National Marine Science **Plan**

Science program to support **Decision-making**

Implementing Integrated Ecosystem Assessments (IEAs) Working Group Report

TECHNICAL REPORT

NATIONAL MARINE SCIENCE
— COMMITTEE —

Prepared by the National Marine Science Committee, with Toni Moate as Chair and Kim Picard as Deputy Chair.

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Acknowledgement of Country |

The NMSC acknowledges the Traditional Custodians and Elders of the land and sea on which we work and observe, and recognises their unique connection to land and sea. We pay our respects to Aboriginal and Torres Strait Islander peoples past, present and future.

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Summary

The use of ocean and coastal area resources is expanding at a rapid rate, causing mounting pressure on coastal and marine ecosystems through the activities of multiple sectors such as fisheries, oil and gas, marine renewable energy, seabed mining, shipping, and urban and coastal development.

All these activities are occurring against a background of climate-driven impacts and shifting baselines, necessitating climate-resilient decisions about the use of coastal and marine resources. Ensuring the sustainable management of these increasingly crowded marine spaces is difficult as it means balancing the needs and desires of the many competing users (including conservation), each with their own, and often competing, objectives, values, drivers and effects. Importantly, a variety of things are valued about marine systems – not only their tangible material resources and economic exploitation but also their cultural and existence values. Furthermore, existing approaches to management are sectorally based; different regulatory bodies treat individual ocean use sectors separately, with little formal interaction. Consequently, planning, policies and strategies to develop or reform one sector typically proceed with little (if any) consideration of the ramifications for other aspects of the system.

The full benefits and opportunities for maximising community wellbeing through careful management of the blue economy (greater than $100 billion in Australia alone (NMSC (2015)) cannot be fully met without adopting a new approach that comprehensively considers the various objectives, requirements and values of the multiple sectors. Such an approach could not be focused only on biophysical components but would need to be explicitly transdisciplinary – linking the physical environmental, natural world and the human parts of marine and coast systems by calling upon many expert disciplines (e.g. First Nations, science, industry, regulatory bodies, non-government organisations (NGOs), community groups). This new approach would not be a replacement for individual sector regulatory processes or marine spatial planning but would provide a broader context – a system level picture of what is going on. This would more transparently identify what needs to be considered with marine spatial planning and regulatory processes, going further than simple map overlays to look at interactions and trade-offs between different parts of marine and coastal systems (i.e. physical, natural and anthropogenic).

This report was developed in response to the recommendations within the National Marine Science Plan 2015–2025 for a dedicated and coordinated science program to support decision-making by policymakers and marine industry. Science priorities included: improving the scientific evidence base and the available decision-support tools for those managing the impacts of multiple and cumulative drivers and pressures on marine systems; and the integration of social, economic and cultural factors into marine estate assessments, and into decision processes for resource allocation and development. The report provides a roadmap for how to achieve these priorities within Australian jurisdictions through the use of Integrated Ecosystem Assessments (IEAs).

IEAs are internationally emerging as the preferred process to inform the management of increasingly crowded and contested marine and coastal estates. The IEA approach was originally developed in the US and Europe to serve as a scientific foundation for marine ecosystem-based management. It is most useful in identifying trade-offs in the management of different marine industries and sectors, identifying cumulative impacts, and dealing explicitly with uncertainty. It is important to note that an IEA is a strategic planning approach that is not a replacement for operationally focused sector-based regulatory processes. Nor does it supplant formal marine spatial planning. Instead, an IEA provides the (socio-ecological) context for those processes, acting as a means of injecting science into the policy–management interface. This means those processes can operate from a firm and transparent evidence-based foundation, which explicitly considers cumulative effects, interactions and trade-offs.

The IEA process includes several distinct steps, which are applied iteratively. It is an interdisciplinary and policy-orientated process for combining, interpreting and communicating knowledge from diverse knowledge systems (i.e. multiple scientific disciplines including economics and social sciences, traditional and local knowledge, and experiential knowledge from industry) to inform and enhance decision-making. An IEA Working Group was established by the National Marine Science Committee (NMSC) to: (i) examine how the approach builds on, and is complementary to, other existing multi-sectoral processes, including marine spatial planning) and newer processes such as the United Nations (UN) System of Environmental-Economic Accounting (SEEA), (ii) assess how close we have already come to completing a marine IEA in Australia, and (iii) determine what would be required to undertake a pilot IEA.

While full IEAs have never been undertaken in Australia, there are examples where other approaches that contain some or many of the elements of IEAs have been undertaken. Based on these, we selected several marine and coastal case studies (Ningaloo, Gladstone Harbour, South East Australia – Alternative Management

Strategies, and the Great Barrier Reef). It was also noted that there are useful terrestrial and freshwater analogues to draw on too, such as the Bioregional Assessment Program. We assessed these case studies against the steps in an IEA process to provide insights into what worked and what was less successful.

To assist with implementation of IEAs in Australia, four potential pilots – Spencer Gulf, Victorian Coast, New South Wales (NSW) Marine Estate and Northern Seascapes – were selected to make sure the approach meets Australia's needs. The proposed pilots cover different spatial extents and user complexity, including different competing objectives, needs and uses, and different levels of data and knowledge. These contrasting examples were selected to enable the effectiveness of IEA tools with different requirements of scientific certainty in data and information to be evaluated in conjunction with decision-makers and stakeholders. By testing the IEA approach across a diverse range of locations, a benchmark set of needs and approaches will be articulated for other future uses, locations and jurisdictions.

Objectives and enabling elements exist in many cases, but delivery of IEAs in Australia has so far not progressed much beyond the scoping and data collation stages, except perhaps in the NSW example. For the case studies, indicators and evaluation of management options have been undertaken to some degree, but this is generally not common nationally.

The Working Group reviewed the case studies and determined future requirements to complete an IEA for each pilot. In doing so, criteria and considerations to assist implementing IEAs in Australia were identified and are recommended to ensure the approach is as effective as possible. These are:

- a clearly articulated need
- a preference for enabling elements (like policy, governance and long-term funding)
- effective and truly participatory (not just 'talking at') stakeholder engagement
- a socio-ecological focus
- the need to get the available data into a discoverable and coherent form
- the recommendation that IEAs be conducted in a staged manner
- the need to use an ensemble approach, including qualitative and quantitative approaches
- the need for clarity around spatial extent and scale
- the need for IEAs to be positioned within an adaptive management context.

While jurisdictional complexities remain a challenge, there is now a greater desire to coordinate across departments and levels of government to simplify administrative requirements and legal complexities, while simultaneously allowing for collaborative and respectful Indigenous partnerships, creation of climate resilience and streamlined marine spatial planning. A more risk-based approach is driving thinking, in part motivated by observations and lived experience that interactions and cumulative risk are being realised as population and pressures grow. Importantly, the presence of enabling elements (such as legislation and governance frameworks) certainly help motivate and legitimise the process, especially long term, but should not been seen as a barrier to beginning the work. Even without these, the process reveals important insights into uncertainty and trade-offs supporting decision-making.

Indicative costs required to complete each pilot were identified. This level of indicative investment is not trivial, but all the pilots show great benefit in terms of: delivery into policy and reporting processes (such ocean accounts now required at a national level in line with UN SEEA guidelines), development, and planning; delivery into the expansion of knowledge of these systems in question; and development of the transdisciplinary collaborations necessary to grow our national expertise in complex decision-making. In all cases there are significant advantages to using a staged approach to deliver the components of the IEA and progressing the package, as this allows for continuing the process even in the absence of complete information and scientific certainty. That is, start with manageable components of the larger, seemingly intractable problem, recognising that as an iterative process, each component can be updated in a subsequent iteration.

While the IEA process can seem daunting, it is a process that is increasingly seen as the only way forward for crowded, stressed and changing marine and coastal systems. Without such a process, and without an understanding of how to do it well, significant tension/conflict, economic loss and environmental degradation will result. Having some integrated decision-making process is ultimately cheaper, less risky and more robust than none at all. IEA is most helpfully developed as an incremental process, which results in direct management benefits even from its early stages.

Integrated assessment and methods for minimising and avoiding cumulative effects are an increasing focus for national and international policy and initiatives. Maximising sustainable development benefits, while minimising and avoiding degradation due to cumulative effects, is at the heart of the UN Sustainable Development Goals. Similarly, as a member of the High Level Panel for a Sustainable Ocean Economy, Australia has committed to the establishment of a Sustainable Oceans Plan by 2025 to ensure that 100 per cent of ocean areas under Australia's jurisdiction are sustainably managed. The process of achieving this goal will benefit from the approaches described in this document because integrated assessments are an evidence-based means of developing such plans. Assessing cumulative impacts is also central to the UN Decade of Ocean Science for Sustainable Development. These developments are also consistent with the recent Environment Protection and Biodiversity Conservation (EPBC) review recommendation that formal cumulative effects assessments should be central to the certified application of national environmental standards under a revitalised EPBC Act. In addition, through the Department of Agriculture Water and the Environment, Australia is starting to develop a framework for environmental-economic accounting – to facilitate reporting to the UN SEEA process, which has seen the development of methods for deriving ecosystem accounts since 2018. Recognition of ecosystem assets, including marine ecosystem assets through national statistical offices would both increase the need for appropriate data and monitoring and provide a sound basis from which to measure the performance of IEA initiatives. The United Nations Environmental Program (UNEP) integrated environmental assessment and reporting framework also shares the same basic steps as the IEA process presented here. While the explicit terminology used for the two approaches may differ, the core concepts are analogous.

Finally, while Australia has pockets of relevant best practice capability for integrating decision-making in marine systems, these are dispersed across the country. There are good examples of partially integrated decisions in different locations. However, we lack a coordinated and consistent approach and a strong national capability to deliver these processes to scale to enable more effective decision-making for the national benefit.

It is recommended that:

1. the NMSC continues to support IEAs as the preferred way of addressing the National Marine Science Plan recommendation for a dedicated and coordinated science program to support decision-making by policymakers and marine industry
2. a national trial of the potential pilot(s) is undertaken, and the process and results of these pilots are evaluated and reviewed and used to develop a set of IEA guidelines for implementation nationally
3. the criteria and considerations identified by the working group are adopted to ensure the effectiveness of future IEAs
4. the Working Group be expanded and tasked with developing an implementation plan in conjunction with decision-makers and other stakeholders.

Image: John Turnbull, www.marineexplorer.org

Introduction and context |

The use of ocean and coastal area resources is expanding at a rapid (close to exponential) rate (Plagányi and Fulton, 2019; Jouffray *et al.*, 2020), causing mounting pressure on coastal and marine systems through the activities of multiple sectors such as fisheries, oil and gas, marine renewable energy, seabed mining, shipping, and urban and coastal development.

All of these activities are occurring against a background of climate-driven impacts (IPCC, 2019) and shifting baselines (Pauly, 1995), necessitating climate-resilient decisions about the use of coastal and marine resources. The challenge of this complexity becomes particularly clear where sectors have conflicting objectives or result in user conflict. All of this makes ensuring the sustainable management of these increasingly crowded marine spaces difficult – as it means balancing the needs and desires of the many competing users (including conservation), each with their own objectives, values, drivers and effects. Importantly, a variety of things are valued about marine systems – not only their tangible material resources and economic exploitation, but also their cultural and existence values (Ogier and Macleod, 2013).

Managing coastal and marine resources will become more difficult as the demands of multiple users increase. The Organisation for Economic Co-operation and Development (OECD) conservatively estimated the value of the blue economy in 2010 at US$1.5 trillion and this is anticipated to grow to US$3 trillion by 2030 (OECD, 2016). Continued growth will place additional pressures on the ecosystems that support this economic activity. The three largest global risks are now perceived to be environmental – climate action failure, extreme weather and biodiversity loss (World Economic Forum, 2020). In fact, most estimates of increased value are additive. They do not consider interactions within and between sectors, cumulative impacts or 'social licence to operate'.

The number of interactions involved in these complex systems quickly exceed 'common sense' judgment and can overwhelm those tasked with management, leading to conflicts between users, additional pressure on the systems and contentious decision-making. Furthermore, existing approaches to management are sectorally based, treating individual ocean-use sectors separately; fisheries, conservation, energy, shipping and coastal zone management are generally all handled separately, by different regulatory bodies and jurisdictions, with little formal interaction, and generally through different legislative and policy instruments. While integrated frameworks are emerging in some states (e.g. marine spatial planning approaches in Victoria[1] and the Marine Estate Management Authority work in NSW), they are not yet implemented (Victoria), or have only been operating for a short period (NSW). Planning, policies and strategies for development or reform of one sector have typically proceeded with little (if any) consideration of other aspects of the system. Even seemingly related industries such as aquaculture and fisheries are under different legislative and jurisdictional arrangements. In other cases, such as marine renewable energy or offshore aquaculture, policy either does not exist in some jurisdictions or is only just being formulated (but often without reference to other marine activities in the same areas). This complexity can have potentially costly outcomes in terms of degradation, which globally is estimated to cost US$13 billion annually in terms of lost resources and clean up.[2] Moreover, it can cause significant costs to industry, for example, in the form of delays in decisions on whether developments can progress. Estimates by the Productivity Commission suggest that these costs can be in the order of tens to hundreds of millions of dollars per year annually (Productivity Commission, 2013).

Interactions between industries can also see a loss in productivity across users or see some users excluded, as has happened to fisheries in some areas, where access is no longer possible. A non-trivial component of all of these negative outcomes is an under-appreciation of the influence of cumulative pressure. Moreover, there are many missed opportunities to exploit win-win situations.

The National Marine Science Plan recommended developing a dedicated and coordinated science program to support decision-making by policymakers and marine industry. Science priorities included: improving the scientific evidence base and the available decision-support tools for those managing the impacts of multiple and cumulative drivers and pressures on marine systems; and the integration of social, economic and cultural factors into marine estate assessments, and into decision processes for resource allocation and development. An IEA Working Group was established by the NMSC to consider how IEAs could be implemented in Australia.

IEAs were chosen as a focus for the working group because they are the emerging international solution to this question of providing a scientific evidence base to complex marine and coastal system management

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1 https://www.legislation.vic.gov.au/in-force/acts/marine-and-coastal-act-2018/003

2 https://www.worldfinance.com/markets/counting-the-cost-of-plastic-pollution

questions. Over the past two decades (but particularly the last 5–10 years), there has been a growing push for cumulative effects assessments to support more integrated management approaches. While this work may have initially been motivated by individual sectors (e.g. fisheries), trying to disentangle drivers and plan for the constraints they would be facing going forward, more recently a more cross-sectoral focus has been evident. A good deal of this has happened in North America and Europe (Korpinen and Andersen, 2016), but there is a growing list of jurisdictions attempting to give broader consideration to multi-sector planning and coordination. IEAs have emerged as the international front-runner for addressing these opportunities and challenges. However, IEAs are yet to be fully implemented in Australia. The IEA approach was developed in the US and Europe to serve as a scientific foundation for marine ecosystem-based management. It is most useful in identifying trade-offs in the management of different marine industries and sectors and dealing explicitly with uncertainty.

IEAs provide a system-wide perspective. They are not focused only on the natural world part of ecosystems, but also encompass the users of the systems, including social, cultural and economic considerations. This is done using transdisciplinary methods, which explicitly involve the engagement of experts on the various parts of the system from sciences (of all kinds) as well as representatives of industry, regulatory bodies, First Nations, NGOs and other community groups. The information from these groups helps set objectives to be judged within the IEA as well as providing information synthesised within the assessment.

An IEA draws on information from many sources, including stakeholder groups, existing monitoring schemes, other sources of geographically relevant data, State of Environment compilations and outlook reports. It is a strategic planning exercise that is not a replacement for operationally focused sector-based regulatory processes. Nor does it supplant formal marine spatial planning. Instead, an IEA provides the (socio-ecological) context for those processes, acting as a means of injecting science into the policy–management interface. This means those processes can operate from a firm and transparent evidence-based foundation, which explicitly considers cumulative effects, interactions and trade-offs.

This report summarises what an IEA is, notes how it builds on, and is complementary to, other existing multi-sectoral processes, including marine spatial planning, examines how close we have already come to completing a marine IEA in Australia, and determines what would be required to undertake a pilot IEA.

> *“IEAs provide a system-wide perspective – they are not focused only on the natural world part of ecosystems, but also encompass the users of the systems, including social, cultural and economic considerations.*

The importance of transdisciplinary engagement

Evidence from the most successful management-related processes globally, whether sectorally or cross-sectorally motivated, is that the process needs to be inherently inclusive and participatory. This is important to note as sectoral distinctions in marine activities are continued in similar distinctions between the researchers, research users and funders of research required for IEA. Bringing these three stakeholder groups together and maintaining collaboration throughout is an essential component of transdisciplinary research, where ‘the domains of science, management, planning, policy and practice are interactively involved in issue framing, knowledge production and knowledge application’ (Roux *et al*., 2010). Note that the knowledge holders and managers involved go beyond industry operators or regulatory bodies to include traditional owners and other sectors of civil society.

Traditional incentive systems for academic researchers, current trends in public sector management, and the loose organisation of many end-users in Australia works against sustained transdisciplinary research, which requires continuity and adaptive learning by all three parties (Campbell *et al*., 2015). Nevertheless, it is still the right approach (so long as those involved understand what is realistically required), as research has greater influence on environmental policy and management when researchers, funders and research users have shared goals, can build trust and can sustain dialogue throughout. There is a suite of tools and approaches to improve knowledge exchange (e.g. Cvitanovic *et al*., 2015). Transdisciplinary research initiatives also require sufficient flexibility in their funding, structure and operation to enable the enterprise to assimilate and respond to new knowledge and situations.

Overview of IEAs and current usage |

The IEA approach is an interdisciplinary and policy-orientated process for combining, interpreting and communicating knowledge from diverse knowledge systems (i.e. multiple scientific disciplines, traditional and local knowledge, and experiential knowledge from industry) to inform and enhance decision-making.

The approach enables governments, investors and key stakeholders to evaluate development and environmental futures at regional and local scales, identifying areas where development and environmental conservation values overlap, compete or complement. IEAs can also ensure that interactions between aspects of the system – natural and anthropogenic – are recognised and that suitable options for processes and assessment practices are identified to reduce the risks involved for all parties.

Before going further, it is important to make clear that IEA is a process distinct from the tools and methods used within each stage of the process. For example, in Figure 1, decision-making and decision-supporting processes are marked in grey, while decision-support tools and management tools are marked in blue.

Tools may change over time as scientists and decision-makers continue to work together to improve how information is delivered and used, while decision-supporting processes are likely to be needed in a similar form, albeit with changing names, for the foreseeable future. (Also see the Glossary for definitions of tools and processes.)

The IEA process allows for early identification of knowledge gaps, underappreciated interactions between uses or system components, and trade-offs between objectives and other barriers in advance of decision-making (e.g. around development decisions). In addition, the process also supports the explicit understanding by each sector or all other sectors' values and concerns.

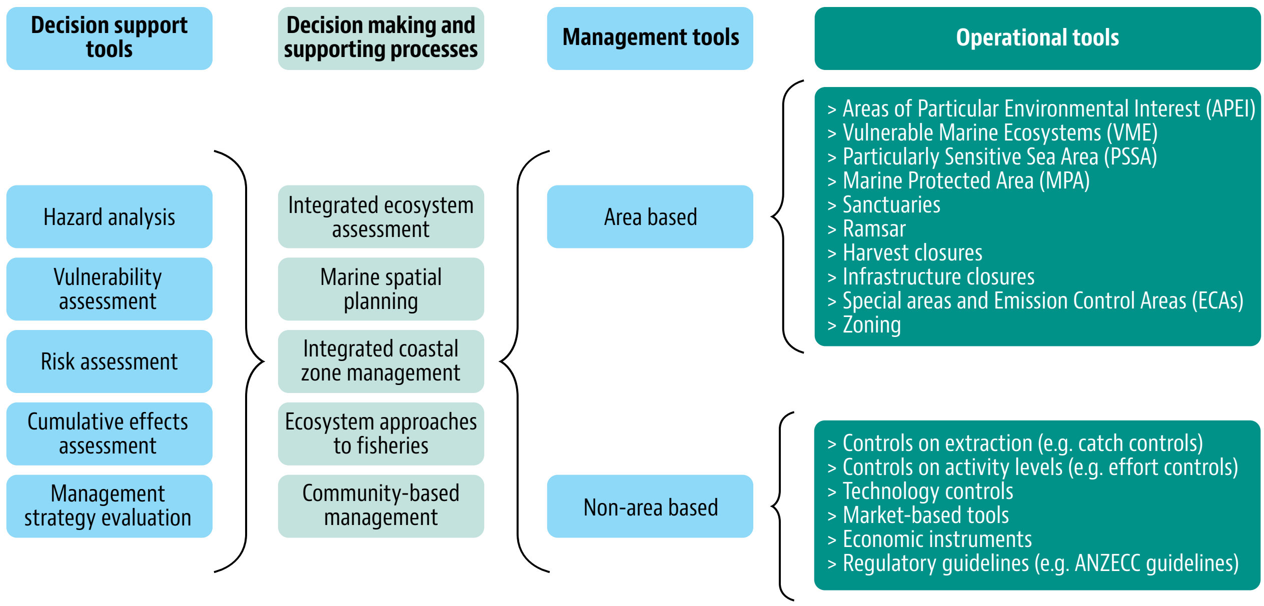

Figure 1: Types of decision-making processes and different management tools that can be used within that process (redrawn from the Second World Ocean Assessment, UN 2021.

IEA has been demonstrated in Europe and the US to have significant potential to improve the handling of development planning and approvals in complex and crowded marine landscapes and in contested areas containing high biodiversity and cultural values. The approach is particularly well-suited for avoiding cumulative impacts from multiple development actions across multiple sectors. In particular, industry and agency decision-makers are better prepared to avoid, mitigate or offset risks to the region's environmental, economic, social or cultural values.

IEAs have previously been used (primarily in the northern hemisphere) to support planning in the marine and terrestrial realm. However, the basic concept underlies the processes supporting the creation of the Commonwealth Marine Areas and has been identified as particularly relevant to strategic assessments under the *Environment Protection and Biodiversity Conservation Act 1999*.

The IEA process initially put forward by Levin *et al*., (2009) is both integrative and management oriented. While evolving in specific detail (as it is tailored to the conditions and needs at individual sites and as new tools become available), this approach is becoming widely used across North America and Europe. The IEA process (summarised in Figure 2) provides a consultative process, inspired by (and thereby similar to) the adaptive management cycle, which allows for identification of management issues across both ecosystem components, cultural values and marine and coastal sectors. The specific intention of the IEA approach is to provide robust decision-support information.

Globally, many means of identifying cumulative effects on ocean health have been put forward. While these methods share some common features, there is as yet no single agreed approach. This has led to the perception that such assessment methods are still in early development (DePiper *et al*., 2017), which they are not. There is surely plenty of scope for refinement or modification for new jurisdictional needs, but examples of the basic structure and flow of the process is demonstrably in place. A common approach taken is the additive mapping of human uses in a region (e.g. Jones *et al*., 2018 for Spencer Gulf; Halpern *et al*., 2012 at the global scale). This overlays intensity of use by individual sectors and maps of the distribution of habitats, flora and fauna, or other ecosystem attributes or services (e.g. as done in Spencer Gulf; Jones *et al*., 2018). Typically, the vulnerability or sensitivity of these habitats and ecosystem components to the activities of individual sectors is also considered through expert-derived impact weights (Halpern *et al*., 2008; Teck *et al*., 2010). This approach has often been taken as 'the best available approach to multiple-use planning' or in support of development activities where there is concern for a particularly vulnerable species (e.g. pink dolphins in Hong Kong; Marcotte *et al*., 2015). While this approach could form the first steps of a larger IEA process, it has typically been treated as an end in itself. However, approaches to date (almost without exception) assume that interactions between activities or stressors are strictly additive; the results are very sensitive to this and other assumptions (Stock and Micheli, 2016), and the approach can lack a formal delivery through to management advice.

The IEA process includes several distinct steps, which are applied iteratively, as summarised in Levin *et al*., (2009). Further details of what this looks like as it is implemented for specific systems can be found on the NOAA website[3] and also on the ICES website[4].

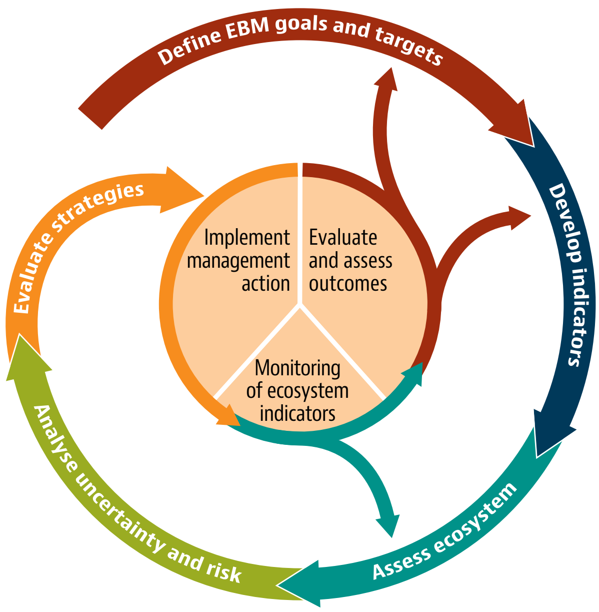

Figure 2: Conceptual diagram of the Integrated Ecosystem Assessment process (reproduced from DePiper *et al*., 2017).

An IEA includes the following steps:

1. **Engagement:** This is both the first and most fundamental step in IEA – creating a true dialogue between the many interested parties for the region of interest, i.e. those who have a tangible interest in or a connection with the outcomes of the assessment. This represents the first two of seven minimum requirements in the EU Marine Spatial Planning directive to 'involve stakeholders' and 'develop cross-border cooperation' (Friess and Grémaud-Colombier, 2019). Resource management, adaptive management and risk assessment literature all also stress the critical importance of effective engagement for successful processes (National Research Council, 1996; Walters, 1998; Pomeroy *et al*., 2001). Success comes from seeing the individual knowledge, concerns, hopes, fears and values reflected in the outcomes and the process, building a common understanding of what the outcomes are expected to be and how they will be judged (as achieved or not), allowing for clear understanding of how an outcome was reached and a sense of ownership of that outcome and the pathway to it. Engagement is not necessarily easy or straightforward. The process must be open and iterative. However, it is still a nuanced process, with differing styles and even level or type of engagement needed across communities, stakeholders and the publics (Colvin *et al*., 2016). It is important to note that in an Australian context, traditional owners are considered rights holders as they have title in some areas over places, cultural heritage and other assets. While traditional owners are often broadly considered stakeholders, the distinction is both culturally and legally important as it gives them a more strongly held stake in any engagement. Crucially, engagement is not a one-off; it needs to occur throughout the process (Table 1).

2. **Scoping:** This step provides a broad systems context. It includes identifying the appropriate spatial and temporal scope of the assessment, either consolidating or specifying objectives, identifying the components or process of the ecosystem (the assets or assessment endpoints) that are valued and to be managed appropriately, and identifying the pressures or stressors (or threats) to these system components and processes. Therefore, an important part of the scoping is to identify values, attributes and assets that people and organisations care about. This first step is critically important to the entire IEA process and can determine its ultimate success or failure (Margerum, 1999). The components and objectives identified in this step determine the scope of the entire IEA process (Dunstan *et al*., 2016). If objectives are only set for one sector, then the IEA process will only deal with that sector. If a multisector process is desired, then components relevant to all sectors need to be defined, objectives (or outcomes) need to be identified for each sector and cross-sector objectives defined, if necessary. To ensure success, this scoping is done in consultation with stakeholders and experts on the system. In this way, existing understanding of the system and its drivers can be used to maximum effect, and the process can be kept tractable in terms of needed resources. Focusing on legislated objectives can facilitate practical implementation of an IEA when disciplinary or sectoral communication blockages or disagreements are hampering progress (DePiper *et al*., 2017). Having existing objectives defined by legislation or policy (whether by sector initially or overarching) is a key enabler for an IEA.

3. **Indicator development:** Assessing system state and trends requires appropriate indicators. Thus step 3 is to identify appropriate indicators, the value of which must also be validated. Indicators are the metrics (measurement endpoints) used to track ecosystem and socio-economic attributes of interest, so it is important to understand their true information content (e.g. how well they correlate with those attributes and what the biases are). These indicators may be the status of a specific species (e.g. target or endangered species) or habitats, or they may be more systemic (e.g. ocean colour), or synthetic (i.e. calculated off some other property, such as ocean health index; Halpern *et al*., 2012), or social and economic indicators. To allow for these indicators to be used as performance measures (to judge progress against objectives), meaningful reference points and any potential thresholds associated with the indicators should be identified (e.g. as described in Samhouri *et al*., 2012). Ideally, indicator selection should be linked to management objectives (Hayes *et al*., 2015), should respond to ecosystem changes in a readily interpretable manner (i.e. including attribution), be easy to measure, and have agreed responses when these thresholds are crossed (like passing a reference point in a fisheries harvest strategy). Ideally, suites of indicators are used, because it has been found that this approach is the best means of spanning a wide range of processes and system components (including groups with fast turnover rates that act as 'early warning' indicators, target species, habitat-defining groups and top predators that provide 'integrated system state' proxies; Fulton *et al*., 2005; Link 2005). This step of an IEA can identify gaps in available data coverage, as data is another key enabler of the IEA process.

3 https://www.integratedecosystemassessment.noaa.gov

4 http://www.ices.dk/community/groups/Pages/IEASG.aspx

4 Ecosystem assessment: An analysis is undertaken for each indicator identified in step 3 to determine the status and trends in performance of the system versus the objectives relevant to that indicator. The individual indicator results can then be quantitatively (e.g. statistically) integrated to provide an assessment of ecosystem status and trends relative to historical conditions, management goals and prescribed targets. The assessment can also include an analysis of environmental assets that have been agreed during the scoping step to reflect the main components to be included in an assessment of threat and risk to these assets. Environmental assets may need to be further characterised, for example by depth, exposure or estuary morphology, to better reflect inherent differences in their structure and composition that are important in an assessment of risks, and/or to make them more relevant to a management objective.

5 Risk assessment: A risk analysis is undertaken to qualitatively or quantitatively determine the likelihood that each indicator will reach or remain in an undesirable state (i.e. breach or remain below a reference limit), within a carefully specified spatio-temporal context. This step evaluates the risk to individual ecosystem components and/or overall system integrity posed by the drivers and pressures identified during the scoping stage. The risk assessment method applied should allow for the inclusion of all relevant activities, identify the stressors (i.e. pressures, hazards) that result in impacts on assets, and then assess the likelihood of impact due to those stressors. This analytical step often takes a hierarchical approach (Dunstan *et al*., 2015) (Figure 3), similar to that used in the ecological risk assessment for the effects of fishing approach employed by the Australian Fisheries Management Authority to assess fisheries in their jurisdiction (Hobday *et al*., 2011).

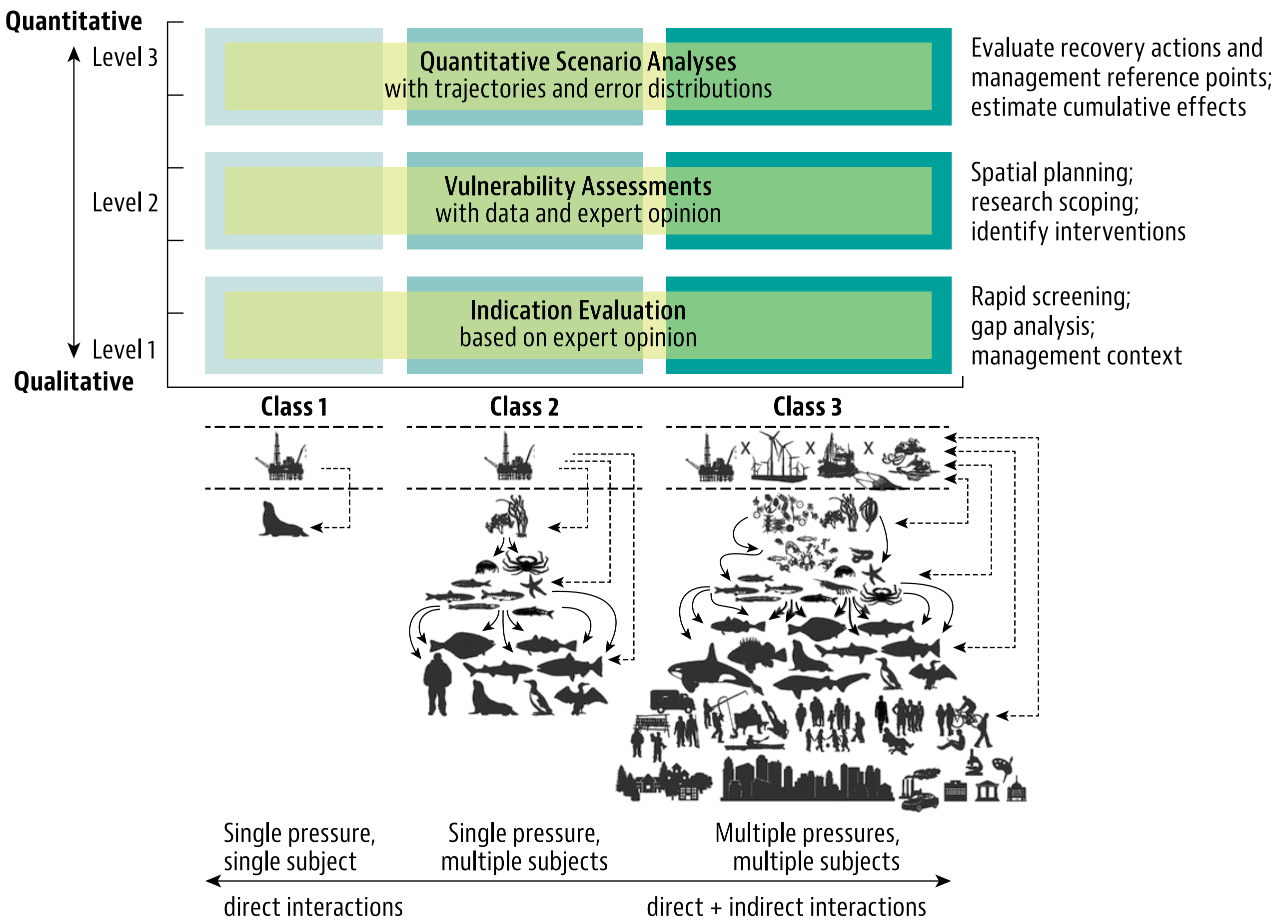

Figure 3: Hierarchical conceptual framework for integrated ecosystem risk assessment. Scoping and stakeholder engagement increase left to right. Data and computational requirements increase diagonally from lower left to upper right. The far right column highlights example applications of each level of ecosystem risk assessment. (Image and caption from Holsman *et al*., 2017).

In these hierarchical approaches, the risk assessment often begins with a qualitative (expert-based) step, where impact pathways (from pressure to hazard to a system component or objective) are identified and rated in terms of likelihood and consequence (level of effect). The scope of the assessment at this stage, typically addressing all possible impact pathways across hundreds or even thousands of system components, usually precludes an empirical analysis. Hence the first stage often relies on qualitative, expert-based information producing nominal (e.g. high, medium, low) risk predictions (see for example BMT WBM, 2017). Many assessments have ended at this point (either due to limited resources or because they have fulfilled the needs of the users who were looking for policy or planning guidelines). Qualitative assessments are also readily applied to evaluating risks to socio-economic and cultural values (e.g. Gollan *et al*., 2019). For assessments that go further, this first stage will have prioritised areas for more quantitative risk assessment.

Further quantification of risk to those components found to be at moderate or high risk in the first stage is possible by progressing to a semi-quantitative approach (ordinal risk predictions), which utilises a variety of frameworks and algorithms that score concepts such as exposure, susceptibility, vulnerability and resilience to arrive at ordinal scale risk predictions (e.g. 1, 2, 3, 4) (see, for example, Samhouri *et al*., 2019). Unfortunately, qualitative and semi-quantitative risk predictions are rarely calibrated to real-world measurable outcomes, so the accuracy of the predictions is generally unknown.

If system components are still predicted to be at risk, then a fully quantitative (ratio-scale risk predictions) assessment can be undertaken. These typically entail some form of statistical and/or process-based modelling, similar to that undertaken during a full stock assessment in fisheries or a digital-twin stress and design assessment in engineering. Management strategy evaluation (MSE) is a commonly used approach within natural resource management that has been extended to the IEA context (e.g. Fulton *et al*., 2017). Fully quantitative risk assessments should make predictions about the likelihood of measurable changes in system components which can be (at least in theory) (in) validated by observations. The advantage of a tiered approach, however, is that it provides a tractable way to deal with the complex interplay of large numbers of factors across many system components, reducing the potential risk domain from hundreds of issues to more manageable numbers, for focused attention on the most significant risks. This is shown diagrammatically in Figure 4.

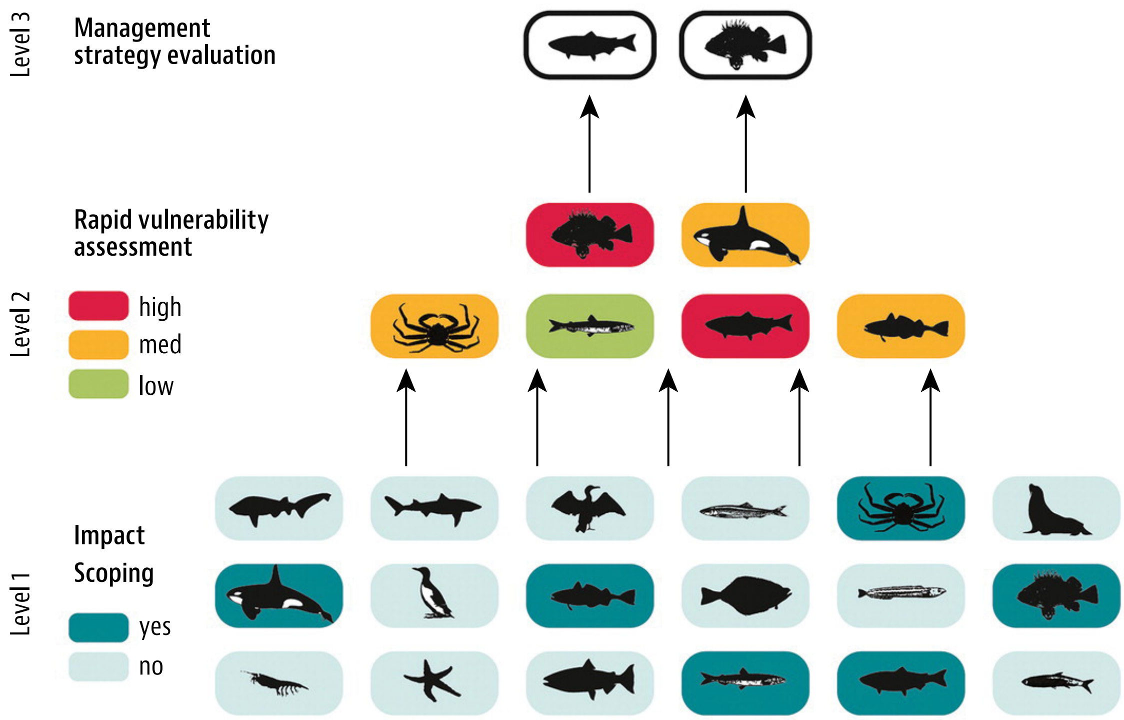

Figure 4: Example (hypothetical) tiered risk assessment (in this case of species, but it could be any system component). Level 1 = rapid scoping and screening; Level 2 = vulnerability assessment for impacted components; Level 3 = full quantitative assessments for high-risk components (including management strategy evaluation of management options). (Image from Holsman *et al*., 2017).

In complex situations involving multiple interactions between pressures and ecosystem assets, a coupled approach (e.g. via simulation or statistical modelling) is encouraged at the final quantitative stage, as this is the best means of assessing socio-ecological vulnerability rather than simply ecological vulnerability. It allows for engagement of a broader range of stakeholders but also direct consideration of non-linear interactions between drivers, pressures and system components across sectors and scales.

The following steps of the IEA process are relevant to all steps of this tiered assessment approach. However, they are critically important when undertaking a full quantitative assessment as they are standard parts of that form of assessment.

6 **Uncertainty assessment:** It is important to explicitly consider uncertainties associated with the risk analyses and indicator values. This includes four fundamental sources of uncertainty: (i) uncertainty that arises through the inherent vagaries of language (linguistic uncertainty), (ii) the uncertainty created by our limited understanding of natural systems (epistemic uncertainty), (iii) the uncertainty created by the irreducible variation in these systems (variability), and finally (iv) the uncertainty associated with our value systems and management decisions (decision uncertainty).

Approaches to uncertainty analysis are many and varied, within and across disciplines, depending on which of these sources is being addressed and the context of the assessment (qualitative or quantitative; this is a very large topic and cannot be covered in depth here). Uncertainty assessment may be inherent to the method being used or it may shape the form of additional analyses used for other steps. For example, if MSE is used to evaluate different mitigation or management options, then uncertainty consideration is built into the process itself via the inclusion of multiple management strategies, systems and parametric specifications.

When basing the uncertainty analysis on quantitative models, it is important to consider both observation uncertainty and structural uncertainties (e.g. how impact pathways run from pressure to system component or how components interact) involved in: (i) understanding and quantifying ecosystem dynamics, and (ii) the effects (positive and negative) that changes in system components have on the attributes of the system (environmental, social, economic and cultural) that are valued. These values are typically captured in the objectives identified for the systems in step 1.

It is possible to provide qualitative (expert information driven) scoring of levels of perceived and relative uncertainty (e.g. low, medium, high) even if there is insufficient knowledge or data available to support more quantitative approaches. When used in a precautionary way (with a lack of knowledge assigned as high uncertainty and increasing risk to the next level by default), this method can be an effective way to flag areas of concern and knowledge gaps to address (as done by the Marine Estate Management Authority for the NSW pilot discussed further in following sections). The principal impediment to uncertainty analysis within qualitative risk assessment is that variability and epistemic uncertainty are confounded with each other and with linguistic uncertainty. Ultimately linguistic uncertainty cannot be removed from the assessment without moving to quantitative methods. Indeed, this is often one of the principal motivators for moving to quantitative risk assessments, at which point probability theory provides a coherent and widely adopted method for uncertainty analysis.

7 **Evaluation of management options:** The penultimate step is to evaluate the different management options that can achieve the management objectives. This may be an informal comparison that explores options or, alternatively, a more formal process that sees the findings of the previous assessment steps translated into implications for management. It does this by exploring management options using system models. These models may be qualitative (e.g. influence diagrams, directed acyclic graphs or signed digraphs; Dambacher *et al*., 2003) or they may be quantitative (e.g. food web models such as Ecopath with Ecosim, or end-to-end ecosystem models such as Atlantis; Fulton *et al*., 2014). These analyses are undertaken using the formal management strategy evaluation approach (Smith, 1994), originally developed for single species exploitation questions (e.g. de la Mare, 1996) but since expanded to ecosystem scales (e.g. Fulton *et al*., 2011, 2014, 2017). This approach uses models to capture the key complexities of real-world dynamics and then to use those models to test management options, identifying trade-offs and unintended consequences, and highlighting those management options that have the greatest potential to meet the objectives identified in step 1.

8. **Monitoring and evaluation:** The IEA process is iterative (and adaptive) by design, so that it can remain responsive to changing conditions, updated information levels and shifting objectives for the system. This iterative and adaptive basis is perhaps clearest in its reliance on continued monitoring and assessment of the indicators. This is required so that risk predictions can be compared to outcomes, and performance can be tracked, thereby demonstrating the effectiveness (or failure) of any implemented management actions. This assessment step allows for 'learning by doing' and subsequent modification of any underperforming activities. Monitoring needs to involve systematic collection of environmental, social and economic data to track changes in the status of the marine estate. The monitoring program provides a holistic understanding of the status and trends of marine habitats, ecological assets and resources, and provides fundamental data needs for environmental, social and economic prediction systems. Importantly, the monitoring program identifies key knowledge gaps and other data limitations that need to be addressed in order to provide for sustainable use of marine resources and effectively manage pressures. It is invariably a challenge to set aside sufficient resources for monitoring, thus managers will need to rely on the collaboration of the scientific community working in industry, academia, government agencies and sometimes overseas (e.g. in remote sensing), to provide data that can be used for their monitoring. Wherever possible, standard protocols need to be developed and/or followed. An important component of the IEA should be to identify these protocols and identify and influence the broader scientific community to follow them (Przeslawski *et al*., 2019).

9. **Iteration:** It is important to re-emphasise that this is an iterative process with the entire cycle, or parts of it, cycling through as needed. Benefits begin to accrue from the initial engagement step and build over time as subsequent steps are initiated or updated as new information becomes available. Revisiting the engagement step periodically through the exercise will be important to keep interested parties informed, update needs and issues, reduce the risk of unsubstantiated rumours or misinformation, and build support for management interventions. This makes the process inherently 'transdisciplinary', bringing together knowledge and perspectives from within and beyond the different scientific (biophysical, economic, social science) disciplines to include industry, regulators, traditional owners and other members of civil society.

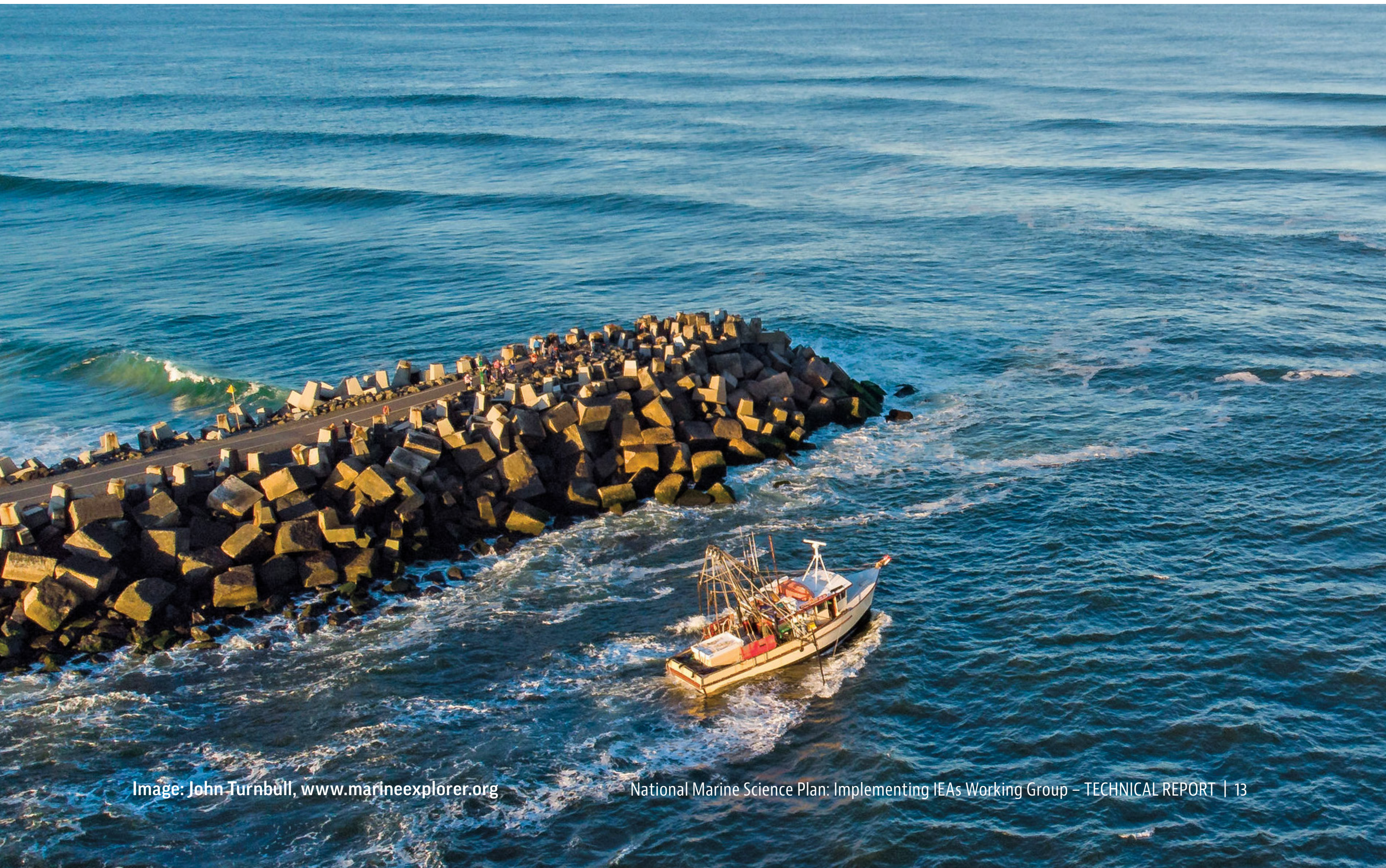

Image: John Turnbull, www.marineexplorer.org

IEA use to date |

Most of the significant attempts to date to apply IEA in a structured way oriented towards management have occurred in regional seas around North America and Europe (Figure 5 – either via NOAA[5] or ICES[6] working groups (Levin *et al.*, 2014; Samhouri *et al.*, 2014; Walther and Möllmann, 2014).

In both of these jurisdictions, IEAs are a natural progression in the movement of management and policy to an ecosystem-based approach to marine management. This progression has seen a requirement to develop integrated management plans; in Europe this comes under the Marine Strategy Framework Directive.

In their present form, these management plans, and the IEAs supporting them, are not dictating tactical day-to-day or year-to-year management rulings on operational matters (such as allowable catches or emission levels), rather they are playing a strategic role, informing planning and large-scale decision-making around spatial zoning and levels of use. In particular, IEA has been used to identify where the cumulative pressure coming from multiple activities could be leading to breaches of intended legislative objectives – breaches that would be missed by a single-sector evaluation of the area. All of this requires an understanding of the relationship between human activities and marine ecosystems, estimates of pressures and effects, and science-based advice regarding sustainable use and management options.

The assessments carried out thus far have been broken up regionally across each continent. This is because there is an appreciation that information availability and understanding that can enable IEA is not uniform across all areas and that there are different mixes of pressures and objectives in the different locations.

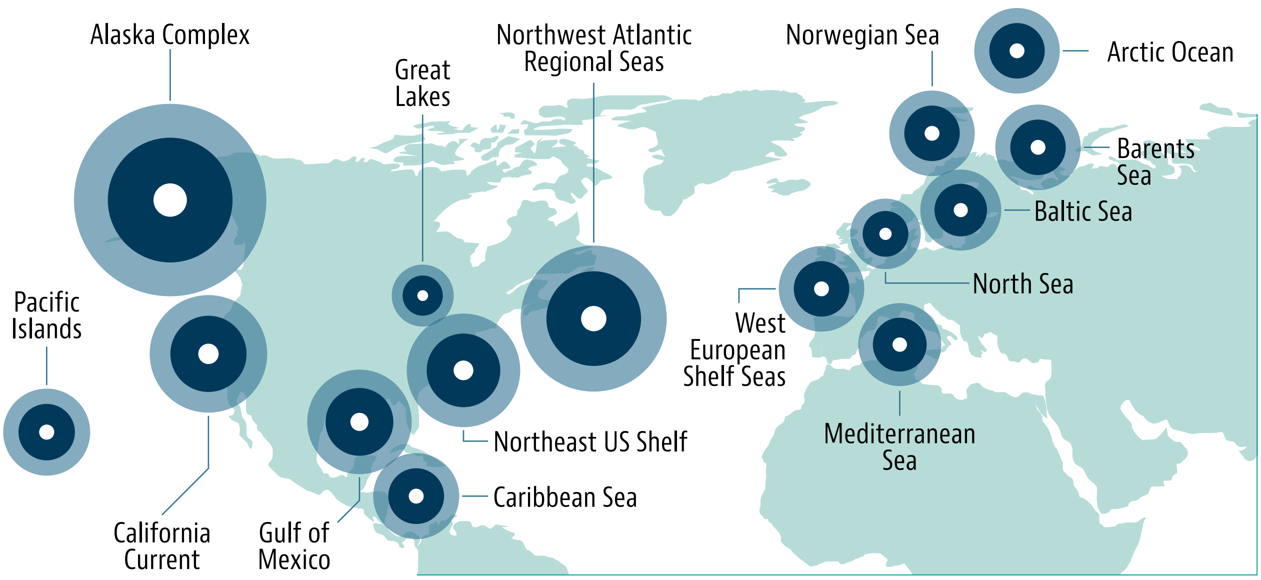

Figure 5: Map showing the indicative locations of IEAs undertaken by NOAA or ICES (all those around North America are under the auspices of NOAA, except for the Northwest Atlantic Regional Seas IEA, which is a working group under ICES that has US participants and some overlap with the NE US IEA). Note that the size of the symbol indicates the amount of work and indicative spatial extent of the assessment.

5 https://www.integratedecosystemassessment.noaa.gov

6 https://www.ices.dk/community/groups/Pages/IEASG.aspx

Comparison of IEAs with other approaches |

Most of the components of the IEA process described above are also seen in other management-related approaches and processes, especially other approaches building on adaptive management.

Management generally involves governance processes and tools for delivering specific activities, where:

(i) decision-making **processes** provide a framework for making decisions and implementing policy focused on the conservation and sustainable use of marine resources, such as marine spatial planning, ecosystem approach to fisheries and integrated coastal zone management

(ii) management **tools** (area based and non-area based) are used to manage or regulate human activity in particular systems, such as marine protected areas and zoning, fisheries closures, particularly sensitive sea areas and fisheries effort controls (see Figure 1).

Several of these processes are compared in Table 1 (derived from Dunstan *et al*., 2016). The concepts behind the development of IEAs are not entirely new and experience with other approaches will assist with implementing IEAs in Australia. The key difference, however, is that the IEA process is more comprehensive and focused on assessing the impacts of multiple sectors with objectives across all sectors and potentially shared objectives between sectors. The other approaches shown in Table 1 are primarily based on single sectors, for example fisheries and conservation. In the cases where processes are applied to single sectors, the objectives identified relate only to that sector – there are no cross-sector objectives.

Table 1: Comparison of IEA and other management-related processes.

IEA components	Marine spatial planning	AFMA* harvest strategy	Systematic conservation planning	FAO† ecosystem approach to fisheries	CEAFM††
Engagement	Identifying need and establishing authority Organising stakeholder participation	Stakeholder engagement and Resource Assessment Groups	Identifying and involving stakeholders Describing the context for conservation area Identifying conservation goals	Initial process planning and stakeholder support	Community involvement process Assess requests, define scope
Scoping	Obtaining financial support Organising the process through pre-planning	Scoping	Scoping and costing the planning process	Defining the fishery, societal values and high-level objectives Finalise a scoping (ecosystem approach to fisheries baseline) report	Set up tasks for the promoting agency – broad goals, public awareness, review, stakeholders, legal basis
Indicator development		Empirical and model-based indicators of stock status		Indicator and performance measure selection	Define indicators and performance measures
Ecosystem assessment	Defining and analysing existing condition	Stock assessment	Collecting data on socio-economic variables and threats Collecting data on biodiversity and other natural features	Asset and issue identification	Identify and prioritise key issues
Risk assessment	Defining and analysing future conditions	Ecological risk assessment for the effects of fishing		Issue prioritisation and risk assessment	Identify and prioritise key issues

Table 1 continued >

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IEA components	Marine spatial planning	AFMA* harvest strategy	Systematic conservation planning	FAO† ecosystem approach to fisheries	CEAFM††
Uncertainty assessment	Implicit	Explicitly considered in quantitative assessments	Implicit	Explicitly considered in quantitative assessments	Implicit
Evaluation of management objectives	Preparing and approving the spatial management plan Implementing and enforcing the spatial management plan	Management strategy evaluation testing Harvest strategy control rules Policy and management response	Setting conservation objectives Reviewing current achievement of objectives Selecting additional conservation areas Applying conservation actions to selected areas	Determine operational objectives Management option, evaluation and selection	Develop community goals and objectives Determine management actions and responsibilities Produce a community-owned management plan Formalise and implement a community management plan
Monitoring and evaluation	Monitoring and evaluating performance Adapting the spatial management process	Monitoring key fishery indicators	Maintaining and monitoring conservation areas	Develop an operational plan and monitor its progress Reporting, communication and auditing of performance Formalisation of the management plan Review performance of the management system	Monitoring performance Reviewing and adapting the plan
Iteration	Public comment cycle and periodic review	Co-management reference group meetings during the management cycle	Public comment cycle and periodic review	Co-management reference group meetings during the management cycle	Community consultation and public comments during the process

* Australian Fisheries Management Authority.

† Food and Agriculture Organization of the United Nations.

†† Community-based Ecosystem Approach to Fisheries Management.

Many of the listed processes in Table 1 include an explicit step of uncertainty assessment (e.g. parametric uncertainty in stock assessment in harvest strategies and many risk assessments). IEA must leverage off these methods because, while clearly recognising uncertainty is important, there is no single accepted method of considering uncertainties in IEA. Instead, how uncertainty is recognised needs to be tailored to the methods used to deliver the IEA overall and will differ in how it is applied across all the IEA steps. There is also linguistic variation in what is meant by uncertainty – it can refer to inclusion of multiple management strategies, system and parametric uncertainty, risk assessment, and uncertainty in indicators and monitoring outcomes. The uncertainty of outputs from each step should also be considered.

The UNEP integrated environmental assessment and reporting framework also shares the same basic steps as the IEA process presented here. While the explicit terminology used for the two approaches may differ, the core concepts are analogous. The UNEP approach may be cast more explicitly in a Drivers, Pressures, State, Impact and Response mode but the steps can be mapped relatively straightforwardly between the two approaches, especially if the pressures and drivers considered under the UNEP framework are kept broad, as intended under the IEA approach outlined in this current document.

Australian **IEA case studies** |

While full IEAs have never been undertaken in Australia, there are examples of similar but partial approaches that would provide useful information on what worked and what was less successful.

The marine and coastal case studies included decision-support frameworks for Ningaloo and Gladstone Harbour (Fulton *et al*., 2015, 2017). In addition, a significant study, the Alternative Management Strategies project, while fisheries focused, considered interactions and trade-offs between multiple fishery sectors in south-east Australia (Fulton *et al*., 2014). Lastly, while the Great Barrier Reef is a crowded and contentious space, lessons can still be learned from the multi-decade journey that management in the region has undergone – for instance transitioning from park management to a more integrated approach with the capacity to conduct IEAs through the strategic assessment process.

It was also noted that there are useful terrestrial and freshwater analogs to draw on too, such as the Bioregional Assessment program (Henderson *et al*., 2017)[7]. A lot may be taken from these terrestrial experiences around issues of handling large-scale cross-jurisdictional and cross-industry efforts and the associated uncertainties.

Below we lay out the best available Australian examples of assessments on the path to an IEA – these can act as case studies for understanding what is required when completing an IEA in the Australian context. Geographically, these are distributed around Australia (Figure 6).

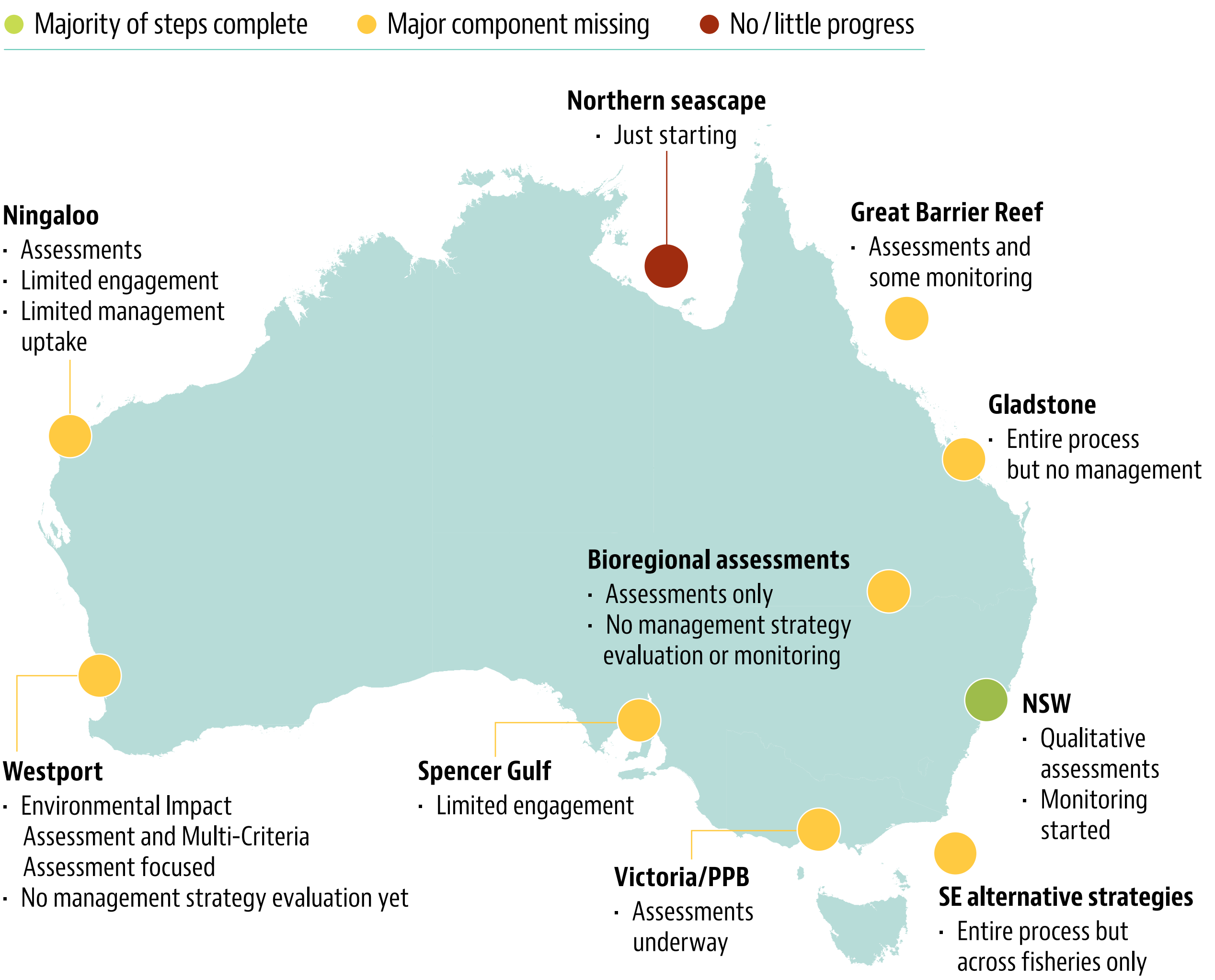


Figure 6: Location of case studies and potential pilots.

7 See https://www.bioregionalassessments.gov.au/methods/submethodologies for a full list of methodological reports.

For each case study, the assessments and available information for the area has been rated by experts on that system in terms of whether the components for a full IEA have been completed, are partially in place or would still need to be completed. The rating system used is outlined in Table 2. Note that the governance structure of the system in question will affect how these steps are implemented. For example, at a state level, managers and scientists sit within the one organisation, meaning they are intimately involved in creation of the content and ownership of the decision-making steps. However, at the Commonwealth level, they are from separate agencies.

Table 2: Description of IEA stage and what is required to receive a rating of 'Complete' (green), 'In progress' (amber) or 'Little progress/not initiated' (red). In the case study and pilot tables (Tables 3–8), the same colours are used to indicate the scores across all of the IEA components. Note that in these cases, light red shading indicates 'little progress' and dark red shading indicates 'not initiated' (i.e. the enabling element does not yet exist or that IEA stage has not been commenced).

Consistent **engagement** is crucial

IEA stage	**Description of what is required to achieve this rating**		
	Complete	**In progress**	**Little progress/not initiated**
Engagement*	Objectives agreed by all parties	Objectives agreed on by some parties (some conflicts or gaps remain)	No agreed objectives
Scoping	Scoping defined and complete	Scope partially defined (e.g. across only some dimensions)	Scoping incomplete
Indicator development	Indicators defined and agreed	Indicators identified for at least some components (may not yet be verified)	Indicators have not been identified
Ecosystem assessment	Assessment complete	Assessment in progress but incomplete (e.g. only for some aspects/sectors)	Assessment just commenced or little progress
Risk assessment	Assessment complete	Assessment in progress but incomplete	Assessment just commenced or little progress
Uncertainty assessment	Assessment complete	Assessment in progress but incomplete	Assessment just commenced or little progress
Evaluation of management options	MSE model exists and assessment complete	Model development in progress/complete but assessment not finalised	No MSE model exists, or assessment has made little progress
Monitoring and evaluation	Monitoring program implemented in adaptive management framework	Monitoring program relatively recently introduced in an adaptive management framework	Monitoring program just being formulated or is not part of adaptive management
Iteration	Ongoing cycle of engagement, review and updates on objectives and performance	Some communication of outcomes or haphazard inclusion of some parties in subsequent rounds	Failure to engage and no updates provided to broader audiences

* Initial engagement is often in the form of objectives defined by all participating groups. This engagement must include all key players across research/academia, industry, other users, regulators, traditional owners and other members of the public.

In Table 3 we present a summary of the expert-based rating of the Australian case studies broken out across the criteria listed in Table 2. Further detail (and references) on the progress of the IEA stages per case study is provided below and summarised in Table 4. Potential pilot study locations for full IEA completion are detailed in the following section (Potential pilots, with report cards).

Table 3: Summary of expert ratings of progress of Australian case studies in terms of IEA equivalent completion. Green = complete; orange = partially complete; light red = little progress; dark red = not initiated. See Table 2 for definitions of these ratings.

	IEA stage								
	Engagement	**Scoping**	**Indicator development**	**Ecosystem assessment**	**Risk assessment**	**Uncertainty assessment**	**Evaluating management options**	**Monitoring and evaluation**	**Iteration**
Case studies									
South East Australia – Alternative Management Strategies	Green	Orange	Orange	Orange	Orange	Orange	Orange	Light red	Green
Gladstone Harbour	Green	Green	Orange / Green	Orange	Orange	Orange	Green	Orange	Green
Ningaloo Coast	Green	Green	Green	Orange	Orange	Orange	Orange	Orange	Orange
Great Barrier Reef	Green	Green	Orange	Orange	Orange	Orange	Light red *	Orange	Green
Bioregional assessments	Green	Green	Green	Green	Green	Green	Dark red	Dark red	Orange
Pilots									
Spencer Gulf	Light red	Green	Orange	Orange	Orange	Orange	Light red	Orange	Orange
Victoria – Port Phillip Bay	Green	Green	Orange	Orange	Orange	Dark red	Dark red	Orange	Green
Victoria – outer coast (statewide)	Orange	Orange	Orange	Orange	Light red	Dark red	Dark red	Orange	Orange
NSW Marine Estate	Green	Green	Green	Green	Green	Green	Orange	Orange	Green
Northern seascapes	Orange	Orange	Light red	Orange	Orange	Light red	Light red	Light red	Light red

* A management strategy evaluation exists for coral trout but not at a system level.

CASE STUDY

SOUTH EAST AUSTRALIA – ALTERNATIVE MANAGEMENT STRATEGIES PROJECT

This project focused on management options for Australia's Southern and Eastern Scalefish and Shark Fishery, a multispecies, multi-gear fishery (Smith and Smith, 2001) that was languishing both biologically and economically in the early 2000s. By the mid 2000s, the fishery had been under quota management for a decade and a half, with over 30 individual stocks allocated in an individual transferable quota (ITQ) scheme. This management system was supposed to have improved both the biological and economic performance of the fishery, but it had failed to do so. Many of the stocks were overfished and for most of the early 2000s the net economic returns from the fishery had been negative. The Alternative Management Strategies (AMS) project was initiated in 2004 to explore alternative options for managing this complex fishery.

While the focus here was on one sector, the fishery was composed of multiple gear and a range of management structures. It did cover many of the components of an IEA and hence is reported here.

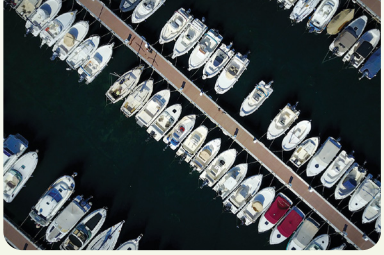
The AMS project was conceived of as an MSE study carried out in two stages. Stage 1 used expert knowledge to make predictions of how alternative management strategies might guide system responses and how those responses might direct system structure and function towards the management objectives – in essence, a qualitative MSE. Stage 2 based its predictions on a quantitative whole-of-ecosystem Atlantis model. The two stages of the AMS project addressed the same problems and objectives by using different methods to predict the consequences of alternative management scenarios. It is important to note that while the study included a quantitative MSE undertaken using the Atlantis modelling framework, which was influential in setting a new direction for the management of the fishery (Fulton *et al*., 2014), arguably the qualitative MSE had a greater influence on management changes and stakeholder uptake and action. This demonstrates how an IEA could progress without the need for development of complex quantitative tools.

The qualitative MSE was undertaken by a project team comprising one fishery manager, one fishery economist and five fishery scientists (both government-based and independent), with a collective involvement in and knowledge of the fishery exceeding 150 years. This group was overseen by a steering committee comprising fishers from each of the main sectors (trawl, longline and gillnet), a senior fishery manager, and one environmental NGO with an active interest in the fishery.

The project team engaged actively through a series of workshops with a much larger group of fishers and other stakeholders in the fishery during the 9-month stage 1 analysis. The method adopted had all the elements of an MSE except the quantitative modelling. It involved identifying the full range of objectives for the fishery, turning these into quantitative indicators, identifying alternative management strategies, and then evaluating their likely performance, taking uncertainties into account (Smith *et al*., 1999). The choice of objectives, indicators and strategies was undertaken with the broad set of stakeholders as well as the steering group. Over 20 performance indicators were identified, covering objectives relating to status of target species, broader ecological impacts of fishing, economic performance, and various aspects of management including cost. Initial strategies considered included the status quo, an expansion of the quota management system, and a 'blue-sky' scenario that involved a mix of input and output controls as well as spatial management and gear modifications. The alternative strategies were evaluated by the project team by projecting each of the indicators forward 20 years, using the expert judgment of the team.

The quantitative analysis was run using the same set of scenarios, management options, indicators and reference points. Once complete, the results of the two stages were compared. Overall, there was a good deal of correspondence between the predicted trajectories in the qualitative and quantitative analyses (for 76 per cent of the projected indicator trajectories) with the two approaches in complete contradiction with each other in less than 5 per cent of cases. For many measures there was a strong match in trends; for others the overall trends matched, though the quantitative trajectories contained more detail (or reflected more uncertainty) in the transitory dynamics. Generally, where there were differences, the qualitative projections were more optimistic and more certain.

In addition, the impact of this stakeholder-driven process was enormous. An important part of the process involved asking stakeholders to design strategies to manage this complex fishery. This resulted in a much broader set of strategies being identified and tested than is normally the case in such exercises. It also changed thinking about what might be possible and forced consideration of trade-offs across multiple objectives. By the end of this relatively short exercise, the strategy originally put forward as 'blue-sky' (because it was so different to the status quo strategy) was seen as a viable and even desirable option. Even before the quantitative stage was completed, significant changes had been made to the management of the fishery, in the direction of the 'blue-sky' option. The results of this study demonstrated that decision-making and policy can be moved along even in the absence of scientific certainty. The study also highlighted the value of a responsive and timely set of interactions with interested stakeholders who are motivated to act.



CASE STUDY

GLADSTONE HARBOUR

Over the past 60 years, Gladstone Harbour has been transformed from an agriculturally focused port, centred on supplying the meatworks and exporting wool (GPCL, 2012), to one of Australia's largest multi-commodity ports and the world's third largest coal terminal (GPCL, 2013). The harbour and surrounds support diverse uses, including areas of conservation value (both terrestrial parks and the adjacent Great Barrier Reef), commercial and recreational fisheries, extensive urban areas, a major power station, heavy industry (such as liquefied natural gas and one of the world's largest aluminium smelters), and export terminals for inland mining and gas. This development has occurred across eight major growth and development cycles, each with its own surge in activity, community interest and contention.

Tension around the cycle of development that began in 2010 grew out of issues related to environmental quality (including air quality and fish kills), which resulted in public outcry and government review of activities and regulations. The review found that the waters around the Port of Gladstone are some of the most studied and regulated in Australia; the port and individual industries had stringent emissions standards and reporting requirements and operators employed advanced environmental monitoring. However, it was also found that:

- some specific activities were inconsistent with industry best practice
- there was a confusingly complex oversight regime from state and federal governments that did not sufficiently address the world heritage setting of the port
- there was poor consideration of cumulative impacts
- community confidence in the science used by the regulators was extremely low, with patchy community engagement, withholding of data and potential conflicts of interest (Commonwealth of Australia, 2013).

The Queensland Government responded to this by establishing the Gladstone Healthy Harbour Partnership (GHHP) in 2012–13, which is supported by an independent science panel. GHHP has 26 partners across industry, Indigenous representatives, regulatory bodies, community groups and academia. While it has no regulatory authority, it does represent a significant step towards an integrated approach, which had widespread support, including high-level state government support.

A period of consultation at the start of the GHHP provided a vision for the partnership and objectives for the harbour – environmental, economic and social. These were then monitored on an annual basis by a regime where the information value of the indicators being tracked had been verified. This process had oversight by an independent science panel, and results were shared with the community via an annual report card. While the GHHP has no regulatory authority, it uses a range of tools to provide advice to policy, management and regulatory agencies, as well as industry and other stakeholders. One of these tools was a systems model for exploring development and management options (Fulton and Hutton, 2017).

The GHHP has been driven by consideration of cumulative effects and has identified some trade-offs. It also remains a voluntary partnership but has been nimble in terms of remaining aware of emerging regulatory requirements and community desires and works collaboratively when new issues arise. However, it does not have a mechanism for resolving or managing these interactions and issues. The strongest contribution of this case study is that it underlines that there is a need to consider cumulative impacts, as individual sector regulations may not deliver no matter how stringent and that transparency and engagement are key to public acceptance and uptake of ecosystem-based management. Moreover, ecosystem-based management can be a bottom-up process, and the longevity of such efforts may be limited without a clear mandate (Smith *et al*., 2017).

CASE STUDY

NINGALOO COAST

The Ningaloo coastal region stretches across much of the coastal area of the Gascoyne region of Western Australia – from Carnarvon in the south to the Muiron Islands in the north. It is most famous for the presence of Ningaloo Reef, the largest fringing coral reef in Australia, which stretches over 300 kilometres along this coastline. The region is sparsely populated, with approximately 7000 residents living in the regional centres of Carnarvon (62 per cent), Exmouth (35 per cent) and Coral Bay (3 per cent). Pastoral leases are the most common land use in the region, with Quobba, Gnaraloo, Warroora, Cardabai and Ningaloo stations abutting the coastal strip. The region's economy features fishing, mining, horticulture and livestock but is most heavily dependent on tourism.

Nature-based and wilderness tourism is the main source of income in Exmouth and Coral Bay, with the region's exceptional natural beauty and conservation values marketed nationally and internationally (Jones *et al*., 2011). While the terrestrial parks are major attractions, many of the tourism activities are water-based experiences, including leading attractions such as whale watching and swimming with whale sharks, dolphins and manta rays.

This human-use pressure, which has grown substantially over the past decade, has raised questions of sustainability. From 2006 to 2011, the Ningaloo Research Program gathered data on the region to provide information and understanding to decision-makers. This research program was a collaboration between CSIRO's Ningaloo Collaboration Cluster, the Western Australian Marine Science Institution, the Australian Institute of Marine Science, the Sustainable Tourism Cooperative Research Centre, a number of universities (Murdoch, Curtin, the University of Western Australia, Edith Cowan, the Australian National University and the University of Queensland), and the Western Australia Department of Environment and Conservation and Department of Fisheries. Significant effort was also put into working with local communities and enterprises.

The intent of the research program was to provide information for use in assessing and modifying (if required) current enterprise operations and management strategies to ensure the sustainability of both the marine resources and human communities in the region far into the future. This work involved not only drawing together existing and new information on the system, but also creating comprehensive assessment tools for the region, including multiple models of the entire socio-ecological system. It also involved working with a wide range of stakeholders to identify what information and key communication processes are required for effective integrated coastal management.

Key highlights from the research program are listed on the Western Australian Marine Science Institution website and include the following:

- System-scale models were developed that can be used to explore cumulative effects and the outcomes of alternative development scenarios and management options. These models can evaluate the implications of enterprise activities and management actions on the economy, the community, tourism, local industry and natural resources, highlighting any trade-offs between objectives held by different groups interested in the system.
- Detailed datasets on the region were compiled, spanning human use (e.g. boating, fishing, hiking, urban activities), physical and biological components of the reef, lagoon and terrestrial systems (including baseline information about abundance, diversity and distribution).
- Understanding of the influence of physical and biological processes on the distribution of different marine species was improved.
- Cost-effective methods for monitoring the park's marine biodiversity and reef health were identified, along with patterns and trajectories of natural and human stressors.

The research program's factsheets and reports (including those detailing the sustainability modelling done with the systems scale models) can be accessed at the Western Australian Marine Science Institution website[8].

8 https://www.wamsi.org.au/research-ningaloo/node-3-reports

CASE STUDY

GREAT BARRIER REEF

The Great Barrier Reef (GBR) is an iconic region that was World Heritage listed in 1981. This was one of the first locations globally where a need was recognised to manage increasing human uses so as not to imperil a diverse range of values (environmental, economic and sociocultural). Beginning in the 1960s, debate around proposed mining and oil exploration in the region led first to a Royal Commission (1970–74) and then to the Great Barrier Reef Marine Park Act 1975. This Act saw the Great Barrier Reef Marine Park Authority (GBRMPA) created as an independent statutory authority, and complementary state legislation was also developed, supported by the GBR intergovernmental agreement. Integrated planning of the GBR then began with the gradual declaration of park boundaries and creation of zoning plans, which came into effect from the 1980s to the early 2000s.

Considerable effort was put into developing a shared vision among all stakeholder groups of what integrated management meant for the region, a vision that has evolved over time (Barr and Possingham, 2013). This is an example of a successful and strong consultative and participatory engagement process that resulted in trusted relationships among participants.

The need to formally deliver plans has seen clear objectives and outcomes defined for the GBR across a suite of values – including environment, biodiversity, heritage values and sustainable uses. These objectives have been updated over time, with further ecological, social, cultural and economic indicators developed to match new objectives or system understanding. An outlook report is published by GBRMPA every five years (e.g. GBRMPA, 2019) detailing the reef's condition, management effectiveness and any risks. Through strategic plans and other ongoing funding processes, GBRMPA (supported by researchers in the region) continues to develop a fit-for-purpose integrated monitoring, modelling and reporting program.

Management of the GBR is built on the principles of adaptive management, with explicit review periods and built-in contingency plans to adapt to changing circumstances (Stephenson et al., 2019). One of the more recent rounds of these reviews involved a comprehensive strategic assessment of the GBR, which examined the impact of multiple activities on values across the marine and coastal zone using an adapted Drivers, Pressures, State, Impact and Response framework. This has translated into plans such as the Reef 2050 Plan and associated policies, which include consideration of a more comprehensive set of objectives and outcomes, explicit consideration of cumulative impacts, and draft offsets guidelines (Stephenson et al., 2019).

While this GBR monitoring and management process has benefited from a longstanding joint agreement on co-funding among state and federal governments and access to a long legacy of reef research and experiential knowledge from regional managers and traditional owners, gaps do still remain (Sutton and Tobin, 2012). For example, much of the focus has been on reef habitat and water quality, with other aspects of the regional ecosystem receiving much less attention.

CASE STUDY

BIOREGIONAL ASSESSMENTS

The Bioregional Assessments are a series of assessments of the potential cumulative impacts of coal seam gas and coal mining developments on water resources and water-dependent ecosystems, such as rivers, wetlands and forests . The assessments were completed in June 2018. They identified where cumulative impacts to water and water-dependent ecosystems might occur as a result of the combined effect of existing and proposed coal and coal seam gas developments across more than 860,000 square kilometres of assessment area in 13 regions of central and eastern Australia. This information is being used by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development to help provide advice to the regulators about new proposed coal resource developments.

The cumulative impact approach taken by the Bioregional Assessments program was designed to analyse impacts and risks of coal resource developments additional to those in production as of December 2012 (baseline). This was done by comparing results for two distinct futures, one resulting from baseline developments and another resulting from the coal resource development pathway, which includes both baseline developments and additional coal resource developments.

The effects of baseline developments and additional coal resource developments on water-dependent ecosystems were predicted using a combination of quantitative groundwater and surface water models – to predict changes in key hydrological variables such as groundwater depth and flood return periods – and quantitative 'receptor impact models' that predict the response of selected components of the ecosystems – such as the foliage cover of woody riparian vegetation – to the combined changes in the key hydrological variables.

The Bioregional Assessments program methodology is described in detail in 10 sub-methodology reports . Sub-methodology reports that are particularly relevant to the IEA working group are M08, which describes how expert elicitation is used to construct informative prior distributions for the quantitative receptor impact models, and M09, which describes how uncertainty is propagated through the quantitative groundwater and surface water models (Henderson *et al*., 2015, 2017; Hosack *et al*., 2017). The modelling approach developed through the Bioregional Assessments Program is one of the world's first examples of quantitative, probabilistic and cumulative risk calculations applied at large spatio-temporal domains, and it was described by the Independent Expert Scientific Committee as 'innovative' and 'game changing'. Viewed in the context of an IEA, however, the Bioregional Assessments program is incomplete. In particular, the program is not truly multi-sectoral – for example it does not account for the effect of agricultural practices on water resources. Furthermore, it does not provide any mechanism for monitoring and evaluation of its predictions and does not evaluate the effect of alternative management strategies. Another notable omission in the methodology is the lack of any accounting for the effects of climate change on the key hydrological variables – notable because the prediction interval associated with the Coal Resource Development Pathway (CRDP) stretches to 2100.

9 https://www.bioregionalassessments.gov.au

10 https://www.bioregionalassessments.gov.au/methods/submethodologies

> *The IEA process is iterative (and adaptive) by design, so that it can remain responsive to changing conditions, updated information levels and shifting objectives for the system.*

Table 4: IEA stage progress for the case studies. Green = complete; amber = partially complete; light red = little progress; dark red = not initiated. See Table 2 for definitions of these ratings.

IEA stage	South East Australia – Alternative Management Strategies	Gladstone Harbour	Great Barrier Reef	Bioregional Assessments	Ningaloo Coast
Engagement	Complete: relatively broad set of interest groups has been engaged around objectives and brought into co-management arrangements	Complete: broad membership is present on Gladstone Healthy Harbour Partnership management committees and considerable effort put into engagement activities	Complete at the time (as described in Fulton *et al*., 2011). Since the project ended, the breadth of direct engagement reduced, though it has recently renewed around new developments (small local population size facilitates connections)	Complete: considerable effort is put into engagement across diverse stakeholder groups	Complete: initial links went quite broadly in terms of connecting with interested parties of many kinds
Scoping	Partially complete: individual sector groups have defined objectives (e.g. fisheries and conservation)	Complete: as outlined in the technical reports and other factsheets on the GHHP website*	Complete (Fulton *et al*., 2011)	Complete: significant effort put into developing a shared vision among all stakeholder groups	Complete: based on expert-elicited advice on objectives and scope
Indicator development	Partially complete: species and ecosystem indicators have been defined for use with ecosystem-based fisheries management and conservation	Partially complete for ecological components. Details on GHHP website* Complete for social, cultural and economic components	Complete (Fulton *et al*., 2011, 2015)	Partially complete: indicators considered for many system components, though focus has been strongest on habitats and water quality. Social and non-habitat ecology more lightly covered	Complete: clearly defined and reported on, as detailed in reports on the Bioregional Assessments website†
Ecosystem assessment	Partially complete: model-based only – initially completed using Atlantis (EwE and intermediate complexity models now also exist)	Partially complete: not all indicators are monitored as yet. Have implemented an ecosystem model	Partially complete	Partially complete for marine spatial planning, report cards, outlook reports and cumulative impact management policies. Not integrated assessment in initial intent but covers many of the same aspects	Complete: based on quantitative analysis, as detailed on Bioregional Assessment website†
Risk assessment	Partially complete: Ecological Risk Assessment-level only; climate and cumulative effects assessment focusing on fisheries activities underway	Partially complete: annual report cards are published, but not all ecological components covered as yet	Partially complete: model-based only	Partially complete: key parts considered for annual and outlook reports. Water quality and habitat focus, more balanced consideration planned	Complete: based on quantitative, probabilistic and cumulative risk calculations
Uncertainty assessment	Partially complete: model-based only, using multiple ecosystem models and parameterisations	Partially complete: included in modelling exercises; not as clearly communicated in report cards	Partially complete: model-based only	Partially complete: carried out but only for key components (habitat, water quality, target species)	Complete: carried out as part of the risk assessment

IEA stage	South East Australia – Alternative Management Strategies	Gladstone Harbour	Great Barrier Reef	Bioregional Assessments	Ningaloo Coast
Evaluation of management options	Partially complete: management strategy evaluation completed for Atlantis ecosystem model work	Complete: full system-wide integrated management strategy evaluation using Atlantis	Partially complete (Fulton *et al.*, 2011)	Little progress at an ecosystem level. Scenario analysis has been completed qualitatively and for habitats. Full management strategy evaluation for individual species (e.g. coral trout)	Not initiated: however, the risk assessment calculations were repeated for two distinct futures – one resulting from baseline developments and another resulting from the coal resource development pathway
Monitoring and evaluation	Not initiated: ad hoc surveys only	Partially complete: annual monitoring in place, but not all ecological components covered as yet	Partially complete: limited program	Partially complete: fine-scale monitoring of habitats and water quality. Long-term time series (surveys for reef species). Less attention to social and economic components (SELTMP is a good start). Off-reef components receive less attention.	Not initiated
Iteration	Complete: co-management, including a diverse set of interest groups, is a standard part of the management arrangements	Complete: annual cycle of reporting and engagement with advisory committees	Partially complete: initially considerable effort put into sharing results. Iteration slowed as funding was difficult to obtain but, with new developments, a new cycle appears to be beginning	Complete: ongoing work with diverse user groups and First Nations custodians; also a structured cycle of reporting	Partially complete: some updating at the time but has not continued now the assessment is complete
Notes on available models	Atlantis (EwE, size spectra and multispecies models also developed)	Ensemble: qualitative, Atlantis, CORSA, economic	Ensemble: qualitative, MICE, EwE, InVitro (Fulton *et al.*, 2015)	Ensemble: qualitative, MICE, EwE	
Key references and links	Bax and Williams (2000) Fulton and Gorton (2014) Fulton *et al.*, (2007) Hosack and Dambacher (2010)	Fulton *et al.* (2017) Fulton and Hutton (2017) Annual reports on GHHP website*	Fulton *et al.* (2011) Fulton *et al.* (2015) Thebaud *et al.* (2014)	Extensive documentation on eReefs†† and GBRMPA website (see RIMREP section of the GBRMPA website§)	All reports documented at Bioregional Assessments website†

* http://ghhp.org.au
† https://www.bioregionalassessments.gov.au
†† https://ereefs.org.au/ereefs
§ http://www.gbrmpa.gov.au/our-work/reef-strategies/reef-integrated-monitoring-and-reporting-program

Potential IEA pilots, with report cards |

To assist with implementation of IEAs in Australia, four potential pilots have been selected to make sure the approach meets Australia's needs.

These pilots cover different spatial extents, represent areas of differing user complexity and different levels of data and knowledge to assess the effectiveness of the tools with different levels of certainty in data and information. The pilots fit into three categories: highly mature; work in progress; and little or no progress. The potential pilots cover areas in Australia with different competing objectives, needs and uses, and with a range of available data and information to stress-test the approach with decision-makers and stakeholders. By testing this range of locations, a benchmark set of needs can be articulated for other future uses, locations and jurisdictions in Australia.

Spencer Gulf

The most appropriate South Australian location for a case study in a national pilot study of implementing IEA is Spencer Gulf (Shepherd *et al*., 2014; Smith *et al*., 2017; Stephenson *et al*., 2019). Spencer Gulf is a region of high economic and cultural importance (Deloitte Access Economics 2017; Tanner *et al*., 2019). It was the focus of a broad attempt to establish ecosystem-based management of the state's coastal, estuarine and marine environments in the early 2000s (Day *et al*., 2008; Paxinos *et al*., 2008). This initiative resulted in the Living Coast Strategy (DEH, 2004) and the Marine Planning Framework for South Australia (DEH, 2006a), but neither was implemented beyond the development of an initial pilot study in Spencer Gulf (DEH, 2006b).

Unique within Australia, Marine Innovations Southern Australia, which was established in 2005, is a collaboration of South Australia's key government agencies responsible for natural resource management and industry development, peak seafood industry organisations, universities and marine research institutions. The involvement of industry, government and researchers in Marine Innovations Southern Australia makes it an excellent vehicle for engagement with a program to trial implementation of IEAs in Australia.

The Spencer Gulf Ecosystem and Development Initiative[11] was established in 2011, when a broad range of stakeholders recognised the need for a more integrated approach to development in the area. The focus of the initiative has been to develop pilot tools to support integrated management and demonstrate the benefits of the approach (Bailleul and Ward, 2019; Gillanders *et al*., 2015, 2016). Risk assessments have been undertaken for key habitats (Doubleday *et al*., 2017) and species (Robbins *et al*., 2017). A spatial cumulative impact assessment has been undertaken that explicitly accounts for uncertainty (Jones *et al*., 2018). An ecosystem model (Ecopath with Ecosim) has been established (Gillanders *et al*., 2013).

The Goyder Institute for Water Research, Fisheries Research and Development Corporation and the Spencer Gulf Ecosystem and Development Initiative recently funded a project to progress a more integrated management in Spencer Gulf. One of the key outputs for the project was a report that collated existing information on the status of key assets and threats to the ecosystems of Spencer Gulf, as well as the value its industries and the socio-economic status of surrounding communities (Tanner *et al*., 2019). The focus of the report was on time-series datasets. Most existing monitoring programs were designed to assess the impacts of and/or manage individual activities, or to monitor particular species. While a broad range of valuable datasets for Spencer Gulf were identified, there were also many gaps, and a number of datasets that are only collected sporadically and for which there is no guarantee of continuation.

Overall, Tanner *et al*. (2019) identified around 170 different data time-series that could be used as the basis for establishing a suite of indicators of the overall social, economic and ecological status of Spencer Gulf. The next step is to consolidate the collated datasets into a smaller subset of indictors that could be utilised to monitor the status of the gulf and evaluate the impacts of future activities. The collation of information undertaken by Tanner *et al*. (2019) was an important step towards undertaking an IEA of Spencer Gulf.

Management of Spencer Gulf is currently delivered through at least 15 different South Australian Government Acts, with limited cross-referencing between different pieces of legislation, despite many having broadly similar objectives (Begg *et al*., 2015). Management decisions are often made without fully considering the overall social, economic and ecological status of the region. Cumulative impacts are not considered explicitly.

11 https://www.adelaide.edu.au/environment/opportunities/spencer-gulf-ecosystem-and-development-initiative-sgedi

There is also no clear basis for assessing trade-offs between different uses of the environment. An integrated monitoring program that includes social, economic and ecological indicators has not been established for Spencer Gulf (Tanner *et al*., 2019).

Currently, there is limited appetite within the South Australian Government to adopt a more integrated approach to management of the marine environment. However, at the request of the South Australian Department for Environment and Water, the South Australian Research and Development Institute recently developed a presentation to promote the concept of integrated management to the broader South Australian Government. This presentation has not yet been delivered to key agencies and would ideally be delivered within the context of a proposed national program to progress IEA.

Much of the preliminary work needed to support an IEA of Spencer Gulf has already been done (see Table 5). Available data have been collated and a range of decision-support tools has been established. The next logical step is to do a full IEA. The project would need to have a strong focus on engagement with key government and industry stakeholders.

Conducting an IEA in Spencer Gulf would demonstrate the benefits of undertaking an IEA in a region where an integrated approach to management of marine systems has not been formally established. It would demonstrate to the South Australian Government the benefits of this approach. The cost of undertaking a full IEA of Spencer Gulf would be approximately $2–3 million.

Table 5: IEA status for the Spencer Gulf pilot. See Table 2 for definitions of these ratings.

IEA stage	Status for Spencer Gulf
Engagement	Little progress
Scoping	Complete
Indicator development	Partially complete
Ecosystem assessment	Partially complete
Risk assessment	Partially complete
Uncertainty assessment	Partially complete
Evaluating Management Options	Not initiated
Monitoring and evaluation	Partially complete
Iteration	Partially complete
Overall status	Partially complete
Notes on available models	Hydrodynamic, SDMs (seagrass) and EwE (Gillanders *et al*. 2015)
Key references and links	Bailleul and Ward (2019) Begg *et al*. (2015) Doubleday *et al*. (2017) Gillanders *et al*. (2013, 2015, 2016) Jones *et al*. (2018) Robbins *et al*. (2017)

Victorian Coast

A Victorian coast site in the national pilot study of implementing IEA could be characterised as a 'work in progress' site (see Table 6).

Victorian sites offer the opportunity of a relatively mature governance and legislative framework with a new and contemporary Act (the *Marine and Coastal Act 2018*[12]), a strong current focus of agencies, state government agenda of reform for climate resilience and sustainable use,[13] new marine and coastal management tools being rolled out and used,[14] and very high public profile and population use,[15,16] all based on a foundation of low to medium data, information and knowledge products.[17]

The first ever Victorian Marine and Coastal State of the Environment report will be completed in 2022–23.[18]

There are growing, large-scale offshore renewable energy projects planned (e.g. Star of the South[19]), which are highlighting the challenges of navigating expanded uses of the offshore environments when there is little understanding of cumulative effects and evolving federal policies and requirements.

Moreover, challenges to historically dominant industries, such as fisheries (due to the impacts of climate change; Pecl *et al*., 2011) mean maintaining sustainability will not necessarily be straightforward.

The Victorian Government is in treaty negotiations with traditional owners,[20] which offers an overlay of traditional owner input and influence on any IEA pilot involving sea country. In a number of places there are active Country Plans that include sea country priorities. (e.g. see footnotes[21] and[22]).

Scope and assessment of a Victorian option in the national IEA pilot

There are two distinct geographic options for a Victorian site in a broader national pilot study of IEA. Both have different drivers and levels of maturity of available data, information and management tools. Much of the available data and information in Victoria is patchy and partial, spatially incomplete and/or strongly sector based.

1. **Port Phillip Bay**: The geographic scope could be confined to Port Phillip Bay – one of Australia's busiest ports. It has active recreational and commercial fishing and aquaculture, and the surrounds are home to 70 per cent of Victorians. It is Victoria's most used waterbody, home to many different recreational pursuits.[23] In addition, it is deeply important to three traditional owner nations, contains four highly protected marine protected areas, and has large areas of important Ramsar wetlands and high quality biodiversity assets. There are more matured and targeted datasets, models and management tools for Port Phillip Bay than any other large marine area in Victoria (e.g. see footnotes[24,25] and[26]).
2. **Statewide ('the Outer Coast')**: As Victoria is the state with the shortest coastline in Australia (only 2512 kilometres long), the geographic scope could be expanded to include the entire Victorian marine environment. This could include or exclude the three other major, fully marine embayments in Victoria (i.e. Port Phillip, Western Port and Corner Inlet). While the Gippsland Lakes are estuarine (and marine in many places), they are not fully marine and could be considered in or out of scope. There are similar traditional owner, recreational and biodiversity drivers for the Outer Coast as for Port Phillip Bay but different industry and fisheries drivers. One important benefit of the Outer Coast being considered as the Victorian option is the new Marine Spatial Planning Framework.[27] This framework is designed to enable decision-making to resolve cross-sectoral conflicts over use in the Victorian marine environment.

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12 https://www.legislation.vic.gov.au/in-force/acts/marine-and-coastal-act-2018/003

13 https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0021/330519/Final-Transition-Plan_August-2018.pdf

14 https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0027/456534/Marine-and-Coastal-Policy_Full.pdf

15 https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0024/405951/Wave_4_Report_270201_FINAL.pdf

16 https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0029/438329/Final-Report-Wave-5-Victorian-Marine-and-Coastal-Attitudes-Research.pdf?_ga=2.43190949.1821754841.1590133832-1640165112.1590133832

17 https://www.ces.vic.gov.au/state-of-reports/state-environment-2018-report

18 https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0021/330519/Final-Transition-Plan_August-2018.pdf (see page 18)

19 http://www.starofthesouth.com.au/the-project

20 https://www.firstpeoplesvic.org/treaty

21 https://gunaikurnai.org/wp-content/uploads/2021/07/Gunaikurnai-Whole-of-Country-Plan-ONLINE.pdf

22 http://easternmaar.com.au/wp-content/uploads/2012/10/EM_CountryPlan_FINAL.pdf

Table 6: IEA status for the Victorian Coast pilot. See Table 2 for definitions of these ratings.

IEA stage	Status for Port Phillip Bay	Status for Victorian outer coast
Engagement	Complete	Partially complete
Scoping	Partially complete	Partially complete
Indicator development	Partially complete	Partially complete
Ecosystem assessment	Partially complete	Partially complete
Risk assessment	Partially complete	Not initiated (partial in marine protected areas)
Uncertainty assessment	Not initiated	Not initiated
Evaluating Management Options	Not initiated	Not initiated
Monitoring and evaluation	Partially complete	Partially complete
Iteration	Partially complete	Partially complete
Overall status	Partially complete	Partially complete
Notes on available models	PPBIM, EwE, (outdated) Atlantis	N/A – there is nothing available that covers the full outer coast of Victoria
Key references and links	Grey literature reports[28]	Grey literature reports[29]

23 https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0029/438329/Final-Report-Wave-5-Victorian-Marine-and-Coastal-Attitudes-Research.pdf

24 https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0024/88710/PPB-EMP-2017-Main-Doc.pdf

25 https://www.ces.vic.gov.au/sotb

26 https://www.ces.vic.gov.au/state-of-reports/state-environment-2018-report

27 https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0027/456534/Marine-and-Coastal-Policy_Full.pdf (see page 64)

28 https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0021/330519/Final-Transition-Plan_August-2018.pdf
https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/49813/Marine-and-Coastal-Ecosystem-Accounting-Port-Phillip-Bay.pdf
https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0024/88710/PPB-EMP-2017-Main-Doc.pdf
https://www.ces.vic.gov.au/sotb

29 https://www.ces.vic.gov.au/state-of-reports/state-marine-and-coastal-environment-2021-report
https://www.ces.vic.gov.au/state-of-reports/state-environment-2018-report
https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0021/330519/Final-Transition-Plan_August-2018.pdf
https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/49813/Marine-and-Coastal-Ecosystem-Accounting-Port-Phillip-Bay.pdf
https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0024/88710/PPB-EMP-2017-Main-Doc.pdf
https://www.ces.vic.gov.au/sotb

Statewide Social research:
https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0029/438329/Final-Report-Wave-5-Victorian-Marine-and-Coastal-Attitudes-Research.pdf

Links to fisheries related research/data can be found at:
https://vfa.vic.gov.au/recreational-fishing/recreational-fishing-grants-program/licence-fees-at-work/your-licence-fees-at-work-research-reports

Where to from here?

There is the need and opportunity for a large-scale pilot of this decision-making process to be trialled in Victoria in the short-term future.

There are current statewide processes that would enable this to occur. The new Marine and Coastal Policy contains a Marine Spatial Planning Framework requiring implementation, and the Commissioner for Environmental Sustainability is required to deliver a State of the Marine and Coastal Environment for Victoria in coming years. Both government-led processes require some of the gaps identified in Table 6 to be filled to achieve their stated outcomes. Hence, there is an opportunity to use the IEA process to achieve Victorian policy outcomes while building on the expanded knowledge base beginning to be created under these scheduled activities.

Given the leverage created by the scheduled activity to deliver on the stated policy objectives and fill the scientific gaps for an IEA pilot for either Port Phillip Bay or the Victorian Outer Coast, an investment in the range of $3–4 million is estimated to be needed.

NSW Marine Estate

The marine estate is one of the most significant natural resources in NSW and includes around 1 million hectares of estuary and ocean, with more than 1750 kilometres of ocean coastline, 6500 kilometres of estuarine and coastal lakes foreshores, 826 beaches, 44 offshore islands, and 185 estuaries and coastal lakes. Over 6 million people live within 50 kilometres of the coastline, including the people of 11 coastal Aboriginal nations who are intimately connected to their Land and Sea Country. The NSW community derives social, cultural and economic benefits from the marine estate, which are underpinned by good water quality, healthy habitats, and diverse and abundant marine life.

The Marine Estate Management Authority was established in 2013 and brings together the heads of the NSW Government agencies with key marine estate responsibilities. It advises the NSW Government on policies, priorities and the direction of management of the marine estate. In 2018, the authority released the Marine Estate Management Strategy (MEMA, 2018), which provides the overarching framework for coordinated management of the marine estate to deliver its vision for 'a healthy coast and sea, managed for the greatest well-being of the community, now and into the future' (Brooks and Fairfull, 2017).

A key input into the strategy was the results of a threat and risk assessment of the entire marine estate (BMT WBM, 2017), which was conducted in accordance with the principles developed by the authority for such assessments and guided by the authority's Threat and Risk Assessment Framework (MEMA, 2015). The purpose of threat and risk assessment, as set out in the *Marine Estate Management Act 2014* (MEM Act), is to:

- identify threats to the environmental, economic and social benefits of the marine estate
- assess the risks those identified threats pose for the attainment of the authority's objectives
- inform marine estate management decisions by prioritising those threats and risks according to the level of impact on the benefits derived from the marine estate.

An important step in categorising risk is the description of a region's environmental assets and evaluation of the threats to these assets from the specific activities (MEMA, 2017a). In NSW, these threats and resulting risks were assessed by defining a set of common stressors that might result in impacts on specific environmental assets, including seabed habitats and associated assemblages, the water column, and threatened and protected species. The environmental risk assessment was supported by a background report that provided

information on the extent and condition of environmental assets, reviewed the available scientific literature about threats to these environmental assets and associated benefits, and detailed the current management arrangements that aim to manage impacts. This included separate evaluation of estuaries and marine waters and consideration of the characteristics of several estuary types (e.g. barrier river, bay, drowned river valley, lakes). The assessment of risks allowed identification of priority threats, key stressors, spatial scale of risk and key activities that result in cumulative impacts.

The process also included the identification and categorisation of the benefits that communities gain from the marine estate and the threats and risks to those benefits (Jordan *et al*., 2016; Gollan *et al*., 2019). A broad range of benefits were identified, including participation (e.g. socialising and sense of community), enjoyment (e.g. enjoying the biodiversity and beauty), cultural heritage and use, intrinsic and bequest values, the viability of businesses, and direct economic values. Threats to community benefits were categorised as resource-use conflict, environmental, governance, public safety, critical knowledge gaps and lack of access.

The Marine Estate Management Strategy sets out management objectives and a series of management actions across nine initiatives that are designed to address priority threats to the marine estate identified in the threat and risk assessment. These were developed with reference to specific Marine Estate Management Authority guidelines that evaluated each management action (MEMA, 2017b)[30]. The nine management initiatives are:

1. improving water quality and reducing litter
2. delivering healthy coastal habitats with sustainable use and development
3. planning for climate change
4. protecting the Aboriginal cultural values of the marine estate
5. reducing impacts on threatened and protected species
6. ensuring sustainable fishing and aquaculture
7. enabling safe and sustainable boating
8. enhancing social, cultural and economic benefits
9. delivering effective governance.

Progress towards implementing the Marine Estate Management Strategy and delivering the vision will be measured and reported through the Marine Integrated Monitoring Program (Aither, 2019)[31].

The program has three key purposes, to:

1. monitor the condition and trend of environmental assets and community benefits to inform a five-year health check
2. evaluate the effectiveness of management initiatives and actions that aim to reduce priority threats and risks
3. fill knowledge gaps that were identified as part of the statewide Threat Assessment and Remediation Analysis (TARA) process.

The Marine Integrated Monitoring Program aims to conduct broad-scale ambient environmental monitoring and evaluate the effectiveness of key management actions. Monitoring and evaluation areas relate to the specific initiatives associated with water quality, habitat management and restoration, impacts on wildlife, climate change, boating impacts and some fishing activities. Specific condition and pressure indicators are being measured across a range of environmental assets, with the range of indicators and spatial scale of monitoring expected to expand during the implementation of the strategy.

The social, cultural and economic component is being evaluated through a community wellbeing framework, which includes an integrated set of wellbeing indicators. This framework will build on relevant indicators identified for objective 2 (management effectiveness) by identifying and filling gaps relevant to objectives 1 and 3 of the Marine Integrated Monitoring Program (i.e. monitoring community benefits and filling knowledge gaps). The monitoring program aims to measure and detect changes in community wellbeing at a local and statewide scale within the NSW Marine Estate.

[30] https://www.marine.nsw.gov.au/__data/assets/pdf_file/0009/721737/Guidelines-for-Assessing-Management-Options-for-the-NSW-Marine-Estate.pdf

[31] https://www.marine.nsw.gov.au/__data/assets/pdf_file/0004/1193296/MIMP-Framework.pdf

Table 7: IEA status for the NSW Marine Estate pilot. See Table 2 for definitions of these ratings.

IEA stage	Status for New South Wales Marine Estate
Engagement	Complete
Scoping	Complete
Indicator development	Complete
Ecosystem assessment	Complete
Risk assessment	Complete
Uncertainty assessment	Complete (qualitative)
Evaluating Management Options	Partially complete
Monitoring and evaluation	Partially complete (recently commenced)
Iteration	Complete
Overall status	Partially complete
Notes on available models	Ecopath with Ecosim, Atlantis (both for 1990s state)
Key references and links	Jordan *et al*. (2016) Brooks and Fairfull (2017) Gollan *et al*. (2019) Key relevant grey literature: MEMA (2015, 2017a,b, 2018) BMT WBM (2017) Aither (2019)

This is the most mature of the four pilots, with most IEA components completed. The components that require further attention include the uncertainty assessment and evaluation of management options. The former would benefit from a quantitative analysis and the latter has only been partially completed. Completing both components would provide greater certainty regarding potential future management options and trade-offs. These could be undertaken for less than $500K.

Northern Seascapes

Northern Australia boasts both significant and new opportunities for economic development and a landscape with environmental and cultural values of global, national, regional and Indigenous significance. However, some aspects of the system's content and function, as well as detail on the benefits provided by the system's values, are poorly understood or articulated. This lack of knowledge hinders the assessment of development opportunities and robs decision-making processes of transparency, hampering state, territory and local government agencies charged with prioritising and de-risking new areas for development while protecting the region's environmental and cultural values. This puts the environment at risk and leaves industries, financiers and communities uncertain and risk-averse about investment. An IEA is the best means of addressing these hurdles.

The collaborative Northern Integrated Environmental Assessment project – undertaken by the research hubs of the Australian Government's National Environmental Science Program (NESP) – aims to develop and demonstrate the value of a holistic IEA approach to strategic decision-making for sustainable development in Australia. The project is documenting the existing information available, data needs, analysis and risk management approaches, and governance settings required for undertaking IEA and associated decision-making. That is, the project is creating a scoping document describing what would be required to undertake an IEA in northern Australia (as a pilot demonstration for how an IEA could be done in Australia). While it will not deliver an IEA in the first instance, it will articulate and demonstrate the value of undertaking an IEA. It will detail how relevant environmental, cultural, economic and regulatory knowledge can be gathered, synthesised, analysed and presented, and provide an assessment of the available options for completing an IEA. These options include identifying tools, data and prioritisation approaches. The report will also set out strategic improvements for governance and engagement that will see significant enhancement of the capabilities of Australian agencies to develop and refine IEA approaches.

Separately, the NESP Marine Biodiversity Hub has, through a project led by Charles Darwin University since 2016, collated the data on values and pressures, undertaken an initial risk assessment for the region (extent shown in Figure 7), including cumulative impacts, and is now updating that initial analysis with improved species distribution models and a systems-based examination of cumulative impacts. Reports are available and a manuscript is under review (Ostwald *et al*., in review).

It is anticipated that these two projects will lead to an increased focus on seascape approaches to marine management in North Marine Region for NESP 2.0, especially in inshore waters where there are many overlaps of habitat use by listed species and greenfield development, including aquaculture. One research focus for NESP 2.0 is resilient landscapes, and it is likely that the coastal and perhaps offshore North Marine region will be a focus, providing a cross-over between the proposed 'Resilient Landscapes' and 'Marine and Coastal' hubs. The scope of the project is as yet undefined but will need to cover many spatial scales from individual development applications to the effective range of listed species. While the overall research and development of advice ready

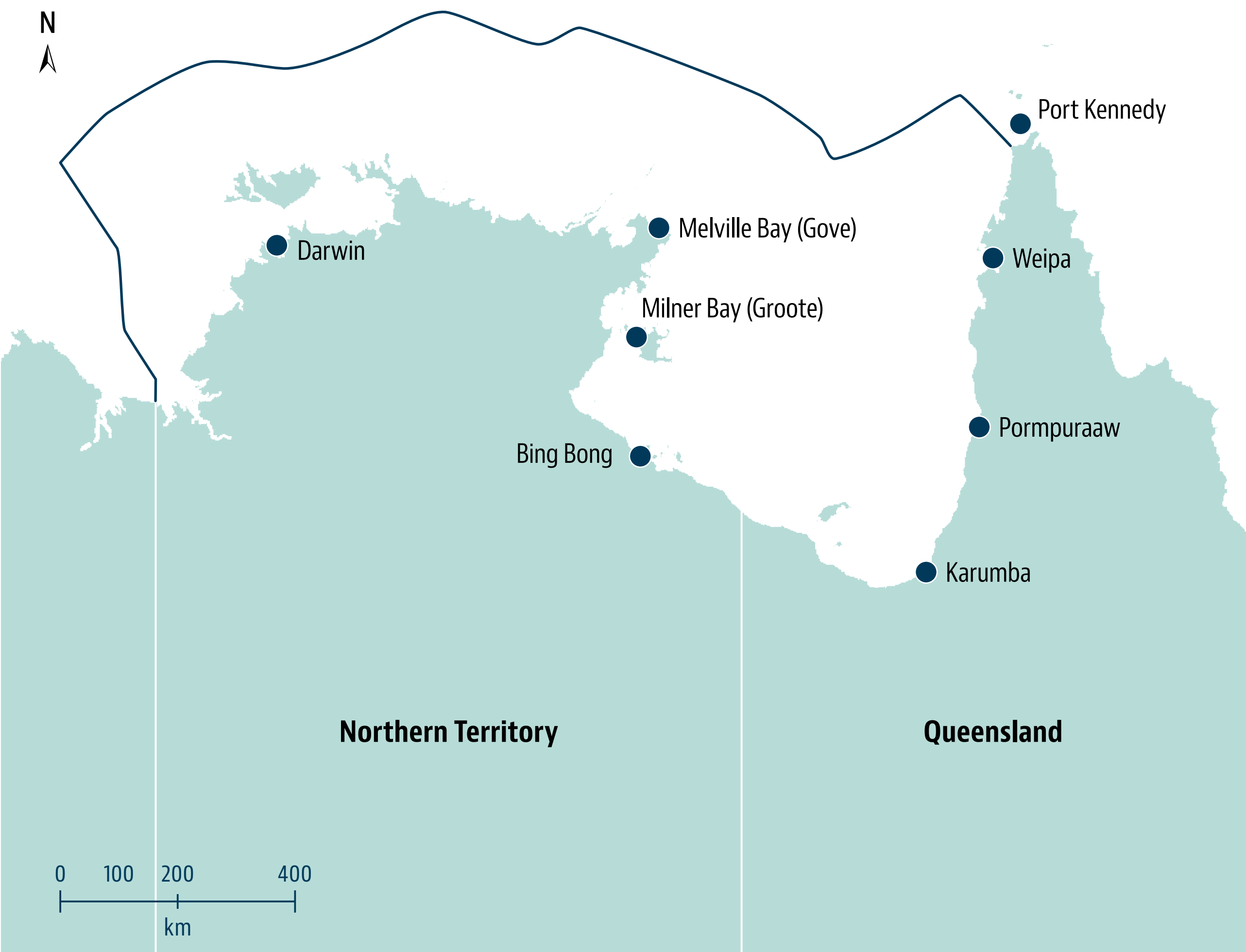

Figure 7: Map of northern Australia, outlining the area of the North Marine Region study (redrawn from Ostwald *et al*., in review).

for uptake and implementation by the Northern Territory and Commonwealth Governments may be achieved by a project under NESP 2.0, the ongoing improvement to data on the populations and distribution of listed species and their habitats will be ongoing for many years.

This pilot remains a work in progress but also an opportunity, comparatively rare in Australia, to initiate IEA before many industries have sunk costs that can make it uneconomic to explore more integrated approaches. It is also an opportunity as it is an area where the government is actively seeking to attract investors by reducing the sovereign risk that develops from multiple jurisdictions and multiple sectors (or sectoral agencies) with non-aligned objectives and expectations. The scientific aspects of the IEA have advanced beyond the scoping and objectives and these latter stages need to be developed in close collaboration with the jurisdictions involved.

Broad policy objectives under the Northern Australia White Paper[32] will need to be further specified as operational objectives before influential indicators can be prioritised, management strategies can be identified or monitoring and evaluation can begin. Some of these stages are being developed for Australian marine parks nationally and approaches developed elsewhere in Australia for all stages will be available to complete an IEA once operational objectives have been articulated.

One complicating factor will be whether decisions in the coastal zone will be made based on a terrestrially derived IEA or a marine-derived one. A successful outcome of the current cross-hub NESP IEA would be complementary or even identical approaches to IEA across land and water. Additional funding to complete this IEA would be around $2 million, but it is certain to identify key uncertainties (scientific, governance and policy) that will require addressing subsequently. If successful, the IEA will be a living document that is periodically refined and reviewed to help scope and prioritise further investments over time.

Table 8: IEA status for the Northern Seascapes pilot. See Table 2 for definitions of these ratings.

IEA stage	**Status for Northern seascapes**
Engagement	Partially complete
Scoping	Partially complete
Indicator development	Not initiated (partial in MPAs)
Ecosystem assessment	Partially complete
Risk assessment	Partially complete
Uncertainty assessment	Not initiated
Evaluating Management Options	Not initiated
Monitoring and evaluation	Not initiated
Iteration	Little progress (just beginning)
Overall status	Partially complete
Notes on available models	MaxEnt, qualitative, and GBR cumulative impacts
Key references and links	Davies and Kyne (2018) Dunstan (2018) Dunstan and Dambacher (2017) Dunstan *et al*. (2019) Kyne *et al*. (2018)

[32] https://www.infrastructure.gov.au/sites/default/files/documents/nawp-fullreport.pdf

Criteria for implementing IEAs |

In reviewing the case studies and determining future requirements to complete an IEA for each pilot, the Working Group identified a number of criteria.

- **Clearly articulated need**: This is a necessary requirement for IEA. This is because an IEA is not an academic exercise but a process to assist managers and industry to deliver sustainable outcomes in an effective and transparent way that maintains community support and reduces sovereign risk to investors. Ultimately, it should provide significant resource and costs savings through better decision-making and less controversy, leading to more influential and timely approvals. The need is clear in all case studies and pilots, and while in the Gladstone Harbour and the South East Australia – Alternative Management Strategies case studies an IEA-like process was driven in response to controversy and declining environmental and economic conditions, IEA would ideally start before conditions started to decline.
- **Enabling elements (like policy, governance and long-term funding)**: The presence of such elements helps motivate and legitimise the IEA process and will usually be essential to implement recommendations evolving from the work, especially long term. However, their lack shouldn't be seen as a barrier to beginning the work. The process reveals important insights into uncertainty and trade-offs supporting decision-making and highlighting the benefits of growing the enabling elements.
- **Effective, truly participatory (not just 'talking at') stakeholder engagement**: This is *critical* and needs to be carried out through the entire process. All case studies demonstrated this, but Gladstone Harbour and Alternative Management Strategies were particularly strong in this respect, perhaps reflecting their genesis. The potential pilots were more variable, with the NSW Marine Estate being the standout. Breadth of engagement is also important (local, state, national governments and regulatory agencies; industries; traditional owners; user communities and other members of the public). The emphasis on engagement is important, as the process by its very nature is collaborative and transdisciplinary. The domains of science, management, planning, policy and practice are interactively involved in issue framing, knowledge production and knowledge application. Here the term science covers not only the biophysical but also economics and social sciences.
- **Socio-ecological focus**: To be of benefit to managers and industry, the approach needs to be explicitly socio-ecological. It needs to capture social and economic as well as bio-physical dimensions – often referred to nowadays as Coupled Human Natural systems. This is increasingly being progressed within a broad wellbeing framework that identifies the specific attributes and indicators that need to be measured to help evaluate management effectiveness.
- **Volume of available data**: The process tends to be knowledge hungry (across multiple industry and science data streams but also local and traditional knowledge); however, the barrier is not typically the existence of the data (there is more than appreciated) but drawing it together in a useful and accessible form (especially if it is to remain or be repeatably accessible). This is often a relatively costly and resource intensive but necessary first step. In all case studies and most pilots, considerable effort was given to getting the available data into a discoverable and coherent form.
- **Staging IEAs is recommended**: Internationally successful IEAs have been approached in a staged manner. In extending this experience to Australia, it is worth acknowledging that some potential case studies have already addressed some stages. For example, data has been collated and data/knowledge systems are available for the NSW Marine Estate, Spencer Gulf and Northern Seascapes. Extensive risk assessments have also been undertaken for the NSW Marine Estate. The NESP Marine Biodiversity Hub has collated extensive information on existing pressures in the Commonwealth Marine Area and is currently considering (through a new national synthesis and Northern Seascapes project) the pros and cons of different methods for organising and describing values within an IEA. Note that while qualitative assessments provide a useful first step, quantitative analyses (implemented where possible) provide the power to thoroughly consider the implications of interactions, which in most cases are non-linear.
- **An ensemble approach**: In terms of the analyses and tools used in the various components, qualitative and quantitative approaches can both be undertaken – separately or in parallel. Where possible, multiple tools (including multiple models) should be used in an ensemble approach – from qualitative mathematical modelling to statistical methods to

end-to-end ecosystem models and MSE. This is the best practice approach and the most sensible for the Australian context. An ensemble approach allows the best handling of uncertainties and can be tailored to available resources most easily. An ensemble approach also provides increased modes and opportunities of communication where products can be tailored to individual audience needs.

- **Need to be clear on spatial extent and scale**: completing the process at the scales needed benefits from the use of nested approaches (from broad-scale qualitative approaches to more detailed analyses for specific geographic extents). Feasibility of quantitative analyses at scales appropriate to the sectors and interest groups involved can be informed by the availability of georeferenced habitat information and the extent of the values that the IEA is trying to protect. Taking a staged and pragmatic approach is likely to be far more beneficial, and much more practical, than simply trying to address expansive (i.e. whole of state) spatial scales by default.
- **Governance**: the NSW Marine Estate has an overarching governance framework in place, the Marine Estate Management Authority. IEAs can, however, be undertaken without an overarching policy or governance framework, particularly in making interactions and trade-offs between multiple sectors explicit. But having the governance link is helpful to resourcing and to legitimise and implement outcomes. In the absence of supporting governance, it is likely that an additional stage would need to be added within the IEA process to help demonstrate the 'need' for the IEA on that scale (in order to help secure funding and longer-term legitimacy).
- **Positioned within an adaptive management context**: IEAs are designed to inform adaptive management and rely on completion of the adaptive management loop. Impactful completion of such an iterative approach (rather than simply status reports) requires an ongoing commitment from management and industry to collect data and evaluate the effectiveness of management activities, as best exemplified in fisheries management.

These criteria are based on lessons drawn from experience to date, which resonates with international experience. The list of criteria below illustrates the US experience (from table 2 in Samhouri *et al*., 2014):

1. Engage with stakeholders, managers, and policy-makers early, often, and continually.
2. Conduct rigorous human dimensions research.
3. Recognise the importance of transparently selecting indicators.
4. Set ecosystem targets to create a system of EBM accountability.
5. Establish a formal mechanism(s) for the review of IEA science.
6. Serve current management needs, but not at the expense of more integrative ocean management.
7. Provide a venue for EBM decision-making that takes full advantage of IEA products.
8. Embrace realistic expectations about IEA science and its implementation.

Completing or progressing the pilots |

Previous assessments have had only mixed uptake. This was because once assessments were complete there was mixed appetite politically for uptake, reflecting differing degrees of siloing of relevant regulatory and planning agencies.

However, that policy landscape is changing. While jurisdictional complexities remain a challenge, there is now a greater desire to coordinate across departments and simplify administrative requirements and legal complexities, while allowing for traditional owner inputs, creation of climate resilience and streamlined marine spatial planning. A more risk-based approach is driving thinking, in part motivated by observations and lived experience that interactions and cumulative risk are being realised as population and use levels grow. This has seen various threats to economic and environmental status, along with other community benefits. In turn, this has seen tensions grow around resource-use conflict, incremental environmental degradation, governance, public safety, critical knowledge gaps and lack of access.

Australia has pockets of relevant best practice capability for integrating decision-making in marine systems that are dispersed across the country. There are good examples of partially integrated decisions in different locations. However, we lack a coordinated and consistent approach to build a strong and distributed national capability that can support this process at scale, to enable more effective decision-making for the national benefit.

While objectives and enabling elements exist in many cases, delivery of IEA in Australia has not gone much past scoping and data collation stages, except perhaps in the NSW Marine Estate example. For the case studies, indicators and evaluation of management options have been undertaken to some degree, but this is generally not common nationally. Some of the case studies highlight this range. In terms of a fully quantified process, the Bioregional Assessments case study (by its very nature) came closest, but it was terrestrial and even it did not put in place an explicit MSE (though it did undertake some model-based simulation analyses of impacts and some mitigation options) or longer-term monitoring and evaluation process. Within the marine realm, the NSW work is furthest through the process, although many of the steps have been undertaken qualitatively, given issues with available data and resources.

In terms of what the specific pilots provide:

- **Spencer Gulf**: Represents a significant opportunity, as much of the preliminary work needed to support an IEA has already been done. Data collation is complete, and some decision-support tools have been developed. While a strong focus on engagement with key government and industry stakeholders would need to be renewed, conducting an IEA in Spencer Gulf would: (i) illustrate nationally the benefits of undertaking an IEA in a region where enabling governance structures focused on integrated management are already established; and (ii) demonstrate to the South Australian Government the benefits of the approach more generally. The cost of undertaking a full IEA of Spencer Gulf would be approximately $2–3 million.

- **Victorian Coast**: Presents an opportunity for a large-scale pilot to be delivered relatively quickly, as there is an existing need to trial the decision-making process in Victoria in the short-term future as part of ongoing statewide processes (including delivering on the Marine Spatial Planning Framework and State of the Marine and Coastal Environment reporting). The state government processes already require many of the gaps identified in Table 6 to be filled to achieve their stated outcomes. Consequently, this presents an ideal opportunity to use the IEA process to achieve Victorian policy outcomes, while simultaneously building on the expanded knowledge base created by these already scheduled activities. To complete such a process (either Port Phillip Bay or the Victorian Outer Coast), deliver on the stated policy objectives, fill the scientific gaps and maximally leverage scheduled activities would require an estimated investment in the range of $3–4 million.
- **NSW Marine Estate**: As the most mature of the four pilots, the components that require further attention in this case are uncertainty assessment and evaluation of management options, both of which have only been partially completed at best and would benefit from quantification. Completing these activities would provide greater certainty regarding potential future management options and trade-offs and could be undertaken for less than $500K.
- **Northern Seascapes**: This is the least developed pilot, with the scientific aspects not having progressed through the initial data collation and early cumulative impact assessment. Scope and objectives are under active review, including whether an IEA will focus on the marine and coastal realms and/or terrestrial and coastal realms. Nonetheless, some of the process development is being actuated for Australian marine parks nationally and approaches developed elsewhere in Australia for the various IEA stages will be available to complete an IEA once operational objectives have been articulated. Moreover, this pilot presents a comparatively rare opportunity to initiate an IEA in an area prioritised by the Australian Government for development but before many industries have sunk costs that can make exploring more-integrated approaches uneconomic. IEA outputs in this context could minimise sovereign risk by avoiding a situation where non-aligned objectives and expectations exist across sectors due to jurisdictional complexities (this would directly meet a government need to attract investors). Additional funding to complete this IEA would be around $2 million, with the outputs (e.g. key uncertainties identified by the process) becoming the basis of an iterative and ongoing process that is refined and reviewed to help scope and prioritise further investments over time.

None of these investments are trivial, but all show great benefit in terms of delivery into policy processes, development and planning, and also into the expansion of knowledge of these systems in question. In all cases there are significant advantages to using a staged approach to complete the components and progressing the package, as this allows for the conclusion of the first iteration of the process even in the absence of complete information. Further iterations may refine the information and the learnings, but even in the first (often qualitative) iteration, significant advances can be made in terms of prioritising actions, identifying gaps in knowledge, and bringing together the scientific community and other sectors of civil society in a collaborative problem-solving context. Furthermore, the individual steps have value in and of themselves, progressing understanding, synthesising data critical to decision-making (whether within or beyond an IEA) and bringing stakeholders together in a dialogue around expectations, objectives and feasible actions. It is a by-product of human psychology that in the absence of certainty there is a tendency to 'wait and see'. However, in the rapidly changing socio-ecological environments characteristic of Australia's marine and coastal areas, not taking action is now detrimental. Consistent global experience has shown that scientific certainty is neither required nor sufficient to make significant steps forward in supporting good decision-making and achieving sustainability.

While the IEA process can seem daunting, it is a process that is increasingly seen as the only way forward for crowded and stressed marine and coastal systems. Without such a process, and without an understanding of how to do it well, significant tension/conflict, economic loss and environmental degradation will continue to result.

Implications for **national and international initiatives**

Integrated assessment and methods for minimising and avoiding cumulative effects are an increasing focus for national and international policy and initiatives.

Maximising sustainable development benefits while minimising and avoiding degradation due to cumulative effects is at the heart of the UN Sustainable Development Goals. Similarly, well-managed, sustainable and equitable development of marine sectors is at the heart of the High Level Panel for a Sustainable Ocean Economy call for transformation.

This is predicated on each coastal or island country instituting national sustainable ocean plans, which guide sustainable use of the entire exclusive economic zone. As a member of this panel, Australia has committed to the establishment of a Sustainable Oceans Plan by 2025[33] to ensure that 100 per cent of ocean areas under Australia's jurisdiction are sustainably managed. Achieving this goal will benefit from the approaches described in this document because integrated assessments are an evidence-based means of developing such plans. As discussed below, the capability and experience to implement this are already present in Australia, if not well coordinated. These developments are also consistent with the recent Environment Protection and Biodiversity Conservation review recommendation that formal cumulative effects assessments should be central to the certified application of national environmental standards under a revitalised Environment Protection and Biodiversity Conservation Act.

Assessing cumulative impacts is also central to the UN Decade of Ocean Science for Sustainable Development. The main motivation is to support efforts to reverse the cycle of decline in ocean health and create improved conditions for sustainable development of the ocean. The impact of multiple stressors on the ocean is also projected to increase as the human population grows towards the expected 9 billion by 2050. Scientific understanding of the ocean's responses to these pressures and management action is fundamental for sustainable development. IEAs provide a powerful process for assisting with this and, in particular, to help identify research priorities.

As indicated above, the UNEP integrated environmental assessment and reporting framework also shares the same basic steps as the IEA process presented here.

Through the Department of Agriculture, Water and Environment, Australia is starting to develop a framework for environmental-economic accounting. The UN SEEA has been developing processes for ecosystem accounting since 2018, based on the Pressure State Impact Response (PSIR) process, to supplement the individual component accounting of the SEEA Central Framework. Including a broad range of ecosystem services expands the concept of wealth in the SEEA Ecosystem Accounting, as it is recognised that the underlying environmental assets provide a much wider set of benefits than is traditionally recognised [c.f. fish resources and marine ecosystems]. Ocean accounts[34] provide a broad framework to connect relevant elements of the System of National Accounts, SEEA Central Framework and SEEA Ecosystem Accounting to harmonise priority data on the ocean covering economic, ecological, governance and social aspects.

Recognition of ecosystem assets, including marine ecosystem assets through national statistical offices would both increase the need for appropriate data and monitoring and also provide a sound basis from which to measure the performance of IEA initiatives.

33 https://oceanpanel.org/ocean-action/transformations.html

34 'Technical Guidance on Ocean Accounting for Sustainable Development' submitted as background document to the United Nations Statistical Commission, fifty-first session, 3-6 March 2020. Available at: https://unstats.un.org/unsd/statcom/51st-session/documents/BG-item-3h-TG_Ocean%20accounting_ESCAP-E.pdf

Conclusions and **recommendations**

The full benefits and opportunities from maximising community wellbeing, management outcomes and the blue economy (greater than $100 billion in Australia alone (NMSC 2015)) cannot be fully met without adopting a new approach that comprehensively takes into account the various objectives, requirements and values of the multiple sectors.

IEAs are the internationally emerging process to inform the management of this increasingly crowded and contested marine and coastal estate. The IEA process includes several distinct steps, which are applied iteratively. It is an interdisciplinary and policy-orientated process for combining, interpreting and communicating knowledge from diverse knowledge systems (i.e. multiple scientific disciplines, traditional and local knowledge, and experiential knowledge form industry) to inform and enhance decision-making.

While full IEAs have never been undertaken in Australia, there are examples of similar but partial approaches that would provide useful information on what worked and what was less successful. The marine and coastal case studies included decision-support frameworks for the Ningaloo Coast and Gladstone Harbour, the Alternative Management Strategies project, the Great Barrier Reef and a terrestrial example, the Bioregional Assessments program.

To assist with implementation of IEAs in Australia, four potential pilots (Spencer Gulf, Victorian Coast, NSW Marine Estate and Northern Seascapes) were selected to make sure the approach meets Australia's needs. These pilots cover different levels of maturity, spatial extent and represent areas of differing user complexity and different levels of data and knowledge to assess the effectiveness of the process with different levels of certainty in data and information. Objectives and enabling elements exist in many cases, but delivery of IEA in Australia has so far not gotten much past scoping and data collation stages, except perhaps in the NSW example. For the case studies, indicators and evaluation of management options have been undertaken to some degree, but this is generally not common nationally.

The Working Group reviewed the case studies and determined future requirements to complete an IEA for each pilot. In doing so, several criteria to assist implementing IEAs in Australia were identified and are recommended to ensure the approach is as effective as possible. While jurisdictional complexities remain a challenge, there is now a greater desire to coordinate across departments and to simplify administrative requirements and legal complexities, while simultaneously allowing for collaborative and respectful Indigenous partnerships, creation of climate resilience and streamlined marine spatial planning. A more risk-based approach is driving thinking, in part motivated by observations and lived experience that interactions and cumulative risk are being realised as population and use levels grow. Importantly, the presence of enabling elements (such as legislation and governance frameworks) help motivate and legitimise the process, especially long term, but shouldn't been seen as a barrier to beginning the work. Even without these, the process reveals important insights into uncertainty and trade-offs supporting decision-making.

None of the indicative investments that will be required to complete each pilot are trivial, but all show great benefit in terms of delivery into policy processes, development and planning, into the expansion of knowledge of these systems, and developing the transdisciplinary collaborations necessary to grow our national expertise in complex decision-making. In all cases there are significant advantages to using a staged approach to deliver the components of the IEA and progressing the package, as this allows for continuing the process even in the absence of complete information and scientific certainty. That is, we can start with manageable components of the larger, seemingly intractable, problem, recognising that as an iterative process, each component can be updated in a subsequent iteration.

While the IEA process can seem daunting, it is a process that is increasingly seen as the only way forward for crowded, stressed and changing marine and coastal systems. Without such a process, and without an understanding of how to do it well, significant tension/conflict, economic loss and environmental degradation will result. Having some integrated decision-making process is ultimately cheaper, less risky and more robust than none at all.

Finally, while Australia has pockets of relevant best practice capability for integrating decision-making in marine systems, these are dispersed across the country. There are good examples of partially integrated decisions in different locations. However, we lack a coordinated and consistent approach and a strong national capability to deliver these processes to scale to enable more effective decision-making for the national benefit.

It is recommended that:

1. The NMSC continues to support IEAs as the preferred way of addressing the National Marine Science Plan recommendation for a dedicated and coordinated science program to support decision-making by policymakers and marine industry.
2. A national trial of the potential pilot(s) is undertaken, the process and results of these pilots are evaluated and reviewed and used to develop a set of IEA Guidelines for implementation nationally.
3. The criteria and considerations identified by the Working Group are adopted to ensure the effectiveness of future IEAs.
4. The Working Group be expanded and tasked with developing an implementation plan in conjunction with decision-makers and other stakeholders.

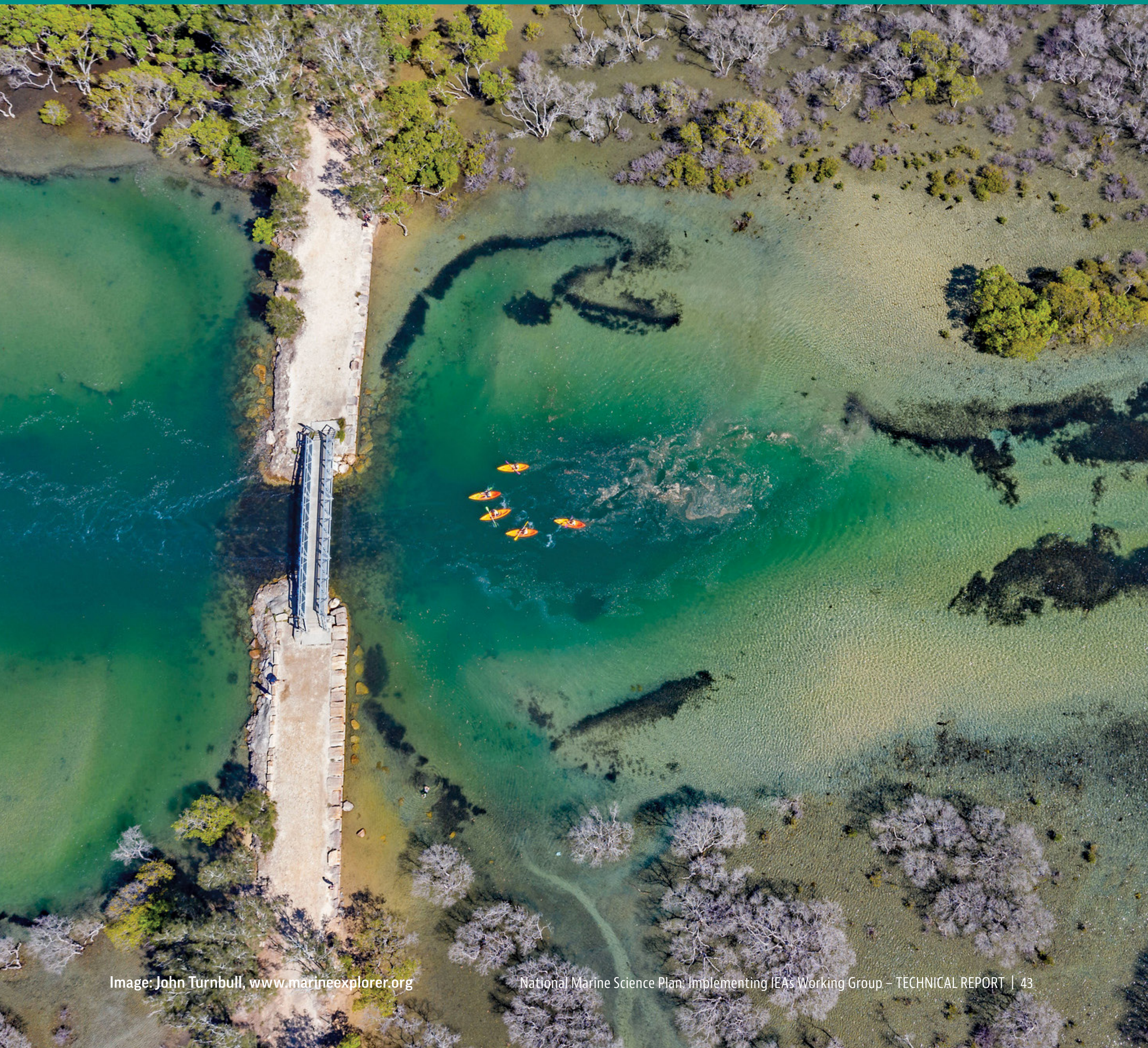

Image: John Turnbull, www.marineexplorer.org

Glossary

Term	Definition or equivalent terms
Activity	Actions by either individual users or sectors.
Approach	Method or framework for working through the problem.
Asset	The physical features of the system (not including people) that can be defined as environmental assets, cultural assets and infrastructure assets.
Communities	People who live close enough to affected areas that they have an immediate and tangible interest in the outcomes (e.g. some First Nations groups, local property owners or recreational user groups).
Community wellbeing	The combination of economic, social and environmental benefits to the community.
Cumulative impacts	The impact (positive or negative) resulting from the effects of one or more impacts, and the interactions between those impacts, added to other past, present and reasonably foreseeable future pressures.
Evaluation of Management Scenarios	A transparent and structured means of assessing management options (e.g. Management Strategy Evaluation).
Hazard	Any activity, event or substance that can cause damage to individuals or to valued aspects of a system (including system function). A failure to act can also pose a hazard.
Impact	A marked effect or influence on an individual or valued aspect of a system. More recently the term 'effect' rather than 'impact' has become more widely used as responses are not always negative, but all sources of change should be noted for planning purposes.
Indicator	A metric that tracks the state of a system attribute of interest – it may be a direct measure or it might be a more easily sampled proxy, and it may measure system condition or pressure.
Monitoring	Collection of data on specified indicators that allows an assessment of the extent and trend of progress towards achievement of objectives.
Objective	A desired outcome – can be specific to a particular stakeholder group or set in policy.
Outcome	The consequence of a process; what changes once the process is complete.
Pressure	Stressor exerting influence on the system, potentially creating disruption or disturbance (typically and anthropogenic activity or environmental driver).
Process	In this context it is the steps taken in completing an assessment and feeding that information to decision-makers. In a policy context it is manner in which public policy is formed, implemented and evaluated.
Public	Group who lacks a direct connection to the outcomes but nonetheless has an interest in contributing (e.g. specific interest groups).
Risk	The likelihood of an undesired event occurring or of suffering a loss or damage as a result of a hazard.
Risk assessment	A process made up of the steps of hazard identification, exposure and effects assessments and risk characterisation – essentially: 'what are the potential hazards?', 'what is the level of exposure or likelihood of occurrence?', 'what is the consequence should it occur?', 'what is the final level of risk?'. This process should also highlight risk-reducing and risk mitigation measures. Risk assessments have many uses, but a major one is to assist decision-makers with the complex choices regarding the options in managing or reducing risks to the system.

Term	Definition or equivalent terms
Risk management	A structured process for identifying and analysing potential risks and devising and implementing responses appropriate to their effect. It begins by taking the risk characterisation from a risk assessment (which provides a prioritisation of risks, categorisation of recommended safeguards and mitigation measures, including their feasibility of implementation) and then steps through the decision-making process, which includes identifying risk tolerance, and comparing regulatory options, to select the appropriate response to a potential hazard.
Stakeholders	Groups that have a professional or personal interest sufficient to justify engagement (e.g. some First Nations groups, government regulators, industry representatives, NGOs).
Trade-off	The process of foregoing of one benefit or value for another that is regarded as more desirable or of greater importance.
Tool	A piece of software or framework for working through a problem.
Value	In the context of an IEA, a value is equivalent to an Attribute, Asset or 'Feature that is special'. This terminology is related to the broader definition from psychology that values are the standard a culture uses for discerning what is desirable/good/just in society. In this broader context, values are deeply embedded and are central to conveying a culture's beliefs (tenets or convictions held by that culture to be true).

Image: John Turnbull, www.marineexplorer.org

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NATIONAL MARINE SCIENCE COMMITTEE

NATIONAL MARINE SCIENCE PLAN

Implementing Integrated Ecosystem Assessments (IEAs)
Working Group Report

TECHNICAL REPORT

This full technical report, and a PDF of the summary, are available at

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