Biodiversity Conservation and Ecosystem Health

White Paper: Discovery, Prediction and Monitoring

Abstract (100 words)

Australian researchers in marine biodiversity and ecosystem science have a disproportionally high impact on global research as measured by their number of publications and their high profile leadership of international initiatives. At least 170 researchers from over 32 institutions contributed to this research which has a high uptake in government agencies and industries as this topic area is the basis from which the impact of human development is measured. Despite this, we know surprisingly little of our marine environment – only 5.2% of the seafloor in Australia's Commonwealth Marine Reserve network has been mapped to acceptable precision, and only about 10% of marine species has been identified. In order to improve and assess marine management initiatives in light of funding accountability, marine biodiversity and ecosystem research needs to be prioritized to fill the knowledge gaps that would have most impact on the diverse set of marine stakeholders. For example, monitoring, evaluation and reporting of ecosystem health and management performance of marine reserves is a clear need that has made some initial progress. Discovery targeted at identifying conservation values, including key ecological features, is another. Improved species inventories, environmental baselines and maps for all habitats ranging from the coasts to the deep sea and from tropical to polar, including nationally consistent approaches are essential to monitoring, evaluating attributing and managing increasing human impact (including cumulative impacts), and ensuring that Australia has a productive and clean marine environment. The difficulty of research in often extreme environments requires a substantial increase in Australia's marine infrastructure for seabed characterisation and biological sampling.

Background (1 page max)

Aboriginal knowledge of Australia's flora, fauna, and ecological systems, collected over the last 40,000 to 60,000 years remains cryptic (Butler et al. 2010). European scientific study began with the first scientifically staffed voyages of discovery in the 18C emphasizing the taxonomy and descriptive ecology of organisms on accessible shores leading to a strong tradition of experimental ecology (e.g. Connell and Gillanders 2007). Fisheries research was an early focus in the 20C (e.g. Mawson et al. 1988) together with targeted environmental research in coastal waters near capital cities (e.g. Poore and Rainer 1979) and tropical reefs (e.g. Fisher et al. 2011a). More recent work has explored deeper waters, (e.g. Williams et al. 2006) with interests in exploration, biodiversity conservation, sustainable fisheries, and supporting marine bioregional planning (Last et al. 2009).

Australia is respected internationally for its marine science research supporting management and conservation. 32 Australian institutions contributed 1% or more of the 710 global publications on marine biodiversity and 1391 publications on marine ecosystems from 2004-2013. This included 6 research agencies, 4 museums and 22 universities. Organisations included on at least 5% of the publications were CSIRO, JCU, UQ, UTAS, UWA and AIMS (Web of Science 2014).

There were 170 researchers working in relevant marine environmental areas in 2013, a reported decline of 8 since 2009, with decreases most noticeable in benthic ecology but compensated by increases in habitat mapping and ecosystem modelling (Murphy and Lewis 2014).

The Web of Science entries for the last 10 years (2004-2013) indicates that for the 4,632 papers on the topic of marine and biodiversity, 15% included Australian addresses; for the 14,253 papers on ecosystems, 10% had Australian authors. This level of performance across both fields was second only to the USA, and similar to Canada, England and France, despite our much smaller population. Biodiversity was included as a topic in 9% of the marine papers published in the last 10 years that included Australian addresses, while ecosystem was included in a further 17% (3% used both terms).

Citations are only one (and arguably not a particularly effective) way at estimating impact of research. Australian marine biodiversity and ecosystem research outputs have been widely adopted throughout the world for marine spatial planning (MARXAN, EBSAs), ecosystem and fisheries management (Ecological Risk Assessment, Atlantis); while global standardized surveys (Edgar et al 2014), biogeographies (O'Hara et al 2014) and geological maps (Harris et al. 2014) are changing the way that the world looks at its global oceans and their conservation and sustainable use, informed by what are the world's best studied and longest managed coral reefs (De'Ath et al. 2013). Australian researchers lead a multitude of international initiatives in this area. See "additional comments".

ARC and other sources of university funding, including PhD scholarships, are a primary source of funding for marine biodiversity research; noting that ARC funded 256 'projects' related to marine biodiversity between 2005 and 2014, which were worth $143M. This included 121 Discovery Projects (28% of funding), one Centre of Excellence (20%) 65 linkage projects (17%) and 28 Future Fellowships (14%). Funding for this area also comes consistently from major research agencies (CSIRO, AIMS, GA), research collaborations (WAMSI, NERP/NESP), Commonwealth and state

environmental and fishery departments, management agencies (GBRMPA, AFMA) and the FRDC. More focused funding comes from the fishing industry (e.g. environmentally responsible deep sea trawling fishing), the oil & gas industry (e.g. Scott Reef, GAB), shipping and ports, environmental NGOs (Antarctica), tourism interests, and philanthropic organisations.

Relevance(1 page max)

Commonwealth and State Environment departments are directly and indirectly (through the requirements placed on marine industries) the largest user of research outputs including data, maps, technical reports and scientific papers to used to develop and monitor progress against their management objectives. The discovery and characterisation of important shelf and deepwater habitats has led to voluntary closures of vulnerable areas and informed the development and delineation of marine reserve systems. It has helped identify Key Ecological Features – conservation values identified to influence off-reserve management and environmental impact assessment by resource management agencies including AFMA and NOPSEMA and their stakeholders (an area likely to increase as marine spaces become more intensively used by a range of industries). Improved interpretation of existing discovery information will increase its uptake in policy and management (e.g. national submarine canyon classification; Huang et al., 2014). Discoveries also drive public awareness and interest in the marine environment benefitting the recreational and tourism sectors, improving education of future generations and providing research opportunities for universities.

Predicting what may exist in remote or poorly known areas is important for more effectively utilising existing information, for highlighting areas with key data gaps and for extending user uptake of research outputs. Predicted biogeographies (e.g. Integrated Marine and Coastal Regional Atlas, IMCRA4) were especially useful in designing marine reserve networks (including the CMR network) and rezoning (GBR), while tools to interpret these biogeographies and other environmental and cost layers (e.g. MARXAN) are used by states, nationally and globally. Predicted distribution maps for habitats and vulnerable species (e.g. EPBC listed fauna such as marine mammals, sharks and rays) are supporting environmental impact assessment and management by industry sectors including fisheries and oil &gas.

A national marine biogeographic classification was first developed by Commonwealth and State agencies in 1985 and endorsed as a basis for planning a system of marine protected areas. IMCRA 3.3, endorsed in 1998 as the national and regional framework for the National Representative System of Marine Protected Areas, contained a demersal and pelagic regionalisation, and included a detailed inshore bioregionalisation based on selected data that varied between jurisdictions. A National Marine Bioregionalisation endorsed in 2005, extended these regionalisations from the continental shelf to the edge of the EEZ. IMCRA4 assembled these different elements and added geomorphic units. It was anticipated that IMCRA4 would be updated no sooner than 2010, be driven by management and planning needs, occur only after advances had been made in conceptual classification models, data coverage, and ecosystem understanding including surrogates, and would be in response to a request from a Ministerial Council. Scientific knowledge has advanced well in all these areas and we propose that IMCRA be updated as part of the 10-yearly CMR network reviews, to support assessment against adequacy and representivity of the network. Updates should include new biogeographies, further consideration of deep water and pelagic environments and especially the links between pelagic and benthic biogeographies.

Monitoring, evaluation and reporting against specific objectives and targets is intrinsic to adaptive management, a management approach that is widely accepted in Australia, though it is rarely fully implemented (Westgate et al 2013). Australia generally has a poor record in marine ecological monitoring, with a few notable exceptions including the AIMS Long-Term Reef Monitoring surveys (De'ath et al. 2012), the LTTRMP (Barrett et al. 2009), some of the larger commercial fisheries (eg. SBT and orange roughy), and some University-based research programs (eg. Curtin bio-acoustic monitoring). Management need, supported by scientific expertise and national infrastructure expenditure (e.g. IMOS), is starting to change this situation, with monitoring of marine ecosystem health to support SOE reporting, monitoring of marine reserve performance, and an integrated monitoring framework that links monitoring to objectives in the GBR all beginning to grow. Developing national standards (e.g. CATAMI – Collaborative and Automated Tools for the Analysis of Marine Images and video – the standard for ecological analysis of underwater imagery) have the potential to unify monitoring through all sectors, so that greater value can be made from current expenditures in this area, including the new need for monitoring against baseline environmental information by the oil & gas and further new marine industries (e.g. marine mining or energy generation). "Implementing robust national monitoring, reporting and evaluation" is a key action of Australia's Biodiversity Conservation Strategy 2010-2030.

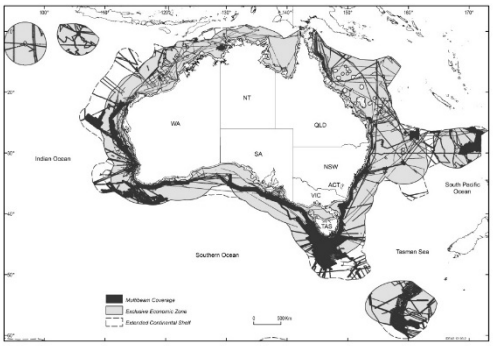
Biodiversity discovery, prediction and monitoring continues to inform ecosystem process models and decision support systems, although this is not matched by process understanding research.

Globally, seabed classifications are being used in the CBD EBSA process in workshops attended by >100 countries and an equal number of NGOs and IGOs and will influence ongoing UN discussions on managing biodiversity beyond national jurisdiction, while Australia's combined science and policy approach to, and experience in, ecosystem-based management – marine spatial planning, ecological risk assessment and ecosystem assessment – is having global impact.

Science needs (2 pages)

Key science gaps/needs/challenges

Approximately 28% of Australia's EEZ and Extended Continental Shelf had been mapped using modern sonar systems by Jan 2013 (Heap et al. 2013), to provide seabed topographies used to characterize marine habitats and ecosystems Furthermore, only 5.7% of the EEZ has been mapped at high resolution, including 5.2% of the CMR network (CSIRO unpublished); a far smaller percentage would have any biological sampling.



Assuming only one fifth of marine species in Australian waters have been sampled and retained, then less than 13% have been identified (Butler et al. 2010). Poore et al (2014) suggest that as few as 10% of marine species have been identified. Distribution patterns and organism-habitat relationships are even more poorly understood and vary between ecosystems (Fisher et al 2011b). Continually improving taxonomic methods including genetic approaches to support automated sampling have the potential to increasingly inform marine science and management – if the capacity is there (see Taxonomy white paper).

Australia has a spatially limited and dated national "integrated" classification and mapping system for managing its marine resources (IMCRA4, Commonwealth of Australia 2006). Lacking are national maps of biodiversity assets, key ecosystem services, pressures and existing legislative response. This compromises the goals of "improving and sharing knowledge" and "delivering conservation initiatives efficiently" that are prioritised in Australia's Biodiversity Conservation Strategy 2010-2030 and the "approval simplification" identified in A Plan for a Cleaner Environment (2013). Developing robust maps requires synthesising existing information and accessing new information on biota, habitats and processes in a targeted approach to provide quantitative, nationally consistent baselines, that can be used to identify matters of national environmental significance (MNES), assess environmental impacts and develop offsets as applicable. Data accessibility is improving (AODN, e-Atlas, ALA, Ningaloo eAtlas, Data Trawler) but improvements in discovery and delivery of data, especially for priority users of marine environmental information in the marine sector, are still required.

With the declaration of Australia's Commonwealth Marine Reserve network and state MPA networks, survey emphasis is shifting from discovery to monitoring (or establishing the first quantitative baseline). Non-destructive sampling approaches will frequently be required. The diversity of sources from which Australian marine biodiversity data are obtained means that there are few repeat surveys. Notable exceptions are the AIMS Long-Term Monitoring Programs that showed that coral cover had declined from 28.0 to 13.8% (0.53% y-1) between 1985-2012 (De'ath et al. 2012) the Long-Term Temperate Reef Monitoring Program that has shown that it takes decades for closed areas to recover (Barrett et al. 2009). These, some additional university-led programs (e.g. Curtin University's

Australian bio-acoustic monitoring program, underway since the late 1990's) and the much newer IMOS are the only large-scale, long-term sustained monitoring programs in Australian waters. Quantitative, nationally consistent monitoring programs are required to establish where we have come from and what remains possible under changed management and a changing climate.

Terrestrial activities including the planned increased use of Northern Australia will have significant downstream impacts on fragile estuarine habitats that are characterised by low biological connectivity and provide essential habitat to vulnerable species (e.g. euryhaline elasmobranchs). Understanding the services that these habitats provide will be required before effects of upstream developments can be assessed.

While improved scientific knowledge will meet many needs, here we focus on an improved understanding of the science that supports evidence-based policy and management decision making.

Key outcomes/ national benefit that would flow from investment in this area

by 2020

- A nationally consistent integrated intertidal and sub-tidal habitat classification system for coastal, marine and estuarine habitats, building on existing systems, and including key representative ecosystem types to provide quantitative baselines, that can be used to identify MNES, improve environmental assessments, guide development, allow for attribution of sources of change and establish offsets as required.
- Nationally consistent faunal archives (including larval fish) would support cross-comparison and evaluation of fishery and environmental issues at the national scale.
- Quantitative understanding of organism-habitat relationships across major habitat types, and throughout species life-histories, would support more efficient spatial management of co-occurring species, potentially reducing cumulative impacts on marine users.
- Improved understanding of the distribution, abundance and environmental requirements of (non-target) animals affected by fishing and on and off-shore development and resource extraction, would support more informed environmental management of listed EPBC listed species, and reduce likelihood of other species becoming listed, including those considered data deficient by IUCN standards.
- An assessment of knowledge gaps of structure and function of marine ecosystems (including KEFs), followed by targeted research, would support ecosystem-based management.
- An improved national data infrastructure including national standards and protocols for data collection and interpretation, would improve the efficiency and accuracy of Environmental Impact Assessments, and provide wider (open) access to information for regional initiatives, including monitoring ecosystem health, marine reserve effectiveness and cumulative impact.
- Improved capacity and frameworks to identify cumulative impacts together with clear criteria for sustainability would inform the long-term management of biodiversity resources through improving EIAs, thus increasing the probability of biodiversity assets staying at of above sustainable levels.
- A nationally consistent monitoring and reporting framework to support evaluation of clearly defined operational management objectives for all CMRs and state-based MPAs, with

monitoring in place against a quantitative baseline inside and outside priority areas, would inform the effectiveness of this management approach and options for its improvement.

- Quantitative monitoring in place for priority KEFs and other biodiversity assets used in SOE would provide reliable indicators of trends in marine ecosystem health.
- Improved understanding of the consequences of climate change including range shifts and the adaptability/resilience of receiving environments would improve options to reduce and/or mitigate predicted impacts.

by 2025

- An initial evaluation of the performance of the CMR network against objectives to provide an initial measure of its success and review any interim management adjustments that would improve future performance against objectives.
- A review of ecosystem health monitoring in EEZ and state waters to provide an initial measure of its success in informing SOE and other national accounting and any adjustments necessary to improve its future performance.
- A nationally accepted framework to assess new environmental impacts against cumulative impact and long-term sustainability criteria, providing (where necessary) new options for mitigating or offsetting any new impacts.
- Established evidence-based policy framework to evaluate ecosystem intervention (assisted translocation, genetic engineering) to mitigate ecosystem impacts from climate change.
- IMCRA5 – providing a nationally consistent integrated classification of coastal, shelf and offshore waters including habitats, high-value areas, ecosystem services, pressures and existing legislation that will provide a common platform for individual sectoral management, contribute to identifying cumulative impacts and support the initial evaluation of the performance of the CMR network and the NRSMPA.
- Improved physical models and predictive capability to predict the distribution of biodiversity at increasingly finer scales of relevance to assessing environmental impact and monitoring.
- Harmonisation or coupling of macroecological biodiversity projection methods and process-based ecosystem models in support of evolving whole of system projections for use as synthesis tools but also to support integrated adaptive management of all marine industries.
- Increased palaeoecological work to establish historic and present day “baselines” for marine communities to quantify existing cumulative impacts and future climate-induced changes.
- Increased appreciation by those that use coastal, estuarine and marine environments through greater scientific understanding

by 2035

- IMCRA6 including microbiological community and ecosystem functioning to support CMR network and NRSMPA reviews
- An in-depth review and adjustment of the CMR network and state-based MPA systems based on the results of quantitative monitoring and evaluation frameworks.
- An in-depth review and adjustment of ecosystem health monitoring and SOE reporting using KEFs and equivalent state-based initiatives.
- A comprehensive assessment of sustainability for marine biodiversity and ecosystem resources that can be used to guide decisions on further development and use.

Perspective

Priorities to 2020

Develop in consultation with the private and primary industries sectors a nationally representative set of biodiversity indicators and monitoring protocols (ABCS 2010-2030 Priority Action 24).

Improve monitoring, evaluation and reporting on ecosystem health in the marine environment. (MBP Strategy F)

Develop and implement a framework for the long term scientific monitoring of changes in key conservation values protected by the Commonwealth marine reserves and on the pressures on those values (Strategy 1, SE Implementation Schedule, PA 2014)

The top science priority over the next 5 years needs to be the development of national set of biodiversity indicators that will inform management decisions and review how effectively we are progressing against agreed management objectives.

A model-based qualitative approach for monitoring marine ecosystem health built around Key Ecological Features in Australia's EEZ has been developed (Dambacher et al. 2012) and is now being tested. Existing and developing long-term monitoring programs including the AIMS Long-term monitoring programs (De'ath et al. 2013), the long-term temperate reef monitoring program (Barrett et al. 2009) and Reef Life Survey (Edgar et al. 2014) and programs under the Integrated Marine Observing System, need to be integrated with the KEF-based approach to develop a nationally-consistent integrated program that provides the quantitative basis for SOE reporting for coastal areas and the EEZ.

Marine reserves and MPAs provide the best opportunity to understand what the current undisturbed status of the marine environment is once local pressures are removed. However, MPAs take a long time to have an effect and many are not effective (Edgar et al. 2014). A national monitoring, evaluation and reporting program based on clear objectives is required, as recommended in 2008 by the NRM Council Marine Biodiversity Decline Report, using principles agreed under the integrated monitoring framework recently developed for the GBRMPA (Hedge et al. 2013).

An essential part of these monitoring programs will be continuing to develop national sampling standards (e.g. CATAMI), that can be used by government, universities, NGOs, industry to increase data usability for regional and national monitoring and management decisions.

Develop tools to help guide and support priority setting for threat management at different scales. (ABCS 2010-2030 Priority Action 17)

Increase understanding and use of a whole-of ecosystem approach in biodiversity management. (ABCS 2010-2030 Priority Action 12)

Develop in consultation with community and industry stakeholders national guidelines for incorporating adaptive management into biodiversity conservation.(ABCS 2010-2030 Priority Action 26)

Increase collaboration with relevant industries to improve understanding of the impacts of anthropogenic disturbance and address the cumulative effects on the region's key ecological features and protected species (Marine Bioregional Plans Strategy D)

Protect the conservation values of the marine reserves network through management of environmental incidents. Hazard identification, hazard/risk assessment and control of hazards/risks evaluation (2014-17).(Strategy 1, SE Implementation Schedule, PA 2014).

While many of the management measures implemented in the Great Barrier Reef Region and beyond are making a positive difference the ability to address cumulative impacts remains weak. … In particular, knowledge and understanding of the cumulative impacts of the multitude of uses and activities remains to be developed. (Independent assessment of the GRB Outlook Report 2014)

A second science priority until 2020 is to develop the research that would enable jurisdictions to understand and manage the impacts of multiple pressures on the environment including different sectors and over time. This will help provide scientific advice that highlights the relative risk of different activities and identifies where management can have the greatest effect.

There is a clearly articulated need to develop scientific approaches to estimate cumulative pressures over time on the marine environment and the relative impact of different sectors. The lack of this capability means that decisions are now made based only on the individual impact without taking into account other activities, pressures and their interactions. While many individual impacts may be acceptable, their cumulative impact may not, especially given environmental variability and trends (e.g. increased temperatures, increased ocean acidity and storm/cyclone frequencies). This is leading to a lack of transparency, uncertainty, costly delays and tension between interest groups with different perspectives and objectives – such as proponents who may see the impacts of their action as being relatively minor, and conservationists who see the overall resource as being driven below sustainable or “acceptable” levels. While it may prove difficult to estimate cumulative impacts without appropriate systems knowledge, it may prove easier to estimate a) relative impacts or b) estimate sustainability of biodiversity resources. This would provide the opportunity for different industry sectors to engage and determine how their cumulative pressures could be reduced through an integrated adaptive management approach, potentially including mitigation and offset activities to increase the probability that the affected biodiversity resource(s) would be sustainable over an agreed time period.

An ecosystem-based approach, which would take into account cumulative impacts, was developed by the former NRM Ministerial Council but was never implemented. Combining robust science with an appropriate management framework is a key step to successfully managing cumulative impacts. Consideration should be given to pilots that could test such an initiative.

Provide relevant, accessible and evidence-based information to support decision-making with respect to development proposals that come under the jurisdiction of the EPBC Act (Marine Bioregional Plan Strategy C)

A third science priority to 2020 is to provide the scientific data infrastructure that provides the majority of relevant scientific information collected in Australia to managers in an appropriate format and at an appropriate time to inform their decision making.

A key outcome of the Marine Bioregional Plans is to assist the minister in making decisions on activities that may impact marine values, especially matters of national environmental significance (MNES) protected under the EPBC Act (1999). Information on likely impacts of an activity is often

limited, however at the same time considerable information is not available at an appropriate time and format to inform proponents (in developing their activities and mitigation) or managers (in determining whether the activity needs to be referred under the act) and when strategic assessment is appropriate. While progress is being made in improving the availability of national environmental data, more needs to be done, and in particular this needs to be undertaken from the perspective of how additional (or updated) information would improve decisions. This will require a) increasing application of national standards in metadata delivery through AODN, b) increasing availability of key datasets online and linked to national data systems, and c) developing specific data query tools to provide developers and managers access to the best available information at appropriate scales and levels of detail. Key data will relate to key ecological features and protected species and the pressures on them.

Collate information on the ecosystem components, functioning, pressures and potential cumulative impacts on priority key ecological features in the region and develop effective ecological indicators that will facilitate future monitoring, evaluation and reporting of marine ecosystem health (medium to long term). Marine Bioregional Plan Strategy F

Complete assessments at national, state and regional levels to identify knowledge needs and gaps and to set research priorities for biodiversity conservation at all levels. (ABCS 2010-2030 Priority Action 19)

By 2015, nationally agreed science and knowledge priorities for biodiversity conservation are guiding research activities: 1) An increase in the accessibility of science and knowledge for biodiversity conservation; 2)An improvement in the alignment of research with biodiversity conservation priorities. ABCS 2010-2030 Priority Action 8

Engaging all Australians in biodiversity conservation through: mainstreaming biodiversity (ABCS 2010-2030. Priority 1)

With only a small proportion of the Australian EEZ surveyed, additional discovery will inform existing management needs for CMRs, KEFs and identifying biodiversity values in state waters. Improved understanding of physical processes (including nearshore hydrodynamics and sediment transport to understand fluxes and interactions between the coast and shelf; canyon and slope biodiversity value and productivity; bentho-pelagic coupling, and connectivity) will enhance capability to predict biodiversity values in areas that are not sampled, how these areas might change when impacted by pressures including those due to climate change, and assist in interpreting the results of long-term monitoring. It is important that predictions of biodiversity properties or potential change are provided with uncertainty so that decision makers understand the scientific basis informing their decisions and scientists can evaluate the underlying assumptions and resulting information gain. Communication of the results of biodiversity discovery can be both compelling and supports the need to increase the knowledge of biodiversity and the need for its sustainable management and conservation by all sectors.

Building ecosystem resilience in a changing climate by: 1) protecting diversity 2) maintaining and re‑establishing ecosystem functions, and 3) reducing threats to biodiversity. (ABCS 2010-2030. Priority Action 2)

Identify and protect climate change refugia to strengthen opportunities for genetic and ecological adaptation (ABCS 2010-2030. Priority Action 14)

Support research to improve information on the impacts of climate change on protected species and key ecological features; in particular, their vulnerability and adaptive capacity to predicted changes (Marine Bioregional Plan, regional priorities 1–6, 11)

Climate change research relevant to biodiversity and ecosystems discovery, prediction and monitoring is required to inform future management decisions, but the research need not be independent of other

biodiversity activities, indeed it is better for it to be considered as an integral component of all biodiversity and ecosystem research. Importantly, by providing the scientific information that will inform management responses to short-term climate variability, many of the responses to long-term change will be developed.

Priorities to 2025

Identify landscapes and seascapes in which habitat linkages are important for biodiversity conservation and secure these areas through mechanisms such as complementary land uses and partnerships between governments and private landholders. (ABCS 2010-2030 Priority Action 13)

In addition to those priorities identified for 2020, a new synthesis of biodiversity information is required to update the knowledge base on which marine spatial planning and management is based.

Biodiversity information underpinning resource management decisions includes national maps of the distribution of biodiversity and the underlying geospatial data. The Integrated Marine and Coastal Atlas (IMCRA4; Commonwealth of Australia 2006) was used in determining the boundaries of the CMR network IMCRA4 and IMCRA 3.3 was used to delineate MPAs in state waters. Such maps are required to determine whether reserve networks meet the goals of comprehensiveness and representativeness as agreed under the ANZECC guidelines They are also needed to inform the management (including EIAs) of off-reserve areas that being larger will typically have greater importance to long-term sustainability of most habitats and taxa in a strictly representative system. However IMCRA4 is dated and is due to be updated at some time after 2010. Significant advances in scientific understanding since 2006 support development of IMCRA5, however this needs to be driven by management and planning needs. IMCRA5 also needs to provide a nationally consistent approach, include coastal habitats, extend the taxa and species considered, identify areas of particular importance for vulnerable species; attempt to link benthic and pelagic habitats and be based on new biogeographies. The potential for including connectivity between habitats should also be examined. We suggest that IMCRA5 should be developed in time to assist the 10-year review of the CMR Management Plans.

- Nationally consistent biogeographies for at least 2 additional taxa groups
- National genescape –initial 3d map of microbial community structure and function
- Baseline and monitoring protocols for ecosystem health, including disease, to be included in national ecosystem health monitoring
- Status, growth and recovery rates of temperate and tropical marine communities
- Predictive maps for distribution of mangroves, saltmarshes, seagrass meadows and corals in 25 and 75 years, including identified adaptation bottlenecks to guide mitigation activities
- Identification of habitats facing a high risk of extinction due to global change
- Predictive maps for changes in status and migratory routes of fauna at high risk and/or with high value in providing ecosystem services.
- Protocols and prioritisation for assisted translocation established to manage help first-invaders from warming seas and changing currents, or to replace departing keystone species e.g. coral zooxanthellae

- Adaptive monitoring coupled with predictive modelling and adaptive learning

Priorities to 2035

In addition to earlier priorities, by 2035 marine science needs to be provided in an integrated framework that supports complementary management of marine resources by individual jurisdictions.

- Complementary management in place informed by sustained long-term monitoring of agreed priorities.
- Nationally consistent biogeographies for 2 additional taxa, as informed by information gain
- Updated Integrated Marine Coastal Atlas (IMCRA 6) including new biogeographies and genescape

Realisation

Key infrastructure and capability requirements/impediments

Maintain and expand existing monitoring and discovery following review against national objectives and priorities

Given the paucity of long-term monitoring programs in Australia, the first key requirement is the continuation of existing programs, plus their modification and expansion as needed following their evaluation and review of national requirements. Existing long-term monitoring programs, including AIMS LTRMPs, the RLS, the LTTRMP and IMOS biological programs need to be maintained as part of national monitoring infrastructure. A review of other monitoring programs is required to determine whether they meet national (Commonwealth and state) objectives, and if not how or whether they can be modified to do so, and to identify their links to international monitoring programs (e.g. GOOS).

Given the vast extent and remoteness of much of our EEZ, and the significant data gaps in many of our more familiar shelf and coastal regions, there is a pressing need for biodiversity discovery, including the fundamental characterisation of marine ecosystem processes. While academic funding will be prioritised to meet a range of requirements, state and national funding needs to be prioritised against established management needs and be consistent with and support international programs whenever possible. There are developing strategies to support this in Commonwealth waters, which a) need to be expanded to include state waters, and b) need to have greater profile in the scientific community:

- Improve knowledge and understanding of the conservation values of the marine reserves network and the pressures on those values. (Strategy 1, SE Implementation Schedule, PA 2014).
- Knowledge gaps identified and a scientific research and monitoring strategy developed that includes priority research areas and ecological baselines (2013/15).
- South-east priority research/monitoring commenced including: pilot deep water habitat monitoring; comparing areas inside and outside reserves, and recovery/response to cessation of trawling (2013-17) and other activities within sanctuary zones.
- Partnerships are identified and in place to actively support and deliver identified South-east research and monitoring priorities (2013-17).

Increase survey capabilities and capacities to achieve national monitoring and discovery needs

New technologies are providing a step increase in sampling capacities for marine systems and it is important that Australia starts to access these at an appropriate level to capitalize on existing investments in human resources and new infrastructure (e.g. the new MNF). Increased standardisation and capacity for monitoring in shallow waters requires additional investments in cameras on multiple platforms including AUVs (www.imos.org.au/auv), BRUVs (Letessier et al. 2013) and diver-held cameras, while a new investment in deep survey capability is required, especially to meet the needs of surveying and monitoring the new CMR network. To take advantage of the recent investment in the MNF at least 4 deepwater AUVs and 1 ROV should be used concurrently on deepwater surveys from 100-2000+m. These gears plus improved active and passive acoustic

samplers/monitoring networks and existing physical samplers on research and ships of opportunity would form the backbone of a national biodiversity sampling capability, while additional more advanced infrastructure options (e.g. hybrid glider/AUVs for long-distance programmed sampling, and even manned submersibles) should be examined for specific projects. Additional non-destructive sampling approaches with the potential for (semi) automation need to be developed, especially new samplers for bio-optics and assessing the genescape (Thomsen et al. 2012) for mounting on a variety of existing and new platforms, including in collaboration with industry and the public to access the widest possible range of sampling platforms (e.g. Kloser et al 2009, Stuart-Smith et al. 2013).

Standardized national data infrastructure

While substantial progress has been made in moving towards national standards for data infrastructure (eg. AODN, NEII), the current situation does not adequately support the needs for national consistency for the archival, access and interpretation of data. Similarly, the information requirements of key users of marine information in government and industry are not being adequately addressed. Thus scientific data is not having the impact that it could in meta-analyses, in informing state and Commonwealth decision making nor in improving the productivity of marine industries. A standardized national data infrastructure is required that includes:

- Improved data cataloguing, archival and communication
- Improved data processing, including automation and semi-automation algorithms (e.g. image processing, satellite data interpretation, and acoustic signal processing)
- Common data vocabulary in place and used by all main agencies, universities and consultants collecting biodiversity information
- An agreed national approach to classifying marine habitats and ecosystems (e.g. Australian National Aquatic Ecosystem toolbox and the National Intertidal and Subtidal Benthic Classification Scheme).
- An agreed subset of national data and interpreted products available through geonetwork (including biodiversity values, ecosystem values, regulations and pressures) to support industry users and decision-makers
- Development of new methods to combine disparate datasets in a meaningful way in analyses, in order to maximise their benefit
- Nationally consistent approaches to predictive mapping of marine species and assemblages that have been tested against common (known) datasets, and have direct measures of uncertainty are required specifically to inform national monitoring and risk assessment.

Infrastructure to support national marine ecosystem health monitoring:

The need to develop quantitative national indicators of marine ecosystem health is clear and progress has been made. Limited resources will restrict the development of this area and it is therefore essential that scientists make the most of all data being collected – by agencies, universities or industry consultants. This requires agreed national monitoring protocols for environmental assessment, biodiversity discovery and baseline monitoring.

Improved use of remote sensing, including satellite products, is required including:

- enhanced model products for biologically important oceanographic variables – upwelling strength, position and intensity of eddy fields, with output for coastal models at biologically relevant scales;
- Enhanced satellite products for primary production (plankton, mangroves, saltmarsh, seagrass and potentially corals) including coastal and Antarctic areas
- In situ verification of satellite products using UAVs, USVs , AUVs, smart phones and in situ measurements

Increased public engagement

Further/ re-engagement of the public with marine science and citizen science. Extending programs like reefwatch in SA, RedList, or the ABC's recent image scoring project should be mutually beneficial. This would require investment in websites, other digital technologies, marketing and data management.

Funding and coordination requirements/impediments

Maintain and expand existing monitoring and discovery following review against national objectives and priorities

Prioritising monitoring requires clear national (Commonwealth and state) operational management objectives for the CMR network, state-based MPAs, and off-reserve management in all waters, including coastal and estuarine. Progress has been made in establishing conservation values in the EEZ through the Marine Bioregional Plans (that define listed species, biologically important areas, key ecological features, and protected places including the CMR network), and the SE CMR Management Implementation Plan that provides strategies and actions against high-level objectives . These need to be completed nationally with similar (and hopefully comparable) priorities established for state waters. Stable long-term support through dedicated funding is required to ensure the sustainability of prioritised monitoring programs, many of which are now maintained by individual research providers.

Prioritising discovery should include prioritising research against Commonwealth and state objectives; research will often be required at early stages of monitoring programs and to increase understanding of existing and new conservation values, especially those subject to new and/or increasing pressures. A new national program supporting biodiversity discovery in the marine environment is required to complement those already available for terrestrial environments.

Increase survey capabilities and capacities to achieve national monitoring and discovery needs

While there has been substantial recent investment in marine research infrastructure (e.g. IMOS, the MNF), there is no nationally consistent approach to the prioritisation, development and operation of these assets. For example, despite the substantial investment in the MNF, there is not a comparable investment in its operating costs, so that currently it can only be used at ~60% capacity, and survey priorities are determined independently with little input to cover Australia's national interest.

Australian marine scientists need to continue to expand national (and international) collaboration to improve impacts and opportunities. There is also a need to increase engagement of national and state agencies to ensure that national and state priorities are given adequate consideration in research infrastructure decisions. This would require coordination across ministerial portfolios. However, such coordination would benefit integrated management of marine ecosystems and users more broadly.

Infrastructure needs (especially deepwater) may be prohibitively expensive for one agency to operate. The funding model of IMOS where national facilities are established servicing multiple users needs to be continued and expanded, possibly to include regional partners (e.g. NZ, SE Asia). This national approach should also be used to meet the need for smaller (24m) inshore vessels to support CMR and KEF shelf to slope monitoring and research, as well as state research. Partnerships or leasing with (through) the oil and gas industry could satisfy some of the new infrastructure needs.

Standardized national data infrastructure

National research institutions have up to now failed to adopt a single standard in data architecture, including vocabularies. An initial investment may be required to attain a single national standard.

General

Table 1. Researcher FTEs by area of expertise. (Murphy & Lewis (2014) Draft). Note: 10 of 32 institutions identified as contributing to 28-24% of publications in these areas not included in survey.

Area of Expertise	2009 (FTE)	2013 (FTE)	Change
Environmental impacts (incl. bycatch, wildlife interactions and biosecurity)	50	63	+13
Benthic Ecology	71	23	-48
Habitat mapping	10	22	+12
Pelagic ecology	18	15	-3
Ecosystem modelling	29	47	+18
Total	178	170	-8

Key contacts

- NERP Marine Biodiversity Hub – Director Nic Bax, University of Tasmania/CSIRO
- NERP Tropical Ecosystems Hub – Science Director, Peter Doherty, AIMS
- Australian Antarctic Division – Chief Scientist, Nick Gales, Department of Environment
- GBRMPA – Bruce Elliot, General Manager, Environment and Sustainability
- Department of Environment – MBH contact Travis Bover, or FAS Science Division Tony Fleming

Details of Australian researchers' global engagement

- The first global standardized survey of marine life on temperate and tropical reefs, and arguably the world's first standardised biodiversity survey
- The first two global biogeographies of deep sea invertebrates since Zezina (1997) making three in all
- The first updated global maps of the seafloor since the 1970's including characterisation of the world's large canyons
- The most widely used systematic reserve planning software in the world (Marxan)
- The world-leading expertise in developing decision support tools
    - Ecological Risk Assessment, which is now used globally for over 175 fisheries through the Marine Stewardship Council
    - Tactical ecosystem assessment models (Plaganyi et al. 2014)
    - Whole of system ("end-to-end") ecosystem models (e.g. Atlantis) (that have been designated by the FAO as best available for considering strategic ecosystem

management; these models designation). Atlantis is now being used in 26 countries, with 11 institutes using it to provide information to regulatory bodies covering 25 ecosystems.

- Led description of Ecologically and Biologically Sensitive Areas throughout the Southern Hemisphere
- Australian coral reefs are among the best studied in the world (Fisher et al 2011a) yet recent sampling discovered an estimated 1200 new species.
- Major contribution to the evidence base for a joint international submission (Australia, France, EU) for the nomination to CCAMLR of four Marine Protected Areas offshore from Australian Antarctic Territory (nomination pending)
- Leadership positions on numerous international marine biodiversity and ecosystem initiatives, including Census of Marine Life, CITES (IUCN RedList Specialist Groups for species and ecosystems), Global Ocean Observing System, Southern Ocean Observing System, Southern Ocean Research Partnership, UN World Ocean Assessment.

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Attachments

None