


Figure 87: Schematic of anthropogenic mixing and potential flow-on effects, taken from Dorrell et al., 2022, Figure 14.

Floeter et al. (2017) collected water quality measurements along transects through two operational wind farms in the German Bight (North Sea). They found a consistent weakening of stratification near the OWF centre that extended over an area around half a tidal excursion diameter in length. Floeter et al. (2017) could not delineate OWF effects from local topography effects without baseline measurements. Schultze et al. (2020) conducted transects upstream and downstream of a single wind turbine within an OWF and found that the potential energy anomaly was generally reduced in the downstream wake (by up to 65%). Changes were observed in all downstream observations which extended away from the turbine up to 90 times the monopile diameter.

Numerical modelling of offshore infrastructure is challenging as it requires capture or parameterisation of processes across a wide range of scales (e.g., drag and turbulence to shelf scale flow). Dorrell et al. (2022) reviewed previous modelling work and recommended modification of the turbulent closure scheme to account for structure-induced turbulence. Christiansen et al. (2023) implemented this as their parameterised approach and found that the wind farms changed horizontal current velocities by ±10% (slower through the farm and faster in adjacent areas). They also found reductions of around 10% over a 5-year average, with maximum values up to 30% inside OWF footprints. These effects were not limited to the OWF footprint, however, with area-wide stratification reduced by an average of around 5%.

Following from Christiansen et al. (2023) the present best-practice approach to modelling offshore infrastructure is using a 3D hydrostatic numerical model with the turbulent closure scheme to account for structure-induced wake turbulence. Unstructured model grids allow for refinement around structures and quicker adaption to new project layouts, but structured grids could also provide adequate results given sufficiently high-resolution. Most research and commercial numerical models that have up-to-date development should support this functionality.

Dorrell et al. (2022) noted that both modelling and collecting observations of anthropogenic mixing present significant challenges. Modelling of mixing due to structure wakes in stratified flows is poorly understood and advances are desired to improve results. Modelling approaches used in literature produce results with high uncertainty and require in-situ observations to confirm the magnitude (and in some cases even the sign) of the result. Collecting observations of an unsteady multi-scale problem presents its own challenges, with adequate pre-installation observations required to reduce uncertainty when interpreting the data. Cascade effects from anthropogenic mixing, such as changes to nutrient and oxygen fluxes and primary productivity, introduce additional uncertainty and have not been studied in detail, but results could be inferred from changes to ocean processes.

11.3.2. Increased turbidity

Another potential impact related to anthropogenic mixing is increased turbidity (suspended particulate matter) in the water column. Additional mixing from energy infrastructure sources should in many cases produce elevated turbulence, and hence allow for more particulates to remain suspended and for longer periods. This effect has been observed remotely in shallow regions with OWF but has not been directly observed or modelled in deeper areas. Increased turbidity and its flow-on effects (e.g., decreased light availability) can have important biological and biogeochemical implications.

Vanhellemont & Ruddick (2014) observed turbid wakes using satellite (Landsat-8) from monopile OWF in the North Sea. The OWF were 0 to 53 m deep with arrays from 30 to 175 turbines. They observed individual wakes 30 to 150 m wide and several km in length. Baeye & Fettweis (2015) collected in-situ measurements at a Belgian OWF and confirmed plumes of around 5 times the background turbidity were generated at the turbine piles under normal tidal conditions. They hypothesised that “epifaunal communities colonizing the monopile surface” were a key source of plume material. Huang (2022) also observed turbid wakes around OWF off Taiwan which showed wake-wake interactions when monopiles and tidal currents aligned.

The construction of offshore energy infrastructure in deeper water is likely to increase particle suspension and turbidity, but these effects may not be visible at the surface. Shelf regions outside the surf zone can be reservoirs for fine particles (Cheriton et al., 2014) that are easily lifted from the sea floor and maintained in suspension for long periods. Different structure designed will have different impacts on local mixing at the sea floor and in the water column. Both the local sediment conditions and structure geometry need to be considered when assessing the potential impact of offshore energy infrastructure.

11.3.3. Benthic changes (scour)

The installation of offshore infrastructure that interacts with the seafloor (e.g., monopiles, footings, anchors) will have direct impacts on seafloor scour and aggradation. Such structures typically result in rapid increases in erosion proximal to the structure (scour holes) and can result in ongoing alteration in the pattern of seabed scour and sediment accretion (as bedforms). These altered processes can directly impact benthic organisms within the scour footprint and may, have flow-on effects, such as changes to broader local to regional-scale hydrodynamics or and sediment transport processes.

The magnitude of seabed scour is highly dependent on the sea floor sediment type, structure geometry, and current regime. Any assessment of the potential impacts from installation of offshore infrastructure should include knowledge of the local sediment, consideration of the installed structure, and assessment of the benthic habitat’s ecological significance and sensitivity. Whitehouse et al. (2011) assessed scour at several European windfarm sites. At an energetic site with unlimited thickness sand (typical worst-case scenario) they found large scour patterns developed quickly, with significant variation in scour depth between close sites (0.25 to 1.4 times the monopile diameter deep). Scour hole diameters were up to 20 times the monopile diameter before scour protection was installed. A post scour protection survey along a 1200 m transect (three turbines) showed an average erosion depth of 1 m (in 11 m water depth) for the whole transect (CEFAS, 2006; Whitehouse et al., 2011). These significant scour holes also produced scour wakes – areas containing larger amplitude bed features than the surrounding seabed– but their spatial extents were not quantified. Changes to seafloor morphology likely have consequent impacts on the biological activity within the affected area (e.g., Weber et al., 2004).

11.3.4. Wind wake effects

The installation of OWF specifically has the potential to generate wind wake effects that translate to changes in ocean processes. A wind wake is a region inside and in the lee of an OWF where wind stress is lowered. The primary wind wake effect is the generation of an upwelling / downwelling dipole of ocean currents, proposed by Broström (2008). They used idealised analytical models with wind speeds of 5 – 10 m/s to predict upwelling and downwelling velocities greater than 1 m per day in scenarios where the wind wake is equal or larger in size than the internal Rossby number. They concluded that the local ecosystem would be strongly influenced by the presence of a wind farm that met these criteria.

Daewel et al. (2022) used numerical modelling to investigate how predictions by Broström (2008) would translate to an area of active wind farm development in the North Sea. They identified a range of effects on ocean processes (averaged over a year) including clearly defined upwelling and downwelling patterns, changes to the mixed layer depth, changes to ocean current velocity, changes to sediment carbon and nutrient fluxes, and changes to primary production. Changes to primary production were ±10% and spatially variable, which could impact the distribution of fish species and survival of fish early-stage life (Daewel et al., 2022). When averaged over the entire study area, however, net changes to primary productivity were only small (-0.5%; -1.2% for OWF footprints).

Floeter et al. (2022) collected observations of the water column in the wake of an operational wind farm using a towed CTD. They claimed to identify the first empirical evidence of the wind wake generated dipole proposed by Broström (2008). They presented observations showing changes in the mixed layer depth and potential energy anomaly over a 5 km distance in the lee of the wind farm.

Akhtar et al. (2022) used numerical models to changes to the sea surface climate as a result of OWF installations. They found a reduction in air-sea heat fluxes due to the reduced wind speeds and a net cooling effect on the lower atmosphere when averaged over a year. This implies an increase in ocean heat content within the study area. They also modelled an increase in low level clouds and mean precipitation in the vicinity of large wind farms.

Observing and quantifying the real-world impact of energy infrastructure such as large-scale OWF presents significant challenges. Both the drivers of wind wake effects (wind) and the impacts are nonstationary. Multiple processes can influence ocean characteristics such as the mixed layer depth and primary productivity, and temporal variation at daily and seasonal timescales may be much greater than the influence of the OWF (as noted by Floeter et al., 2022). It is probable that both observations and modelling of the physical and biological processes will be required before installation of 'dense' infrastructure such as OWF to deduce potential impacts with any degree of certainty. The degree of uncertainty in both physical and biological models and the presence of significant natural variation means that even after detailed studies unexpected impacts are likely.

Other minor impacts that have been proposed, for example, include changes to the wind field from OWFs changing ocean mixing due to the increased turbulence in the wind wake. Preliminary estimates of additional mixing generated by atmospheric turbulence suggest this effect, however, will be at least an order of magnitude lower than additional mixing generated within the ocean (Christiansen et al., 2023).

11.3.5. Emerging technology

There are numerous emerging and concept-stage renewable energy technologies that may impact the environment if they are installed. We briefly outline some of the existing research on several emerging technologies, noting that there are many others not covered here. It is pertinent to reiterate that the installation of any infrastructure in the shelf sea region has the potential to impact existing hydrodynamic processes, with flow-on effects to nutrient pathways, sediment transport, and other processes.

Tidal turbines are typically installed in narrow high-flow channels and the extraction of energy may alter dynamics of the entire channel flow. Nash and Phoenix (2017) reviewed literature on tidal turbines and noted that single devices were unlikely to have a significant impact, but turbine arrays could produce significant far field hydrodynamic impacts and flow-on ecological effects. Vennell et al. (2015) also reviewed the literature and provided summary advice on how to balance turbine array design requirements with hydrodynamic impacts. Neill et al. (2009, 2012) used numerical modelling to show how such hydrodynamic changes could increase sedimentation and alter nearby morphological features.

Wave energy converters (WEC) are typically designed to be installed in arrays of many structures. The impact on nearshore currents, wave energy, and sediment transport was assessed by David et al. (2022) using both wave-averaged and wave-resolving models. They found that impacts were minimised when infrastructure was installed at least 3 km from the coast, with all impacts generally reduced with distance from the coast (minimum of 1 km) and increased spacing of the WECs in the array.

The effects of installing wind turbines on local and regional oceanography is based on changing the underlying physical process and this thus and mostly transferable between locations, yet to summarise this required significant expertise and effort. We provide this case study as an example of one of the more well-studied impact types which would need to be multiplied in effort to summarise effects of the other 17 identified impact types. Further, the remaining impact types require consideration of the response types and multitude of receptors associated with each impact type and the more complicated nature of identifying needs for these less transferable topics.

11.4. Another potential impact: pollutants

One long-term, pervasive impact, for which we found comparatively little information directly related to OWFs, was toxicology. Although some initial studies suggest low to medium impact (Ebeling et al., 2023; Kirchgeorg et al., 2018) there are significant gaps (Schutz-Stellenfleth et al., 2023) and this stressor needs to be considered in an ecosystem model (Baulaz et al., 2023). Multiple guidelines for water quality exist in Australia (e.g., van Dam et al. 2018) that although their frameworks could be applied to offshore wind farms, have limitations that they may not account for toxicity modifying factors such as chemical speciation changes in response to local conditions, do not consider impacts associated with any bioaccumulation/biomagnification, do not consider interactivity from multiple stressors, and are limited to describing toxicity based impacts. Offshore wind infrastructure use coatings or galvanic anodes for corrosion protection.

While they are likely to experience similar issues for the operational phase of oil and gas infrastructure (or essentially any metal structure in the ocean) as each steel pile will have equivalent anodes for similar reasons. However, there may be a difference in the concentration of offshore wind anodes given their size and number, i.e. higher concentration of large structures within a given area than for oil and gas infrastructure. These may be major sources of chemical emissions to nearby environments that would continue for the life of the installation. For example, a German study found that 150 to 750 kg of anode material is released into the marine environment per wind turbine per year (BSH & Hereon, 2022). Ecotoxicology data for the metals associated with anodes (Al, Zn, Ga, In, Pb, and Cd) suggests that harm to sensitive marine organisms may occur at concentrations on the order of 1 µg/L. Although there have been studies on responses invertebrates to anode metals (Levallois et al., 2022; Mao et al., 2011), further research is needed to quantify the marine behaviour of anode metals to determine their environmental fate and the area of potential toxicological effects to marine receptors.

12. Lessons from oil and gas industry research in Australia's south-east

In Australia, scientific literature examining marine communities associated with oil infrastructure has increased rapidly in the past 10 years, with 26 peer-reviewed ecological studies published as of May 2023 (McLean et al., 2024). The heightened research focus aligns with increasing public awareness and the imminent need of industry and decision-makers to plan for structures reaching the end of their operational life (Shaw et al., 2018; Higgins et al., 2022). Australia's offshore energy regulator (NOPSEMA and OIR), has published a Research Strategy 2024-2027 that aims to drive collaborative approaches to prioritising, funding and designing research that will deliver outputs that will enhance confidence in the environmental management of offshore energy projects, and includes consideration of offshore renewable energy projects. The NOPSEMA/OIR Research Strategy promotes research to enhance understanding of ecological and cultural environment, and how offshore energy projects may affect particular environmental values and sensitivities. The Research Strategy also identifies where suitably targeted research could help with improving monitoring and mitigation associated with different parts of oil and gas project life cycles and offshore energy sectors. Many of the research priorities identified by NOPSEMA/OIR in the revised Strategy require multi-year dedicated research campaigns to understand temporal variability. An opportunity exists for the OWF industry to ensure ongoing and appropriately robust monitoring occurs throughout project life.

There are clear synergies between the O&G sector and OWF with respect to artificial structures being placed in the ocean and the types of associated stressors they introduce (light, noise, shipping, hydrodynamic changes, etc). Indeed, several of the references found in the Project 3.3 OWF Impacts inventory comprise transferable information from O&G related studies. As such, proponents, researchers, and Government should aim to learn from this research, not only about the main findings but also the methods used to obtain the information (models, survey techniques, etc). Further, substantial decommissioning research is presently being undertaken in Australia's south-east that can inform new developments in the same region.

Ecological research on O&G infrastructure in Australia has demonstrated the value of infrastructure to commercially and recreationally important fish species and has provided information on how communities present on infrastructure compare to those in natural ecosystems (Bond et al., 2018a, b, c; Schramm et al., 2020; 2021; McLean et al., 2021). Research findings include a diverse and abundant marine life on and around structures (Neira, 2005; McLean et al., 2018; 2019; Sih et al., 2022), residency of fish on subsea wells (Fowler et al., 2012, 2015), and interactions between structures and megafauna (Arnould et al., 2015; Thomson et al., 2021). Scientists are also working closely with industry to conduct quantitative scientific surveys of O&G infrastructure (McLean et al., 2019; Schramm et al. 2020; 2021).

To date, however, the majority of published scientific research in Australia has been on tropical marine communities associated with infrastructure in the north-west and usually involves just a single snapshot in time. Although O&G infrastructure has been present in the south-east region for over 50 years, research into the extent and nature of the industry's influence on marine ecosystems and fisheries in this region has only commenced in more recent years (Neira, 2005; Arnould et al., 2015; Sih et al., 2022; Ierodiaconou et al., 2023; Birt et al., 2024; McLean et al., 2024; Galaiduk et al., 2024).

A plankton survey study by Neira (2005) around nine offshore platforms documented the larval and early-stage juveniles of 55 fish taxa. Arnould et al., (2015) found evidence that

O&G infrastructure has become foraging habitat for Australian fur seals (*A. pusillus doriferus)*. Sih et al. (2022) documented the diversity of fish and invertebrate species on two platforms and two pipelines in the region and reported a low overlap in species observed on structures with those retained in surrounding fisheries. Ierodiaconou et al. (2023) found different fish and benthic communities associated with Cooper Energy flowlines and wells, driven by habitat and depth preferences, and noted several species of ecological importance including the Australian fur seal, long-lived foxfish (*Bodianus frenchii*), and rare handfish (Brachionichthyidae spp.). Recently, research by McLean et al. (2024) documented 497,835 individual fish, representing 132 species/genera and 62 families across ten pipelines, eight platforms and natural habitats across the Bass Strait region. In 2023-2024, 300 stereo-BRUV deployments have been conducted for research around the influence of O&G structures in the Bass Strait providing great insights into fish communities present in natural habitats and those around artificial structures.

There were clear distinctions in assemblages across the various different types of structures, with some fish species affiliated with the base of platforms, others with surface sections, and others with pipelines. Similar associations might be expected for OWF structures and cables. Platforms, with some analogous to OWF structures, are dominated in cover by the jewel anemone (*Corynatis australis*) across all depths with the exception of the base of platforms where diverse morphologies of sponge biota are prevalent. It is likely that these same species will dominate the coverage of new OWF installations over time. The study also examined seasonal shifts in benthic and fish communities, undertook 'hotspot analyses' (Radford et al., in prep), and documented the presence of various invertebrate (e.g. lobster, urchins, crabs) fauna (McLean et al., 2024). The research built upon previous work by Arnould et al., (2015) on Australian fur seals with 223 observations of seals around structures in summer 2021, and 725 observations in winter 2022.

Seals were observed to forage around structures (particularly at night) and to haul-out in very high abundances on platforms during the day. From the literature we know that Australian fur seals exhibit a high degree of foraging site fidelity, which suggests that the removal of O&G structures, and the addition of OWF infrastructure, may alter both their foraging and resting behaviours, potentially with flow-on effects to breeding colonies further afield. Whether this presents a positive or negative impact to the broader populations is not known.

Most recently, Birt et al. (2024) assessed the biomass and fish production of one common and abundant fish (*Caesioperca lepidoptera* – butterfly perch) and two fished species (*Helicolenus percoides* – reef ocean perch*; Nemadactylus macropterus* – jackass morwong) on eight O&G platforms and in surrounding natural habitats in the Bass Strait. Total production (P) across all platforms was estimated at 1244 kg/year for the three species. Approximately 79% of total production is considered 'new' production (984 kg/year) i.e., the production attributed to the presence of the platforms. Most production and biomass was associated with the bottom sections of platforms where they meet the seabed (46%).

The production measures obtained by Birt et al. (2024) are relatively high compared to other artificial reefs and habitats around the world. Galaiduk et al. (2024) modelled the connectivity and metapopulation dynamics of three fish and two benthic invertebrate species that inhabit O&G structures in the Bass Strait, including the aforementioned butterfly perch and reef ocean perch. Using a network approach, the study found that platforms are not major sources, destinations, or stepping-stones for most species, yet act as modest sources for connectivity of *Corynactis australis* (jewel anemone).

In contrast, sections of subsea pipelines appear to act as stepping-stones, source and destination habitats of varying strengths for all study species, except for *Centrostephanus rodgersii* (long-spined sea urchin). Natural reefs in the region were the main stepping-stones, local source, and destination habitats for all study species. The connectivity model was underpinned by a hydrodynamic model that was also developed for the region (Greer and McIntosh, 2023) and both could be utilised to assess how connectivity might change with the addition of OWF structures into the region.

Lastly, recent stereo-BRUV imagery collected in 40-100 m depth in the Gippsland region can be accessed by request through GlobalArchive, providing information on fish species present near infrastructure and in surrounding natural habitats.

13. Nature inclusive designs in offshore wind farms

To work towards reducing a range of environmental impacts, OWF developments could extend beyond mitigation measures by designing for nature positive benefits. While particularly useful for regions where habitats have been degraded or reduced (e.g. North Sea), there is still benefits for augmenting OWF in Australia to create suitable habitat for native species, or to support additional abundances of fishery target species. Examples where this has occurred elsewhere include in the North Sea where research is being undertaken into design options for restoring flat oyster beds (Smaal et al., 2017), adapting scour protection with eco-friendly designs to promote cod and oyster species (Lengkeek et al., 2017) and native invertebrates (van Duren et al., 2016), and to aid in erosion protection (Tamis et al., 2017) – see - Home | The Rich North Sea (derijkenoordzee.nl. Further research is being undertaken in Scotland to weave in nature-inclusive designs; New marine report recommends 'nature-inclusive design' for offshore wind projects in Scotland | Offshore Wind Scotland. In Australia, consideration could be given to how developments could be designed and augmented to promote the abundance of important fishery species, e.g. rock lobster, abalone, demersal fish; particularly if there are access restrictions placed around OWF developments that fishing sectors that presently do have face such restrictions. Further, one should then consider how this may then also affect decommissioning decisions for these structures in the context of nature positive initiatives, e.g. DCCEEW Nature Positive Plan.

In 2022, the Australian Government released a Nature Positive Plan for Australia to reform national environmental standards, approvals and conservation planning. The Plan sets out the Australian Government's approach to achieving better outcomes for the environment and heritage, faster decision making on developments and greater accountability and trust on environmental matters and decision-making. The central elements of the Plan include: reforms to the EPBC Act, new Environmental Standards, a Nature Repair Market and the establishment of an independent Environment Protection Authority (EPA). A regulatory outcome where the projected gain from all measures to mitigate, repair and (where required) compensate for impacts is greater than a baseline that reflects what would have happened in the absence of the relevant action(s). In the U.K. similar plans and policy legislates all developments must have 10% net gain in biodiversity from pre-development baselines. The Australian Government has yet to set legislative quantitative targets for biodiversity net gain.

14. Further development

14.1. Knowledge base

The project 3.3 OWF inventories could become a dynamic, Australian-centred resource, updated with new findings, and expanded to include the appropriate level of information on each stressor and impact type. To complete this would require appropriate funding to achieve unbiased effort across all topics (the various combinations of activity-impact-response group pathways) and provide an appropriate level of information to be a useful resource.

A complete knowledge base would provide the opportunity to conduct a full literature review and knowledge gap analysis of the impacts of OWF that encompasses all topics, with an appropriate level of effort and expertise in each topic. Although we have identified toxicology and cumulative impacts as key areas for which little is known, there are almost certainly more research priorities that should be identified by topic experts via a knowledge gap analysis, prioritised by consultation through stakeholder and technical panels/workshops and supported for continued research.

Although the subjects of these case studies and summaries have been chosen based on subject matter expertise, there are similar knowledge gaps and opportunities in other facets of implementing Australian OWF. Several of these gaps will occur in Australian-specific effects, which cannot simply be derived or perhaps even identified from existing impact literature (e.g., ecotoxicology, unknown impact pathways for Australian species, effects of electromagnetic fields on migrating invertebrates and demersal electrosensitive species). Increasing the current understanding around these factors is an important addition to any resource database. Our suggested inclusions to the current database are a significant increase in the value of any resource available to Australian and global stakeholders. In developing this database, stressor subject matter experts were able to provide publications with information relevant to their own field that may not be included in other global resource databases or discovered by researchers not familiar with the field in question in a systemised search. This highlighted that any resource dataset, literature review and gap analysis will 1) potentially miss valuable information unless it includes expert opinion; but also 2) struggle to avoid bias unless the team includes experts on each of the identified stressors and effort is equally weighted. We therefore recommend that such a resource database is developed using systemised literature searches, in alliance with ad hoc, periodic updates from a team of experts. Such a database could be linked to existing global databases, such as Tethys to enhance their capacity. This has been achieved by providing the Project 3.3 OWF Impacts inventory to Tethys.

In addition, use of existing Australian marine data portals should be considered as the platforms where relevant OWF data are managed and delivered. For example, Seamap Australia (https://seamapaustralia.org/) is a national repository for all marine habitat spatial data developed by the Australian marine science community. It maintains a vocabulary to ensure nationally consistent classification of marine habitat; and develops, maintains and hosts online end user tools to assist with using and interpreting marine habitat data and its derivatives. The AODN Portal (https://portal.aodn.org.au/) provides access to all available Australian marine and climate science data and provides the primary access to data from the Integrated Marine Observing System (IMOS) including access to the IMOS metadata. Further work is needed with EIA to confirm how to best utilise these resources.

Similarly, the AusSeaBed portal (https://portal.ga.gov.au/persona/marine) provides access to publicly available acoustic datasets such as bathymetry, backscatter, side scan sonar data and other marine-related products, as well as a suite of analytical assessment tools to maximise the value of the data. The platform allows seafloor mapping products across Australia's marine jurisdiction to be explored and downloaded. Squidle plus (https://squidle.org/) is a web-based framework that facilitates the exploration, management, and annotation of marine imagery, and collates information on the deployment of marine image gathering platforms (such as AUVs). GlobalArchive (https://globalarchive.org/) is an online centralised repository of fish and benthic image annotations from stereo-video. An important requirement for data acceptance in most of the platforms is use of best practice data collection and processing as outlined for example in the NESP Field Sampling Manuals.

A range of consistent geo-regulatory layers, and contextual information to support marine planning; and tools, visualisations and data to inform Offshore Renewable Energy in Australian waters is delivered through the Australian Marine Spatial Information System (AMSIS) (https://amsis-geoscience-au.hub.arcgis.com/pages/renewables). There are also multiple sources of guidance material, web platforms and tools that are available that provide relevant information and data on such issues as species conservation advice, Ramsar wetlands, Australian Marine Park management plans and other relevant policy documents and gazettal instruments and guidelines. These are outlined in detail in DEECCW (2023).

14.2 Indigenous knowledge

Instances where Traditional Ecological Knowledge of First Nations Peoples have been incorporated into contemporary marine management strategies date back decades (Davies et al. 2020). But there is also a sense and history of Australia's Indigenous peoples being left out of science and management planning, prioritisation, and participation (reviewed in Ens et al. 2015). Early engagement in shaping science direction, design, and implementation is key. Their knowledge and understanding of Country have been a critical element to survival and has been generated through careful observation of the natural world over tens of thousands of years, a compelling point considering that all good science is fundamentally rooted in careful observation. Indigenous communities are therefore uniquely placed to bring new aspects to science and management planning, prioritisation, and participation that can enrich research perspectives and provided guidance to managers and proponents.

Despite often limited capacity, which may vary between Indigenous organisations and communities, Traditional Owners are very likely to want to engage and provide input into the developing OWF sector in Australia.

One identified mechanism for encouraging development of science collaborations with Indigenous communities are Healthy Country Plans (HCP), also termed Indigenous or Joint Management Plans. These are communally generated documents that outline interests and concerns of local municipalities regarding their community, cultural identity, and Country. They often list social, cultural, and environmental values, identify threats, state goals, objectives, and strategies.

Indigenous interests and concerns relating to the OWF industry are likely to be a varying mix of important strategic, cultural, spiritual, environmental, and economic interests. There is a requirement for governments, industry and environmental scientists to engaged Indigenous people in discussions on their interests and concerns about development of the OWF.

Progression of a coordinated research program will encourage governments, industry, and the research community to progress with timely, effective, and respectful engagement with relevant Indigenous communities. This could include exploring the potential for partnerships with Indigenous groups to identify Indigenous ecological knowledge and build capacity to contribute to assessing the key environmental factors. These partnerships should incorporate co-design (problem formulation) and co-delivery (including use of Indigenous ecological knowledge), and interpretation and communication of research.

14.3. Key Offshore Wind Farm environmental knowledge gaps

This inventory of relevant environmental factors has aimed to identify the current knowledge base to inform various processes that will progress the establishment of an offshore wind industry across the defined Australian declaration areas. The key issues identified relating to the environmental factors outlined include:

- High resolution bathymetric data is limited on the continental shelf of most OWF areas, hence full coverage bathymetry data should be acquired following Oceans Best Practice (OBP) guidelines and provided through established publicly accessible data platforms (AusSeaBed). This is important to define the seabed characteristics required for project siting and design decisions, etc; inform various modelling studies, and support the establishment of reference sites for ongoing monitoring. A number of the regions that contain OWF declaration areas have recently had, or have planned, focused hydrographic surveys through the HydroScheme Industry Partnership Program (HIPP) (https://www.hydro.gov.au/NHP/). The HIPP is managed by the Australian Hydrographic Office on behalf of the Department of Defence.

- In most OWF regions sub-bottom profile data is required to confirm the sub-seafloor structure, particularly with the declaration areas. Further sampling is also required in most areas to better survey the surficial sediments to understand their geotechnical properties and habitat characteristics.

- Application of OBP seabed geomorphology mapping approach should be progressed as better seabed mapping coverage is achieved. Improved maps that illustrate the distribution of these geomorphic features at improved resolution will provide the necessary confidence to understand their nature and composition, and associated risks and subsequently inform survey designs for additional factors (benthic habitat, sound, etc).

- Limited seabed mapping within the declaration areas has resulted in little understanding of the habitat extent and distribution and associated benthic biodiversity. Structured surveys using OBP guidelines are required to identify and map the seabed habitat types, quantify benthic biodiversity, and establish baseline measures for impact assessment and monitoring.

- Information on the spatial extent of studies (from our inventory) on the species of interest, along with readily available observation data and overlap with OWF areas has been consolidated, with spatial layers from the fauna maps available for viewing and download on SeaMap Australia. Regular updating of information on abundance and distribution, and detailed consideration of the ecology and biology of priority species is required when considering the key knowledge gaps and impacts mitigation options. Further consolidation of this information is required to inform environmental assessments, modelling and future monitoring. At present there are specific knowledge gaps on many key species, and further prioritisation of research to address this is required. Specific OWF repositories would contribute to facilitating this.

There are many components of the report that, in addition to an inventory of environmental data, provide guidance for future research investment and priorities. These include:

- Adopting OBP approaches to monitoring reduces the bias and variance in sample data and increases confidence in the provision of advice. Importantly it also enables integration across proponent areas and precincts that, for example, could enable the assessment of cumulative impacts and comparison with reference locations where similar approaches have been applied providing comparable data (e.g. Marine Parks estate).
- There is need for coordination and investment to integrate where possible existing marine data portals to allow OWF research and industry data to move towards adopting FAIR data principles. There is a need also for these data portals to create tools which allow monitoring data to be more accessible and easily utilised by data users.
- Indigenous community interest in the OWF industry could be a varying mix of important strategic, cultural, spiritual, environmental, and economic interests across the six offshore declared areas. Indigenous input early into the OWF development pipeline is recommended, and engagement benchmark documents such as the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and the principles for engagement developed by the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) provide guidance to an emerging OWF industry.
- The report provides an impacts inventory containing information relevant to understanding impacts of offshore wind. The value of the impacts inventory would be increased if it captured information at all levels of the activity-exposure-response relationship. This would require subject matter expertise and systemise literature searches across the numerous combinations of activity, stressor, and receptor responses. There is potential for this inventory to be a dynamic resource, and as new publications emerge, they can be added to enhance its comprehensiveness and relevance, should this be of interest. Such an understanding of these impacts is key to planning how to avoid, mitigate or offset the effects of specific OWF activities consistent with EPBC legislative requirements.
- Assessing the cumulative impacts of OWF at whole of life-cycle relevant scales will require a shift towards assessment methods that include ecological connectivity across regional scales. In addition, cumulative probabilistic risk assessment for migratory species will require innovative risk assessment approaches that can subsequently feed into cumulative effects assessments that are continually updated as knowledge gaps are filled. It is also a requirement that the approach is consistent with EPBC legislative requirements. These issues are being addressed in the NESP Marine and Coastal Hub project 4.7 (https://www.nespmarinecoastal.edu.au/project/4-7/).

14.4. Coordinated research and a national environmental supply chain to support sustainable Offshore wind farms

An effective pathway to fill identified knowledge gaps would be through the development of a framework for identifying integrated research questions related to the various impacts of OWF, through consultation with scientists, regulators and industry. This should consider international approaches and a process for regulators to coordinate consistent approaches, A coordinated Australian OWF research program structured to best support developments in

Australia is one approach, although specific institutional structures could also deliver effective coordination. Overall, such frameworks should link targeted studies of varying size (and funding streams) to answer application-driven scientific questions, coordinated through a consortium of government, industry and stakeholders through a transparent, peer-reviewed process.

The NOPSEMA and OIR Research Strategy (2024-2027) provides guidance on priorities, funding and designing research to deliver improved outcomes in the environmental management of offshore energy projects, including that for Offshore Renewable Energy https://www.nopsema.gov.au/blogs/nopsema-and-oir-revised-research-strategy-2024-2027. This includes information on key effects studies, improving monitoring and mitigation techniques, and priority avifauna species.

Improved coordination is also required to ensure implementation of standards, and effective and efficient sharing of research data through the design and building of data sharing and analytics infrastructure to support government, industry and research (Figure 88). This is essential to ensure that the data supply chain is consistent with the principles of being Findable, Accessible, Interoperable, and Re-useable (FAIR).

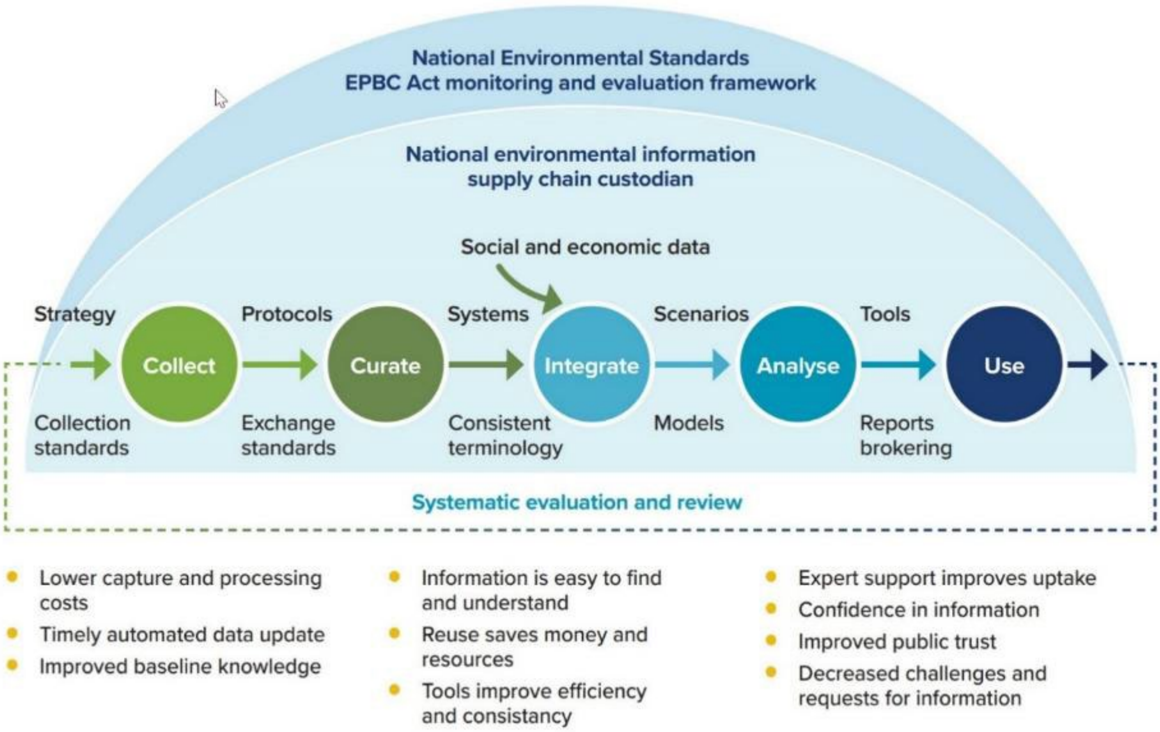


Figure 88: Characteristics of the envisaged national environmental information supply chain of national environmental data (Source: https://epbcactreview.environment.gov.au/resources/final-report/chapter-10-data-information-and-systems/103-recommended-reforms).

There are several coordinated OWF environmental research management programs and models in place or being tested during auction and permitting process internationally. A broad list of international programs associated with the environmental research and management of OWF's is presented in Table 1. Some of the relevant models that could be evaluated for use in Australia include:

- **The Regional Wildlife Science Collaborative for Offshore Wind (RWSC):** This collaborative serves as a coordination hub for offshore wind research to facilitate collaboration across federal and states agencies, eNGOs, and the offshore wind industry in US Atlantic waters (https://rwsc.org/). This includes conducting and coordinating relevant regional monitoring and research of wildlife and marine ecosystems, suggesting common data standards, and increasing data sharing and transparency. It has developed a Science Plan with the research community to inform future offshore wind data collection and research (https://rwsc.org/science-plan/).

- **The UK Offshore Wind Evidence and Change Programme (OWEC):** This program aims to create a shared data and evidence base held on the UK Marine Data Exchange (https://www.marinedataexchange.co.uk/). One of these is the UK Planning Offshore Wind Strategic Environmental Impact Decisions (POSEIDON) project that aims to support delivery of a robust evidence base and new mapping tools to improve understanding of environmental risks and opportunities for future offshore wind developments. The project focus is on collating and assessing relevant data on seabirds, marine mammals and the seabed to help identify knowledge gaps, with new data collection initiatives focussed on seabed surveys and digital aerial surveys of seabirds and marine mammals (https://naturalengland.blog.gov.uk/2023/02/01/poseidon-offshore-wind-and-nature/). A full list of OWEC research projects are available at https://www.marinedataexchange.co.uk/content/info/offshore-wind-evidence-and-change-programme

- **Other international research initiatives:** There are also several developing initiatives in the United States that aim to facilitate and coordinate offshore wind research collaborations across federal and states agencies, eNGOs, and the offshore wind industry. These include Bureau of Ocean Energy Management's (BOEM) 'Realtime Opportunity for Development Environmental Observations' (RODEO) platform (www.boem.gov/rodeo), and the Wildlife and Offshore Wind (WOW) collaboration (https://offshorewind.env.duke.edu/). There are also some key offshore renewable energy environmental databases that aim to facilitate knowledge transfer for offshore wind research, including the OES-Environmental 'Tethys' knowledge base (https://tethys.pnnl.gov/about-tethys), and U.S. Offshore Wind Synthesis of Environmental Effects Research (SEER) (https://tethys.pnnl.gov/us-offshore-wind-synthesis-environmental-effects-research-seer).

- **Minimum requirements to OWF research and conservation fund**: In some regions developers are required to make a contribution to a national fund during an auction process. This fund finances actions to fill knowledge gaps on the impact of OWF or to preserve biodiversity, extending beyond the EIA process of development projects. For example, in Belgium developers have contributed to a nationally coordinated programme since 2005. The Royal Belgian Institute oversees and coordinates this programme, reviews monitoring needs, provides adaptive management advice, and assesses cumulative impacts through a centralised database (Degraer et al., 2023). In Germany, 5% of the proceeds from the 2023 auction were allocated to marine nature conservation and promoting sustainable fishing (Bundesnetzagentur) https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2023/20230712_OffshoreResults.html

- **Minimum Requirements to monitor and management measures**: Minimum requirements are established during the auction, EIA consenting, or permitting process, providing clear guidelines for OWF developers. This model is adapted for well-understood risks and solutions. Developers must implement measures to mitigate specific impacts and document their effectiveness. Monitoring is often carried out by an external party to validate compliance with the permit. Data collected can inform scientific projects and the environmental management of future projects. For example, for underwater noise from pile driving of monopiles, monitoring ensures that noise levels do not exceed those estimated in the EIA and approved in the permit. Data collected informs future project assessments and modelling https://www.itap.de/media/orjip_recon-final-report.pdf

- **Non-price auction criteria**: This approach awards auctions to developers proposing the most environmentally friendly wind farms. The auction includes environmental criteria that promote innovation, large-scale mitigation efforts, and monitoring. An example is in the Hollandse Kust West auction (Site VI) in 2023 https://english.rvo.nl/topics/offshore-wind-energy/wind-farm-zone

There are likely advantages and drawbacks to all models, and ideally a mix, tailored to suit the Australian regulatory context could provide an optimal solution. A coordinated research initiative should be sufficiently comprehensive that it provides a knowledge base not only for informing proponent environmental impact assessments, but the cumulative and regional-level impacts associated with developments.

This report has focussed on a range of defined environmental factors, but it is recognised that further research is also needed to broaden the discussion here (largely on impacts on key environmental factors), to consider all aspects of OWFs and potential implications for stakeholders. This includes research and robust approaches to transparently consider and quantify how expected environmental changes might affect marine users (fishers, recreational users, environmental charter operators etc.), interact with adjacent marine parks, and affect the local place identify. This is important both to facilitate informed discussion, but also identify opportunities for adaptive pathways for coastal communities.

As part of this, research is required to better understand the drivers of community engagement and trust in information, and how research elements, such as use of best-practice standards, transparent and FAIR data provision and research independence, interacts with community perceptions and receptiveness to information. Ensuring that research on OWFs is accepted and trusted by local communities and interest groups will be an important component to ensure and build social licence.

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16. Lists of report figures and tables

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17. Appendix A: Developing the inventory and knowledge base

17.1. Seabed and oceanography

17.1.1. Bathymetry

See further detail in Section 3.1. Available bathymetry data can be viewed and downloaded from the AusSeabed Portal or the sources listed therein (https://www.ausseabed.gov.au/), and some of these data can be viewed using web feature services (WFS) and web map services (WMS). Coverage maps include those that indicate the extent of bathymetry data at the time of submission by third party contributors to the AusSeabed data portal. In some areas there has been a delay in processing at AusSeabed, so where possible, contacting local data providers may provide a more comprehensive extent of coverage available, including ancillary products such as backscatter intensity data not currently available via the portal. Summary information presented in this report is available in the associated database Project 3.3 OWF bathymetry-sediments inventory.

17.1.2. Geomorphology

See further detail in Section 3.2. Summary seabed geomorphology overviews presented herein are intended to summarise the breadth of geomorphic diversity and the associated management considerations for each region (A-Table 1); however, these summaries are not exhaustive. More detailed and systematic analyses of higher resolution seabed data and geotechnical analyses will be required to create definitive, standardised marine geomorphology maps (following Dove et al., 2020; Nanson et al., 2023). These analyses will provide important insights into seabed features and processes, including sediment dynamics and seabed stability.

A-Table 1: Geomorphic and geologic units and their potential interaction with OWF infrastructure

Geomorphic units	Potential interactions
Canyons, mass-movement scars, continental shelf breaks, gullies	Potentially unstable and should be assessed for suitability of bottom-fixed OWF infrastructure; sudden mass movements may have turbidity current/tsunamigenic potential.
Canyons and gullies	Conduits for erosive, sediment-laden currents that may impact infrastructure.
Bedforms (e.g. ripples, dunes, plane bed, sediment ribbons, etc.), barforms (drifts, banks), scour holes	Indicate a potentially mobile seabed that may be undergoing morphodynamic change. Emplaced infrastructure may alter sediment transport and downdrift supply (e.g. to the coast), and current energy may interact with infrastructure and cause both sedimentation and scour of the seabed.
Palaeochannels	Substrates may contrast to surrounding seafloor and may act as conduits for submarine groundwater movement.
Submerged beach ridges and dunes	Often form hard, semi-lithified rocky reefs that provide important habitat, and have palaeo-environmental (as relict shorelines) and archaeological potential.

Geomorphic units	Potential interactions
Pockmarks	Indicate fluid or gas escape and represent seabed instability.
Thick accumulations of unconsolidated sediment	Potential instability for bottom-fixed infrastructure and may host gas accumulations; requires investigation of composition and depth to hard substrate.
Beaches and estuaries	New infrastructure may impact oceanographic processes and sediment transport on the shelf, and on- and along-shore, and may impact rates of sediment supply to beaches and estuaries.
Carbonate substrates	Carbonate sediment properties vary (e.g. engineering behaviours of ooid grains and planktonic Foraminifera are fundamentally different: Watson et al., 2019) and carbonate dissolution of drowned karst environments can cause high lateral and vertical geotechnical variability at the seabed (e.g. large voids beneath the seafloor).

17.1.1. Seabed habitats and benthic biodiversity

Across southern Australia, there has been extensive historical and modern collections of benthic imagery over the continental shelf (e.g. Jordan et al., 2010, Langlois et al., 20220; Barrett et al., 2020). There have been a number of developments in recent years to make seabed biodiversity data finable and accessible. In particular, the Australia's Integrated Marine Observing System (IMOS) *Understanding of Marine Imagery Facility (UMI)* provides a marine image data management, discovery and annotation platform, and provides a large repository of openly accessible, georeferenced seafloor images with annotations (https://imos.org.au/facility/autonomous-underwater-vehicles/understanding-of-marine-imagery). It is underpinned by Squidle+, which is a web-based framework that collates information on the deployment of marine image gathering platforms (such as AUVs). The platform indexes imagery from existing cloud storage repositories, enables discoverability of new survey data for various marine image data collection programs, and features a sharing framework that facilitates collaboration between users and external algorithms. These datasets can also be viewed through the Australian marine spatial data portal, Seamap Australia, and data presented in this report reflects the data layers available with Seamap.

The last decade has seen an increasing use of stereo-BRUVs as the primarily tool to collect standardised information on fish abundance, diversity, and size distribution of assemblages from continental shelf habitats. They are also increasingly being used to simultaneously characterise the benthic habitats captured by their imagery within their horizontally facing field of view. More recently, BOSS systems have been found to be an efficient sampling method for benthic assemblages, collecting a wide horizontal field of view of habitats, which can inform construction of broad scale habitat maps at resolutions of 5 m^2 to 250 m^2 (Langlois et al., 2022). Benthic composition annotation from stereo-BRUV and BOSS, and subsequent habitat extent predictions are available through GlobalArchive and can be accessed using the GlobalArchive R package and API call. Towed video and imagery collected by autonomous underwater vehicles (AUVs) or remotely operated vehicles (ROVs) are also widely used for benthic community assessments (including of mobile invertebrates).

In addition, NESP Marine and Coastal Hub Project 2.1 'Improving seabed habitat predictions for southern Australia' used a synthesised open access stereo-BRUV and BOSS benthic annotation data, collected across southern Australia to create robust broad-scale models of 'functional reef' spanning the continental shelf from Shark Bay to Bass Strait. The term 'functional reef' goes beyond the traditional rocky reef definition used in shallow-water mapping projects and is defined here as any seabed area functioning as a reef, which may include dense beds of sessile invertebrates or molluscs.

These broad ecosystem maps, produced using the 250 m resolution national bathymetry product, provide a first pass assessment of habitat extent. Higher resolution bathymetry grids have been developed for some areas, including the Zeehan Marine Park where a 2 m grid supported the development of a seabed geomorphology map (McNeil et al., 2023). A regional 30 m bathymetry grid has also been interpolated for the Bass Strait region using these and higher resolution multibeam data (Beaman, 2022), and was used to develop a marine geomorphology map for the Beagle Marine Park (Nanson et al., 2023). However, the lack of higher resolution seabed data across the majority of the regions limits the reliability of these models at a scale useful to inform management due to the reliance on heavily interpolated existing data sources.

17.1.2. Oceanography

There are some useful public data sources that can employed at the early stages of OWF project design (A-Table 2). It should be noted that, given the sparsity of suitable oceanographic data, virtually all OWF projects will require *in-situ* baseline observations and the below listed public data sources will not be an adequate substitute. This report provides a summary of available oceanographic information within the defined OWF regions assessed.

A-Table 2: Public oceanographic data sources that can inform early stages of OWFs.

Source	Description
AODN	Australian Ocean Data Network led by Australia's Integrated Marine Observing System (IMOS), a resource that aggregates most of the publicly available physical oceanography data for Australia, including IMOS data, such as Ships of opportunity (SOOP), National acoustic telemetry network, National reference stations, ARGO drifter data, ocean gliders, wave buoys and more(https://imos.org.au/data).
CARS	The CARS database (CSIRO Atlas of Regional Seas) provides a gridded climatology of temperature using modern ocean measurements (CSIRO, 2009), from which the strength of stratification may be coarsely estimated in regions of suitable data density.
TPXO8 / 9	Global tidal solutions derived from satellite altimetry which can be used to estimate horizontal current speeds (Egbert and Svetlana, 2002). The performance of this product may be poor in areas of complex bathymetry.
250 m gridded bathymetry	Geoscience Australia bathymetry (depth) interpolated product that covers the entire Australian continental shelf. The AusSeabed (https://www.ausseabed.gov.au/) portal may have additional higher resolution data for particular areas.
MARS sediment database	Seabed sediment samples generally containing particle size distribution information, located as point measurements across the Australian continental shelf (MARS: Geoscience Australia, 2024). Care should be taken interpreting and interpolating sparse data points.
Global model hindcasts	A number of Australian and global hindcast products are available that predict historic atmospheric and ocean variables often back to the late 1980. Examples include the CAWCR wave hindcast (https://www.AusSeaBed.gov.au/) and ERA5 hindcast (https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5).

17.2. Threatened and migratory marine species

17.1.1. Published papers/reports inventory

The project team liaised with DCCEEW and NOPSEMA to compile a list of priority species and species of secondary importance including birds, cetaceans, bony fish, sharks, pinnipeds and marine turtles (A-Table 3).

In total, publications and data were sourced for 100 species (A-Table 4).

Literature on each species were searched for in multiple ways, including i) using the online Species Profile and Threat (SPRAT) database; ii) cross-checking literature from Evans et al., 2024; iii) using Google Scholar with the search term of ‘species Latin name’, ‘species common name’, and “Australia”’; and iv) using the project team’s knowledge (especially relevant for reports). Each publication was looked at by one of the project team to determine (by eye) whether the study locations were within or near the OWF areas. If so, the publication was added to the Project 3.3 OWF species inventory and relevant information was extracted.

The publication was then read to fill in the fields of the inventory which included potential impacts of OWF on species, study location, if the literature had overlap with an OWF area (yes, no, maybe), OWF area of overlap, methodology, and main subject area. Note that publications that were scored ‘no’ as not overlapping with the OWF areas were still included in the inventory for several reasons; i) if the study area was nearby (as determined by eye when the publications were assessed) or was deemed potentially relevant for future OWF areas being proposed; ii) for species where their distribution is not well defined and there may be overlap with OWF areas (e.g. short-finned pilot whale); iii) for cetaceans strandings as they potentially indicated offshore species distributions within the nearby OWF area; and iv) coastal birds as they may use the OWF areas as migration corridors.

The potential impacts of OWF for each species was noted in the species inventory by selecting one or more of; ‘collision with turbines’, ‘habitat change’, ‘trophic cascades’, ‘barrier effects/displacement’, ‘vessel strike/disturbance’, ‘noise disturbance’, ‘light pollution’, ‘electromagnetic field’, and ‘pollution’. The main subject was scored as one of 1: threats/disturbance, 2: distribution/movement behaviour/habitat utilisation, 3: population abundance/density/temporal trends/monitoring, 4: population structure/genetic connectivity/sub-speciation, 5: diet/foraging ecology/feeding behaviour, 6: behaviour, 7: pathogens/disease, 8: physiology.

A-Table 3: Species included in the Project 3.3 OWF species inventory. Inclusion was based on priority (1) species identified by DCCEEW and NOPSEMA in association with the Gippsland declaration area and other species identified by DCCEEW that should be considered as a secondary (2) research priority, other species suggested by research users during the consultation phase of Project 3.3 and those suggested by project team taxa experts. Six other species (black-tailed godwit, Great-winged petrel, blue-winged parrot, green turtle, hawksbill turtle and flatback turtle) were included in calculations of overlap with OWF areas (and depicted maps in summary tables) because the SPRAT distribution or occurrence data overlapped with the OWF area. These species were not included in the initial lists (and so a publications search was not formally conducted for them) as they were previously not thought to be present in the OWF areas under consideration here. Note that some species listed here do not appear in the maps and summary tables due to no calculated overlap found between the species data and OWF areas.

Common Name	Scientific Name	EPBC Act listings	Priority for Gippsland	Suggested by research users	Suggested by project team experts
Birds, shorebirds and seabirds					
Amsterdam Albatross	*Diomedea amsterdamensis*	Endangered, Marine, Migratory	1		
Antipodean Wandering Albatross	*Diomedea antipodensis antipodensis*	Vulnerable, Marine, Migratory			*
Australian Fairy Tern	*Sternula nereis nereis*	Vulnerable	2		
Australasian Gannet	*Morus serrator*	Marine		*	
Australian Gould's Petrel	*Pterodroma leucoptera leucoptera*	Endangered	1		
Australian Lesser Noddy	*Anous tenuirostris melanops*	Vulnerable, Marine			*
Bar-tailed godwit	*Limosa lapponica*	Marine, Migratory	2		
Black-tailed godwit	*Limosa limosa*	Endangered, Marine, Migratory			
Black-browed Albatross	*Thalassarche melanophris*	Vulnerable, Marine, Migratory	2		
Blue Petrel	*Halobaena caerulea*	Vulnerable, Marine			*
Blue-winged parrot	*Neophema chrysostoma*	Vulnerable, Marine			
Bullers albatross	*Thalassarche bulleri*	Vulnerable, Marine, Migratory	2		
Campbell Albatross	*Thalassarche impavida*	Vulnerable, Marine, Migratory	2		
Chatham Albatross	*Thalassarche eremita*	Endangered, Marine, Migratory			*
Crested tern	*Thalasseus bergii*	Marine, Migratory		*	
Curlew Sandpiper	*Calidris ferruginea*	Critically endangered, Marine, Migratory	1		

Common Name	Scientific Name	EPBC Act listings	Priority for Gippsland	Suggested by research users	Suggested by project team experts
Double-banded Plover	*Charadrius bicinctus*	Marine, Migratory			*
Far Eastern Curlew	*Numenius madagascariensis*	Critically endangered, Marine, Migratory	1		
Gibson's Albatross	*Diomedea antipodensis gibsoni*	Vulnerable, Marine	2		
Great Knot	*Calidris tenuirostris*	Vulnerable, Marine, Migratory			*
Great Skua	*Catharacta skua*	Marine			*
Great-winged petrel	*Pterodroma macroptera*	Marine		*	
Greater sand plover	*Charadrius leschenaultii*	Vulnerable, Marine, Migratory			*
Grey-headed Albatross	*Thalassarche chrysostoma*	Endangered, Marine, Migratory	1		
Indian Yellow-nosed Albatross	*Thalassarche carteri*	Vulnerable, Marine, Migratory	2		
Lesser Sand Plover, Mongolian Plover	*Charadrius mongolus*	Endangered, Marine, Migratory	1		
Little penguin	*Eudyptula minor*	Least Concern		*	
Little Tern	*Sternula albifrons*	Marine, Migratory,	2		
Northern Giant-Petrel	*Macronectes halli*	Vulnerable, Marine, Migratory	2		
Northern Royal Albatross	*Diomedea sanfordi*	Endangered, Marine, Migratory	1		
Orange-bellied Parrot	*Neophema chrysogaster*	Critically endangered, Marine	1		
Red Knot	*Calidris canutus*	Endangered, Marine, Migratory	1		
Salvin's Albatross	*Thalassarche salvini*	Vulnerable, Marine, Migratory	2		
Short-tailed shearwater	*Ardenna tenuirostris*	Marine, Migratory		*	
Shy Albatross	*Thalassarche cauta*	Endangered, Marine, Migratory	1		
Swift Parrot	*Lathamus discolor*	Critically endangered, Marine	1		
Soft-plumaged Petrel	*Pterodroma mollis*	Vulnerable, Marine	2		
Sooty Albatross	*Phoebetria fusca*	Vulnerable, Marine, Migratory	2		
Southern Giant-Petrel	*Macronectes giganteus*	Endangered, Marine, Migratory	1		

Common Name	Scientific Name	EPBC Act listings	Priority for Gippsland	Suggested by research users	Suggested by project team experts
Southern Royal Albatross	*Diomedea epomophora*	Vulnerable, Marine, Migratory	2		
Tristan albatross	*Diomedea dabbenena*	Endangered, Marine, Migratory			*
Wandering Albatross	*Diomedea exulans*	Vulnerable, Marine, Migratory	2		
White-capped Albatross	*Thalassarche steadi*	Vulnerable, Marine, Migratory	2		
White-throated Needletail	*Hirundapus caudacutus*	Vulnerable, Marine, Migratory			*
Cetaceans					
Antarctic blue whale	*Balaenoptera musculus intermedia*	Endangered, Cetacean, Migratory	1		
Antarctic Minke whale	*Balaenoptera bonaerensis*	Migratory, Cetacean			*
Bryde's whale	*Balaenoptera edeni*	Migratory, Cetacean			*
Dwarf minke whale	*Balaenoptera acutorostrata subsp.*	Migratory, Cetacean			*
Fin whale	*Balaenoptera physalus*	Vulnerable, Migratory, Cetacean	2		
Humpback whale	*Megaptera novaeangliae*	Migratory, Cetacean	2		
Omuras whale	*Balaenoptera omurai*	Migratory, Cetacean			*
Pygmy blue whale	*Balaenoptera brevicauda*	Endangered, Cetacean, Migratory	1		
Pygmy right whale	*Caperea marginata*	Migratory, Cetacean			*
Sei whale	*Balaenoptera borealis*	Vulnerable, Migratory, Cetacean	2		
Southern right whale	*Eubalaena australis*	Endangered, Cetacean, Migratory	1		
Arnoux’s beaked whale	Berardius arnuxii	Cetacean		*	
Andrew’s beaked whale	*Mesoplodon bowdoini*	Cetacean		*	
Blainville’s beaked whale	*Mesoplodon densirostris*	Cetacean		*	
Common bottlenose dolphin	*Tursiops truncatus*	Cetacean			*
Common dolphin	*Delphinus delphis*	Cetacean			*
Cuvier’s beaked whale	*Ziphius cavirostris*	Cetacean		*	

Common Name	Scientific Name	EPBC Act listings	Priority for Gippsland	Suggested by research users	Suggested by project team experts
Dwarf sperm whale	*Kogia sima*	Cetacean			*
Dwarf spinner dolphin	*Stenella longirostris*	Cetacean			*
Dusky dolphin	*Lagenorhynchus obscurus*	Migratory, Cetacean	*		
False killer whale	*Pseudorca crassidens*	Cetacean	*		*
Fraser's dolphin	*Lagaenodelphis hosei*	Cetacean			*
Gray's beaked whale	*Mesopldon grayi*	Cetacean			*
Hector’s beaked whale	*Mesoplodon hectori*	Cetacean		*	
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Cetacean			*
Killer whale	*Orcinus orca*	Migratory, Cetacean			*
Long-finned pilot whale	*Globicephala melas*	Cetacean			*
Sperm whale	*Physeter macrocephalus*	Migratory, Cetacean			*
Pygmy sperm whale	*Kogia breviceps*	Cetacean			*
Risso's dolphin	*Grampus griseus*	Cetacean			*
Shepherd's beaked whale	*Tasmacetus shepherdi*	Cetacean			*
Southern bottlenose whale	*Hyperoodon planifrons*	Cetacean			*
Southern right whale dolphin	*Lissodelphis peronii*	Cetacean			*
Spectacled porpoise	*Phocoena dioptrica*	Migratory, Cetacean			*
Strap toothed beaked whale	*Mesoplodon layardii*	Cetacean		*	
Striped dolphin	*Stenella coeruleoalba*	Cetacean			*
True’s beaked whale	*Mesoplodon mirus*	Cetacean		*	
Reptiles					
Flatback turtle	*Natator depressus*	Vulnerable, Marine, Migratory			
Green turtle	*Chelonia mydas*	Vulnerable, Marine, Migratory			

Common Name	Scientific Name	EPBC Act listings	Priority for Gippsland	Suggested by research users	Suggested by project team experts
Hawksbill turtle	*Eretmochelys imbricata*	Vulnerable, Marine, Migratory			
Leatherback Turtle	*Dermochelys coriacea*	Endangered, Marine, Migratory		*	
Loggerhead turtle	*Caretta caretta*	Endangered, Marine, Migratory		*	
Pinnipeds					
Australian fur seal	*Arctocephalus pusillus doriferus*	Marine			*
Australian sea lion	*Neophoca cinerea*	Endangered, Marine		*	
Long-nosed fur seal	*Arctocephalus forsteri*	Marine			*
Fish					
Grey nurse shark	*Carcharias taurus (E coast population)*	Critically endangered		*	
Grey nurse shark	*Carcharias taurus (W coast population)*	Vulnerable		*	
White Shark, Great White Shark	*Carcharodon carcharias*	Vulnerable, Migratory	2		
Speartooth shark	*Glyphis glyphis*	Critically endangered			*
Spotted handfish	*Brachionichthys hirsutus*	Critically Endangered			*
Whale shark	*Rhincodon typus*	Vulnerable, Migratory			*
Whites seahorse	*Hippocampus whitei*	Endangered		*	
Red handfish	*Thymichthys politus*	Critically endangered			*
Other					
Cauliflower Soft Coral	*Dendronephthya australis*	Endangered			*
Giant kelp forests of south east Aus	*Macrocystis pyrifera*	Endangered		*	
Seagrass	*Posidonia australis*	Endangered		*	

The literature search was completed in January 2024 and so studies published after this date were not included into the inventory. We focussed on more current publications (~last 10 years) if data sources were numerous, but we also included older publications where data sources were less and in some specific cases such as whaling literature (<1900s) for priority cetacean species (e.g., on blue whales, southern right whales, humpback whales, sperm whales). As such our literature search was not exhaustive. Strandings data were added to the inventory if available, although the strandings were predominantly on the coast and outside of OWF areas. However, stranding data was used to indicate potential offshore species distributions within the nearby OWF areas. Any species for which we did not find any published studies within or near each OWF area was still included in inventory but in the Source column was noted as ‘no Australian studies found’.

A-Table 4: Summary of the marine flora and fauna inventory of priority species and species of secondary importance.

Fauna group	Number of species in inventory	Number of publications in inventory	OWF impacts
Cetaceans	42	175	Noise disturbance, vessel strike, electromagnetic fields, entanglement
Pinnipeds	3	14	Habitat change, barrier effects/displacement, vessel strike/disturbance, noise disturbance, electromagnetic fields
Birds	43	90	Collisions with turbines, barrier effects/displacement, light pollution, noise disturbance/habitat change
Sharks	5	26	Barrier effects/displacement, vessel strike/disturbance, pollution, electromagnetic field, habitat change
Reptiles (turtles)	2	4	Barrier effects/displacement, vessel strike/disturbance, light pollution, pollution, electromagnetic fields
Bony fish	3	3	Habitat change, electromagnetic fields
Cnidarians	1	1	Vessel strike/disturbance/habitat change
Macroalgae	1	1	Habitat change
Thallophyta	1	1	Habitat change
Total	**100**	**330**	

The main impacts thought to be associated with birds included ‘collisions with turbines’, ‘barrier effects/displacement’, and ‘light pollution’. These were chosen because fatalities due to direct collisions with the offshore structures can occur, they may shift away from favoured habitats due to disturbances from operational turbines and related vessel and aircraft traffic, hindrances to preferred movement patterns or migration routes, attraction to artificial resting spots and enhanced food sources resulting from the establishment of new substrate at turbines, including restrictions to fishing at sites, and the potential interference in movement due to light from turbines or vessels/aircraft (Bailey et al., 2014; Best and Halpin, 2019).

The main potential impacts of OWF on cetaceans included ‘noise disturbance’ due to the potential underwater noise effects from construction, vessels and operating, and ‘vessel strike/disturbance’ from known vessel strike collisions with cetaceans (where strikes are likely to go unreported) and/or due to vessel disturbance to the behaviour and/or physiology of animals. Habitat change and barrier effects/displacement resulting from the installation of structures such as wind turbines was another commonly listed potential impact for a number of fauna groups because some species are known to use offshore structures for resting both above (seals and birds) and below (fish, sharks) the surface. In addition, many of these species use structures (pipelines, cable routes, subsea components of OWF) for foraging opportunities and/or these structures may create a barrier to movement or displace species from areas they once used (McLean et al., 2022).

17.1.2. Development of spatial layers from publications

For each publication added to the species inventory, we extracted spatial information including coordinates of the study site(s) and any maps. Coordinates were relevant for deployment for point data such as where BRUVs/PAM equipment might be deployed, and maps were usually provided for surveys and telemetry data for example. If the spatial information was contained in coordinates, those coordinates were entered into the inventory under 'Coordinates of study site' and the coordinates used to create a circular shapefile with a 50 m radius in ArcGIS Pro v3.1.1 (ESRI, 2023) centred on those coordinate locations. If the information was contained in a map, screenshots of those maps were taken and brought into ArcGIS Pro where they were georeferenced using the georeferencing tool. Once georeferenced, a polygon was drawn around the study area and attributed with all the inventory information associated with that study. These polygons were then overlaid with the polygons for the OWF areas and the total area of overlap within each OWF areas were calculated for each fauna group (birds, cetaceans, pinnipeds, sharks, fishes, and reptiles). Details are provided with the inventory file Project 3.3 OWF species inventory.

17.1.3. Compilation of existing, freely available species observation data

To complement spatial data obtained from publications, observation data were also compiled for the priority species (and species of secondary importance) in our inventory from BirdLife Australia, Atlas of Living Australian (ALA), Ocean Biodiversity Information System (OBIS), and Victorian Biodiversity Atlas (VBA). It is to be noted that not all sightings of each species are the result of systematic surveys but are also the result of individual observations from citizen scientists and naturalists and can be biased to areas more commonly used/accessible to these groups such as in areas where boat traffic and human populations are greatest. Given these limitations the observation data should be used as a guide to species presence and absence (i.e. distribution) rather than definitive and the absence of a species in an area may not indicate true absence and species misidentification is possible. Data quality is likely to be better for BirdLife Australia than the other sources and so was treated separately. The database search included the years from the earliest records available (post 1700 for ALA) to 2024. As for the spatial data extracted from publications, the observation data were overlaid with the polygons for the OWF areas and the total area of overlap within each OWF areas were calculated for each species within each fauna group (birds, cetaceans, pinnipeds, sharks, fishes, and reptiles). Details are provided with the inventory file Project 3.3 OWF species inventory.

In addition, for sharks, fishes, and rays we queried open access data from GlobalArchive.org, a repository of stereo-video annotations data. GlobalArchive provides a repository for presence absence, abundance, and body-size information from a range of stereo-video platforms including stereo-BRUV, diver-operated stereo-video (stereo-DOV), and ROV. While anyone can load data into GlobalArchive, there are checks and balances place (e.g. CheckEM), that ensure alignment in data uploaded, identification of data errors, and the onus placed on data owners to address these. Data housed in GlobalArchive is used by the

National BRUVs working group in large synthesis papers, with further QA/QC readily performed to ensure high data standards. GlobalArchive provides full open access to the spatial metadata of all sample records and provides to option of private or public sharing of annotation and summary datasets.

BirdLife Australia

BirdLife Australia data were accessed by submitting a request form on their website (birdlife.org.au) and provided in a .csv format, which was then filtered in R for only the bird species in the inventory. The filtered data was then brought into ArcGIS Pro and plotted in space. All birds inside and within a 10 km buffer of each OWF area were then selected for and assigned an attribute associated with the corresponding OWF. This information was used to calculate the total number of observations for each species of bird within each OWF and recorded in a summary tab in the inventory (OWF overlap tab in the excel spreadsheet).

Atlas of living Australia (ALA) and Ocean Biodiversity Information System (OBIS)

All species in the inventory with OWF overlap were searched for in ALA (ala.org.au) by inserting the scientific name into the search function under “Search and Download Data”. If there were occurrence records available for that species, they were first filtered using the ‘ALA General’ data profile. The filtered occurrences were downloaded using the ‘Full Darwin Core’ download format as a .csv. All ALA records for each species group were then brought into R where the scientific and common names were made equal for each species (e.g., spelling and capitalisation) and then concatenated into a single file for each fauna group. Once combined, these files were saved as .csv files and brought into ArcGIS Pro where, using the same methods as for BirdLife Australia, the observations were first associated with the OWF areas and then the total number of observations for each species was calculated per OWF area, including those observations within the 10 km buffer.

Data from OBIS were downloaded using the *robis* package in R statistics program through the OBIS API. All species in the inventory were selected through the API using the “occurrence” function. Once all species were selected, they were combined into data frames for each species group and saved as .csv files that were brought into ArcGIS Pro. Once in ArcGIS Pro, as with the other datasets, the observations were associated with the OWF areas and the total number of observations for each species was calculated, including those observations within the 10 km buffer.

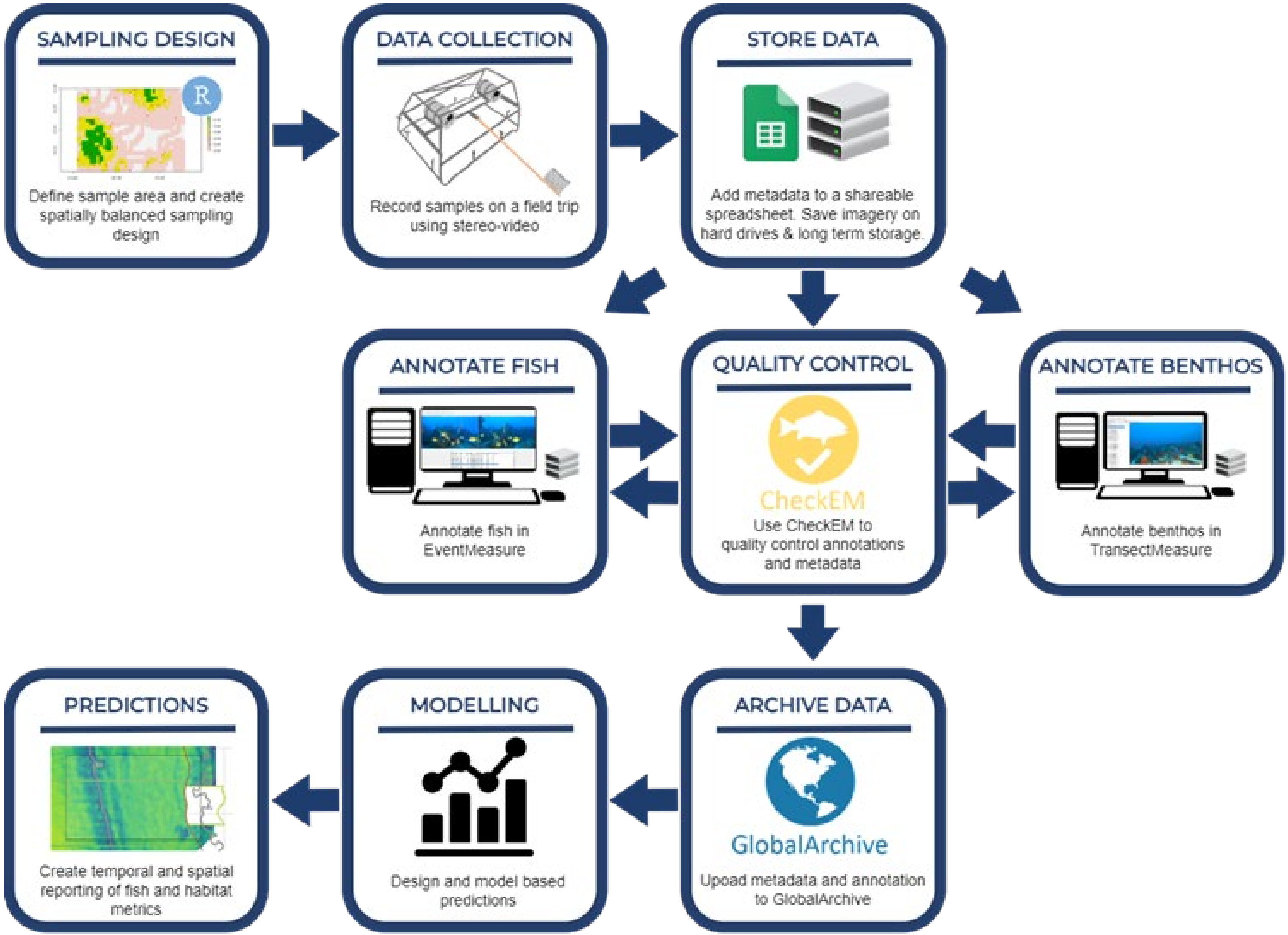
To eliminate double observations, the OBIS and ALA datasets were filtered in ArcGIS Pro to remove coincident observation points that had the same species and date of observation. Once these coincident points were removed, the OBIS and ALA observations were combined within each OWF area to provide a total number of observations for those two databases. BirdLife Australia observations and VBA were presented separately.

Victorian Biodiversity Atlas (VBA)

The VBA data were downloaded from the VBA website (vba.biodiversity.vic.gov.au) as a polygon shapefile that was then brought into ArcGIS Pro. The polygons provided areas for species occurrences within the Victorian coastal waters, which were used to calculate the area of coverage for each species in the inventory within the OWF areas. This was only done for the Bass Strait and Southern Ocean OWF areas since they are the only ones that overlap with the waters off Victoria.

GlobalArchive

Open-access annotation data for sharks, fishes and rays obtained using stereo-BRUV were queried from GlobalArchive using the GlobalArchive R package and API call. Spatial models were constructed for some region using available national scale bathymetry derivatives (after Langlois et al., 2022; A-Figure 1) and used to spatially predict patterns in demersal fish assemblage species richness from the shore to 250 m depth. Prior to data upload into GlobalArchive, data is run through CheckEM to identify errors which must first be fixed. However, if using data directly from GlobalArchive, further QA/QC checks should be performed prior to use. For example, many species have name changes which will need updating for older data.



A-Figure 1: Workflow for stereo-BRUV fish and benthic annotation used to produce spatially prediction of patterns in demersal fish assemblage species richness.

17.1.4 Summarising information and assessment of overall overlap and potential knowledge gaps in species inventory

A scoring system was developed to assist in understanding the level of overlap between areas that species use and the OWF areas (A-Table 5). Area usage for each species was summarised based on the percentage of overlap between the OWF areas and 1) the study areas extracted from the published papers, 2) the area of use defined by VBA and 3. The species distribution downloaded from the Species of National Environmental Significance (SNES) database (also known as SPRAT). Note that the SNES/SPRAT distributions are considered indicative rather than definitive and are produced using modelled and observation data to map the known and predicted areas of occurrence and potential habitat which also includes areas they may occur. In addition, we summed the number of OBIS-ALA and BLA observations occurring inside the OWF areas and summed the number of studies for each species. Each of the values was then given a relative score as per A-Table 3 as low (1), medium (2) or high (3). The scores were then summed to provide a relative overall score of overlap as low, medium and high. When the overall overlap score was low, we determined whether this was actually due to low overlap of the area of species use or whether it constituted data deficiency. To confirm the former for birds, one may refer to the occurrence data in the summary tables for each OWF area for birds. Where overlap was low (red) and bird occurrence is ‘rare’ or ‘vagrant’, it is possible to determine very low occurrence/absence from the OWF area. For other taxa reference to the number of publications found for each species assists in identifying species that may be data/research deficient. Note that VBA observations were only available for the Victorian OWF areas, which may result in higher scores for the Victorian OWF areas.

A-Table 5: Scoring matrix to determine level of overlap as presented in summary tables for each species in each taxa group for each OWF area.

	Low		Medium		High	
	Value	**Score**	**Value**	**Score**	**Value**	**Score**
Overlap with study areas from published papers	<25%	1	25-50%	2	>50%	3
Overlap with VBA	<25%	1	25-50%	2	>50%	3
Number of OBIS/ALA observations	<5	1	5-42	2	>42	3
Number of BLA observations	<28	1	28-131	2	>132	3
Number of studies	≤1	1	2-3	2	>3	3
Overall score all taxa	0-5		6-10		11-15	
Overall score birds only	0-6		7-12		13-18	

For each taxonomic group and OWF region, tables were generated with one row per species. The table fields included common species name, scientific name, family name, occurrence (for birds only - Common, Rare, and Vagrant, Threat (EPBC – Critically Endangered, Endangered, Vulnerable) or other (Migratory, Marine, Cetacean) status if not listed Threatened and the percentage of the OWF area that overlapped with 1. the SNES distribution, 2. the spatial data extracted from published papers in the inventory and 3. observation counts (VBA, OBIS-ALA and others). Details on each species seasonality for each state (WA, Victoria and NSW) is presented for each OWF area noting months in the year when present and absent and when peak occurrence occurs. This information was obtained from the literature and species experts in the project team (K. Sprogis for cetaceans, M. Klaassen for birds, M. Thums for turtles and D. McLean for fish). For seasonality we adopted a conservative approach, only adopting three different levels of occurrence (peak, low, absent), and opting for “peak” only throughout the year where good information was absent but they may be present, notably in the case of critically endangered species, such as e.g. orange-bellied parrot and swift parrot and the toothed whales. The last column of the tables contained the overall overlap as a coloured polygon noting high (green), medium (orange), low (red) overlap. The number of publications overlapping with the OWF area was denoted inside the polygon in the last column to allow for assessment of whether a deficiency in studies exists.

17.3. Environmental impacts from offshore wind farms

A searchable database of publications was created by asking key subject-matter experts within the project group to provide details of reports and information portals they deemed relevant and by conducting a non-systematic search on Google Scholar using combinations of the categories and subcategories for stressors, impact groups and potential responses (i.e. terms in A-Table 6).

Specific details regarding the formation of the database, including categories and sub-categories and their individual descriptions can be found in the instructions page of the inventory (Project 3.3 OWF Impacts inventory). The database was constructed to be explorable by article type, risk focus, project stage/activity, stressor, impact type, response type and impact group. Sub-categories for each searchable category are outlined in A-Table 6. Each cell in the database allowed multiple selections to be included, i.e. removing the need for having a single row for every single combination of stressor, response, and impact group. Each reference occupied only on row and each cell was allowed to have multiple selections for several of the categories, i.e. the database does not have an individual row for every combination of stressor, impact or response type and impact group/sub-group.

The International Union for Conservation of Nature (IUCN) and DCCEEW have separately identified a selection of priority impact types (Bennun et al., 2021, DCCEEW, 2023a), and these were amalgamated and added ‘Cultural Heritage’ and ‘Entanglement’ as two additional impact types of likely importance in Australia. However, these are not exhaustive, and do not encompass all potential effects. We have, therefore, Impact types as defined (and possibly prioritised) by the IUCN and DCCEEW have also been included as columns in the database, in case any user wished to prioritise their search, aligning priority categories with those identified by these two institutions.

To avoid duplication of effort, unless a reference contained information specific to Australia, where possible, references were checked and included here only if they were identified as a high priority or missing from the Tethys knowledge base. The searchable database is designed to give quick and easy access to key publications of relevance to OWF in the Australian context. When no specific information was available, other data that may have been collected for other industries (e.g. O&G fields) was added if it was deemed relevant in terms of region, species, or type of infrastructure.

The value of Project 3.3 OWF Impacts inventory would be increased if it captured information at all levels of the activity-exposure-response relationship; however, this was out of scope and would come at the cost of considerably increased effort. Often, substantial subject expertise would be required in addition to systemised literature searches. The Project 3.3 OWF Impacts inventory of the input of only some subject matter experts, not covering the entirety of impact categories evenly.

For example, inclusion of reports that provide information about characteristics of stressors, how they compare to baseline conditions, and how the species can detect such changes mechanistically, provides a better understanding of how responses vary under different conditions. Such information is essential for quantifying dose-response levels (Pedersen et al., 2009, Tyack et al., 2019). However, to incorporate such level of detail into a holistic impacts inventory, without bias, would require significant effort levels from multiple experts representing each stressor and impacted group of organisms, which was out of scope of this project.

Further, information on specific stressors and response levels may be location and species-specific. For example, in the case of noise, Australia's unique combination of seafloor substrate and marine fauna differ in the propagation of noise and the response thresholds of animals to it, respectively, when compared to other locations. Thus, while some information is transferable from elsewhere, other information requires expert consideration. To illustrate these issues, three short case studies are provided on example topics for which this team has significant expertise; impacts of impulsive noise (e.g., from pile-driving) on receptors; the effect of Australia's substrate on the foundation requirements to install and operate a wind turbine; and the oceanography around monopile wind turbines.

A-Table 6: Searchable categories of the Project 3.3 OWF Impacts inventory. Impact type includes whether this has been identified as a priority by either the International Union for Conservation of Nature (IUCN) or Department of Climate Change, Energy, the Environment and Water (DCCEW).

Searchable category	Sub-categories
Article type	Offshore renewable energy review Topic (stressor) review Research study Report Portal
Risk focus	Identify/characterise Mitigate
Project stage/activity	Exploration Construction Operation Decommissioning
Stressor	Noise (impulsive - acute) Noise (continuous - chronic) Vessel (non-noise) Dredging/scouring/deposition Installed structure Light Restrictions
Impact type	Collison (IUCN, DCCEEW) Habitat loss (IUCN, DCCEEW) Hydrology/Hydrodynamics (IUCN, DCCEEW) Habitat creation (IUCN)

Searchable category	Sub-categories
	Trophic cascades (IUCN) Barrier (IUCN, DCCEEW) Electrocution (IUCN) Vessel strike and avoidance (IUCN, DCCEEW) Noise (IUCN, DCCEEW) Electromagnetic fields (IUCN, DCCEEW) Pollutants (dust, light, solid/liquid waste) (IUCN, DCCEEW) Vessel displacement (IUCN, DCCEEW) Ecosystem service (IUCN) Species introduction (IUCN, DCCEEW) Visual disturbance (humans) (DCCEEW) Cumulative/synergistic impacts (DCCEEW) Cultural heritage Entanglement
Response type	Behaviour Health/mortality Species displacement/attraction or introduction Trophic/Ecosystem Social licence-resources-heritage Geophysical
Impact group Level I	Fauna Flora Human Geophysical
Impact group Level II	Mammals Fish Invertebrates Reptiles Birds Bats Macroalgae Seagrasses Commercial fishers Recreational fishers Traditional owners’ community Local community
Impact group Level III	Odontocetes Mysticetes Pinnipeds Teleosts Elasmobranchs Crustaceans Molluscs Cephalopods Sponges Turtles
Study location	Only provided if is a study specific to an Australian location

17.4. Best practice guidelines

This report provides guidance on monitoring needs for OWF in the Australian context. As large-scale OWF projects are yet to be implemented in Australia, the report does not provide prescriptions on specifics of monitoring needs, but rather identify broad consistent themes across international experience that are important for consideration in the Australian context.

An Australian database of monitoring best practice guidelines relevant to OWF projects was developed (Project 3.3 OWF best practice inventory). Best practice guidelines were identified from the literature. This includes cross searching for guidelines through the OBP repository, and NESP MAC Hub Field Manuals for Marine Sampling to Monitor Australian Waters. Where possible Australian-specific best practice standards were identified (e.g., Magrath et al., 2010). A list of methods considered by topic is provided in A-Table 7, A-Table 8.

A detailed review of the best practice data requirements to support OWF data collection and management is outside the scope of this report, but is guided by the systems (such as the AODN; https://imos.org.au/data) that are already in place.

A-Table 7: Methods for which best practice guidelines were identified.

Topic	Method
Birds	Aerial surveys, Shipboard surveys, Vantage point surveys, Telemetry, Radar, LiDAR and other sensors such as infrared, Animal-borne sensors
Marine mammals	Aerial surveys, Shipboard surveys, Telemetry, Aerial line transects, Digital aerial surveys, Satellite imagery surveys, Passive acoustic monitoring, Satellite tracking, Haul-out surveys, Vantage point surveys, Satellite imagery surveys, Animal-borne sensors, Photo-ID mark recapture, eDNA
Fish, sharks, rays	Benthic baited remote underwater video systems, Pelagic baited remote underwater video systems, Remotely operated vehicles, Autonomous underwater vehicle, Drop camera systems, Underwater visual census, Sleds and trawls, Fishing surveys, Telemetry, Animal-borne sensors, Satellite tracking, eDNA
Benthic biodiversity	Grab sampling, Sleds and trawls, Box corers, Diver observation, Drop camera systems, Sleds and trawls, Fishing surveys, Benthic baited remote underwater video systems, Towed camera systems, Remotely operated vehicles, Autonomous underwater vehicle, Multibeam echosounder, eDNA
Seabed bathymetry	Multibeam echosounder, Aerial Bathymetric Light Detection and Ranging (LiDAR)
Seabed geomorphology	Geomorphology classification
Underwater noise	Hydrophones, Geophones, Accelerometers
Oceanography	Oceanographic moorings, Seabed mounted instrumentation, Ship-based and autonomous (e.g. glider) vertical profiles, Satellite observations Numerical modelling
Traditional Owner engagements	United Nations Declaration on the Rights of Indigenous Peoples. Australian Institute of Aboriginal and Torres Strait Islander Studies. - Principles for Engagement in Projects concerning Aboriginal and Torres Strait Islander peoples. - Code of Ethics for Aboriginal and Torres Strait Islander Research and subsequent guide to applying. Clean Energy Council/KPMG/First Nations Energy Network engagement guidelines. Considerations for Offshore Wind Industry on Community Engagement.

A-Table 8: Summary of best practice guidelines by topic and method.

Topic	Method	ORE specific	Australia specific
Benthos	Box corer	1	1
Benthos	Diver observation	1	0
Benthos	Drop camera systems	2	1
Benthos	Fishing surveys	1	0
Benthos	Grab samples	1	0
Benthos	Grab sampling	3	1
Benthos	Multibeam	3	1
Benthos	ROVs/AUVs	3	2
Benthos	Sleds and bottom trawls	1	1
Benthos	Towed camera systems	0	1
Fish, Sharks and rays	Animal-borne sensors	0	1
Fish, Sharks and rays	Drop camera systems	1	2
Fish, Sharks and rays	Fishing surveys	2	1
Fish, Sharks and rays	ROVs/AUVs	1	2
Fish, Sharks and rays	Sleds and bottom trawls	0	1
Fish, Sharks and rays	Telemetry	0	1
Fish, Sharks and rays	Underwater visual census	1	1
Marine mammals	Aerial surveys	5	1
Marine mammals	Animal-borne sensors	0	1
Marine mammals	Haul-out surveys	1	0
Marine mammals	eDNA	0	1
Marine mammals	Pasive acoustic monitoring	5	1
Marine mammals	Photo-ID mark recapture	1	0
Marine mammals	Satellite imagery surveys	1	1
Marine mammals	Shipboard surveys	5	1
Marine mammals	Telemetry	3	0
Marine mammals	Vantage point surveys	3	1
Microplastics	NA	0	1
Oceanography	Numerical modelling	1	0
Oceanography	Through-water-column moorings	1	0
Seabirds	Aerial surveys	5	1
Seabirds	Animal-borne sensors	0	1
Seabirds	Radar/LiDAR/other sensors	6	0
Seabirds	Shipboard surveys	5	1
Seabirds	Telemetry	2	0
Seabirds	Vantage point surveys	2	0

Topic	Method	ORE specific	Australia specific
Traditional Owner engagements	NA	2	4
Turtles	Aerial surveys	1	1
Turtles	Passive acoustic monitoring	1	1
Turtles	Shipboard surveys	1	1
Underwater noise	Passive acoustic monitoring	1	0

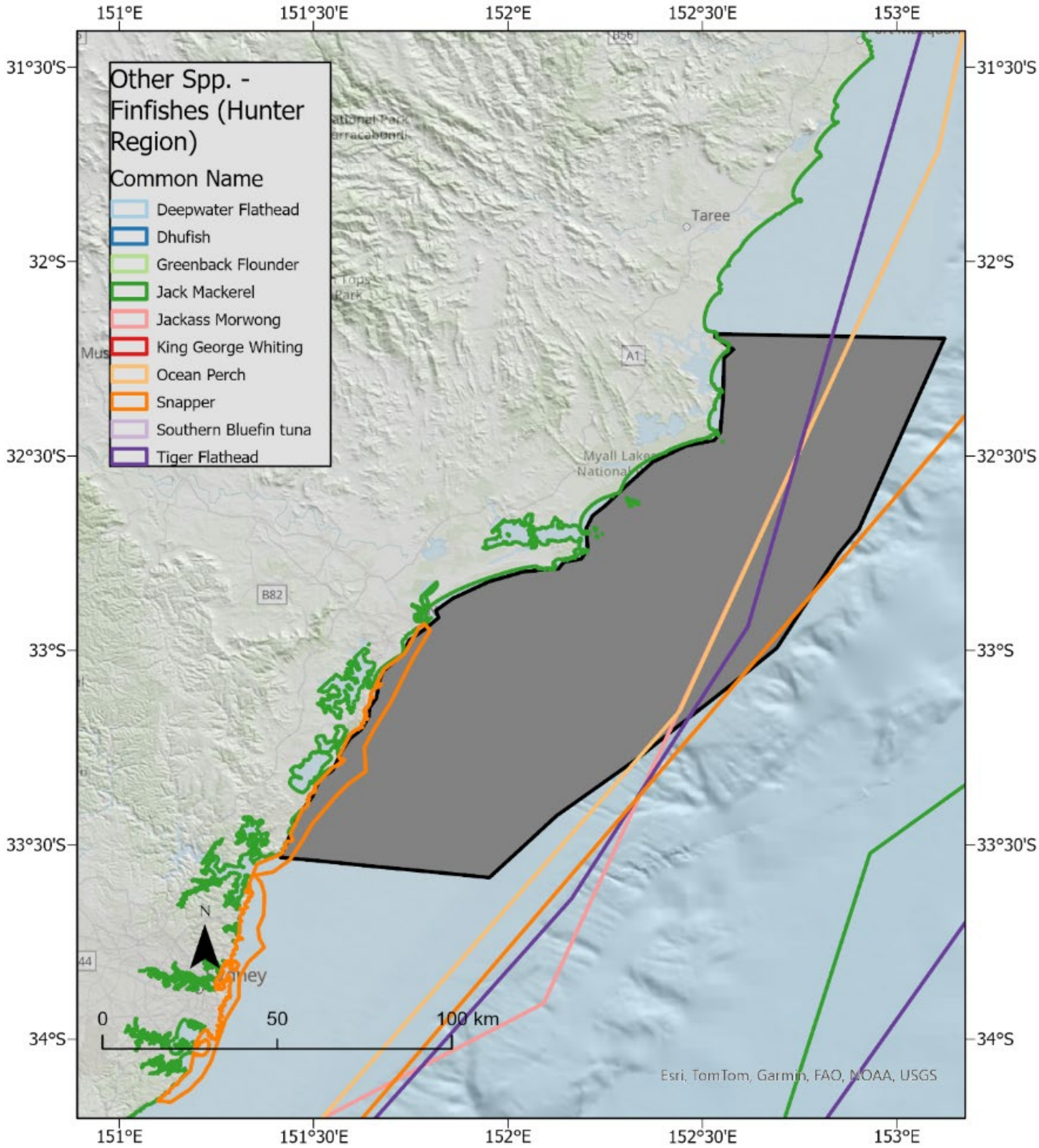
18. Appendix B: Additional species and habitat information

A-Table 9: A summary of introduced pest species that may overlap OWF region.

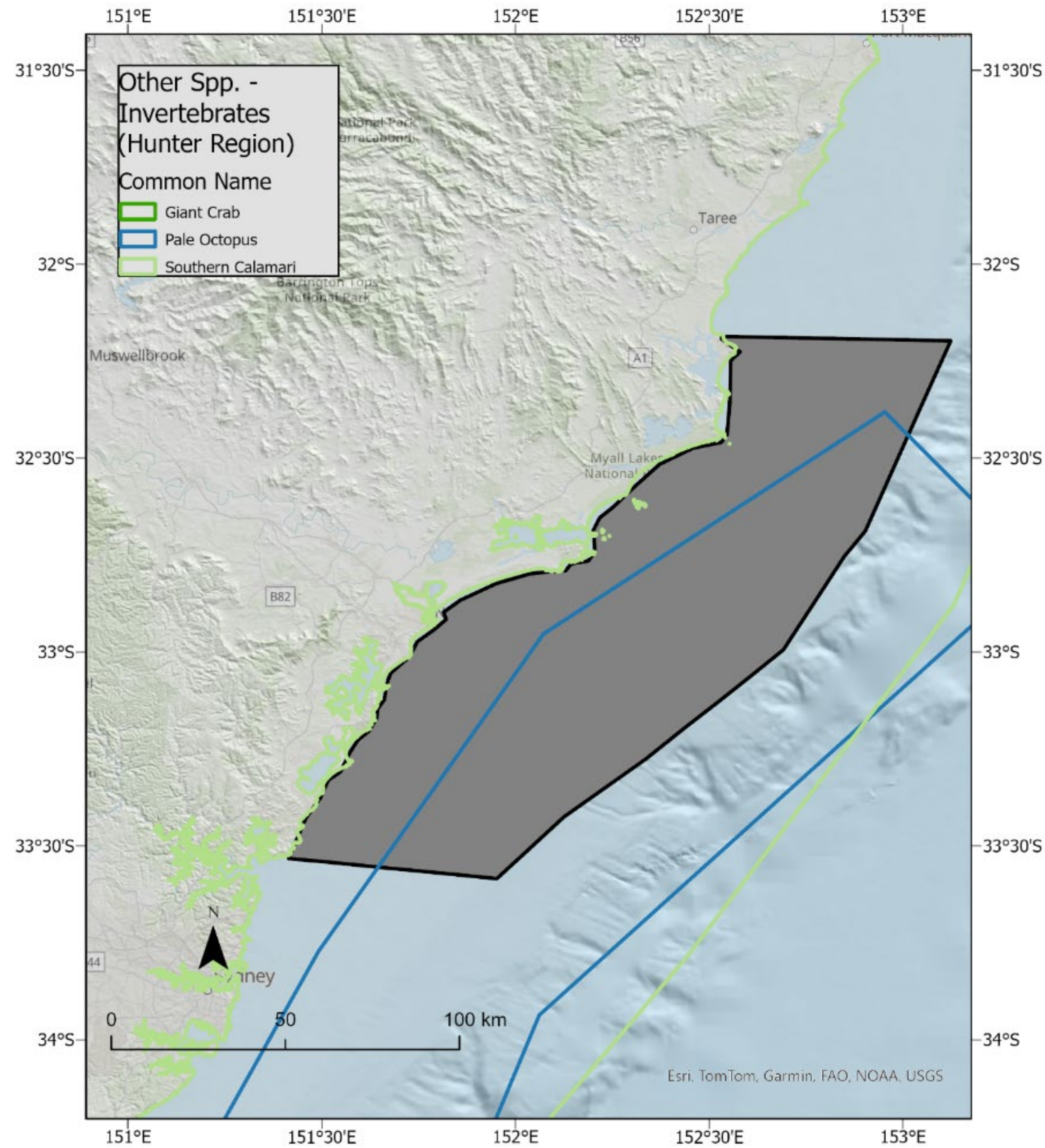
Species	***Scientific name***	**OWF Area it overlaps with**					
		Hunter	**Illawarra**	**Bass Strait, Gippsland**	**Southern Ocean**	**South-west**	**Citation**
Bryozoan	*Amathia distans*	✓	✓	✓	✓	✓	Wells et al. 2009
Bryozoan	*Bugula flabellata*	✓	✓	✓	✓	✓	Wells et al. 2009
Bryozoan	*Bugula neritina*	✓	✓	✓	✓	✓	Wells et al. 2009
Bryozoan	*Schizoporella errata*			✓	✓	✓	Wells et al. 2009
Bryozoan	*Watersipora arcuata*	✓	✓	✓	✓	✓	Wells et al. 2009
Bryozoan	*Watersipora subtorquata*	✓	✓	✓	✓	✓	Wells et al. 2009
Bryozoan	*Amanthia verticillata*	✓	✓	✓	✓	✓	Wells et al. 2009
Acorn barnacle	*Megabalanus rosa*	✓	✓			✓	Wells et al. 2009
Asian shore crab	*Hemigrapsus sanguineus*	✓	✓	✓	✓		https://marinepests.gov.au/pests/identify/asian-shore-crab
European shore crab	*Carcinus maenas*	✓	✓	✓	✓		https://www.marinepests.gov.au/pests/identify/european-green-shore-crab
Northern Pacific sea-star	*Asteras amurensis*	✓	✓	✓	✓		https://www.marinepests.gov.au/pests/identify/northern-pacific-seastar
Hydroid	*Gymangium gracilicaule*					✓	Wells et al. 2009
Aquarium caulerpa	*Caulerpa taxifolia*	✓	✓	✓	✓		https://www.marinepests.gov.au/pests/identify/european-fan-worm

Species	*Scientific name*	OWF Area it overlaps with					
		Hunter	Illawarra	Bass Strait, Gippsland	Southern Ocean	South-west	Citation
Dead man's fingers and oyster thief	*Codium fragile spp. fragile*	✓	✓	✓	✓	✓	Wells et al. 2009
False codium	*Pseudocodium devriesi*					✓	Wells et al. 2009
Forked Grateloup's weed	*Grateloupia imbricata*					✓	Wells et al. 2009
Japanese kelp	*Undaria pinnatifida*	✓	✓	✓	✓	✓	https://www.marinepests.gov.au/pests/identify/japanese-kelp
Aeolid nudibranch	*Godiva quadricolor*	✓	✓			✓	Wells et al. 2009
Asian date or bag mussel	*Musculista senhousia*	✓	✓			✓	https://www.marinepests.gov.au/pests/identify/asian-date-bag-mussel
Bivalve	*Theora lubrica*	✓	✓	✓	✓	✓	Wells et al. 2009
Blue mussel	*Mytilus edulis ssp. planulatus*	✓	✓	✓	✓	✓	Wells et al. 2009
European flat oyster	*Ostrea edulis*					✓	Wells et al. 2009
Hedgepeth's dorid	*Polycera hedgpethi*	✓	✓	✓	✓	✓	Wells et al. 2009
Mudwhelk	*Batillaria australis*				✓	✓	Wells et al. 2009
Nudibranch	*Okenia pellucida*	✓	✓			✓	Wells et al. 2009
Pacific oyster	*Magallana gigas*	✓	✓	✓	✓		Wells et al. 2009
Scallop	*Scaeochlamys livida*					✓	Wells et al. 2009

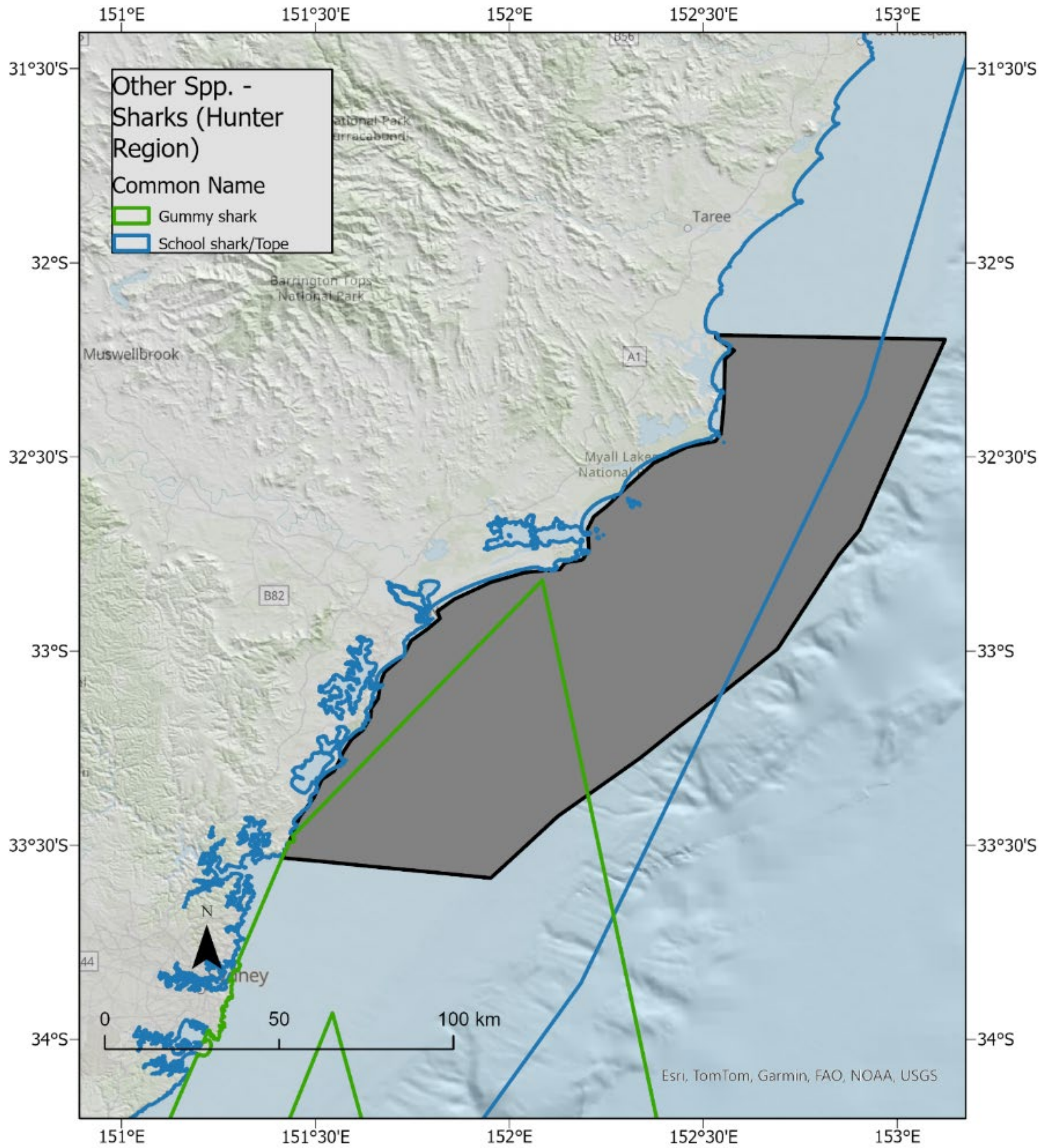
Species	*Scientific name*	OWF Area it overlaps with					
		Hunter	Illawarra	Bass Strait, Gippsland	Southern Ocean	South-west	Citation
European fan worm	*Sabella spallanzanii*	✓	✓	✓	✓	✓	https://www.marinepests.gov.au/pests/identify/aquarium-caulerpa
Slime feather duster worm	*Myxicola infundibulum*	✓	✓	✓	✓	✓	Wells et al. 2009
Colonial ascidian	*Botrylloides leachi*	✓	✓	✓	✓	✓	Wells et al. 2009
Solitary ascidian	*Ciona intestinalis*	✓	✓	✓	✓	✓	Wells et al. 2009
Solitary ascidian	*Styela plicata*	✓	✓	✓	✓	✓	Wells et al. 2009



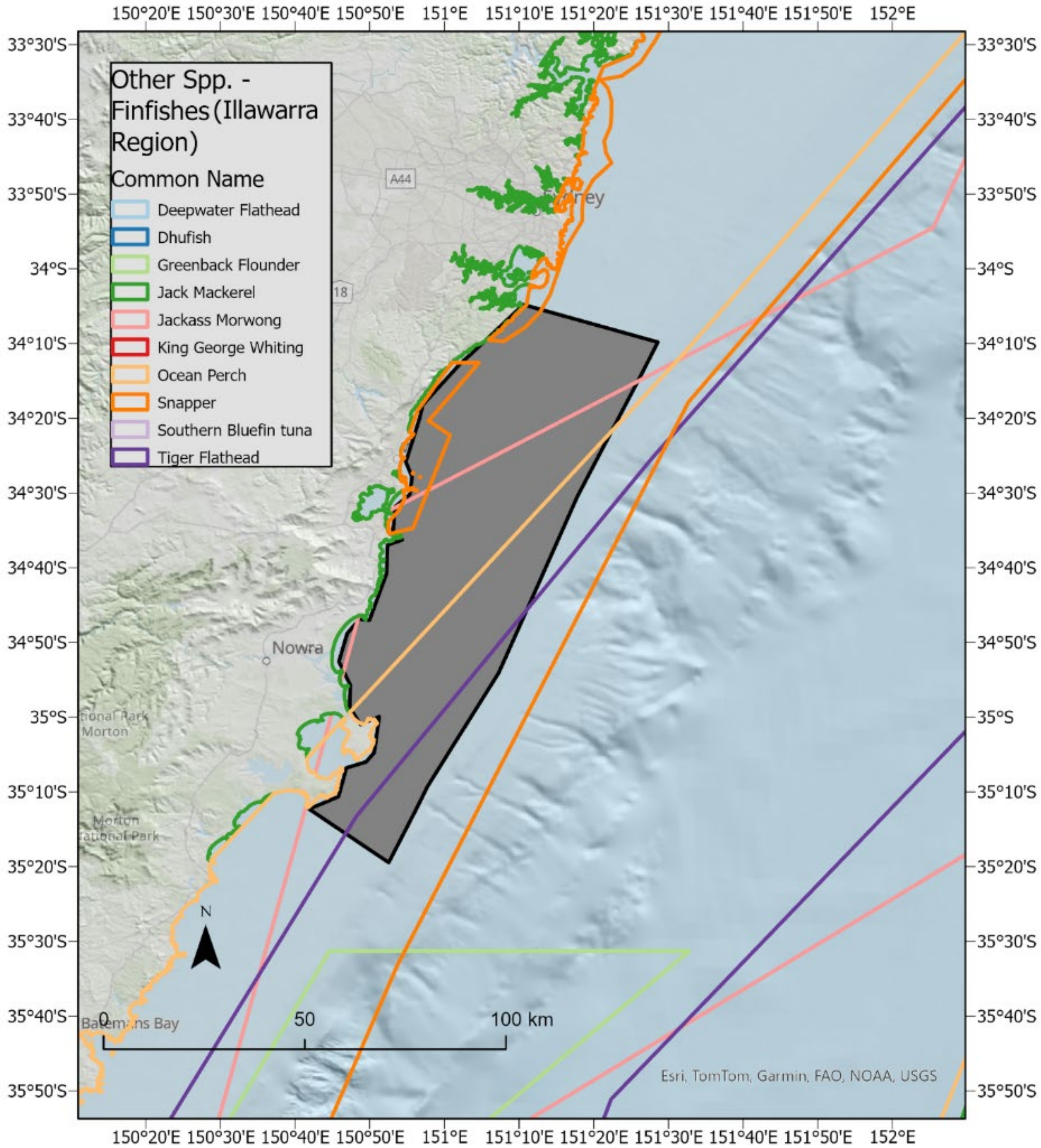
A-Figure 2: Polygons around the Hunter OWF region showing the spatial coverage of the study areas from the publication inventory where finfishes occurred. The different species are represented by the different colours and the grey polygon shows the study region for Hunter OWF development.



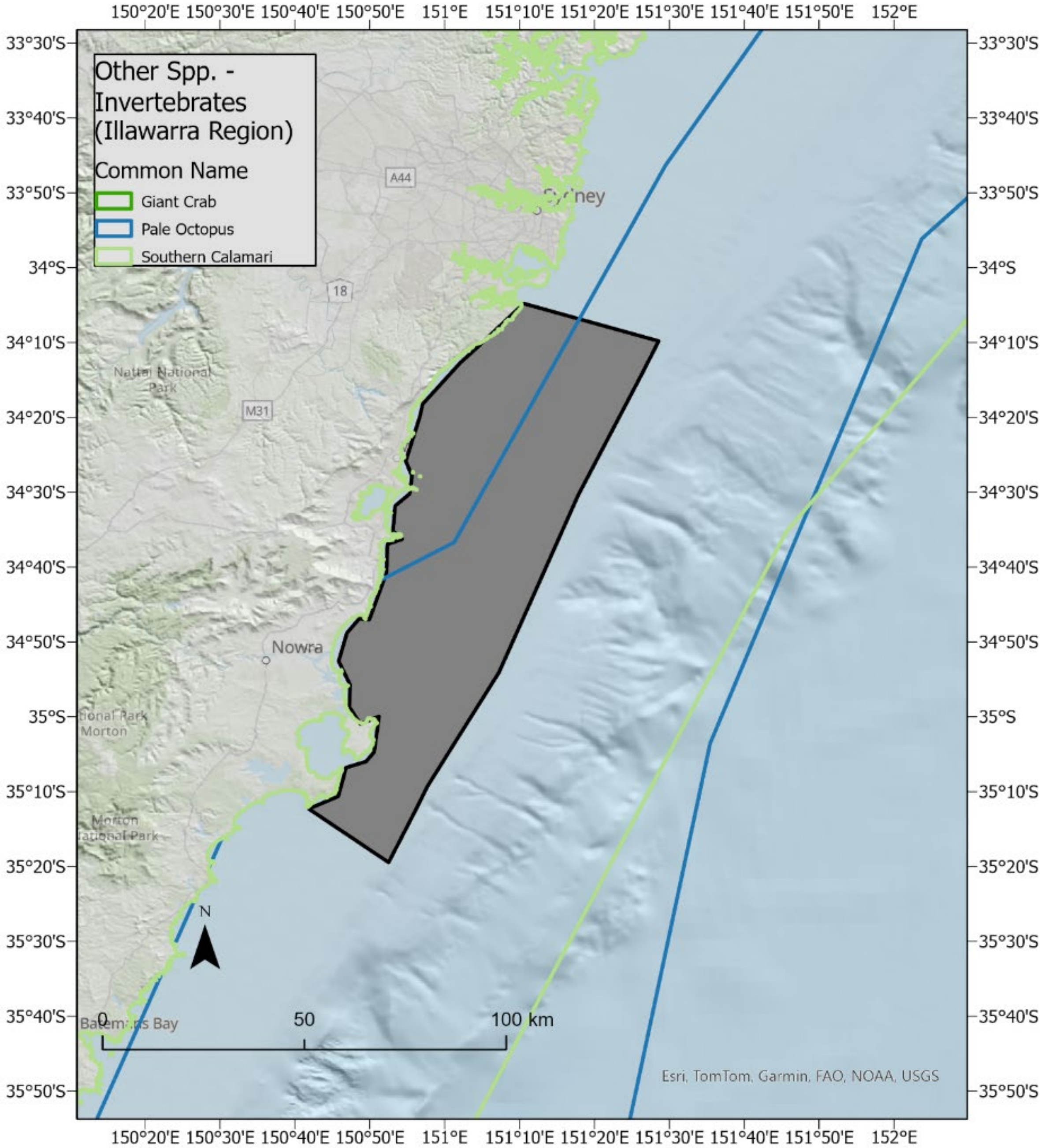
A-Figure 3: Polygons around the Hunter OWF region showing the spatial coverage of the study areas from the publication inventory where invertebrates occurred. The different species are represented by the different colours and the grey polygon shows the study region for Hunter OWF development.



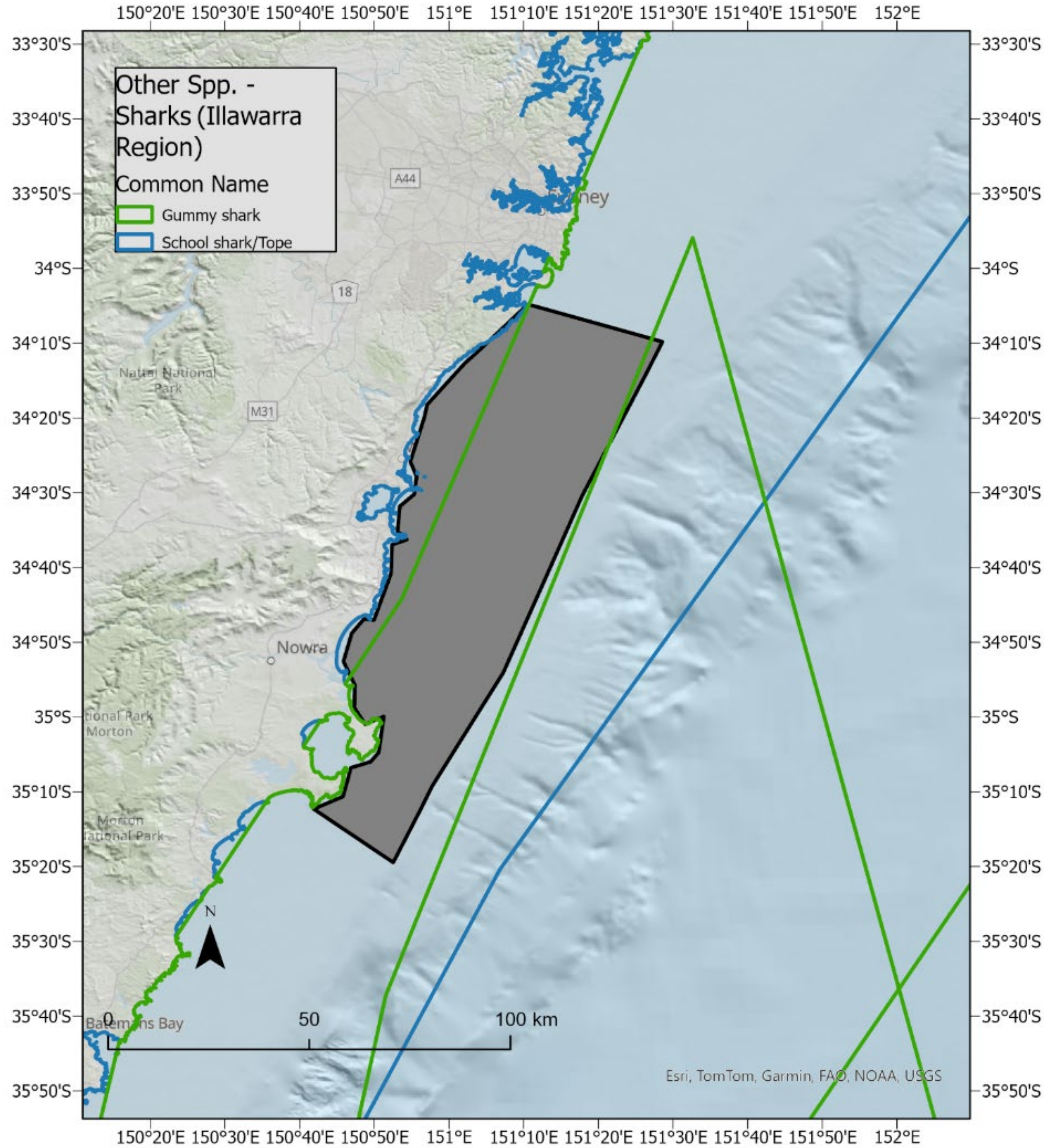
A-Figure 4: Polygons around the Hunter OWF region showing the spatial coverage of the study areas from the publication inventory where sharks occurred. The different species are represented by the different colours and the grey polygon shows the study region for Hunter OWF development.



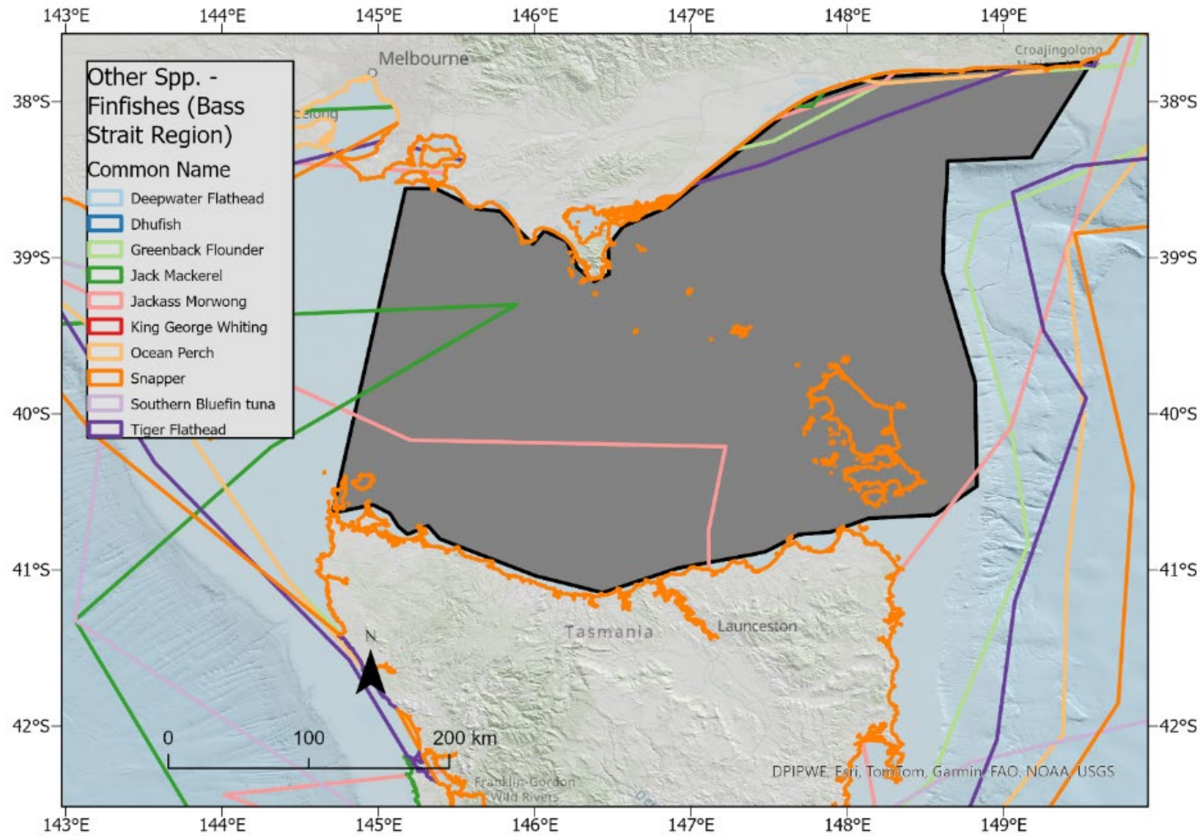
A-Figure 5: Polygons around the Illawarra OWF region showing the spatial coverage of the study areas from the publication inventory where finfishes occurred. The different species are represented by the different colours and the grey polygon shows the study region for Illawarra OWF development.



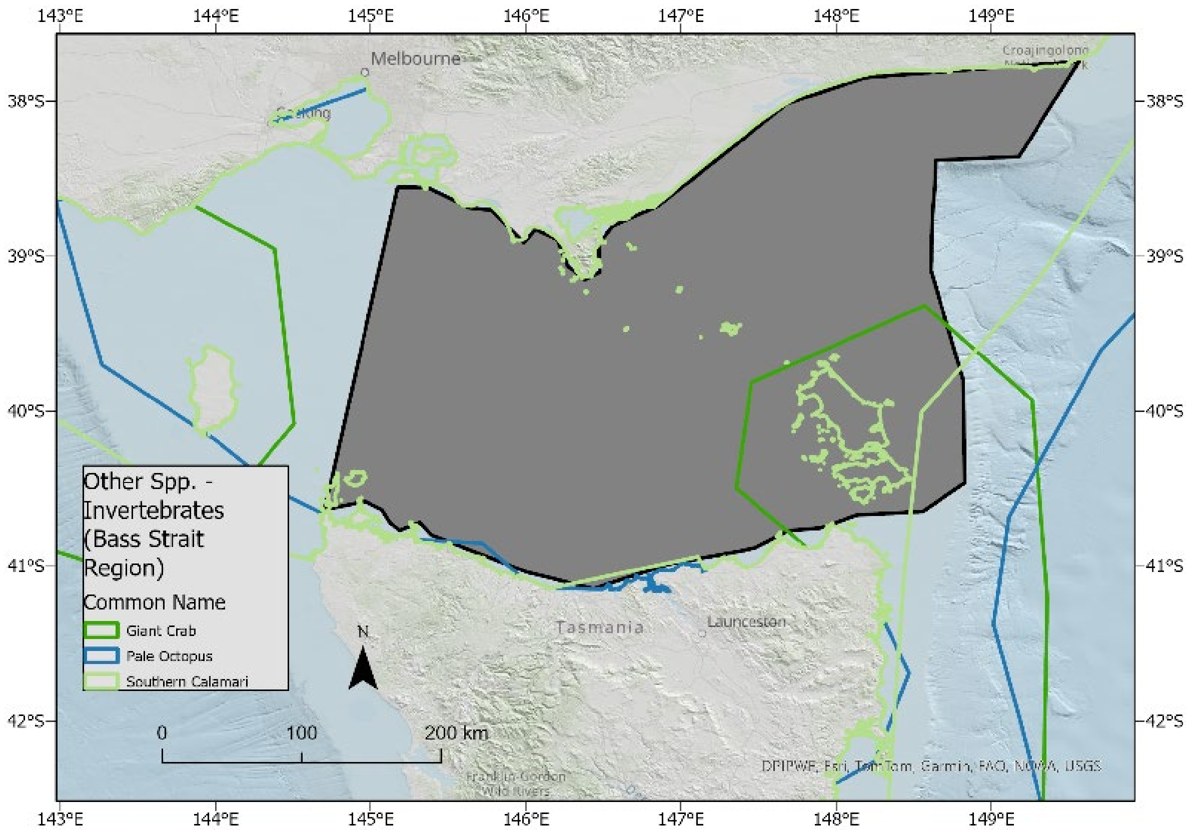
A-Figure 6: Polygons around the Illawarra OWF region showing the spatial coverage of the study areas from the publication inventory where invertebrates occurred. The different species are represented by the different colours and the grey polygon shows the study region for Illawarra OWF development.



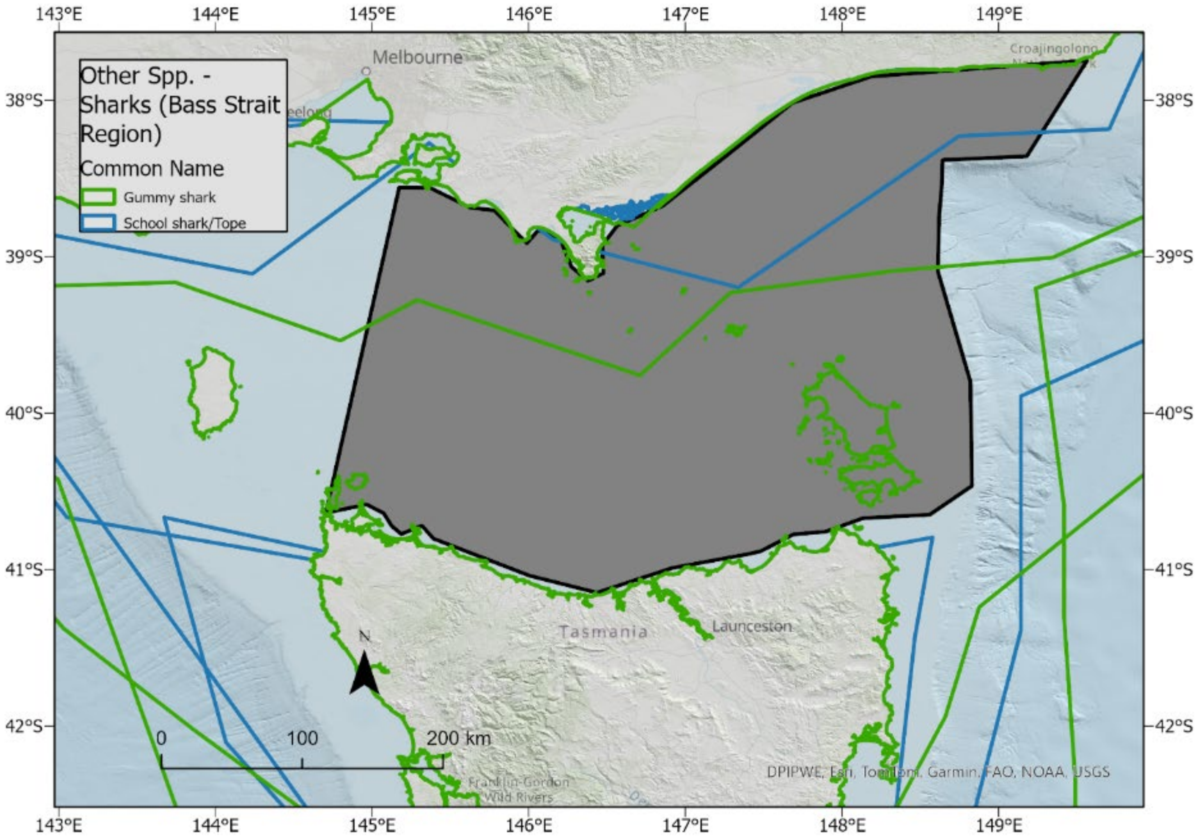
A-Figure 7: Polygons around the Illawarra OWF region showing the spatial coverage of the study areas from the publication inventory where sharks occurred. The different species are represented by the different colours and the grey polygon shows the study region for Illawarra OWF development.



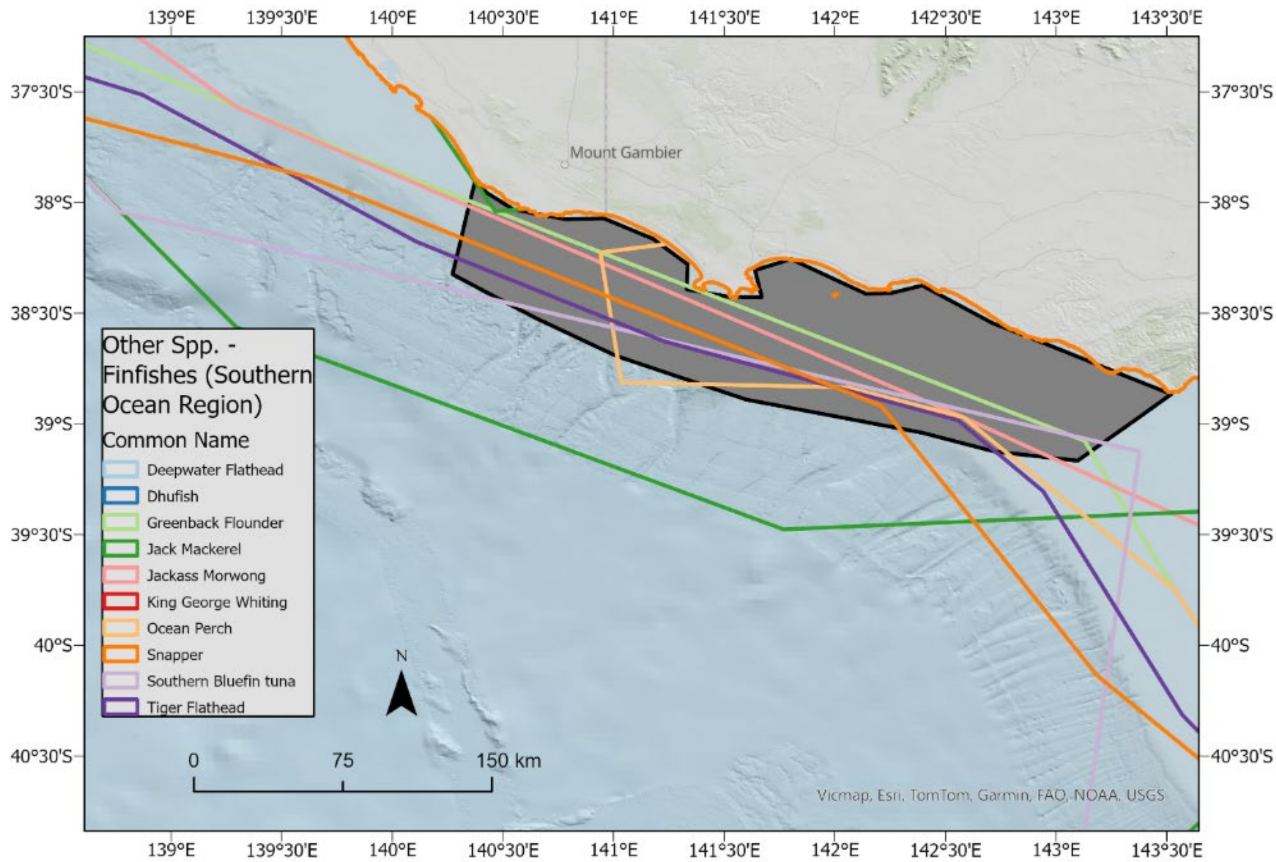
A-Figure 8: Polygons around the Bass Strait OWF region showing the spatial coverage of the study areas from the publication inventory where finfishes occurred. The different species are represented by the different colours and the grey polygon shows the study region for Bass Strait OWF development.



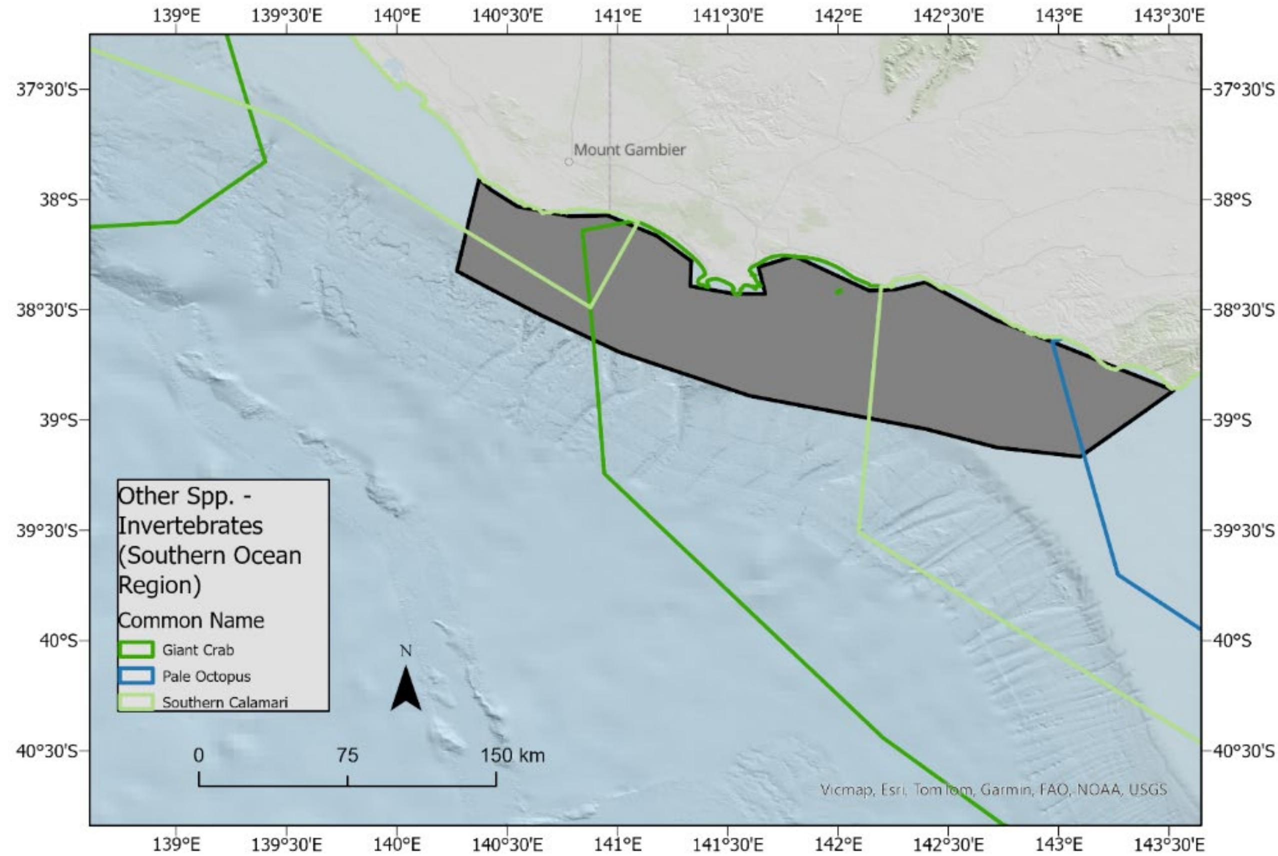
A-Figure 9: Polygons around the Bass Strait OWF region showing the spatial coverage of the study areas from the publication inventory where invertebrates occurred. The different species are represented by the different colours and the grey polygon shows the study region for Bass Strait OWF development.



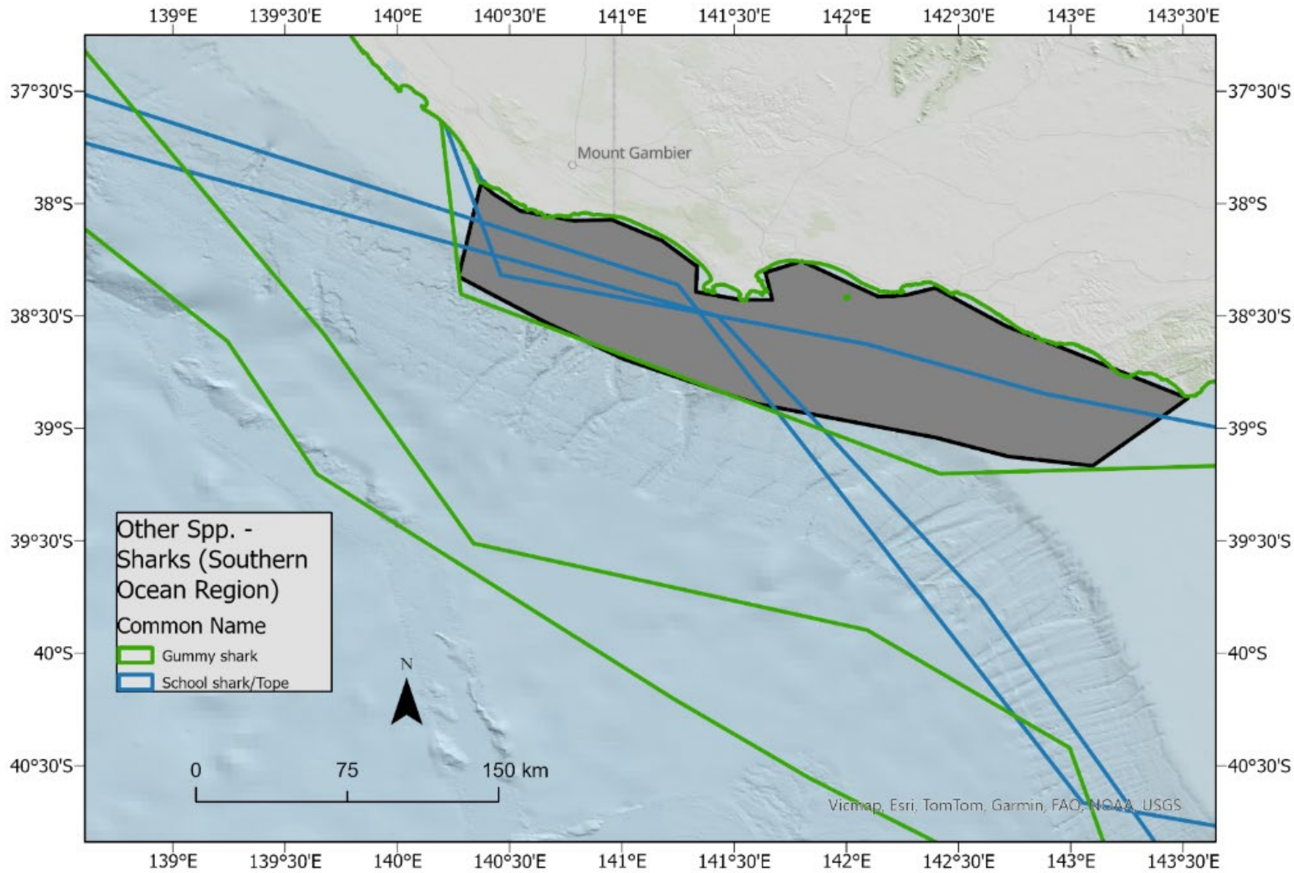
A-Figure 10: Polygons around the Bass Strait OWF region showing the spatial coverage of the study areas from the publication inventory where sharks occurred. The different species are represented by the different colours and the grey polygon shows the study region for Bass Strait OWF development.



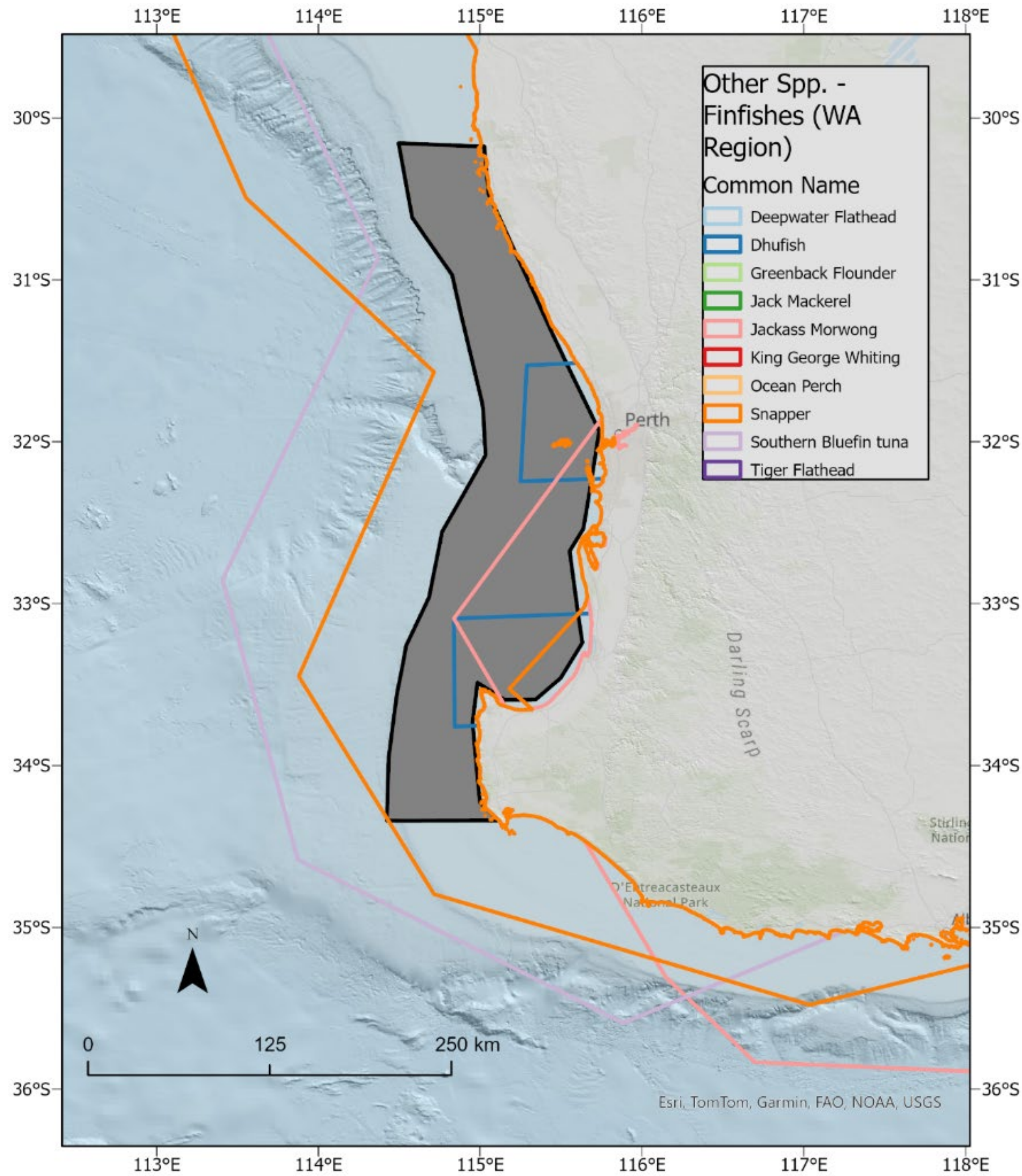
A-Figure 11: Polygons around the Southern Ocean OWF region showing the spatial coverage of the study areas from the publication inventory where finfishes occurred. The different species are represented by the different colours and the grey polygon shows the study region for Southern Ocean OWF development.



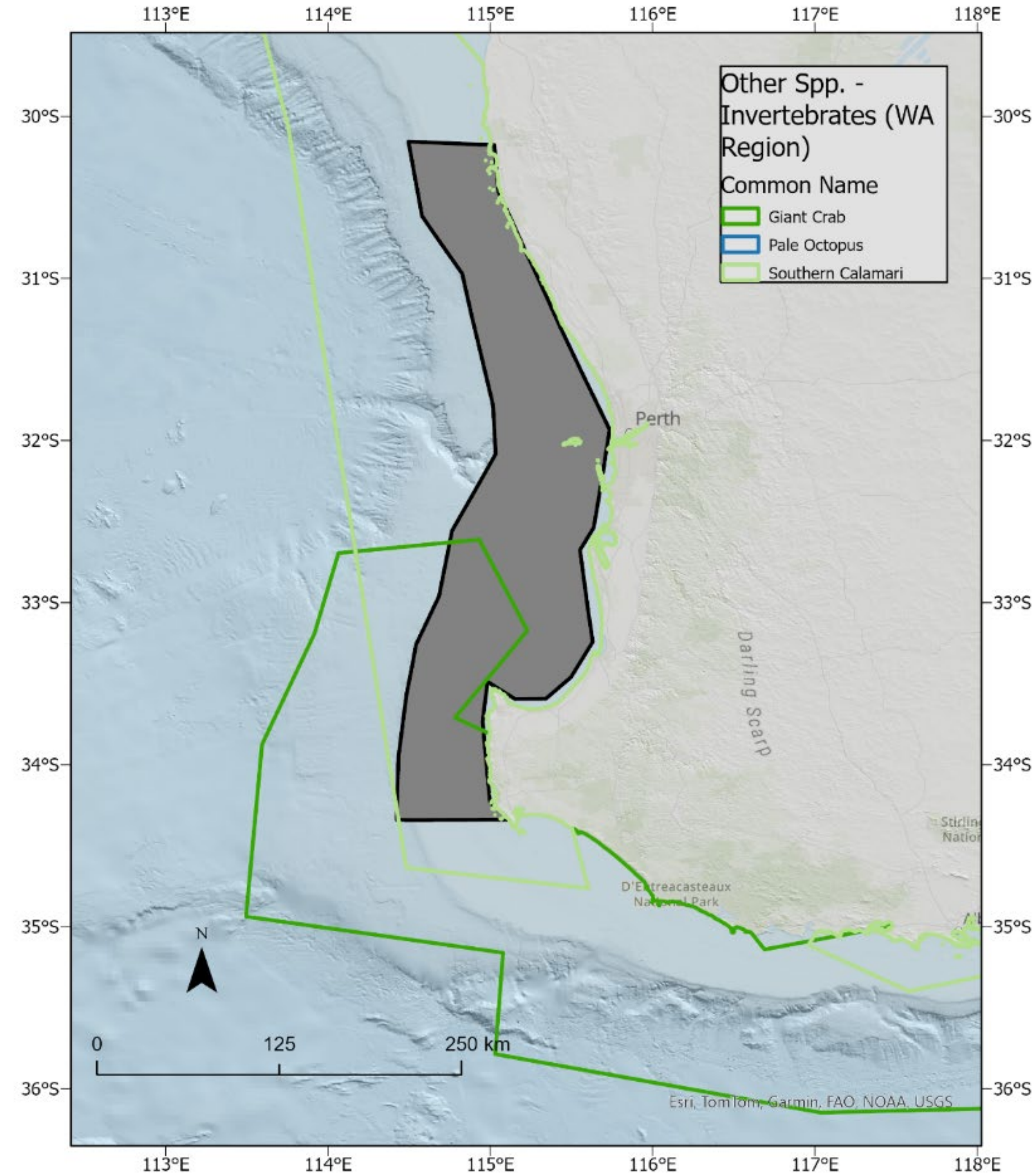
A-Figure 12: Polygons around the Southern Ocean OWF region showing the spatial coverage of the study areas from the publication inventory where invertebrates occurred. The different species are represented by the different colours and the grey polygon shows the study region for Southern Ocean OWF development.



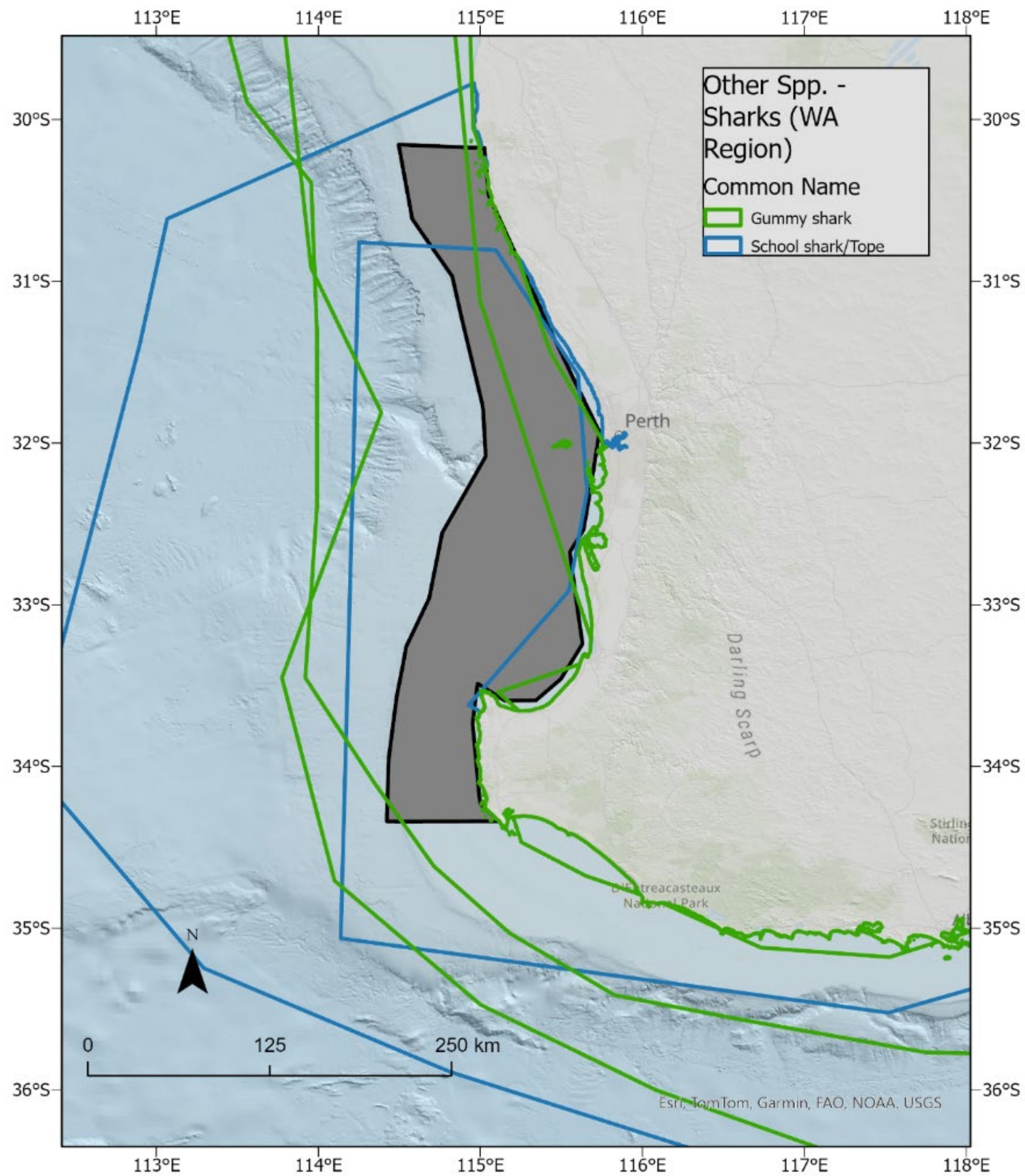
A-Figure 13: Polygons around the Southern Ocean OWF region showing the spatial coverage of the study areas from the publication inventory where sharks occurred. The different species are represented by the different colours and the grey polygon shows the study region for Southern Ocean OWF development.



A-Figure 14: Polygons around the south-west OWF region showing the spatial coverage of the study areas from the publication inventory where finfishes occurred. The different species are represented by the different colours and the grey polygon shows the study region for the south-west OWF development.



A-Figure 15: Polygons around the proposed south-west OWF region showing the spatial coverage of the study areas from the publication inventory where invertebrates occurred. The different species are represented by the different colours and the grey polygon shows the study region for the proposed south-west OWF development.



A-Figure 16: Polygons around the proposed south-west OWF region showing the spatial coverage of the study areas from the publication inventory where sharks occurred. The different species are represented by the different colours and the grey polygon shows the study region for the proposed south-west OWF development.

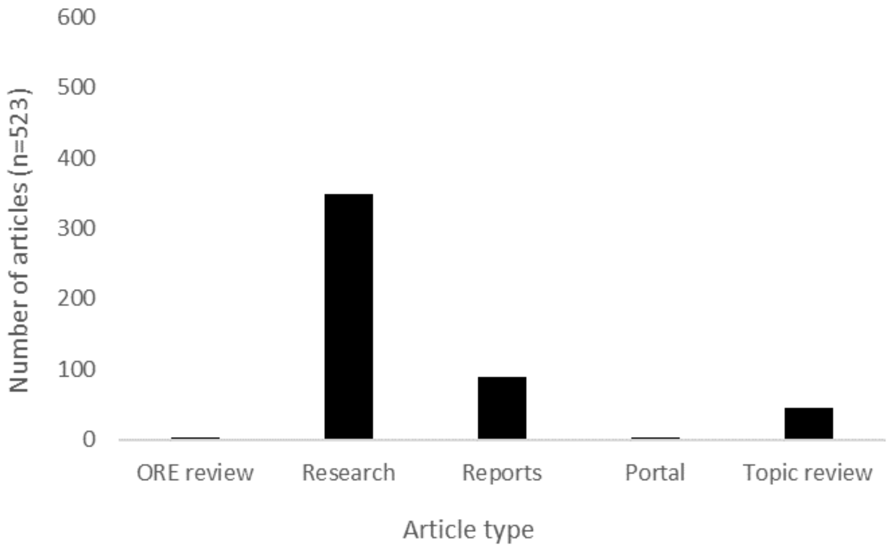
19. Appendix C: Summary of impacts inventory

The following summary provides information on the distribution of references within the Project 3.3 OWF Impacts inventory by subject category. There is inherent bias in the inventory, due to the unequal effort and expertise applied in sourcing and assessing the literature. It should therefore not an exhaustive list and should not be considered a true assessment of where knowledge gaps lie or used to prioritise research focus. We recommend such a full and impartial review be supported as it would be invaluable tool to understanding impact pathways for various receptors.

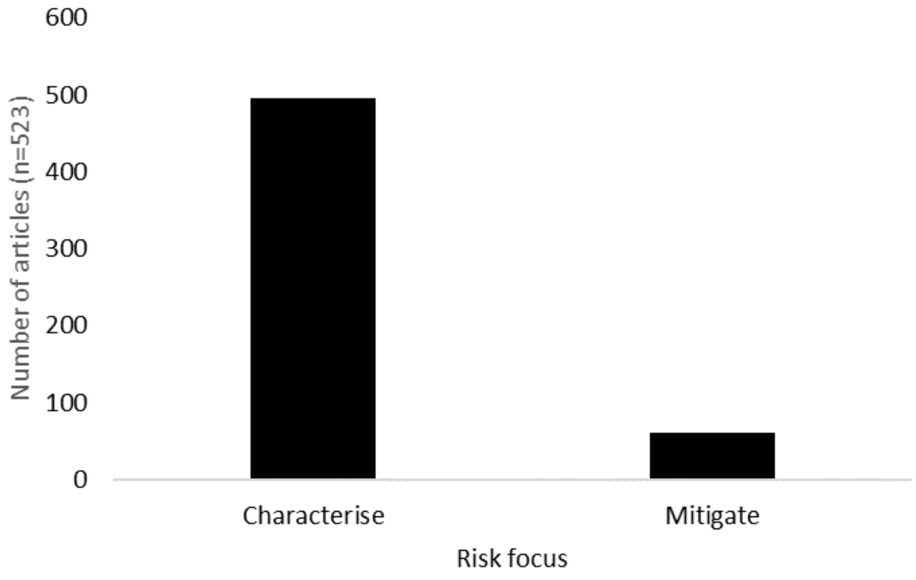
Stressors are unevenly represented in the Project 3.3 OWF Impacts inventory. Since the scope of this study was not commensurate with a systematic literature search, only broad trends in available literature are given here. The interplay of the thematic speciality of those within the project team who compiled the database, and the effort are likely to have affected the results. Still, broad trends in our current knowledge are detectable. The impact of the presence of OWF subsea structures on the seafloor was by far the most frequent stressor described, followed by noise and light (A-Figure 20). Impacts from vessels was the least frequently represented (A-Figure 20, A-Figure 21), but it mostly applies to mobile megafauna which is only a subset of all organisms potentially impacted by OWF development. Dredging, carried out during the exploration and construction phase, and which is known to have an impact (Todd et al., 2015), also represented a minor proportion of all studies in the Project 3.3 OWF Impacts inventory (A-Figure 21). Additionally, the inventory contains only few publications on the effect of restrictions on human activities (e.g., exclusion zones) or other impact of OWF on humans.

The impacts of noise, light, habitat creation/loss constitute the bulk of the references in the inventory. As a concerted effort was made to find literature on noise and pollutant (e.g. light) the prevalence of this topic in the database is explainable (see 'Case Study 1: Baseline information on the impacts of noise'). The frequency of habitat creation/loss publications probably accurately reflects the global research effort to date, along with collision and barrier impacts for vertebrates (A-Figure 21). Impact types such as visual disturbance to humans, species introduction, vessel strike/avoidance and electrocution are the least represented in the database (A-Figure 21), but these proportions could be due to bias originating from the uneven effort in the literature stemming from the time and expertise of the topic experts in the project team (i.e. numbers of papers identified may be biased towards topics of the subject matter experts). For these reasons, note that this inventory should not be interpreted as a knowledge gap analysis and we recommend a full review of all topics (activities, stressors, environments and species-specific responses) and potential impact pathways be conducted to identify where knowledge is lacking and where priority research should be conducted.

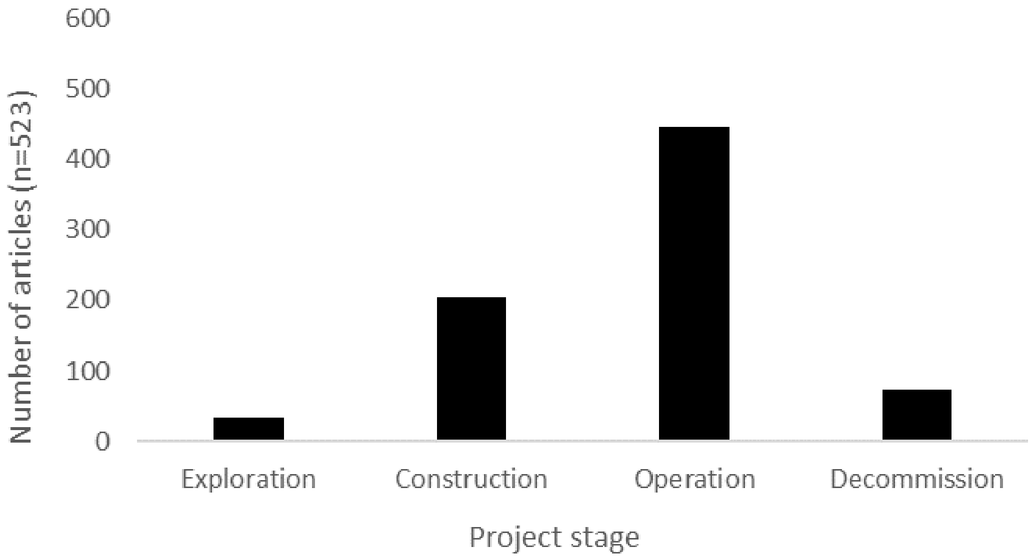
The organism response types most frequently represented in the Project 3.3 OWF Impacts inventory are 'behaviour', animal 'health and mortality' and 'species displacement'. Substantially fewer studies in the database were response types such as 'trophic or ecosystem' responses, 'social licence' or the 'geophysical' dimension (A-Figure 22). This trend is also reflected in the dominance of 'fauna' as the type of organisms most studied for potential impacts by OWF (Impact group 1) (A-Figure 23). Although not all inventory entries were tagged with a more specific impact group (impact group 2) label, the broad trend shows that marine mammals (mysticetes, odontocetes and pinnipeds), fish (teleost elasmobranchs), marine invertebrates (crustacea, cephalopoda, and sessile invertebrates), and birds dominate the database (A-Figure 23), with reptiles much less represented in the inventory (A-Figure 24).



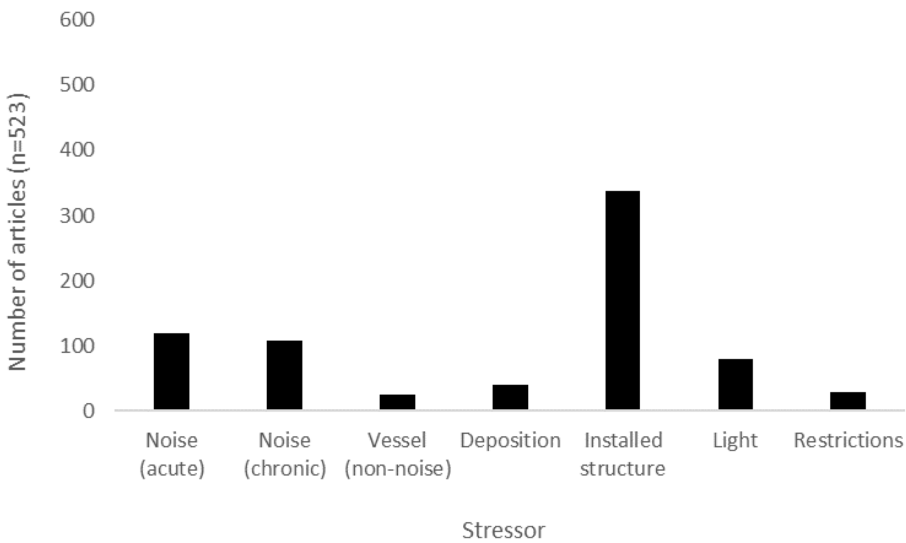
A-Figure 17: Visual summary of the content of the Project 3.3 OWF Impacts Inventory by article type. Note: this is not to be interpreted as equal to research gaps.



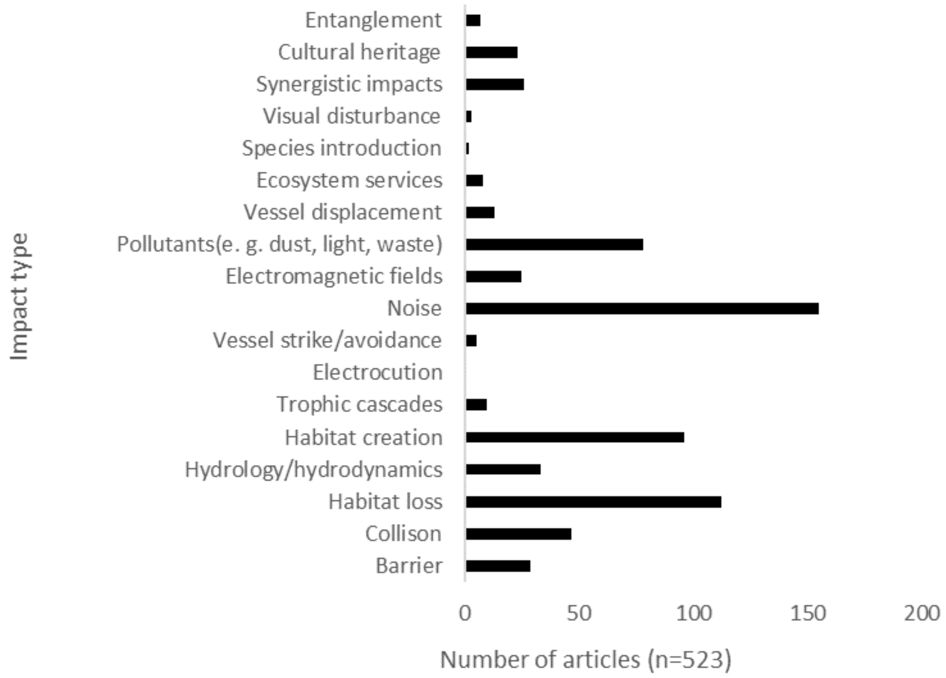
A-Figure 18: Visual summary of the content of the Project 3.3 OWF Impacts Inventory by risk focus showing whether the publication was about characterising or mitigating the impact of OWF. Note: this is not to be interpreted as equal to research gaps.



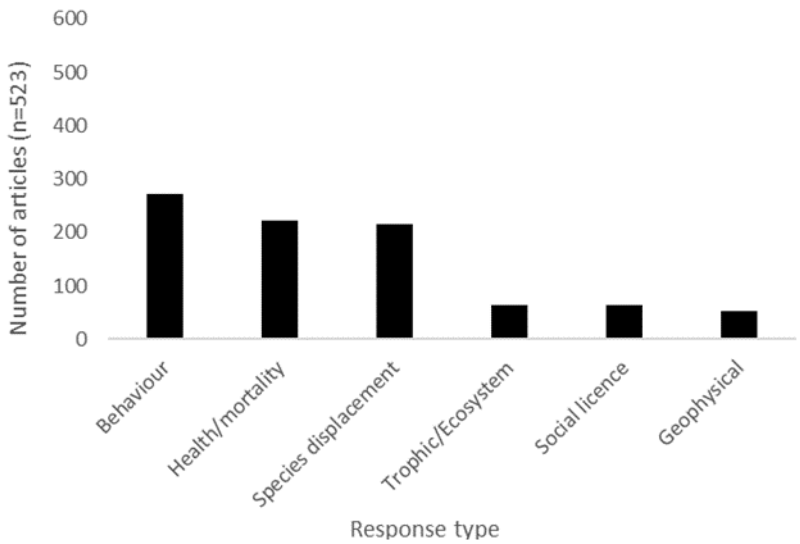
A-Figure 19: Visual summary of the content of the Project 3.3 OWF Impacts Inventory by project stage. Note: this is not to be interpreted as equal to research gaps.



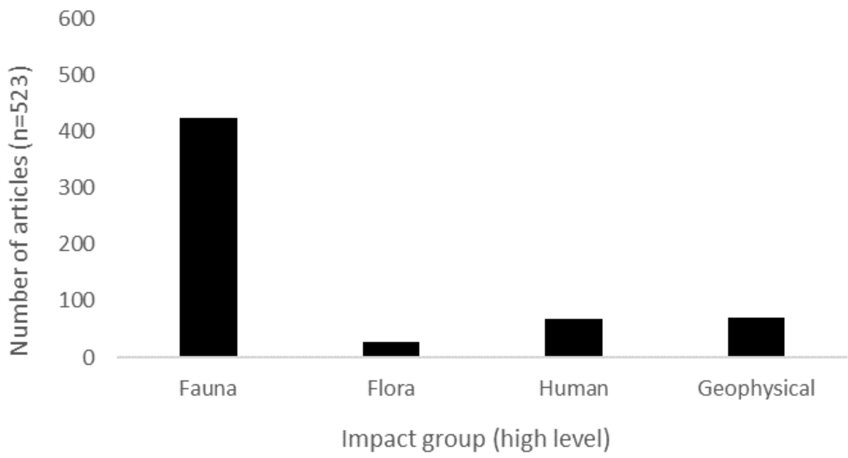
A-Figure 20: Visual summary of the content of the Project 3.3 OWF Impacts Inventory by stressor type. Note: this is not to be interpreted as equal to research gaps.



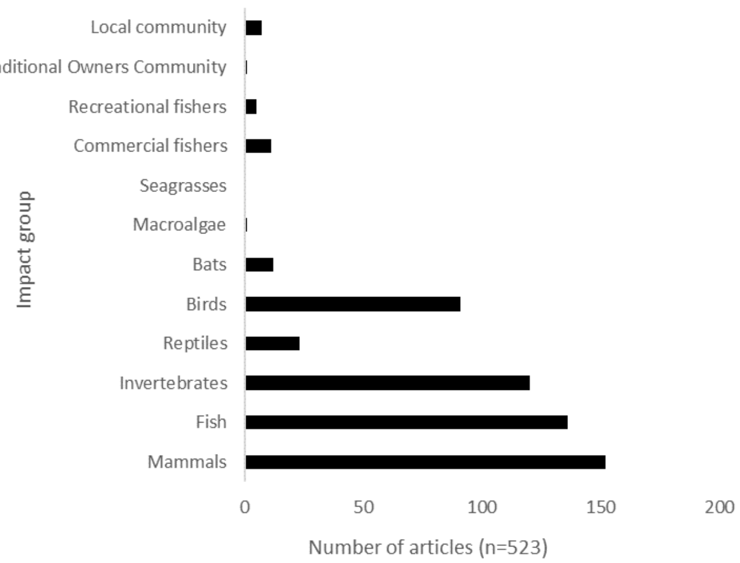
A-Figure 21: Visual summary of the content of the Project 3.3 OWF Impacts Inventory by impact type. Note: this is not to be interpreted as equal to research gaps.



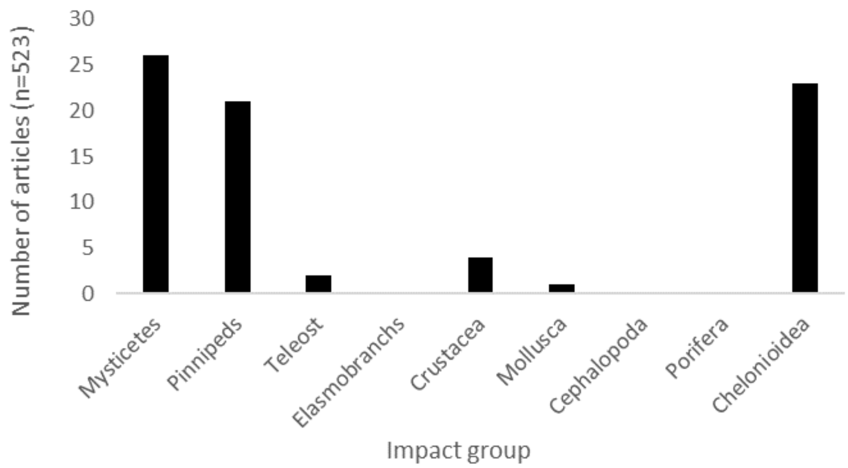
A-Figure 22: Visual summary of the content of the Project 3.3 OWF Impacts Inventory by response type. Note: this is not to be interpreted as equal to research gaps.



A-Figure 23: Visual summary of the content of the Project 3.3 OWF Impacts Inventory by group impacted (high level, corresponding to 'group 1' in the inventory). Note: this is not to be interpreted as equal to research gaps.



A-Figure 24: Visual summary of the content of Project 3.3 OWF Impacts Inventory by broad taxonomic/community groups. Does not apply for geophysical or human impact group (referred to as impact group 2 in the inventory). Note: this is not to be interpreted as equal to research gaps.



A-Figure 25: Visual summary of the content of Project 3.3 OWF Impacts Inventory by deeper taxonomic information on the impact groups. Note: this is not to be interpreted as equal to research gaps.

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