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Climate change, scenarios and marine biodiversity conservation

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ABSTRACT

This paper explores the utility of qualitative scenario approaches to examine the potential impacts of climate change on marine biodiversity conservation on the east coast of Australia. This region is large and diverse, with considerable variation in marine biodiversity and, concomitantly, considerable diversity in the likely impacts from climate change. The results reinforce a number of key points. Engaging with stakeholders in scenario planning provides not only a focus to discuss the future in a disciplined way, but also provides ongoing reference points for contemporary decision making and planning. The paper illustrates how qualitative scenario planning provides opportunities to address the challenges of marine biodiversity conservation in a changing environment.

1. Introduction

Contemporary policy making is developed under conditions of uncertainty. Some policy arenas such as marine biodiversity conservation are particularly volatile given uncertainties over assessment of the state of the marine environment and impacts upon it. This paper explores the utility of qualitative scenario planning to examine the potential impacts of climate change on marine biodiversity conservation in east coast Australia.

This paper first provides a background to the use of qualitative scenarios and outlines the approach used to identify and explore plausible futures for marine biodiversity conservation in east coast Australia. It then describes the case study areas and outlines four generalised scenarios based on different levels of (i) climate change and variability; and (ii) development and use. The paper concludes with considering how such scenarios can guide opportunities to address the challenges of marine biodiversity conservation in a changing environment, given that decision makers have to make choices over decisions and policy 'investments' with imperfect knowledge of all consequences. This dilemma is at the core of contemporary strategy making and planning. While prediction and forecasting is difficult if not impossible, scenarios can support decision-makers to:

- consider what sort of future is desired (in consultation with stakeholders);
- test these ideas against what might plausibly happen in the future; and
- develop flexible strategies from this conversation which do not unnecessarily pre-empt future decisions.

2. Addressing the future: qualitative scenario development

Scenarios are narratives or stories about *plausible* futures (see [1–5] for more details on the history, principles and methods of scenario approaches to futures thinking). Scenario development provides opportunities to explore alternative options and offers a powerful tool to assist in developing understanding of a range of options, or plausible alternative futures. These opportunities arise because scenarios enable deep learning that results from understanding the structural dynamics (including system structure, causal relationships, driving forces and assumptions) of the system at issue and so avoidance of reactive responses [5]. Scenario approaches provide an opportunity to address uncertainties in marine biodiversity conservation through the engagement of stakeholders in the management process, and particularly in the building of scenarios, either qualitative or quantitative. Qualitative scenarios:

- promote strategic conversation;
- provide a risk management tool;

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- expose new challenges (look outwards) rather than prediction;
- release people from 'straight line extrapolations';
- provide potential for increased insight;
- validate current policy settings and guidance; and
- give 'front-end' input into strategic planning and policy development processes [15].

At the same time qualitative scenarios are constrained through:

- sensitivity in speculating about the future;
- inability to provide prescriptive solutions;
- limits in setting the context rather than guiding decisions; and
- expense in terms of time commitment [6].

Qualitative scenario planning follows systematic and recognisable phases, and is a highly iterative, intense and imaginative process [7]. There is no set ideal number of scenarios but problems arise if either too few or too many scenarios are developed. Richness can be lost, too, if a simple continuum of 'good, indifferent, bad' is used. The key to scenario development is to identify a key focusing issue or set of related issues. This can either be given by the need to focus on a particular problem or issue or be established by a focused discussion or 'brainstorming' exercise. Such discussions typically lead to a range of ideas, from which key issues that guide the development of narratives can be identified. The brainstorming exercise provides a number of alternatives as well as focusing issues. The narratives are written following consideration of the way in which options can be developed around the focusing issues. The narratives can be tested or 'wind tunnelled' to ensure that they are plausible [7], giving an opportunity to revise and clarify the scenarios. After the narratives have been tested, they can be used to develop policy or management options. This stage is critical, as often the development of the scenarios is seen as an end point, when in fact they are the starting point for further planning. The narratives can be used to evaluate challenges, identify opportunities and threats, and strengths and weaknesses of various options.

One of the outcomes of a scenario exercise is that, in exposing new challenges by encouraging participants to look outwards, it can be effective in breaking path dependency. In providing potential for increased insight, the process may also give validation to current policy settings and guidance and help strategic planning and policy development processes. It is important to include opportunities for thinking outside the square – in Steve Jobs's words to "stay foolish" [8].

At the same time there may be justifiable sensitivity in speculating about the future, and problems in dealing with wild cards or black swan events arising from the external environment. Wild cards and 'black swan' events [9] are previously unheard of or unconsidered events or impacts prior to an event or discovery, but once such a black swan event has occurred, decision-making automatically takes account of them.

Initial scenario development was undertaken through focused workshops in three case study regions (see Section 3 for description of these study areas). Workshop participants comprised technical advisors, management agency staff and stakeholders. The first section of each workshop involved brief discussions of, and orientations to, the case study regions. After this scene setting, workshop participants discussed the key underlying values of the marine and coastal environments of their region. Participants were then invited to consider the key issues likely to affect their region from 2012 to 2030. Along with key issues, discussion also identified the major drivers affecting the region and associated key uncertainties. The rationale behind the interest in critical drivers and uncertainties is that they provide information about the change dynamics of the system in question. Discussion of uncertainties affecting the area into the future included asking workshop participants to consider the possibility of wild cards or black swan events. Ranking of the issues and uncertainties provided a means of identifying critical or focussing issues. Identifying uncertainties, together with consideration of values, issues and drivers, helped workshop participants shape plausible 'regional scenario narratives' for each study area.

To provide for scalability of the findings from the case regions to other levels, from local to national, four generalised 'scenario spaces' were then developed from the regional scenarios. In this paper, we focus on these generalised scenarios, which were constructed using two parallel approaches. First, rankings of issues and uncertainties from each workshop were consolidated by the research team to identify two critical uncertainties (important drivers that have significant associated uncertainties) that are likely to have major consequences for marine biodiversity. These were 'climate change and variability' and 'development and use'. Second, the workshop drivers data were used to construct influence diagrams that showed relationships identified by the research team between the drivers for each region and important habitats for biodiversity. Thematic classification of these drivers revealed the same two critical influences on biodiversity outcomes. Generalised scenarios were therefore created by intersecting the two antipodes, climate variability and change and development and use of the marine and coastal environment. Antipodes express the extreme outcomes of key uncertainties and enable construction of four scenario narratives associated with combinations of high and low levels on each antipode.

3. Study areas: east coast Australia

The east coast of Australia (including the island state of Tasmania) stretches from Cape York at latitude 10.68° South, to South East Cape in Tasmania at latitude 43.39° South, giving a latitudinal distance of 3680 km, with the coastline length much longer. This span, from the tropics to cool temperate waters, includes significant marine biodiversity, and includes the Great Barrier Reef (GBR), the world's largest coral reef system, with over 2900 individual reefs and 900 islands. The east coast includes 16 meso-scale bioregions under the Integrated Marine and Coastal Regionalisation Australia (IMCRA v 4.0), "a spatial framework for classifying Australia's marine environment into bioregions that make sense ecologically and are at a scale useful for regional planning" [10]. More than 80% of Australia's population lives adjacent to these east coast marine environments. Major population centres include Australia's three largest cities, Sydney, Melbourne and Brisbane as well as extensive settlements in the Gold Coast (Queensland) and Newcastle (New South Wales), Australia's largest non-capital cities. The east coast also includes major centres of industry and infrastructure. Three of the 16 meso-scale marine bioregions within this vast domain were selected for analysis of the impact of climate change on marine biodiversity conservation. These study sites, the Whitsundays in North Queensland; the Tweed-Moreton (straddling the border of Queensland and New South Wales); and East Coast Tasmania, provide broad representation but also allow exploration of key issues, drivers and uncertainties at the meso-scale.

3.1. The Whitsundays

The Whitsundays marine area is principally valued for its ecological attributes (including continental islands and fringing reefs, coral reefs, seagrass habitat, coastal wetlands and marine fauna), tourist attractions, and fishing productivity. The ecological values of the Whitsundays include a calving ground for whales,

seabird roosting areas and dugong seagrass habitat. The Whitsundays area has very good access by boat, air and land and there is a diverse range of activities for tourists. The inner reefs are one of the most accessible areas of the GBR for tourism and recreation. Waterways around the islands are well known for their sailing while the offshore reefs are attractive to divers. There are significant commercial and recreational fishing areas, both inshore and offshore. The region is experiencing major coastal development including urban settlements, and port infrastructure to serve an expanding coal export industry, with likely impacts on the coastal and marine environment, and at the same time is subject to significant extreme weather events and climate variability.

3.2. The Tweed-Moreton

The Tweed sub-region includes the Solitary Islands Marine Park (SIMP), the Cape Byron Marine Park (CBMP) and the Commonwealth Solitary Islands Marine Reserve. These reserves are located in the southern part of the Tweed-Moreton marine bioregion, which constitutes a transition zone between tropical and temperate waters. The SIMP has an unusually large range of ecosystems, including extensive reef areas and major islands that provide important habitat for a range of species, including 550 species of fish, 900 molluscs, and 90 coral reef species [11]. Of mangrove species found in NSW, seven are found in the northern areas of Cape Byron Marine Park. Threatened species present within the Tweed sub-region include dolphins, hump back whales, white shark, green turtle, black petrel, shearwaters, and loggerhead turtle (in the SIMP). The region is also valued for its relatively intact natural landscapes, clean beaches and waters, rocky headlands and national parks. The region's economic health is linked to the tourism values of the SIMP (which provides an all year round influx of tourists), and commercial and recreational fishing. Marine mammal watching is increasing in value, particularly in the CBMP. In the adjacent coastal hinterland, agriculture – mostly blueberries and bananas – is a significant industry.

In contrast to the Tweed sub-region, the Moreton Bay Marine Park is adjacent to the highly urbanised south-east Queensland. The region adjacent to Moreton Bay is one of the most populous and fast-growing in Australia [12]. The principal ecological values comprise the barrier islands of Moreton and North and South Stradbroke, areas of seagrass, the southern-most population of dugongs, turtle species, the grey nurse shark and a Ramsar site that is a major area for wading birds. The eastern side of the bay has more oceanic influences, while the western side is more vulnerable to urban and agricultural impacts. Moreton Bay's marine economic values include major commercial and recreational fishing activities; and commercial port facilities. The hinterland is an important agricultural region, while the region is experiencing rapid population growth.

3.3. East Coast Tasmania

This region is characterised by the uniqueness (average 70% endemism), diversity and abundance of its marine life. It has valuable coastal wetlands, including Ramsar sites, and it also has value as a scientific reference site [13]. The region's economic value is based on the advantages provided by the natural environment. There is a safe, all-weather, deep-water port at Triabunna, while an unpolluted marine environment is an asset for tourism, which provides employment in the region. Wild fisheries and aquaculture (in Little Swanport and Georges Bay) are significant contributors to the region's economy. There is a diversity of towns whose viability is linked to fishing, ports, and tourism and which attract sea-changers. As well, the coastal region experiences relatively high land values because of its attractiveness to Tasmanians as a holiday shack area. The region is highly valued for its recreational amenity. It has a mild climate and attractions such as national parks, beaches and intact Indigenous and European cultural heritage. It is not overcrowded and the lifestyle is attractive to diverse groups including fishermen, forestry workers, sea-changers and retirees. There is a strong sense of community with properties commonly passed down through the generations and for this reason there is an historical sense of place amongst long-time residents.

4. Qualitative scenarios for east coast Australia

4.1. Development of the generalised scenarios

The lists of issues and uncertainties from each case study workshop were consolidated into two tables. Tables 1 and 2 show the rankings that participants in the three workshops gave to these consolidated lists of issues and uncertainties. Note that the tables only capture the issues and uncertainties ranked by participants and do not encompass all the issues discussed. The rankings of issues (to identify key drivers) and uncertainties were integrated by the research team to identify two critical uncertainties (important drivers that have significant associated uncertainties) that are likely to have major consequences for marine biodiversity. These were 'climate change and variability' and 'development and use'. These were therefore provisionally selected as antipodes for constructing four generalised scenario spaces.

Table 1
Relative importance of issues in the three case study regions.

Importance	Whitsundays	Tweed-Moreton	East Coast Tasmania
High	Coastal and port development Water quality Extreme weather events	Population and development growth[a] Impacts of terrestrial activities Politics and jurisdictional issues	Demand for/access to marine resources Climate change and associated impacts
Intermediate	Resource extraction (fishing, mining) Species and habitat impacts	Fishing Knowledge, information and awareness Climate change	Future of fishing Tourism and other commercial pressures Global economic climate Community awareness of marine environment Political influences on resource management
Low	Increased potential for shipping accidents Access to offshore reefs for tourism Better monitoring	Habitat and species populations	Land-based impacts[b]

[a] Includes port development and shipping.
[b] Includes effects of poorly planned coastal development, catchment activities and industrial pollution.

Table 2
Relative importance of key uncertainties in the three case study regions.

Importance	Whitsundays	Tweed-Moreton	East Coast Tasmania
High	Coral reef decline as a result of climate change	Climate change science (control of emissions) Terrestrial impacts Political cycles (their effect on community values) Community values towards marine environment	Resilience of ecosystems to climate change Potential for stock enhancement/ aquaculture
Intermediate	Limits of acceptable ecosystem change	Ecological effects of climate change Fisheries stock assessment and sustainable use	Changes in community values
Low	Shipping accidents (incl. oil spills) Levels of risk Longer term prospects for tourism	Growth in whale population and associated tourism industry (In)coherent marine legislation	Energy costs for fishing and tourism Economic value of species shifts Disease and biosecurity Mix of future economic activities Future geopolitical outcomes

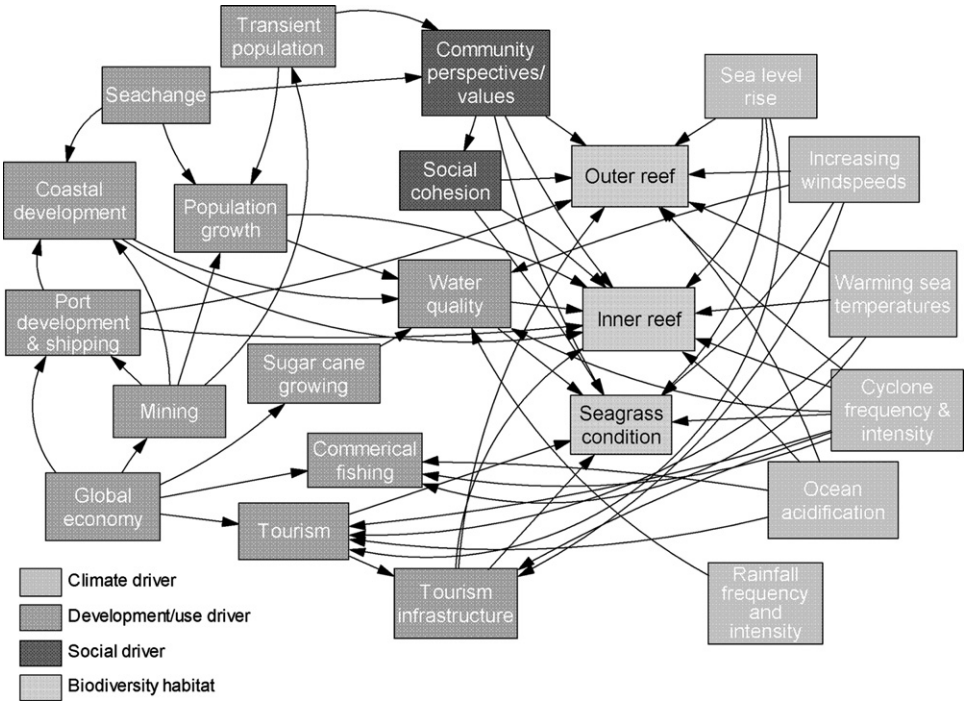

Fig. 1. Model of Whitsundays case study drivers and their influence on marine biodiversity habitats.

Second, the workshop drivers data were used to construct the influence diagrams shown in Figs. 1–3. These diagrams show relationships identified by the research team between the drivers for each region and important habitats for biodiversity. Thematic classification of these drivers revealed the same two critical influences on biodiversity outcomes – climate change and variability and development and use. Development drivers appear as a cluster on the left of each figure. Port development and associated onshore infrastructure, increased potential for shipping accidents associated with a growing volume of coal exports, coastal development allied to population growth, and tourism pressures on coral reef systems are considered major drivers of change in the marine environment of the Whitsundays region. In the Tweed-Moreton region, coastal development as a result of in-migration and the demand for recreational and tourist infrastructure and services were found to be the major drivers. For East Coast Tasmania, tourism pressures, coastal population growth and development, and resource demand are considered the main development influences on marine ecosystem change.

Warming sea temperatures, sea level rise, higher rainfall, and increased storm frequency characterise climate change and variability in all three regions. However, while increased cyclone severity and frequency may damage the coral reef ecosystems of the Whitsundays and Tweed-Moreton regions, increasing ocean salinity may prove a problem for those species accustomed to the lower salinities of the cool temperate waters of East Coast Tasmania. Further, while changes in the East Australian Current will stimulate the poleward movement of tropical species, significant changes are likely to occur in temperate waters where the current high level of productivity is likely to be substantially reduced by upwelling reductions [14,15] and keystone species such as macroalgae are highly vulnerable to predation by invading species from warmer NSW waters [16].

Non-development/non-climate drivers vary among the regions. Thus, the absence of community cohesion and understanding may result in negative outcomes for the marine environment of the Whitsundays, while deficiencies of coordination among the levels of government may produce similar outcomes for marine

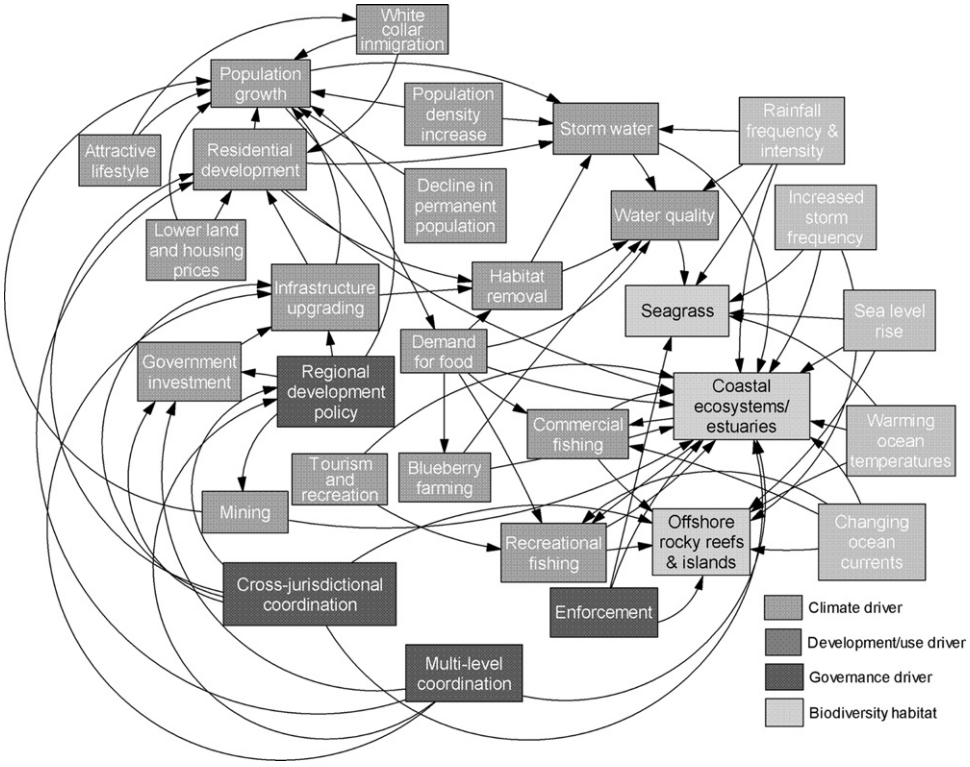

Fig. 2. Model of Tweed-Moreton case study drivers and their influence on marine biodiversity habitats.

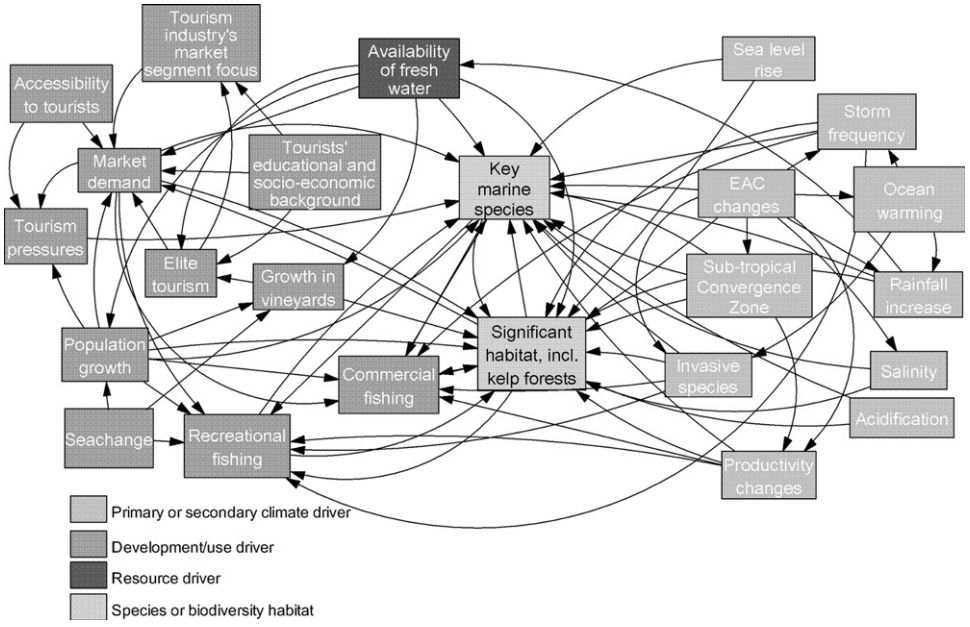

Fig. 3. Model of East Coast Tasmania case study drivers and their influence on marine biodiversity habitats.

biodiversity in the Tweed-Moreton region. For dry East Coast Tasmania, availability of freshwater influences tourism pressures and agricultural activities in catchments and ultimately is a key determinant of estuarine ecosystem health.

The generalised scenarios were created by intersecting the two antipodes, *climate variability and change* and *development and use of the marine and coastal environment*. Antipodes express the extreme outcomes of key uncertainties and enable construction of four scenario narratives associated with combinations of high and low levels on each antipode. The scenario spaces are depicted in Fig. 4 and described in the following sub-section. The titles given to the four scenarios are

- *You don't know what you've got …*
- *They paved paradise …*
- *Clouds from both sides now …*
- *Don't it always seem to go …*

These titles are taken from singer–songwriter Joni Mitchell's *Big Yellow Taxi* and *Both Sides Now*. They are intended to be

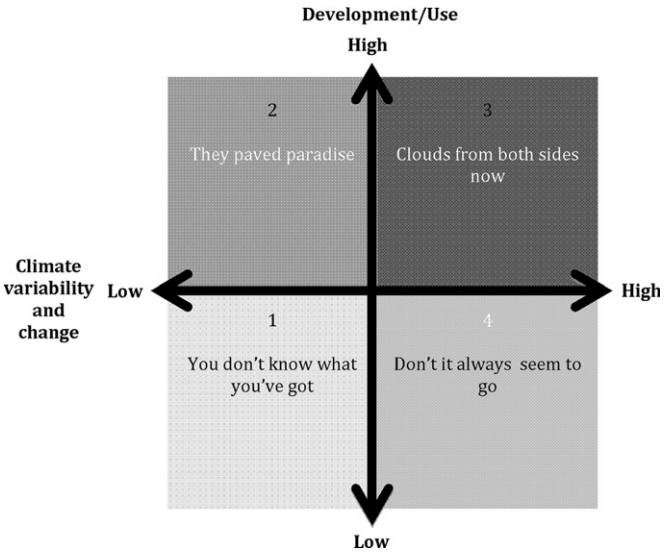

Fig. 4. Scenario spaces.

thought provoking and provide apposite and evocative snapshots of each scenario.

4.2. Scenario narratives

4.2.1. You don't know what you've got (scenario 1)

This scenario space is characterised by relatively low to moderate development and use of the marine environment and adjacent coastal region and by a relatively low to moderate level of climate variability and change. Tourism continues to be a major industry, with increasing interests in nature-based tourism in key areas. Fishing, both commercial and recreational, remains an important activity in coastal areas, although it has been changing over the past two decades, and more control on commercial fishing is being enacted. Coastal infrastructure and development have placed stresses on natural values, although areas buffered by both terrestrial and marine parks have been somewhat protected from this despite increasing pressure from growing visitor numbers. Sea level rise has been slow enough to allow saltmarshes, sea grasses and mangroves to adapt without being impeded by solid structures. Changes in fishing activities and practices have occurred; less invasive gear types are used and more targeted fishing is practised.

4.2.2. They paved paradise (scenario 2)

The 'they paved paradise' scenario space is differentiated by high levels of development and use of marine and coastal areas but relatively low levels of climate variability and change. Development and infrastructure in coastal Australia has continued to increase, with resulting major impacts on the proximate coastal and marine environment. Recreation and tourism in coastal areas have also increased. There is increasing pressure to intensify agriculture in drier areas by building dams to drought-proof farms. Intensification has resulted in increasing pollutant inputs into marine waters during high intensity rain events but reductions in freshwater inputs to adjacent estuarine areas at other times. Increasing variability of climate has had impacts but the scale of change and its impacts has led to a range of adaptation responses. Economic development pressures trump the formal legislative commitments to a balanced scorecard approach to ecologically sustainable development.

4.2.3. Clouds from both sides now (scenario 3)

Advanced development and use with climate change and variability tracking at the higher level mark this scenario space. This scenario is similarly underpinned by a high growth paradigm with expansion of shore based infrastructure, and road and rail services, and increasing size of coastal centres and population hubs for both coastal industry and activities in the hinterland and further inland. Climate change impacts are felt through increase in water temperatures while sea level rise is tracking at the upper end of predictions, and being managed by increasing use of hard infrastructure and engineering solutions to protect assets. Dredging and shoreline sand replenishment, as well as warming sea temperatures, increasing freshwater runoff and extreme climatic events increasingly impact marine biodiversity. Climate-related effects have forced major changes in fishing operations to manage impacts of fishing on marine biodiversity. Some inshore areas close to major urban agglomerations are thought to be vulnerable to ecological collapse.

4.2.4. Don't it always seem to go (scenario 4)

The 'Don't it always seem to go' scenario space is distinguished by lower to moderate levels of development and use of marine and coastal environments but higher levels of climate variability and change. The damaging impacts of climate change and weather extremes have resulted in reductions in economic activity. The coast continues to be a major attractor because many inland areas experience frequent droughts and lack adequate water for food-growing. Coastal infrastructure and development have placed stresses on natural values. Areas buffered by both terrestrial and marine parks have been somewhat protected from these impacts, but are under pressure from increasing visitor numbers. Agriculture has diversified from large-scale enterprises to smaller scale owner-farmers practising organic and sustainable farming and producing for local rather than export markets. Climate change impacts are felt through increases in water temperatures with temperature and sea level rise tracking at the upper end of predictions. Extreme events such as storms and rain events have had major impacts on coastal margins with significant impacts on marine flora and fauna. Fishing operations have, however, been constrained as climate-related effects have forced major changes in commercial and recreational fishing operations to manage impacts of fishing on marine biodiversity.

4.3. 'Wind tunnelling' the scenario narratives

The success of a scenario narrative is related to its plausibility, not its probability. At the same time a plausible scenario needs, as noted above, to recognise the potential of wild card and black swan impacts. While scenario narratives are to be contested, they should be 'realistic'. This test is an integral part of qualitative scenario building – wind tunnelling (or taking an apposite marine-themed metaphor, 'tank-testing') of the narratives. The narratives were presented to experts[1] who provided important review and input, as part of the testing of scenario plausibility.

This testing emphasises the need to reiterate the uncertainties related to climate change, as well as the recognition that short-term inter-annual variability (for example, changes in rainfall associated with La Niña-El Niño processes) can have major impacts. The frequency of extreme events as opposed to their severity was raised as a key uncertainty, repeated storm events – for example, repeated cyclonic events – were seen to have significant

[1] Members of the project's technical advisory panel (scientists and researchers) and representatives of key agencies (managers) with expertise in or responsibilities for the regions under study.

impacts on the marine environment, particularly on ecosystem resilience. Impacts of development were recognised as a key issue and uncertainty, but the testing of the scenarios emphasises the range of factors likely to affect development in the time frame under consideration: out to 2030.

4.4. Marine biodiversity futures

An analysis of the scenario spaces revealed six main categories of future drivers of impacts on marine biodiversity, namely marine infrastructure and port development, general coastal development, catchment-based pollution, climate change, fishing pressure, and community attitudes to the marine environment and marine conservation. Although there is a significant degree of commonality in drivers across the scenario spaces, they vary in impact according to their relative importance in each scenario space and according to how development and climate change impacts combine and interact (Table 3).

In the high development scenarios (2 and 3), the situation is one of increasing infrastructure development through an increase in the number of ports and allied infrastructure, increases in shore based infrastructure, road and rail services, and increasing size of coastal centres and population hubs to support both coastal industry and inland activities. These developments are anticipated to have major impacts on the proximate coastal and marine environment. In scenarios 1 and 4, the impacts of infrastructure development are more moderate due to the emphasis placed on natural values since terrestrial and marine parks have been somewhat protected from development pressures although they are under increasing stress from growth in visitor numbers. In scenario 2, changes in habitats associated with development have driven calls for stronger protection for the marine environment and buffering of less developed areas from impacts.

With respect to catchment-based impacts, scenario 1 sees new opportunities in agriculture that result from long-term changes in weather patterns but unfortunately these add further stress on the marine environment from impacts that have not been adequately managed or controlled. In scenario 2, pressure to intensify agriculture in drier areas by building dams to drought-proof farms has resulted in increasing pollutant inputs into marine waters. In the higher climate change scenarios 3 and 4, the volume of freshwater and pollutants entering the marine environment may have increased as a result of greater intensity high rainfall events. Mining developments make a significant contribution to the pollutant load in scenario 3.

The shift of population to the coast continues across all four scenarios although its degree varies with the level of development. This shift manifests as demands for shore-based infrastructure, housing, and visitor amenities and ultimately to increasing impacts on coastal habitats. In scenarios 2 and 3, the impact of increasing visitor numbers has seen recreation and tourism in coastal areas increasing with both active and passive marine-based tourism popular. In scenario 4, marine parks in particular are under pressure from increasing visitor numbers. In scenario 3, dredging for expansion of port infrastructure and maintenance of shipping channels and shoreline sand replenishment results in significant ecosystem impacts in localised areas. Here also, significant changes in habitats associated with increased coastal development and increasing climate variability are occurring.

Table 3
Main drivers and associated levels of impacts on marine biodiversity by scenario.

Scenario	***1. You don't know what you've got*** • *Lower development impacts* • *Lower levels of climate change*	***2. They paved paradise*** • *Higher development impacts* • *Lower levels of climate change*	***3. Clouds from both sides now*** • *Higher development impacts* • *Higher levels of climate change*	***4. Don't it always seem to go*** • *Lower development impacts* • *Higher levels of climate change*
Main driver				
Infrastructure and port development	Infrastructure development: moderate impact	Increased infrastructure: major impact	Increased port infrastructure: major impact	
Coastal development	Coastal infrastructure & visitor numbers: moderate but increasing impact	Visitor numbers: increasing impacts	Shore based infrastructure: increasing impact. Visitor numbers and associated development: increasing impact. Coastal development: increasing impact. Dredging: significant impacts in localised areas.	Coastal infrastructure development & visitor numbers: significant and increasing impact
Catchment-based pollution	Hinterland development: increasing stresses	Agricultural development and pollution: increasing impacts		Freshwater pollution: increased impacts
Climate change	Storm events and damage to fishing grounds: moderate increase in impact	Extreme weather events: impacts managed.	Rising water temperature: increasing climate impacts. Extreme weather events: major impacts.	Extreme weather events: major impacts. Rising water temperature: impacts increasing.
Fishing impacts		Fishing: increasing but sustainable impacts	Recreational fishing: increasing and uncontrolled impacts	
Community attitudes towards marine environment & conservation		Community reaction: lowered concern about impacts. Social attitudes to marine conservation: limited appreciation of impacts.	Marine environment funding diverted: lowered concern about impactsLoss of social cohesion: major impacts	

Climate change impacts range from extreme to moderate across the scenarios. Extreme weather events such as cyclones and rain events are having major impacts on coastal margins with significant yet less visible impacts on marine flora and fauna especially in scenarios 3 and 4. In scenario 1, a moderate increase in the number of extreme events has occurred generating significant debate over damage to fishing grounds. In scenario 2, extreme events as well as coastal surges have been managed with existing arrangements although environmental impacts remain an ongoing policy issue. Climate change impacts on marine biodiversity are largely felt through increasing water temperatures with temperature tracking at the upper end of the IPCC global and downscaled regional predictions in scenarios 3 and 4. The result is that the combination of warming waters, increasing freshwater runoff and extreme climatic events, such as storms and surges, increasingly affect marine biodiversity in these scenarios. In scenario 2, concern is being shown for the loss of habitat exacerbated by ongoing climate change, with changes considered by some to be harbingers of further more substantial regime shifts in the future.

In scenario 1, changes in fish assemblages and range in response to climate impacts are providing opportunities for fishers to diversity their catch but also challenges for those operators lacking sufficient flexibility to target different species or move to different fishing grounds. In scenario 2, fishing has continued to develop in terms of type and focus of activity although there are signs that demand for wild-caught fish is decreasing and sustainable harvest strategies are being implemented. In scenario 3, the impacts of recreational fishing are ongoing. Growth in recreational fishing vessels adds to fishing pressures. This outcome is largely due to the lack of political will to adequately control the impacts of recreational fishing. In addition, the relative wealth of mine-workers enables them to afford more and larger boats and more sophisticated fishing technology.

Community attitudes towards marine conservation are an important factor. The scenario process highlighted the likely variation in community focus and interest, and even some concern that the community could become desensitized to climate change. Community capacity could be affected by in-migration of large numbers of people with limited understanding of and commitment to their localities of residence and the values of the marine environment. A lack of social engagement may be an impediment to developing such an appreciation.

Across the scenarios, changes in species and habitat are being observed in response to the impacts of development and climate change although to varying degrees. Tropical and sub-tropical coral reefs are being badly affected by these impacts but particularly in scenario 3. In scenario 4, major changes have been observed in range, spread and density of species of marine flora and fauna. In scenario 2, while changes in habitats associated with development impacts and climate change have driven calls for stronger protection for the marine environment and buffering of less developed areas from impacts, changes in marine species are also seen to provide opportunities as well as challenges.

5. Changing currents: lessons and opportunities from scenario building

This process of developing and interrogating scenario narratives for marine biodiversity conservation in east coast Australia has a number of broader outcomes and lessons. Scenario development is a powerful, strongly iterative approach that rather than focusing on an accurate prediction of *the future*, provides opportunities to develop and consider a number of *alternative futures*. Unlike other forecasting techniques, scenario development allows the presentation of alternative narratives of the future rather than extrapolating current tends from present conditions.

The use of a qualitative scenario approach provided an opportunity to engage with stakeholders in consideration of the future by reflecting on current issues and uncertainties. Stakeholders involved in such discussions contributed useful input into the process and supported greater understanding of the scientific and social and economic factors affecting marine biodiversity conservation. Such engagement can carry through to the implementation of policies and management practices and foster a greater level of partnership between stakeholders [17]. The opportunities to build on stakeholder knowledge, and incorporate this knowledge into policy development supports the view that 'advice should be a dynamic process of expert judgement, incorporating separate parallel concurrent, lines of scientific evidence from quantitative and qualitative modelling exercises and factual knowledge' [18, p. 119].

The participation of stakeholders in the present scenario process not only afforded them the opportunity to consider alternative futures, but specifically to consider alternative options for governance and management of marine biodiversity in a dynamic context. In particular, the scenario process provided an opportunity to examine the capacity of current and future governance arrangements to address marine biodiversity needs in terms of a number of alternative futures. Ongoing work entails an assessment of the ability of current governance and management regimes to achieve acceptable biodiversity outcomes across the range of plausible futures presented in this paper followed by consideration of the kinds of reforms that might be required to achieve such outcomes.

Marine biodiversity conservation is affected by a range of factors including uncertainties over changes in the marine environment, especially climate change. This paper has outlined the use of qualitative scenario approaches in considering future challenges affecting marine biodiversity conservation in east coast Australia. This large and diverse region has considerable variation in marine biodiversity and concomitantly considerable diversity in the likely impacts from climate change. This research reinforces a number of key points. Engaging with stakeholders in scenario planning provides not only a focus to be able to discuss the future in a disciplined way, but also provides ongoing reference points for contemporary decision making and planning. The paper illustrates how scenario planning approaches provide opportunities to address the challenges (the changing currents) of marine biodiversity conservation in a changing environment.

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