Biodiversity and Ecosystem Health

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Abstract

Australia's marine biodiversity is extraordinary and includes several world heritage areas spanning from Antarctic and sub-Antarctic coasts/islands in the south to Tropical Estuaries in Kakadu National Park in the north. The Australian population is concentrated on the coasts, which places increasing pressure on coastal and offshore ecosystems for our economic, cultural and social wellbeing. Despite being world leaders in marine science, there are substantial gaps in our knowledge of marine biodiversity and how biodiversity responds to uses and pressures - with some marine ecosystems degraded or depleted because of human activities. Understanding the status and trends for marine biodiversity and ecosystem health, and how they change with different uses and pressures will be a key challenge over the next decade. Equipping decision makers with the tools to improve extent, condition and abundance will become increasingly important. Over 80 marine species and communities are listed as threatened under the EPBC Act. In addition, kelp, seagrass, mangrove, coral reef and temperate rocky reef ecosystems across the national estate have suffered catastrophic declines due to increasing ocean temperatures and extreme events, indicating the urgency of this challenge. Scientific and Indigenous Knowledge used to manage these pressures and improve status will be key to meet local and regional needs. Research activities and investments should focus on ensuring that there is appropriate and sufficient information to inform decisions, including information on ecosystem health, distribution, abundance, population structure, population trends, habitat requirements and key pressures on species and marine biodiversity. The management and protection of biodiversity and ecosystem health has three main challenges: Monitoring (how can we measure the status of biodiversity and ecosystem health?), Assessment (is

the status of biodiversity and ecosystem health changing?) and Response (how can we ensure that change is in the direction we want?).

Relevance - Societal Benefits

Healthy marine ecosystems and their associated biodiversity support industries, productivity of coasts and oceans, resilience to climate change and other disturbances, culture and communities. Climate change and human activities apply pressure to marine ecosystems and their biodiversity that can diminish the societal benefits delivered by marine ecosystems. This white paper elaborates the need for targeted research and development (R&D) to support evidence-based policies and actions to enhance marine biodiversity and ecosystem health that benefit government, industry, Indigenous people, and all stakeholders. This white paper highlights the importance of research and development (R&D) focussed on safeguarding and enhancing marine biodiversity, including taxonomic, genetic, functional, and community diversity, for sustaining fisheries, aquaculture, recreation, tourism, and coastal economies. Effective engagement of the wide range of stakeholders' dependent on marine biodiversity, incorporating Indigenous Knowledge, and long-term monitoring are crucial for achieving these goals. The success of biodiversity conservation R&D efforts can be measured through policy adoption that sustains biodiversity, conservation outcomes including improvements in the extent and condition of marine ecosystems, recovery of threatened species and component biodiversity and increased Indigenous governance in marine management. Critically, all these success measures require monitoring outcomes for biodiversity, making monitoring an essential pillar of R&D.

FIgure 1. An illustration of the benefits provided by the oceans. (*Source NOAA and AIMS 2024*).

Australia's coasts and oceans provide an estimated $25 billion worth of ecosystem services, including carbon dioxide absorption, nutrient cycling, fisheries production, and coastal protection. Ocean industries contribute $118.5 billion and 462,000 jobs to Australia's economy each year with this continuing to grow (AIMS Index of Marine Industry, 2024).

The R&D proposed in this white paper is valuable for a wide range of participants and stakeholders (Table 1). Overall, managing and protecting biodiversity benefits everyone by ensuring a healthier environment supporting economic activities, and enhancing the resilience of ecosystems to climate change and other pressures.

Table 1. Key Participants influenced by marine biodiversity and the health of marine ecosystems and the benefits they derive from R&D that supports healthy marine ecosystems.

Key Participant	Benefits of R&D to stakeholders	Indicators of benefit delivery • *How would you know that these benefits have been delivered?* • *Indicators of benefit delivery and verification methods*

Policy Makers and Government Agencies:	• To develop and implement evidence-based policies for biodiversity conservation and ecosystem management. • To ensure that conservation efforts align with national and international commitments, such as the Sustainable Development Goals (SDGs), Convention on Biological Diversity (Kunming-Montreal Global Biodiversity Framework), United Nations Framework Convention on Climate Change, the Ramsar Convention, and others.	• Integration of research outputs into new or updated marine biodiversity policies, plans or regulations. • Alignment of national policies with international agreements (e.g., progress reports on SDGs, CBD, UNFCCC, Ramsar, Kunming-Montreal targets). • Creation or refinement of marine protected areas or biodiversity repair schemes informed by R&D. • Uptake of national ecosystem accounts that include marine biodiversity metrics.
Environmental and Conservation Organizations:	• To prioritize conservation efforts and allocate resources effectively. • To design and implement monitoring programs that measure the impact of conservation initiatives.	• Use of R&D outputs in conservation planning tools or prioritization models. • Implementation of monitoring frameworks that reflect best-available science. • Partnerships formed between researchers, NGOs and other organisations for project co-design and impact assessment.
Researchers and Scientists:	• To conduct targeted research and development that supports biodiversity conservation. • To integrate Traditional Ecological Knowledge	• Growth in interdisciplinary and collaborative projects, especially those integrating Traditional

	with contemporary science for enhanced conservation and restoration outcomes.	Ecological Knowledge (TEK). • Uptake of research in applied contexts (e.g., used and cited in management or industry reports).
Indigenous Communities:	• To ensure that Indigenous perspectives and knowledge are incorporated into conservation practices. • To enhance Indigenous governance and leadership in marine management.	• Increased leadership roles of Indigenous people in marine management or co-governance. • Documentation and application of TEK in marine plans and strategies. • Investment in Indigenous-led monitoring, restoration, or education programs.
Industries and Businesses:	• To understand and incorporate benefits of biodiversity conservation for sectors such as fisheries, aquaculture, tourism, and renewable energy. • To develop sustainable practices that support long-term economic and environmental health. • Discovery of novel genes, products and processes that could be commercialised. • Develop methods that could enhance biodiversity	• Uptake of biodiversity-friendly practices (e.g., low-impact fishing gear, nature-positive tourism). • Growth in blue economy innovations linked to biodiversity (e.g., bioprospecting, restoration-based industries, carbon and biodiversity markets). • Inclusion of ecosystem service values in business risk assessments or Environmental, Social, and Governance (ESG) reporting.

Local Communities	• To benefit and see value from the societal and economic advantages of healthy ecosystems, such as food security, coastal protection and climate adaptation, and cultural benefits. • To engage in conservation efforts and support policies that protect biodiversity.	• Improved ecosystem services (e.g., fish stocks, coastal protection) in community-managed areas. • Community participation in citizen science and stewardship programs. • Perceived benefits through cultural, social, and economic lenses.
Educational Institutions:	• To educate students and the public about the importance of biodiversity and ecosystem health. • To promote awareness and understanding of conservation practices in the ocean and their benefits.	• Enhancement of University curricula teaching for marine biodiversity • Public engagement programs, such as exhibitions, talks, and citizen science events. • Increased enrolment (student FTE) and graduation rates in marine and environmental sciences.
International Organizations and partners	• To share best practices and collaborate on global biodiversity conservation initiatives, including monitoring. • To support coordinated efforts to address pressures like climate change, and pressures on biodiversity, including habitat loss.	• Joint initiatives and shared databases or tools (e.g., global marine biodiversity observing systems). • Harmonized reporting and shared learning from Australian case studies.

		• Contributions to international assessments and policy dialogues and development.

Current R&D on marine biodiversity and ecosystem health are widely used (e.g. by state and commonwealth governments for marine estate management, planning of marine protected areas, and by industry to secure sustainable fisheries, tourism, and shipping) however, fundamental gaps remain in knowledge of marine biodiversity and its condition, and in access to knowledge and data that can facilitate the use of and contributions to R&D on marine biodiversity.

<u>Current state of the science or R&D</u>

Research in Coastal Waters

There has been extensive scientific research in coastal waters to describe the condition and extent of marine ecosystems and species. Many of these programs are mature with long histories of observations in coastal areas. Research programs are conducted by universities, NGOs, and government organizations with significant contributions from research partnerships like the NESP Marine and Coastal Hub. Collation of a significant amount of this information has occurred through Seamap Australia with the National Benthic Habitat Layer (Lucieer et al 2025) and others (e.g. blue carbon potential layer) which has described the distribution of shallow water habitats. Similar programs for satellite observations for coral reefs and mangroves have occurred which are producing national scale understanding of the distribution and change in different habitats (Digital Earth Australia). There are also significant shallow water survey programs that are providing information on reef systems around Australia (eg GlobalArchive, Reef Life Survey, AIMS Long Term Monitoring Program). To support this, the Great Barrier Reef (GBR) has a significant number of research programs focused on delivering to the Reef 2050 plan, but no such coordination exists for other marine ecosystems in other parts of Australia (e.g. The Great Southern Reef), although some national monitoring programs are developing under the Coast Research Infrastructure (RI) initiative (https://www.coastri.org.au/) initial investments (e.g. Australia-wide coastal wetland surface elevation table monitoring (OzSET) network and Shoreline observing systems).

Coastal areas are also the primary habitat for many threatened and endangered species and communities and has resulted in significant effort into understanding the status of these species and groups (e.g. sharks and rays, sea snakes, dugongs, marine turtles and handfish). There are 5 marine fish species, 1 marine mammal, 1 marine invertebrate, and 1 marine community on the DCCEEW Priority Species and Places lists and South-eastern saltmarshes are an *Environment Protection and Biodiversity Conservation Act 1999* (EBPC) listed community. This is a small subset of the total listed species, which is growing. There remains limited knowledge in the coastal areas of East Antarctica within Australia's Antarctic Territory, sub-Antarctic islands (e.g. Macquarie Island, Heard Island and McDonald Islands) and of the Southern Ocean in general.

There is a geographic emphasis on observations being on coastlines due to higher population density, ease of access, and high-value tourism sites. This means that research is more concentrated in high-value areas like the GBR and Great Southern Reef, on beaches on the east coast (e.g. coastal erosion and flooding) and coastal ecosystems within UNESCO World Heritage sites. Water quality monitoring also occurs primarily in coastal areas, often adjacent to cities (and the GBR lagoon) but is largely limited to physical-chemical properties, nutrients, bacteria, and phytoplankton by state governments and the oyster aquaculture industry. There has been minimal consideration of contaminants like pesticides, metals, and pharmaceuticals on both plants (seagrass and algae) and the species which rely on these for food.

Research on the Continental Shelf.

Research in deeper shelf waters (>30 m) is primarily concentrated on the Australian Marine Parks (AMP) network and priority areas like the GBR. These areas are receiving attention due to the need to be able to measure the effectiveness of the management programs of marine parks. There is limited survey work outside these areas, indicating a need for broader geographic coverage to understand the state of ecosystem health across the whole of the Australian EEZ. Parks Australia, in collaboration with the NESP Marine and Coastal Hub, have developed the Natural Values Common Language (NVCL) ecosystems to describe the values in Australian Marine Parks (AMPs). The NVCL ecosystems are extensively used in the South East Network Management Plan (2025) and will be used to support the development of management plan for the other AMP networks. The NVCL ecosystems will also supporting the development of the management effectiveness system for AMPs.

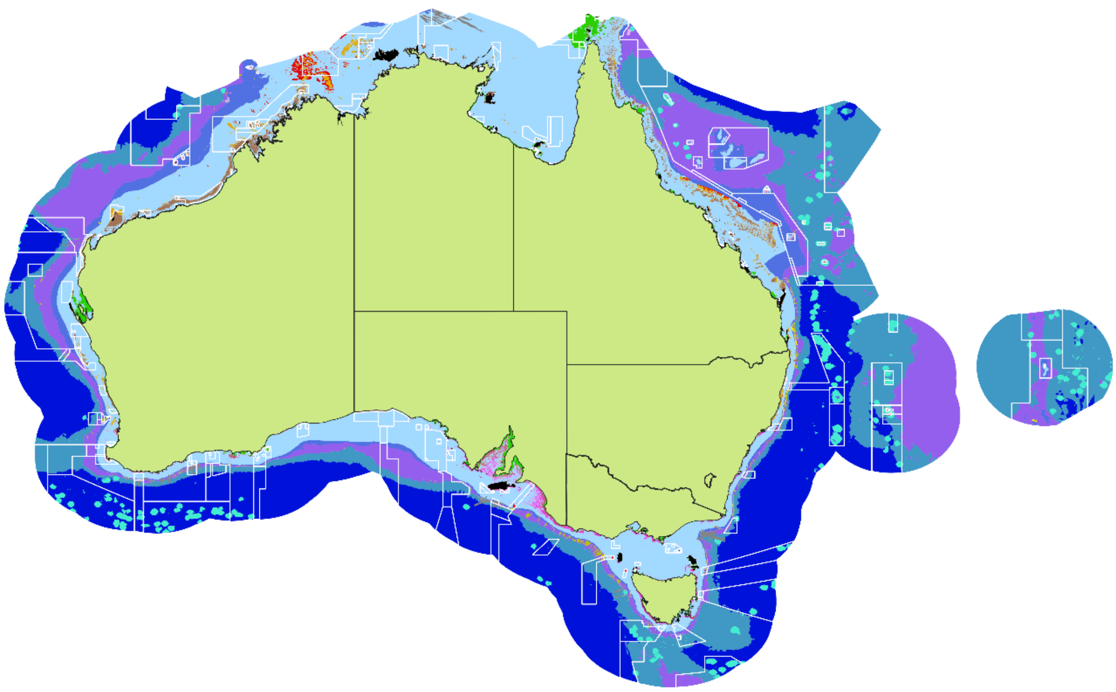


Figure 1: Parks Australia NVCL Ecosystems for Continental Australian EEZ and Norfolk Island

Research on the continental shelf is increasingly being conducted using non-destructive methods (e.g. Baited Remote Underwater Video, Automonous Underwater Video, Towed Video) to understand the distribution, status and trends of deeper water ecosystems. This marks a slow shift from extractive survey techniques to non-extractive technologies. Standard Operating procedures (https://marine-sampling-field-manual.github.io/) have been developed for marine sampling to monitor Australian waters, and survey methods can be combined to characterise and monitor different ecosystems.

There are region specific programs that support focused research. An example is the Great Southern Reef Research Partnership, a partnership led by the University of Tasmania for monitoring reef biodiversity. The program is essential for understanding and protecting biodiversity and ecosystem health across the Great Southern Reef and providing information that can be used to support its conservation and sustainable use. The National Environmental Science Program Marine and Coastal Hub is leading work in offshore renewable energy, focusing on areas proposed for offshore wind. Additional funding is required for risk assessment and simulation approaches. Australia has an established track record in considering the impact of similar scale developments from oil and gas. Other parts of the Australian EEZ have less extensive research programs and are often related to the priorities of the research institutions in that region.

Species level research on the continental shelf is patchy across Australia, typically concentrated on listed species and tourism attractions (eg grey nurse shark, whale shark, shite shark, southern right whales, seabirds). All these species face significant challenges due to the difficulty in monitoring them in often remote locations. In particular, seabird research is underfunded and patchily distributed, with significant gaps in data. The Australian Seabird Group coordinates and supports seabird research. Marine mammal research was historically coordinated by the Australian Marine Mammal Centre but there is currently no agency filling this role. With over 700,000 domestic and international tourists annually, the conservation and ecotourism organisation Phillip Island Nature Parks, perform detailed and long-term research on little penguins, short-tailed shearwaters and fur seals. The white shark cage-diving industry has been monitored since 2013 when a new policy and regulations were implemented and led to the residency of white sharks returning to baseline levels before a substantial increase in tourism activities (Niella et al 2023).

Research off the continental shelf

Research off the continental shelf is primarily conducted using large research vessels. These involve a mix of national (Marine National Facility Investigator) and private (Schmitt Ocean Institute RV Falkor) vessels. These and other vessels have a variety of platforms that can deploy gear to survey different parts of deep-water ecosystems (pelagic, mesopelagic and benthic). However, these platforms are expensive to run and have limited availability. As a result, deep water ecosystems are the most under-sampled, in particular deep water benthic and mesopelagic ecosystems. The primary focus of deep-water benthic surveys has been seamounts, and the continental slope associated with Australian Marine Parks.

Antarctica and the Southern Ocean:

Due to its remote location, the Southern Ocean is relatively insulated from threats associated with dense human populations. However, it faces significant and growing pressures from environmental change. Ocean warming, freshening, and acidification—combined with persistently low and record-breaking sea-ice concentrations in recent years—pose serious risks to its unique and highly specialized ecosystems. Human activities such as increased tourism and commercial fishing are also emerging threats. While less widespread than in other regions, pollution and invasive species represent additional concerns that could escalate with greater human presence.

The Australian Antarctic Program addresses critical issues related to climate change, conservation, and sustainable management of Southern Ocean fisheries, driven by Australia's commitment to Convention for the Conservation of Antarctic Marine Living Resources CCAMLR. Funding for Australian Antarctic operations and infrastructure maintenance is secure, but field support for science projects is limited. Long term monitoring has been mostly limited to seals and seabirds in a few specific locations and to some targeted fisheries and by-catch using fishing vessels. Wandering Albatross populations have been monitored for more than 65 years at Macquarie Island, while for other albatross and petrels, monitoring has been going on for more than 30 years on the island. Fur seals and elephant seals are also being monitored at Macquarie Island since the 90s, with some interruptions.

Biodiversity and ecosystem research is primarily undertaken through large collaborative centres such as the Australian Antarctic Program Partnership (AAPP), Australian Centre for Excellence in Antarctic Science (ACEAS) and Securing Antarctica's Environmental Future (SAEF). Each of these centres has differing funding horizons which undermines Australia's ability to retain critical capacity and deliver the long-term research needed.

Biodiversity and ecosystem research in the Southern Ocean has addressed all levels of the marine food web—from plankton to apex predators—though not evenly. Species such as krill and marine mammals have received particular attention due to their ecological importance and visibility. Research has also explored the impacts of climate change and human activities, species distributions, and the development of large-scale ecosystem models to better understand and predict ecological dynamics in this rapidly changing region.

Offshore territories (e.g. Christmas, Cocos Keeling, Norfolk, Lord Howe Islands):

Most of the research in offshore territories has been ad hoc. There has been a recent increase of research with recent limitations on overseas travels and with Parks Australia's support in evaluating the value of the offshore marine parks around these islands.

Indigenous Sea Country Research:

Indigenous Sea Country research is growing, and programs like the Sea Country Indigenous Protected Areas Program and co-designed projects within NESP are championing co-designed projects to develop capacity and capability within Indigenous organisations to undertake monitoring and collect baseline data and strengthen conservation and protection of Australia's marine and coastal environments. However, greater investment in long-term Indigenous-led programs is needed, particularly in remote areas where investments can directly benefit communities and the environment. More effort is required to engage directly with Indigenous Leaders and Traditional Owners to incorporate regional priorities into research and monitoring programs. There are vast regional differences in culture, and capacity, and a strategic approach tailored to both social and environmental issues is required.

Gaps

There are a range of gaps identified in the geographic and taxonomic R&D activities by the research community, including:

- There is a limited understanding about how the condition of critical marine habitats and the biodiversity that they support is changing across the Australian continental shelf, including mobile and sessile species across our intertidal, shallow, rariphotic and mesophotic habitats and reefs.
- Lack of data on movement and distribution of species across their range, particularly in relation to overlap and pressures from anthropogenic activities, climate change and ultimately, the benefit of spatial closures (within Marine Protected Areas) on a variety of species with differing movement abilities/strategies. Greater understanding of species movement can be used to evaluate and model the implications of different management

actions, including development of nearshore and offshore energy much more effectively. This is especially apparent for long ranging species such as seabirds, pelagic sharks, whales and other marine mammals which are using Australian waters.

- Biodiversity values in mesophotic (30 to 70 m) and rariphotic (low light, 70 – 200 m) shelf depths are only known from a few sites, such as within Australian Marine Parks. These areas show high levels of use (Dunstan et al 2022) and more data on the impacts of use and climate change are having on these systems are needed. Our ability to rapidly document and characterise the hyper-diverse groups such as marine invertebrates is hindered by limited taxonomic expertise. A recurring issue with research in mesophotic to rariphotic depths is that despite now having reasonable time series of image-based surveys in the southeast AMP network, we are often unable to make causal (or even correlative) links between observed patterns in benthic communities and/or species and environmental drivers. because physical data such as temperature, bottom current velocities, and chemical properties are not collected at these depths alongside the collected imagery. Limited research has shown that temperature and nutrient levels at these depths often do not mirror shallower depths. Therefore, there is a need for better physical and chemical data collection at these depths
- Biodiversity off the continental shelf remains poorly surveyed and understood. While there is typically lower use than in shallower waters, these systems can take longer to recover from disturbance.
- Links between the physical environment and the types of phytoplankton that grow, how that will change with climate change and the impacts on the food chain, are still very poorly constrained.
- More data on the impacts of land-use, sedimentation and agrochemical contaminants on marine ecosystem health and seafood production and safety are required. Integration of environmental economics could be used to assess the cumulative effects of diffuse source pollution and reduced environmental flows on biodiversity that supports marine based industries, recreational amenities, habitat and biodiversity value.

Long term monitoring

There is a need for better integration of long-term monitoring data, Traditional Knowledge and models, e.g. coastal oceanographic models, to aid understanding the impacts of human activities on coastal ecosystems and their fauna (e.g. utilising hydrological models to better understand causes of low oxygen levels in Macquarie Harbour thought to be impacting the endemic and listed-Endangered Maugean skate). Moreover, there has been limited research assessments of the risks of management inaction (versus action) in achieving goals for ecosystem or species management.

Without long-term data, acquired via sustained and secured resourcing, it is impossible to understand how ecosystems and species are changing as a result of anthropogenic pressures and uses including climate change, fishing, coastal and terrestrial development. For example, there have been limited funding and logistics to undertake research on offshore islands, essential for many endemic and endangered species. Long-term projects need to be agile but are fundamentally important to detect and understand and mitigate changes. Identifying thresholds for action remain a challenge for monitoring programs. Sustained monitoring will inform the development of new approaches to managing biodiversity and, when linked with well described thresholds, can help to ensure long term sustainability and conservation.

Human capacity

Limited human capacity is another barrier to increasing R&D. The loss of high-quality scientists associated with short term contracts and short funding cycles hinders the pace and scale of R&D. There has been a loss and erosion of scientific diving capability, as well as loss of taxonomic expertise for many taxonomic groups (including macroalgae and invertebrates). While there has been a focus on AI/ML to identify species and evaluate abundance, in many instances manual processing, curation, and validation is still required as some stage. If the goal is to model how biodiversity and ecosystem health are changing across Australia, continued investment in skilled field ecologists is required.

Policy and Regulatory Challenges:

R&D on marine ecosystem health and biodiversity would benefit from large scale coordinated biodiversity projects that directly address management needs. For example, increasing coordination among policies on land (agriculture, waste-management, and other sectors) and those in coastal waters (e.g. aquaculture or marine conservation). It would be beneficial for governments to have clear, transparent and measurable goals and priorities for marine biodiversity. The marine research community can contribute to setting and devising strategies to achieve goals.

All disciplines and sectors need to be integrated to address the challenges of sustainable marine resource use and conservation of marine biodiversity (e.g. multidisciplinary science, social science, policy, economics, engineering, technology, industry and communications). Social sciences, economics and policy research must be integrated to understand governance, equity, and stakeholder engagement in marine conservation and ocean governance. Barriers to addressing these challenges include institutional silos and under representation of social science research in marine policy development.

A key example is the strong division between the science, management and policy of fisheries versus conservation (including Marine Protected Areas and threatened species). Both sectors require data on numbers and trends in marine species to make management and policy decisions, as well as assess the outcomes of those decisions. The division between these different groups of participants and stakeholders of marine biodiversity creates strong barriers to progress towards better outcomes underwater. Co-designed and productive collaborative monitoring and research between fisheries and conservation sectors may represent one of the biggest opportunities for real progress, if difficult social and communication issues could be effectively addressed. Australia's Sustainable Ocean Plan identifies similar challenges in balancing sustainable use with the need to protect and restore Australia's Oceans.Furthermore, with deeper integration among scientists and policy makers, data from such projects could be used to further develop policy and decisions.

Infrastructure and capability needs

Australia has significant investments in marine observing infrastructure; however, few national programs are focussed on biodiversity, but rather focus on assessment of physical conditions (e.g. ocean conditions, water quality). When considering capability needs, clearly defining goals is important to evaluate success of increased investments.

Marine Observing Programs

Australia has high levels of investments in marine observing systems and programs are world-class (e.g. IMOS), but gaps remain in deep-sea monitoring, high-resolution habitat mapping, and real-time biodiversity and ecosystem health assessments and their links to physical data streams.

Improvements that could be made include:

- Continuing to develop Standard Operating Procedures for marine surveys and ensuring harmonisation of the data collected in curated, publicly accessible databases to allow for the integration of many survey types.
- Maximise our use of existing data and monitoring networks by developing national portals and facilities to support the standardisation and best practices for biodiversity data collation and synthesis. The availability and visibility of marine biodiversity and ecosystem state data streams are improving (e.g. reef and seagrass cover in the Great Barrier Reef, and national assessment of the condition of mangroves), but more investments are needed to make data accessible (including historical data held in museums) and easy to use.
- Enhanced data collection on drivers of change at scales relevant for biodiversity and ecosystem health such as human use, temperature and bottom current velocities, across depth (and elevation) profiles will allow full use of biodiversity monitoring data sets.
- Expanding portals and facilities to support existing data collection on natural values data (such demersal fish and mobile invertebrates) and aiming for better integration across platforms is crucial. The Australian Ocean Data Network (AODN) could be improved and diversified with well-defined and prioritized datasets that facilitate reporting of status and trends. Developing CoastRI at a national scale is important opportunity to include monitoring of marine coastal biodiversity and ecosystem health.

- The development of national fleets of equipment (with access managed transparently) such as UAVs (drones), ROVs and BRUVs, would boost data productivity (assuming investments in data processing and communication) and ensure the exchangeability of data.
- Long-term support for technological development and ground truthing is required. In some locations there are monitoring tools, e.g. benthic monitoring tools that could be shared (scaled up) and used consistently across jurisdictions. Developing rapid response teams for comprehensive investigation into unexpected mortality events (e.g. impacts of extreme weather events, pathogens, oil spills) is an important capacity that could improve adaptation to extreme events.
- Extensive training of human resources in the use of monitoring technologies .
- A national repository for tissue samples on Threatened Endangers and Protected Species to enable researchers access to historical and contemporary samples to enable abundance and trend to be estimated using emerging genetic methods such as close kin mark recapture.

Capability and Infrastructure Gaps

Identification and monitoring of marine biodiversity and ecosystem health is challenging as we have limited capacity in some areas, but there are emerging technologies that can augment traditional methods. Gaps in capability include:

- Capabilities in the taxonomy of marine species, particularly hyper-diverse and hyper-endemic groups (e.g. invertebrates, microbes, macroalgae). Capabilities for using new approaches, such as reference DNA databases and digital specimens, are needed, integrated with existing and new monitoring programs
- Infrastructure to share data and turning bio-physical data into usable information for various needs is important. Investments in e-infrastructure are required concurrently with enhancements in other capabilities.
- Increased capacity for marine spatial population modelling integrated with current monitoring of physical conditions could help to develop management plans for conservation of marine species that range across habitats (e.g. over reefs, coastal wetlands and shelf habitats) and groups of species (e.g. penguins, tuna, sharks, whales).
- Capacity to develop and deploy new and innovative observational technologies.
- Development of AI tools can improve the timeliness of assessments and automate them. Infrastructure and capabilities in quantitative and software development skills are needed to support AI developments. This could include novel digital twin technologies to assess scenarios, including analysis of changed management and climate change. Extensive training of human resources in data analysis, modelling, and visualisation of data derived from new technologies

Importance of partnerships for effective monitoring of biodiversity and ecosystem health

Monitoring partnerships can help enhance the scale and frequency of marine biodiversity and ecosystem health monitoring and offset the cost of extensive monitoring programs. The development of multidisciplinary monitoring partnerships and high-level citizen science (in some cases) could enhance infrastructure and skills needed for large-scale, frequent monitoring using fewer people, increasing cost-effectiveness of monitoring.

Partnerships can increase the uptake of research by governments, industry and communities. Partnerships between government and non-government entities (e.g. Reef Guardians program, Ecosystem Health Monitoring Partnership of Healthy Land and Water, NESP Marine and Coastal Hub) and collaborative networks (e.g. the Reef Life Survey, GlobalArchive, The Fish Collective, Great Southern Reef Research Partnership, the coastal wetland surface elevation table (OzSET) monitoring network within TERN, the Seagrass Restoration Network, Australian Coastal Restoration Network, and others) could strengthen and expand on current capabilities, and co-design monitoring programs for biodiversity and ecosystem health at a relevant scale that could increase uptake of monitoring programs. Blue-water biodiversity monitoring initiatives can be based on international collaboration (e.g. Secretariat of the Pacific Regional Environment Programme (SPREP), Indian Ocean Rim Association) that builds trust and leverages international contributions. For Antarctica and the Southern Ocean, the large scales and broad challenges need continued national and international coordination. Existing programs such as the Southern Ocean Observing System (SOOS), and the Antarctica InSync program of the UN Ocean Decade can play important roles in facilitating these partnerships.

Cross-Disciplinary approaches

Cross-disciplinary collaborations and partnerships are key to increasing the effectiveness of marine biodiversity monitoring and uptake. Processes that would enhance cross-disciplinary collaboration include stronger and sustained collaborative partnerships across industry-academia-government-Indigenous organisations to develop effective monitoring should be incentivised. For example, monitoring of Indigenous Sea Country in Northern Australia is achieved through collaboration among multiple science institutions and Indigenous ranger groups, supported through NESP Marine and Coastal Hub. Because marine biodiversity often utilises multiple ecosystems, cross-ecosystem Working Groups could be highly beneficial to reducing discipline and sector silos and for enhancing effectiveness of cross-ecosystem (and cross-sector) monitoring and management.

Upskilling and Career Progression

Upskilling the R&D workforce through advanced training, career incentives, and mentorship to pass on expertise to larger groups of people are essential to increasing marine biodiversity R&D. Expanding and diversifying the workforce trained across the data value chain is necessary.

Developing career progression in marine biodiversity R&D could utilise workshops and seminars in specific areas and skills that are needed.

Increasing the workforce size and capabilities for marine biodiversity R&D in a sustainable way requires a suite of measures, including clearer pathways for career progression for junior scientists and Indigenous researchers who are currently faced with short-term contracts. Funding to support post-graduate research students and capacity-building initiatives in graduate training are needed as is increasing the capacity for scientific diving programs across Australia. Continued and enhanced investments in programs that train young scientists, like NESP, the Great Southern Reef Research Partnership and others, along with integration and training for participant and stakeholder organisations like the North Marine Parks Advisory Committee and Indigenous organisations (e.g. Northern Australia Indigenous Land and Sea Management Alliance, Northern Land Council), could further increase effectiveness of monitoring programs and data use

Investments in long-term monitoring of marine biodiversity and ecosystem health

Investment in long-term monitoring is critical for understanding trajectories in marine biodiversity and ecosystem health and linking these to management actions and other drivers (e.g. climate variation). Well supported, long-term monitoring programs of marine biodiversity are rare (e.g. marine turtles at Mon Repos, coral cover on the Great Barrier Reef, white sharks at the Neptune Islands) and there is a need to increase investment in monitoring biodiversity and ecosystem health in under-represented regions, ecosystems and taxa. Large-scale cross-institutional funding remains a challenge, and challenges exist in ensuring that funds are equitably distributed.

Progress/Impact Measurement (500 words)

Research on protecting biodiversity and ecosystem health contribute to a wide range of reporting at commonwealth and state levels. State of the Environment (SoE) Reports summarise national patterns and are useful to provide a broad understanding of the current status of biodiversity. Similar initiatives include the GBR Outlook reports, State SoE reporting and Marine Parks Australia & Australian Marine Park reporting processes and documents. However, data used in these reports is limited and often it is difficult to provide information in a format that can be easily ingested into these reporting frameworks. Similarly, while the EPBC Act has Recovery Plans for some species, many of these are out of date and very few have baseline data or population trajectories to determine whether current management is achieving the goals identified with very few examples of species that have been recovered to levels where have been downlisted. The fragmentation of outputs is a consistent challenge, which reduces the ability to measure impact (e.g. through indicators like habitat quality, areas restored, and the speed or quality of ecosystem service recovery). Integration of long-term monitoring programs can ensure research drives meaningful environmental and societal benefits.

Research is translated to participants and stakeholders through a range of processes, which could be enhanced with further investment, resulting in tangible benefits. For example:

- **Science-Policy Interfaces**: Better coordination between researchers and policymakers, including dedicated science-policy interfaces within government, is needed.
- **Co-Designed Research**: Research co-designed with industry, Indigenous groups, policymakers, and relevant stakeholders can improve uptake and application.
- **Interactive Platforms**: Expanding interactive platforms, such as real-time biodiversity dashboards and smartphone apps (e.g. iNaturalist, Animal Tracker, GIS Storymaps, etc.), and increasing funding for knowledge brokers will strengthen engagement.
- **Effective Tools**: Tools like SeaMap and Reef Life Survey's Reef Life Explorer and Reef Species of the World can effectively summarize and communicate extensive survey data, enhancing visibility and access to data.
- **National Biodiversity DNA Library**: This initiative combines expertise in biological reference collections and rapid genomics technology, aiming to support eDNA research and State of the Environment reporting.
- **Report Cards**: These use data to inform society and science, making data more accessible, locally relevant and management focussed.
- **Citizen Science and ocean literacy** – RedMap, iNaturalist, WhaleFace, SealSpotter, Seadragon Search, and more (eg Australian Citizen Science Association – Citizen science is redefining how we do science*)* can support public education on marine biodiversity.

Communication could be improved through:

- **Improved Outreach**: There is a need for better public outreach of research findings. Currently, knowledge is primarily in reports that are publicly available but not often read, and their importance is not effectively communicated.
- **Visibility of Results**: Greater visibility of results through organizations like UNESCO and management bodies such as state and commonwealth environment agencies, and Great Barrier Reef Marine Park Authority can enhance impact.
- **Knowledge Transfer**: Knowledge transfer to stakeholders occurs through reports, briefings, meetings, presentations, online tools, and public forums. More frequent engagement with policymakers and development of "Summaries for Policy Makers" would enhance this transfer.
- **Beyond Scientific Publications**: Measuring impact requires policy uptake. Tracking policy uptake, investment, conservation outcomes, and Traditional Knowledge integration provides a clearer picture of success of marine biodiversity R&D.
- **High-Level Reporting**: Current reporting mechanisms are often too high-level and need mechanisms to make effective contributions at bioregional or catchment levels.

- **Localized Engagement**: Examples like the Philip Island Nature Park conservation research program and the rodent eradication program on Lord Howe Island show successful localized public engagement.
- **Interactive Dashboards**: Tools like interactive dashboards, smartphone apps, AI-driven analysis, and citizen science approaches can enhance data accessibility
- **Traditional Owners**: Sharing of Western science knowledge with Traditional Owners in appropriate modes needs improvement. Dedicated staff for engaging, collaborating and communicating with Traditional Owners is recommended, along with training for scientists on Traditional Knowledge and enhancing skills and capacity for collaboration with Traditional Owners.

Dependencies and Priorities (750 words)

Australia has high levels of marine biodiversity (Rogers et al. 2020), but much of our biodiversity and the health of ecosystems remains undescribed and/or inadequately monitored. R&D required for improving knowledge includes furthering our understanding of the geographical distribution of biodiversity values and pressures on biodiversity that can be used to identify high-value areas that need conservation and monitoring. This knowledge helps in making informed decisions about what needs to be conserved, why and how. An integrated, holistic, and adaptive approach to manage our marine ecosystems into the future will benefit ecosystems health and biodiversity. While more research is needed on how climate change specifically affects different species and ecosystems, a better understanding of the complex interactions among species and how they respond to changes is still limited. Improved understanding of complex interactions among species and habitats combined with modelling techniques and forecasting tools to project climate change impacts on ecosystem health and function, and linking this with established long-term monitoring data would create scalable management solutions.

The management and protection of biodiversity and ecosystem health has three main priorities:

- Monitoring - how can we measure the status of biodiversity and ecosystem health
- Assessment -is the status of biodiversity and ecosystem health changing and what are the responses to management actions.
- Response - how can we ensure that change is in the direction we want.

Monitoring

Monitoring programs have been uncoordinated and have often used different approaches to observe biodiversity and ecosystem health. Nationally agreed standards that are applied to most (or as much as possible) of surveying will allow the development of a national understanding of the status and trend of biodiversity and ecosystem health. As Australia experiences increasing climate shifts and movement of species and ecosystems, we will need to have monitoring systems that can track these changes and the effects of human uses and have a suite of proactive interventions that can be used where needed to ensure continuing ecosystem integrity and health. There is a need for improved integration of AI to convert image-based surveys into usable data. Continuing to develop standardized protocols in data collection is essential to improve comparability across studies. There are a set of standard protocols (https://marine-sampling-field-manual.github.io/) that can be built on to ensure that as new technologies become available

Well-designed and resourced enduring biodiversity monitoring programs are essential to measure long-term trends in health, outcomes of conservation strategies (programs and projects) for marine biodiversity and species and ecosystem recovery, and to establish societal benefits including assessment of equality of benefits among stakeholder groups. Currently, the long-term monitoring and its reporting (using publicly accessible formats like web-based dashboards) is limited to relatively few regions and assets (e.g. the Great Barrier Reef, Australian Plankton Survey, Reef Life Survey). Expansion and resourcing of monitoring programs should include less-well serviced regions, ecosystems, and components of biodiversity that could support policy and management decisions, benefiting various industries such as fisheries, marine parks, and climate change adaptation. The Commonwealth-State partnership (and investment) for monitoring of the GBR offers many lessons on how effective monitoring with policy and management outcomes that have been achieved with long-term funding commitments. This model should be expanded to other regions. Furthermore, effective monitoring programs can measure the benefits delivered by conservation of marine ecosystems and biodiversity. These benefits include better understanding of the distribution and change in marine ecosystems and biodiversity and its pressures, what management actions could effectively manage pressures, and the resilience to climate change and other perturbations.

Advanced genomic tools can help in understanding adult abundance (close kin mark recapture), genetic diversity, ecosystem health and resilience of species (environmental genomics, bioinformatics and nanotechnologies). Emerging technologies should be ground-truthed with physical observations and experimental data to ensure they are verified.

Assessment

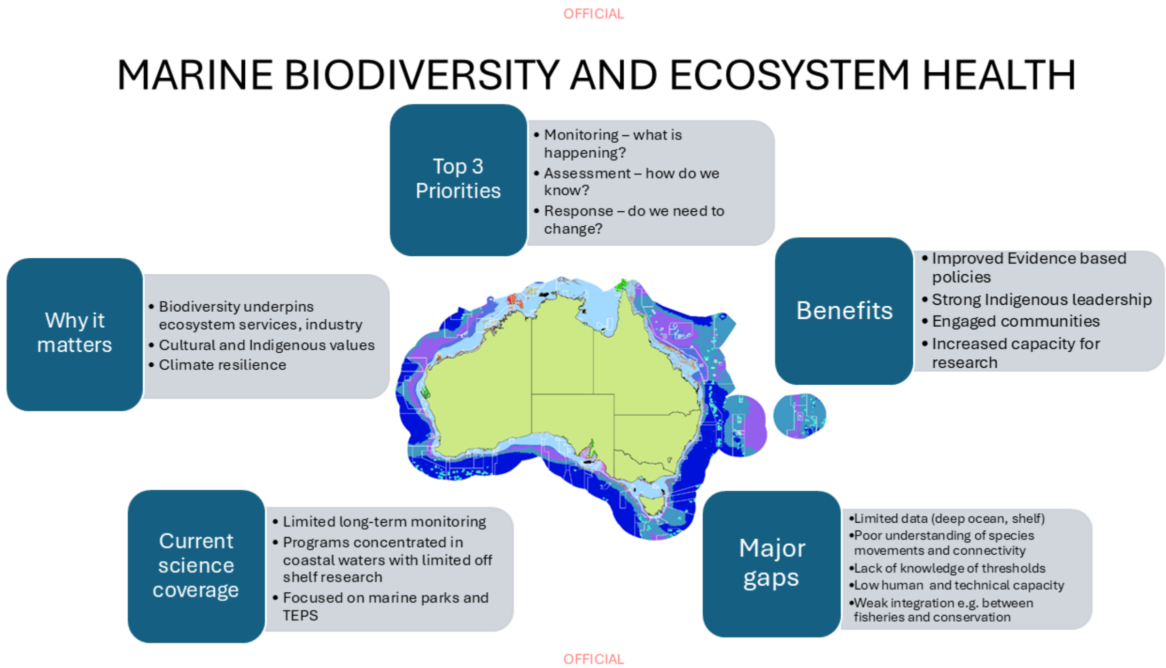
Verified tools like AI/ML-driven species identification, and predictive modelling will increase our understanding and enable cost effective and comprehensive biodiversity assessments. Autonomous systems, remote sensing, and big data analytics offer new opportunities but face barriers including funding constraints and data integration challenges. Improved satellite and drone technologies for monitoring large and remote areas in conjunction with AI technologies that can be used to cost effectively annotate images can be used to obtain abundance data on species of interest, noting that AI/ML technology for identifying individuals is still developing. Integration of existing methods of physically sampling and observation with evolving methods (e.g. data analysis, statistics, AI/ML technology, omics, digitisation) while ensuring that key taxonomic skills in certain areas (e.g. invertebrates) are maintained, and that evolving methods are appropriately ground-truthed is key to success for monitoring programs. There is a need to integrate across science, engineering and technology to ensure decision makers have the range of inputs needed to make management decisions.

The ability to respond to change will be increased through understanding the cumulative impact of use and pressure (e.g. coastal development, fisheries bycatch, climate change) and how these effect the status and trend of species and ecosystems. Improved collaboration, data sharing, collaborative databases and sample storage (e.g. tissue and/or molecular samples) will become increasingly important to understand long-term changes in marine biodiversity.

Response

Australia is a global leader in the management and conservation of marine biodiversity and should also be leading in development of conservation and restoration practices to conserve and enhance marine ecosystem health. Efforts should focus on maintaining and enhancing biodiversity and ecosystem health. Enhanced R&D to develop effective conservation and enhancement practices can lead to informed management with flow on benefits for marine biodiversity. Well-designed and pro-active conservation and restoration practices will help to ensure resilience to climate change and a better state of marine ecosystems and the services they provide.

Conservation of marine biodiversity requires effective engagement with rightsholders and stakeholders, to ensure that research is communicated and applied in policy and management decisions. This includes collaboration among communities, industries, and Indigenous groups. Indigenous perspectives and knowledge can be incorporated and enhanced through co-design, collaboration, and self-determination. Integrating Traditional Ecological Knowledge with contemporary science strengthens conservation outcomes.



Solutions

Marine biodiversity and ecosystem health are currently exposed to simultaneous and interacting anthropogenic pressures that result in environmental change. R&D can support conservation of biodiversity through a focus on understanding and mitigating pressures on biodiversity and enhancing ecosystem resilience and maintenance of ecosystem services. Improved monitoring, reporting, and data-sharing would enhance collaboration among scientists and other participants, stakeholders and support adaptive management. Effective participant and stakeholder engagement ensures that research is communicated and applied appropriately. Integrating Traditional Ecological Knowledge with contemporary science enhances conservation outcomes and thus R&D should facilitate Indigenous-led monitoring and research. Indigenous perspectives on marine biodiversity can be incorporated through co-design, collaboration, and self-determination such that conservation and monitoring efforts are inclusive and respectful of Indigenous knowledge and practices. Long-term benefits of R&D in marine biodiversity and conservation include development of improved biodiversity indices and sustainable resource management strategies.

Investments in characterising biodiversity and ecosystem health are dependent on participant and stakeholder priorities. Such priorities can be driven by academic fields of excellence, through funding success and/or by government priorities. To further prioritise R&D investments for sustainable marine biodiversity participant and stakeholder priorities can be weighed against both the geographical distribution of biodiversity values and the pressures on marine biodiversity.

<u>References:</u>

Provide 5-10 key references that substantiate your recommendations and priorities.

Deloitte 2021. Cost benefit analysis of a mission to discover and document Australia's species. [*https://www.deloitte.com/au/en/services/economics/perspectives/cost-benefit-analysis-mission-discover-document-australia-species.html*](https://www.deloitte.com/au/en/services/economics/perspectives/cost-benefit-analysis-mission-discover-document-australia-species.html)

Duarte, S., Simões, L. and Costa, F.O., 2023. Current status and topical issues on the use of eDNA-based targeted detection of rare animal species. Science of the Total Environment, 904, p.166675

Dunstan PK, Woolley SNC, Monk J, Barrett N, Hayes KR, Foster S, Howe SA, Logan D, Samson CR, Francis SO (2023) Designing a targeted monitoring program to support evidence-based management of Australian Marine Parks: National Implementation. Report to the National Environmental Science Program. CSIRO.

Rogers, A., O. Aburto-Oropeza, et al. 2020. Critical Habitats and Biodiversity: Inventory, Thresholds and Governance. Washington, DC: World Resources Institute. Available online at www.oceanpanel.org/blue-papers/critical-habitats-and-biodiversity-inventory-thresholds-and-governance.

Supporting Graphics:

If possible, provide 1-2 figures or graphics that communicate your recommendations and priorities.

Supporting Annex:

Please feel free to attach any surveys, documents, or additional materials that support and enhance the content of the White Paper.