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ORIGINAL RESEARCH

Developing achievable alternate futures for key challenges during the UN Decade of Ocean Science for Sustainable Development

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Abstract The oceans face a range of complex challenges for which the impacts on society are highly uncertain but mostly negative. Tackling these challenges is testing society's capacity to mobilise transformative action, engendering a sense of powerlessness. Envisaging positive but realistic visions of the future, and considering how current knowledge, resources, and technology could be used to achieve these futures, may lead to greater action to achieve sustainable transformations. Future Seas (www.FutureSeas2030.org) brought together researchers across career stages, Indigenous Peoples and environmental managers to develop scenarios for 12 challenges facing the oceans, leveraging interdisciplinary knowledge to improve society's capacity to purposefully shape the direction of marine social-ecological systems over the UN Decade of Ocean Science for Sustainable Development (2021–2030). We describe and reflect on Future Seas, providing guidance for co-developing scenarios in interdisciplinary teams tasked with exploring ocean futures. We detail the narrative development for two futures: our current trajectory based on published evidence, and a more sustainable future, consistent with the UN's Sustainable Development Goals, which is technically achievable using existing and emerging knowledge. Presentation of *Business-as-usual* and *More Sustainable* futures—together—allows communication of both trajectories, whilst also highlighting *achievable*, sustainable versions of the future. The advantages of the interdisciplinary approach taken include: (1) integrating different perspectives on solutions, (2)

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capacity to explore interactions between Life Under Water (Goal 14) and other SDGs, and (3) cross-disciplinary learning. This approach allowed participants to conceptualise shared visions of the future and co-design transformative pathways to achieving those futures.

Keywords Backcasting · Foresight activities · Futures literacy · Scenario development · Sustainable Development Goals

Introduction

The planet has entered the Anthropocene: a time of increasing anthropogenic impacts and accelerating change to social-ecological systems, with local to global implications for human well-being (Raworth 2012; Steffen et al. 2015a). In response, there has been considerable international focus on conserving ecosystems and enabling sustainable development. Examples of these efforts include formulation of the planetary boundaries framework (Steffen et al. 2015b), and declaration of Aichi targets (CBD 2010a) and the Sustainable Development Goals (SDGs) (CBD 2010b; Steffen et al. 2015b; UN 2015b). Yet, while the scale and urgency of the global environmental crisis have been broadly articulated, the necessary reforms to international governance and institutions, and the on the ground action needed to address the environmental crisis, have not kept pace (Galaz et al. 2016). In particular, there is a need to move from incremental changes to existing governance and institutions to transformational reorganisation. Examples of these transformations include closing regulatory gaps at the international level, and having a step change in equity among developing and developed countries in relation to sustainable development (Biermann et al. 2012; Burch et al. 2019; Kanie et al. 2012).

Driving transformations, while minimising unintended negative outcomes, requires forward-looking approaches that provide decision-makers with the necessary information to be proactive in anticipating and responding to changing social-ecological systems. Those approaches also need to deal with the uncertainty surrounding how the future will play out (Boyd et al. 2015; Guston 2008). A common tool used to explore the future, to help evaluate options and to inform decision-making is quantitative modelling e.g. linked biophysical and economic models such as those used by the Intergovernmental Panel for Climate Change (IPCC). Quantitative models are invaluable in developing understanding of the trajectories of social-ecological systems. However, used in isolation, there is evidence that these approaches may fall short when dealing with the complexity and context-specific variability of the challenges faced by society (Kok et al. 2017; Rosa et al. 2017). Reliance on data and quantitative approaches may constrain users' visions of the future, limiting creativity and leading to an 'imagination gap' when envisioning a more sustainable future and the major transformations needed to achieve it (Pereira et al. 2019).

The development and communication of a tangible vision of a positive future (Pecl et al. unpublished), can help fill this imagination gap. Such tangible, positive futures, sometimes called 'mobilizing narratives', are underpinned by learning, innovation, and creativity (Galaz et al. 2016). Critically, the visions portrayed in these futures are based on multiple types of knowledge, allow reflection and learning, and are 'shared' by those involved in the development process, rather than representing the desires of a dominant few (Costanza 2000). This 'shared' characteristic is important as it has the potential to reduce marginalization of vulnerable groups (Blythe et al. 2018). As part of a new, shared vision of the future, scientists and decision-makers can identify ways to encourage the uptake of behaviours—by individuals communities and organisations, and from local to global scales—that will leverage greater environmental and societal benefit (de Salas et al. unpublished) and a more equitable distribution of those benefits among and within nations (Alexander et al. 2020).

Narrative scenarios use storytelling and descriptions to portray the future, and allow participants to explore a range of social, economic and environmental challenges associated with moving towards the future (Konno et al. 2014). In doing so, narratives identify the capacities, technologies and enabling conditions that must be fostered to achieve desired transformations (Sadowski and Guston 2016). Narrative scenarios offer the opportunity to include diverse knowledge and value systems, and incorporate uncertainties, whereas predominantly biophysical and economic models are insufficient to capture the complexity and

context-specific nature of many socio-ecological problems (Blythe et al. 2018; Pereira et al. 2019).

Scenario development may take a number of different forms (Francis et al. 2011); however, they can be grouped into three broad categories of predictive, normative and exploratory approaches. Predictive scenarios are focused on *what will happen* in the future based on current evidence, conceptualised as the probable future (Amara 1984; Börjeson et al. 2006). For example, social-ecological modelling outputs can be integrated into predictive scenario development around the future consequences of climate change (e.g. Lotze et al. 2019). Normative scenarios are focused on describing what we *would like to happen*, conceptualised as the preferable future (Amara 1984; Börjeson et al. 2006). For example the SDGs provide an internationally negotiated set of normative goals for society's future to direct action internationally (UN 2015b). Exploratory scenarios look at a broader range of futures by outlining *what could feasibly happen*, conceptualised as the possible future, allowing stakeholders to think creatively about what could happen over a given time period and unconstrained by current societal norms, political processes or disciplinary approaches (Amara 1984; Börjeson et al. 2006).

Scenario development provides a way to produce visions of the future, but to drive change and realise the envisioned futures, action is needed. To provide pathways to the imagined future, stakeholders and policymakers need to design and implement complementary and coordinated actions across all levels of society from local community groups to national governments and international organisations. Backcasting is an example of an approach used to create such action pathways, allowing participants to work backwards from a desirable future to create a series of actions to ensure attainment of that future (Robinson 1990). These approaches are essential to ensuring that on the ground action addresses the sustainability challenges society faces.

Ocean futures

In 2016, the First Global Integrated World Ocean Assessment found that a considerable proportion of the ocean has suffered serious degradation leading to significant changes to marine ecosystem structure and function and the ecosystem benefits we receive from the oceans (UN 2016). In response, the United Nations declared 2021–2030 as a Decade of Ocean Science for Sustainable Development. The intent of this initiative is to stimulate international efforts aimed at improving ocean health, and a core emphasis is on generating the knowledge and data necessary to support sustainable development into the future (UNESCO 2019). While generating quantifiable knowledge and collecting data are important to ensure scientific advice on sustainable development is relevant and fit for purpose, major transformations are needed to create a sustainable future for our oceans (Sachs et al. 2019). Transformations are reliant on more than additional data. Rather, transformations require using existing and emerging knowledge to envision "the ocean we need for the future we want" (IOC 2017) and the individual and structural changes necessary to reach that future (de Salas et al. unpublished).

Normative and exploratory scenarios are likely to be particularly useful in the context of the oceans due to the complexities and uncertainties associated with governance of sovereign and common-pool resources both at the national and international level (Game et al. 2009). For example, science fiction prototyping, an exploratory approach, has been used to provide insight into the futures of a range of marine systems (e.g. Merrie et al. 2018). Indeed, there is an emerging literature using narrative scenario development to explore a range of possible futures for the world's oceans (e.g. Merrie et al. 2018; Rintoul et al. 2018). However, there is currently little guidance within the marine science literature on the process of developing narrative scenarios that combine a range of worldviews from within the scientific community and beyond. A notable exception is work by Planque et al. (2019), which first details the development of separate future scenarios based on distinct perspectives and subsequently describes a process for the integration of these individual scenarios into multi-perspective, imagined futures. Nevertheless, their two-step approach does not allow for end-to-end interdisciplinary collaborations that integrate worldviews from the outset. As a result, understanding around the interdisciplinary approach and challenges associated with creating shared, plausible ocean futures to guide action and policy, is currently lacking.

To help address this gap, we provide guidance for co-developing scenarios in an interdisciplinary team tasked with exploring alternative futures for the

Table 1 List of (A) key challenges, and (B) summary papers in synthesising learning from across the Key Challenges

(A) Key challenges	
1. Living with a changing ocean: climate change adaptation and mitigation	Trebilco et al. (2020)
2. Safeguarding marine life: conservation of biodiversity and ecosystems	Ward et al. (2020)
3. Food for all: designing sustainable and secure future seafood systems	Farmery et al. (2020)
4. Connected to the oceans: supporting ocean literacy and public engagement	Kelly et al. (2020)
5. Cleaner seas: reducing marine pollution	Willis et al. (2020)
6. Oceans and society: feedbacks between human and ocean health	Nash et al. (2020)
7. Ocean resource use: building the coastal blue economy	Bax et al. (2020)
8. Deep aspirations: towards a sustainable offshore blue economy	Novaglio et al. (2020)
9. Poleward bound: adapting to climate-driven species redistribution	Melbourne-Thomas et al. (2020)
10. Governing the oceans: governance of sovereign and common pool resources	Haas et al. (2020)
11. Sharing our oceans fairly: improving international relations around ocean issues	Smith et al. (2020)
12. Empowering her guardians to nurture our oceans future	Fischer et al. (2020)
(B) Summary papers	
S1. How do we ensure equity in the future use of our oceans?	Alexander et al. (2020)
S2. Driving desirable change: how do we achieve 'the ocean we need for the future we want'?	de Salas et al. (unpublished)

world's oceans. The objectives of the paper are to: (1) Describe the overall interdisciplinary process that underpinned the Future Seas project; (2) Detail the methods used to create the future scenarios and the action pathways to achieve those futures; and (3) Reflect on the key barriers and enablers to achieving the project aims.

Future Seas project

Future Seas (www.FutureSeas2030.org) aims to improve society's capacity to purposefully shape the direction of marine social-ecological systems over the course of the UN Decade of Ocean Science. To provide strategic insights into 12 Key Challenges (Table 1A) facing the oceans and society, we explored two alternate futures for each Key Challenge in 2030 (the conclusion to the UN Decade of Ocean Science): the anticipated or 'Business as Usual' future and a 'More Sustainable' future that was congruent with the SDGs. Once the futures had been developed each challenge team identified specific actions and activities necessary to help navigate society towards the 'More Sustainable' future.

An interdisciplinary[1] approach was central to the Future Seas project as it: (1) expanded the boundaries of the futures we could explore (beyond disciplinary perspectives of scientists and/or sectarian approaches from different industries); (2) permitted participants to conceptualise shared visions of the future and co-design transformative pathways to achieving those futures (Bai et al. 2016); (3) allowed us to explore the interactions between marine ecosystems and other SDGs; and (4) supported the development of new relationships among researchers from different disciplines and career stages, driving cross-disciplinary learning (Table 1B). Cross-disciplinary learning is fundamental to achieving the UN Decade of Ocean Science (Blythe and Cvitanovic 2020; Teh et al. 2017; Thébaud et al. 2017; Thrush et al. 2016). The development of interdisciplinary marine scientists and provision of leadership training for Early Career Researchers (ECRs) was central to the Future Seas project.

Future Seas was led by 5 members of the Centre for Marine Socioecology (KLN, GP, KA, CN & JMT). Individuals from a range of organisations and disciplines were invited to join the project (Table 2). From this invitation process, 116 participants, predominantly based in Tasmania, agreed to collaborate. Over 40% of the participants were ECRs & PhD students. 62% were female and 38% were male. Although most

[1] Throughout the paper we use the term 'interdisciplinary', but there are elements of transdisciplinarity in our approach where the methods engage with participants outside academia.

Table 2 Organisations and disciplines from which the Future Seas participants were drawn

Organisations	Disciplines
Centre for Marine Socioecology (CMS), Australia	Ecology
University of Tasmania (UTAS), Australia	Climate science
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia	Oceanography
Australian Antarctic Division (AAD), Australia	Marine engineering
Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), Australia	Mathematics
Department of Primary Industries Parks, Water and Environment, (DPIPWE), Australia	Philosophy
Australian National University, Australia	Social sciences
The University of Western Australia, Australia	Economics
University of Adelaide, Australia	Finance & Insurance
University of Technology Sydney (UTS), Australia	Political Sciences
University of Wollongong, Australia	Law
AP University of Applied Sciences and Arts, Belgium	Behavioural psychology
Dalhousie University, Canada	Medicine
St. Andrews Biological Station, Canada	Public health
University of New Brunswick, Canada	Traditional knowledge
Haida Nation, Canada	Indigenous knowledge
Snowchange Cooperative, Selkie, Finland	
Technische Universität München, Germany	
The Pisuna Project, Attu, Greenland	
Pikkoritta Consult, Greenland	
Fauna and Flora International, Myanmar	
Massey University, New Zealand	
University of Waikato, New Zealand	
Indigenous Taiwan Self-Determination Alliance (ITW-SDA), Taiwan	
Leiden University, The Netherlands	
Citi, United Kingdom	
Imperial College London, United Kingdom	
University of North Carolina, United States of America	

participants were currently based in Tasmania, they comprised over 20 nationalities and collectively had substantial work experience across all seven continents.

To address Key Challenges and develop futures that incorporated a wider range of world views than were present within the initial set of participants, Indigenous Leaders and Traditional Knowledge Holders from around the world were brought together to identify and address the 12th Key Challenge for the Ocean. Members for this team were identified in two ways: (1) through the existing network of Future Seas participants (e.g. through IPCC and www.speciesonthemove.com connections) and (2) the Indigenous and Traditional leaders invited by the core Future Seas team were asked to subsequently invite additional people based on their own networks, giving consideration to geographic and gender diversity. This invitation process led to a team of 12 Indigenous Leaders and Traditional Knowledge Holders from Canada, Greenland, Finland, Taiwan, Australia, New Zealand and Papua New Guinea participating in the Future Seas project (Table 2). The Indigenous and Traditional Knowledge team followed a distinct approach to developing their paper and futures, which are detailed in Fischer et al. (2020). This team also co-authored, reviewed and/or provided critical input for the other Key Challenges (Bax et al. 2020; Farmery

et al. 2020; Haas et al. 2020; Kelly et al. 2020; Melbourne-Thomas et al. 2020; Nash et al. 2020; Novaglio et al. 2020; Smith et al. 2020; Trebilco et al. 2020; Ward et al. 2020; Willis et al. 2020), based on their chosen preferences and interests, and initiated and elected to draft a preface for the special issue as a whole (Mustonen et al. unpublished).

Methods

We used a three-stage process (Fig. 1) to develop the alternate futures and pathways to action over the course of a year.

Step 1: problem identification, trust and awareness building

In October 2018, a short survey (Table S1) was distributed to all participants of the project asking individuals to identify issues they felt addressed important challenges facing the oceans and our society. From this survey, a list of potential Key Challenges was drawn up. At the first 2-day workshop (November 2018), participants discussed the Key Challenges and their current framing, and agreed upon a short list of reframed challenges.

At this workshop, participants also explored the meaning of a 'More Sustainable' future, such that a series of common objectives were identified for the 'More Sustainable' futures. Participants agreed that imagining a future that moved as far as possible towards the Sustainable Development Goals (SDGs) would be the core focus of the 'More Sustainable' Future in each Key Challenge, providing a broadly consistent, normative target across the Challenges (Börjeson et al. 2006; Planque et al. 2019). It was, however, made explicit among participants that the different Challenge teams were likely to have distinct starting perspectives. Those differences were likely to manifest in variability in the importance placed on different SDGs and their constituent targets among the Key Challenges. Similarly, it was agreed that the anticipated, 'Business-as-Usual' scenario was to be based upon the current trajectory of trends into the future (Planque et al. 2019), providing a broadly consistent predictive target for all the challenges (Börjeson et al. 2006). It is acknowledged that this

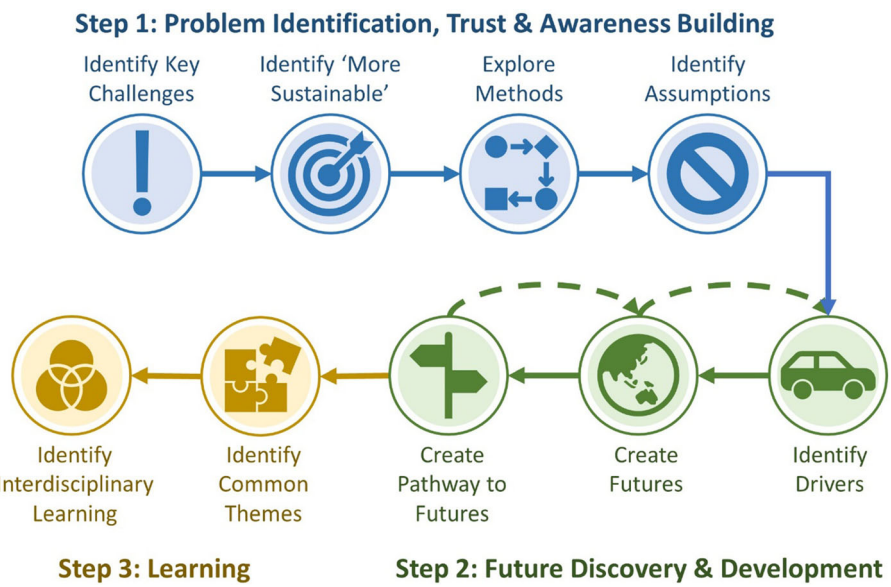

Fig. 1 Three step process of the Future Seas project. Step 1 frames the Key Challenges, identifying what is meant by a 'More Sustainable' future (including the associated value judgements), exploring potential scenario development methods, and identifying common assumptions across the challenges. Step 2 explores the alternate futures and the choices and actions needed to move towards alternate futures. This step is iterative (identified by dashed arrows), with changes and updates made as any gaps and inconsistencies come to light. Step 3 focuses on learning, both by identifying common themes and lessons across the challenges, and synthesising learning around doing interdisciplinary research

split into a predictive 'Business-as-Usual' versus a normative 'More Sustainable' future is somewhat arbitrary. Elements of the 'Business-as-Usual' future implicitly contained judgements by the participants that were normative in nature. Similarly, aspects of the More Sustainable future were based on predictions arising from current trends.

Participants tested a range of scenario development approaches on two example Key Challenges. The subsequent plenary discussion led to participants agreeing on the preferred methods for later use (detailed in *Step 2: Future Discovery & Development*). Finally, at this first workshop, participants identified a series of overarching assumptions that would be consistent across all the Key Challenges and alternate futures ('Business-as-Usual' and 'More Sustainable'). These assumptions were identified to constrain the Future Seas project within a consistent and tractable range of possible future conditions for each of the Challenge teams to explore. Assumptions identified (Table 3) were general in nature and related to: (1) events that were not anticipated within the scope of the Future Seas Key Challenges, (e.g. global-scale conflicts), (2) well-known dynamics for which we assumed current predictions were likely to hold over the next ten years (e.g. climate change), (3) factors that were unlikely to change over the course of the Decade of Ocean Science (e.g. cessation of all fishing). Each team also identified Key Challenge specific assumptions over the course of the scenario development process. These assumptions are detailed in the individual challenge papers.

Prior to the second workshop, the reframed Key Challenges were disseminated to the participants in a second survey (Table 1A, Table S2), and they were asked to choose one (or more) Key Challenge to participate in. Participation was based on individual interest and area of expertise. One of the aims of Future Seas is to enable learning and leadership for ECRs in an interdisciplinary setting, thus each Challenge team was led by and/or included ECRs and was mentored by an experienced researcher as the senior author. Efforts were made to ensure each Challenge team achieved representation across disciplines. Challenge teams had between 11 and 26 participants.

Step 2: future discovery and development

In the second 2-day workshop (February 2019) participants were provided with a refresher on the project's methods. Then each team was given time to discuss their Key Challenge in general terms and identify common and contrasting perspectives across disciplines. For the rest of the second workshop, and in two subsequent 1-day workshops (April and June 2019) each team met to develop scenarios for their

Table 3 Core assumptions used for all the Key Challenges

Cross challenge assumptions
1. The time horizon for the alternate futures is 2030 (the end of the UN Oceans Decade)
2. Population will continue to increase towards 2030 as per UN projections and is expected to be in the order of 8.5 billion by 2030. Global populations will not be equally distributed in space (UN 2015a)
3. The globe is locked into climate change of at least 1.5 °C of warming relative to pre-industrial conditions by 2030 due to existing inertia in the planetary system, and there will be associated consequences of this 1.5 °C warming as articulated in Allen et al. (2019) and IPCC (2019)
4. No new major international agreements will be implemented by 2030. Note this does not include agreements that are already under discussion or in progress
5. No large-scale violent conflicts will playout by 2030
6. There will be some resource use continuing into the future; there will be no radical cessation of activities such as fishing and mining
7. Knowledge production will continue, but there will be no unpredicted giant leaps in new sciences. Note, although participants were aware of the very rapid rate of change in technological advancement (e.g. in the first ten years after the iPhone was launched, 2 billion were sold globally), for the purposes of the Key Challenges, we did not 'invent' any technologies, rather we relied on scaling up of emerging technologies to anticipate possible changes to 2030

These assumptions were negotiated among participants at the first workshop and revisited throughout the process to allow for additions and modifications

Key Challenge and identify potential actions to support achievement of these scenarios.

Scenario development

The first step in the development of the scenarios involved participants from each Key Challenge team brainstorming drivers of change. These drivers were factors that had the potential to impact on the Key Challenge, in the context of the SDGs, over the course of the Decade of Ocean Science (Fig. 2a). To stimulate the brainstorming processes, participants were encouraged to explore drivers in six categories: political, economic, social, technological, legal, and environmental (PESTLE analysis). The list of drivers produced by the participants were examined for significant overlap and duplication (within each Challenge) and grouped to provide a list of higher-level 'umbrella drivers' for use in the later stages of scenario development (Fig. 2b).

Scenario exercises are often employed to explore uncertainties in the future by identifying the broadest range of possible futures. As such, the focus of the scenario development process is on drivers that can be influenced but also have a high degree of uncertainty (Biggs et al. 2007). In contrast, the Future Seas project was focused on exploring differences between a 'Business-as-Usual' versus a 'More Sustainable' future. Thus, the umbrella drivers were mapped onto two axes: 1/degree of impact of the umbrella driver on the challenge and 2/degree of influence that society has on the umbrella driver (Fig. 2c). This mapping process allowed participants to tease out those umbrella drivers that were likely to be central to how each Key Challenge could play out in the future (high impact) and that society had the potential to influence (high influence).

For each of these high impact-high influence umbrella drivers, participants identified trends and/or

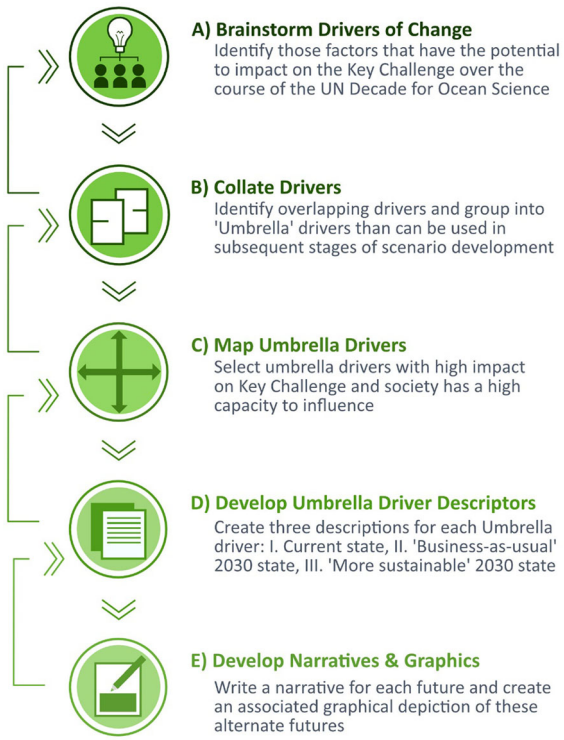

Fig. 2 Process of scenario development used for each Key Challenge to create 'Business-as-usual' and 'More Sustainable' alternate futures for 2030. The process shown in this figure relates to the 'Identify Drivers' and 'Create Futures' components of Fig. 1. The arrows show the iterative nature of the scenario development process

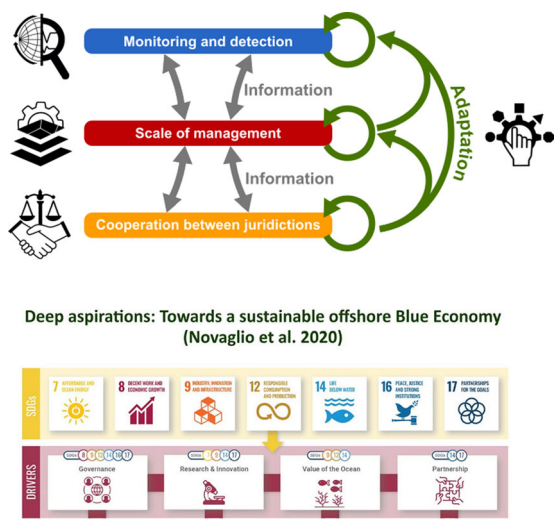

Fig. 3 Umbrella drivers identified by Melbourne-Thomas et al. (2020) and Novaglio et al. (2020) in relation to their Key Challenges. *Poleward bound*: umbrella drivers include monitoring and detection of species range shifts, the temporal and spatial scale of management, the degree of cooperation, coordination and communication between jurisdictions, and social and economic adaptation. *Deep aspirations*: governance of the offshore blue economy, offshore research and innovation, how society values the oceans, and partnership and collaboration between jurisdictions. These umbrella drivers are shown in relation to relevant Sustainable Development Goals. See individual papers for more detail

evidence for plausible future behaviour (following Merrie et al. 2018; references for evidence and trends are identified in the individual Key Challenge papers), and provided descriptors for the status in three contexts: I. Current state of umbrella driver; II. 'Business-as-Usual' 2030 state of umbrella driver; and III. 'More Sustainable' 2030 state of umbrella driver (Fig. 2d). Each Challenge team then identified, based on their collective expertise, the most important set of umbrella drivers (generally 3–5; Fig. 3) and their associated descriptors. This elicitation process led to the construction of a scenario table representing likely umbrella driver behaviour in the three contexts outlined above. At this stage, teams assessed the scenario table for internal consistency to ensure descriptors for the different umbrella drivers were not mutually exclusive. This process of choosing more than two umbrella drivers to incorporate in the development of alternate futures diverged from more commonly employed scenario building methods, which tend to focus on two drivers to produce four or more contrasting futures (e.g. Garard et al. 2018). As the intention of the Future Seas project was to simply identify two futures, the predictive 'Business-as-Usual' versus the normative 'More Sustainable' future, and then explore detailed pathways to achieving these futures, there was scope for more drivers to be incorporated into the narrative. Finally, participants developed a narrative and chose a descriptive name for each scenario (Fig. 2E; Fig. 4). Working with a graphic designer, each Key Challenge team developed a visualisation of their alternate futures (Fig. 4).

The process of developing the scenarios was iterative with participants assessing for internal consistency within their alternate futures at each step. As such, the process was not linear as tacitly implied in the method description above (illustrated by looping arrows in Fig. 2).

Action pathways to alternate futures

Each Key Challenge team used the process of backcasting to identify how society might choose to move towards the 'More Sustainable' future rather than the 'Business-as-Usual' future. Backcasting is a normative approach that involves taking a '*particular desired future end-point … to determine the physical feasibility of that future and what policy measures would be required to reach that point*' (Robinson 1990, p. 823). Our backcasting process extended this approach by also considering a broader range of measures, in addition to management and policy, including for example how to shift societal norms or leverage 'desirable' behaviour change.

First, participants used their expertise and knowledge of existing research and case studies to identify potential actions that could support society in moving towards the 'More Sustainable' future from the current

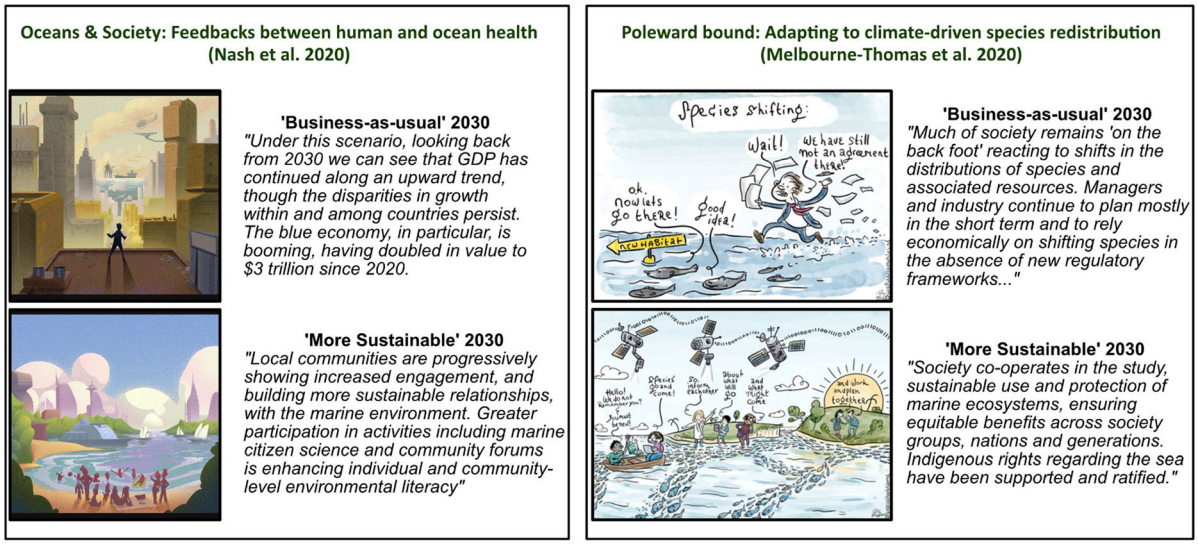

Fig. 4 Excerpts from the narratives developed by Nash et al. (2020) and Melbourne-Thomas et al. (2020), and the associated graphical depictions of these alternate futures. See individual papers for more detail

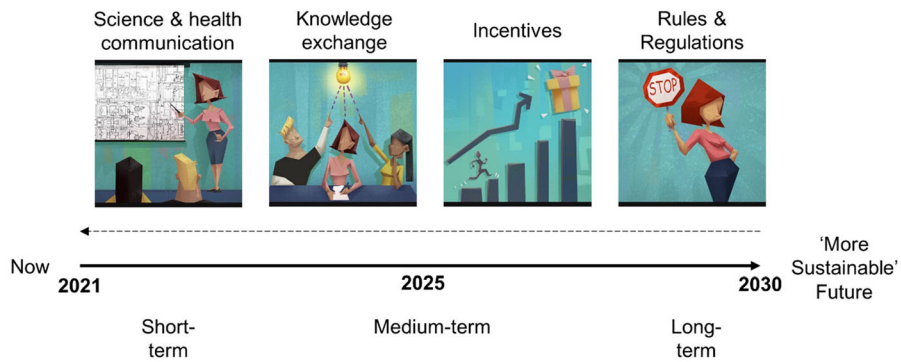

Fig. 5 Backcasting process and timeline. Dotted arrow indicates process of building up actions from 2030 backwards. Icons represent types of action to be implemented over the UN Decade of Ocean Science in relation to creating desirable feedbacks between ocean health and human health (see Nash et al. 2020 for more details)

status of the Key Challenge. Brainstorming of actions was stimulated using a PESTLE framework (just as drivers were identified in the scenario development phase). Next, these actions were put in chronological order by placing them on a timeline of the UN Ocean Decade (2021–2030) (Fig. 5). Participants identified potential benefits and risks associated with the actions, and the data and knowledge necessary to deliver each action. This step helped isolate actions that might result in unintended outcomes or for which there were currently insufficient data and knowledge, or where there might be additional actions necessary to lead to the defined future. Where the identification and timeline of actions showed problems with reaching the 'More Sustainable' future by 2030, iterative revisions were made to the narratives of this future. This iterative process was in line with the intention that the 'More Sustainable' futures should be technically 'feasible', and was necessarily reflective of the participants knowledge and expertise regarding the time taken to accomplish specific actions in the action pathways over the time period from 2021 to 2030. Finally, the timeline of actions was used to create a short- medium- and long-term (in relation to the period of the UN Decade of Ocean Science) plan of action to achieve the 'More Sustainable' future.

Step 3: learning

All the Challenge teams followed the same broad methodological framework. This facilitated discussion and learning across all the Key Challenges, allowing participants to draw out common themes, drivers and actions from the process. However, each team had leeway within this broad framework (as articulated in the individual papers in this issue) to ensure their approach aligned with the needs and context of their specific Key Challenge.

Throughout the course of the year-long process, plenary sessions were used at each workshop to highlight and resolve misunderstandings and potential misconceptions around the scenario development approaches used to create the alternate futures. In a final 5-day workshop (November 2019), all participants met to finalise the futures and action pathways for each Key Challenge, and complete a review of the overall Future Seas process. A series of facilitated plenary discussions synthesised learning across the challenges in two key areas: equity in ocean use and behaviour change (Table 1B). These syntheses explored interdisciplinary lessons learnt during the broader Future Seas initiative and were used to generate an interdisciplinary research agenda to provide a clear foundation for future research activities at local, regional and global scales.

Reflections and discussion

Society faces a number of complex, interacting global challenges, from feeding a population that is predicted to approach 10 billion by 2050, to addressing climate change. These issues are often divisive or lead to feelings of powerlessness due to their apparent intractability (Longo et al. 2019). Simplified, shared, mental models of the future have been proposed as a way to facilitate action in the face of complex global issues (Costanza 2000; Jerneck 2013). Such mental

models provide a 'mobilising narrative' by exploring society's capacity to change our current trajectory to one that better supports a healthy environment, economy and society (Galaz et al. 2016; Jerneck 2013). Currently, there is little guidance available on the process of working with large interdisciplinary groups to form robust teams that provide a safe space to develop shared visions of the future. Here we provide details on this process in the context of the Future Seas project, providing guidance that could be applied in a variety of contexts in marine systems and beyond.

Process: from problem identification to learning

The Future Seas project depended on two types of integration of participants and their ideas: across disciplines and across career stages. The process (Fig. 1) we used to build the Challenge teams, and then develop the alternate futures and pathways to action, was essential to both types of integration.

The progression of discussion, testing and exploration highlighted tensions among the approaches of different disciplines and methodological problems, leading to a series of plenary discussions to solve technical issues and identify common ground among disciplines. The first two workshops (November 2018 and February 2019) were particularly valuable for creating relationships within the interdisciplinary teams addressing each of the Key Challenges, and delivered a number of outcomes (Table 4): First, these workshops provided space to share perspectives, develop trust and build a common language among participants from different disciplines. This trust building process was considered critically important, as although the project was initiated by an interdisciplinary research centre with existing collaborations across many disciplines, the Future Seas project developed new collaborations with philosophers, engineers and medical researchers. The early workshops allowed participants to develop awareness of their own, common and contrasting values and expectations regarding the future: "Thinking about the future is both universal (everyone thinks about the future) and personal (everyone thinks about it in their own way)" (p. 449 Planque et al. 2019). This process of awareness building has been recognised as a critical process in Futures Literacy (Miller 2007). Second, these workshops allowed participants to become familiar with the potential methods for developing alternate futures as most of the participants did not have experience in developing exploratory scenarios of the future. In plenary, participants agreed on the preferred methods for later use. This step was critical to ensure that all team members felt empowered to contribute to scenario development for their Key Challenges, thus supporting a diversity of voices.

Empowering all participants to contribute fully to the processes was central to integrating across career stages. The time spent building trust and sharing perspectives in the early workshops opened up space for the ECRs and students to be an active part of the process (Andrews et al. 2020; Gagnon et al. 2017). Furthermore, the project aim to develop interdisciplinary leadership skills among ECR participants, necessarily required the time and space for ECRs to develop their network and build interdisciplinary confidence (Andrews et al. 2020; Kelly et al. 2019), prior to developing the scenarios.

Integrating across disciplines and career stages relied on regular communication, idea generating surveys and workshops to ensure that all participants were comprehensively briefed on approach and progress. These interactions and open channels of communication supported the interdisciplinary and across career-stage dialogue (Dai and Boos 2019), which underpinned the predictive and normative scenario development (Börjeson et al. 2006).

Mobilising narratives: supporting sustainable development

Scenario development

Scenarios are becoming an increasingly well-established tool, providing a powerful communication strategy, with the potential to galvanise communities to realise previously unimagined futures (Table 5; Pereira et al. 2019). For example, creative scenario development is increasingly being used in the field of social-ecological systems, particularly for participatory planning (Oteros-Rozas et al. 2015). The development of narrative scenarios gives participants a tractable way to cope with the complexity and uncertainty of the real-world in a way that may be limited in quantitative modelling. (Kok et al. 2017). The process allows participants to think explicitly about their perspectives and biases related to a

Table 4 Challenges associated with developing large interdisciplinary projects and potential solutions to address these challenges, arising from lessons learnt during Future Seas

Challenge	Solution	Outcome
Team building and awareness		
Tensions among disciplines and stakeholders—differences in: → Perspective → Language → Approach	Provide time for trust building through facilitated and free discussion Facilitate regular group discussions around challenges and learning	Gave opportunity to find common ground Helped to develop awareness of other's perspectives and approaches Made participants' assumptions explicit
Supporting diversity of voices		
Domination of conversation by a few voices	Social activities and discussion to give space for all to engage Workshopping methods to ensure all on same page and level of knowledge	Opened up space for ECRs and PhD students to be active part of collaborations Ensured that marine scientists did not dominate conversation but had time and space to listen to and learn from other disciplines
Addressing discomfort with a new approach		
Concern among participants around the legitimacy of using narrative methods	Provide time to develop familiarity with and workshop methods Regularly explore potential misconceptions around the methods (Table 6)	Provided participants with a greater degree of comfort around the methods Helped participants understand where the approach chosen sits within the broader suite of scenario methods (both qualitative and quantitative)
Developing leadership skills		
ECR team leaders faced with negotiating and integrating conflicting perspectives of senior participants	Provide open communication and mentoring to support ECRs in their leadership role Detail a clear set of expectations of all participants Introduce a 'culture of learning' to participants from the start of the process	Created a safe space for exchange of ideas and for ECR leaders to coordinate with their team and lead team contributions

problem (Blythe et al. 2017), while supporting integration of these different perspectives and approaches to develop novel and creative futures (Costanza 2000). Participants are able to let go of the idea that imagined futures are 'untrue', but instead understand the strength of this approach for bringing different viewpoints and values to a problem (Jensen 2015). In doing so, creating such scenarios supports the type of transformative learning that will fuel the reform and transformations necessary for building a sustainable future and help remove imagined constraints imposed by focusing on the status quo (Pereira et al. 2019).

Development of narrative scenarios is not without challenges. Future Seas participants experienced a degree of discomfort over the legitimacy of outputs that deviated from more traditional research outputs; such concerns remain common within the scientific community (Dahlstrom 2014). It was challenging to integrate the different perspectives of participants and let go of disciplinary-specific 'safe' and familiar methods, to create a shared vision of the future. The year-long timescale of the Future Seas project and the time explicitly assigned to problem identification, trust and awareness building helped harmonise participants' contrasting research, learning and collaborative agendas. This time period also supported resolution of inter-disciplinary concerns by providing the space to build trust among participants and develop familiarity with the process. While the transaction costs associated with developing this shared understanding in interdisciplinary work are well-recognised (Alexander

Table 5 Challenges associated with addressing complex sustainability issues and the usefulness of the component methods used in Future Seas to address these challenges

Challenge	Method	Outcome
Dealing with complexity		
Considerable complexity and uncertainty around how the future will play out makes predicting the future challenging	Process of creating narrative futures	Allowed participants to let go of 'imagination' constraints inherent to other approaches Allowed transformative learning!
	Process of creating graphical representations of the future	Presented inconsistencies in thinking
Understanding other people's perspectives		
Conflict and lack of understanding of the perspectives of other people around the future	Process of creating shared narratives	Permitted the discussion of each other's disciplinary-based perspectives in a non-confrontational way—may be a useful exercise even when narrative futures are not the ultimate outcome of a project
Addressing feelings of powerlessness		
Inertia/feeling of powerlessness around addressing challenges and creating a sustainable future	Development of action pathways	Provided tangible way to reach imagined future Highlighted positive case studies
Highlighting policy reform needs		
Do not have the requisite research knowledge, policy frameworks or on-the-ground action necessary to create a sustainable future	Development of action pathways	Highlighted mismatches between current global policy and research effort

et al. 2018), we cannot overstate the importance of this time investment (Paasche and Österblom 2019).

Many projects exploring the future of social-ecological systems, develop four alternate scenarios to explore multiple possibilities for the future (e.g. Garard et al. 2018). The most unpredictable drivers of change are selected for use in the development of the alternate futures, to help account for the considerable uncertainty associated with developing visions of the future over a number of decades (World Economic Forum 2017). In contrast, in this special issue the Challenge teams focused on two futures: our current pathway based on published trends and evidence, and a more sustainable future that is technically achievable using current and emerging knowledge. We used a relatively short time horizon (2030) compared to many other studies, and we focused on current knowledge in that we did not account for new knowledge arising over the course of the UN Decade of Ocean Science that could dramatically change the trajectory between 2021 and 2030 (Garard et al. 2018). Challenge teams focused on those umbrella drivers that had a high potential impact on the future but that we also had considerable potential to influence. The decision to focus on two futures was an intentional feature of the project. It allowed us to leverage the vast global effort already employed in defining the SDGs by providing an internationally agreed direction for our detailed action pathways. However, there are limitations associated with focusing on two futures. In particular, this approach prevented the exploration of multiple contrasting 'More Sustainable' futures, and did not deal with the full range of uncertainties inherent to forecasting future events (Biggs et al. 2007; Miller 2007). The impact of this can be seen in relation to COVID-19—the presence of a global pandemic was not included as one of the cross-challenge assumptions but considerable uncertainty around the likelihood of such a pandemic meant that it was not explicitly considered in the initial development of the futures for any of the Key Challenges.

All the Challenge teams used graphic visualisation of their alternate futures to facilitate communication of what is technically feasible in terms of a (normative) 'better' future. These artistic impressions were aimed at engaging a wider audience with the potential for a

more sustainable future (McAfee et al. 2019). It is this type of art-science collaboration that can help address the 'imagination gap' common to quantitative scenarios (Milkoreit 2016), and help the audience grapple with challenging concepts and real-world complexity more effectively than reading of a scientific text may permit (Pereira et al. 2019). Unexpectedly, the process of discussing the narratives with the graphic designer also assisted the Key Challenge teams to develop a deeper awareness of the proposed futures and uncover inconsistencies in the narratives (Cooke et al. 2017). These visualisations are available in the individual papers in this special issue and online at www.FutureSeas2030.org.

The framing of the Future Seas project and presentation of Business-as-usual and More Sustainable futures—together—allow communication of both trajectories whilst also highlighting the potential to *achieve* sustainable versions of the future. Nonetheless, while narrative scenarios have significant benefits for developing a shared vision of the future, they are not 'sufficient'. Rather, they will complement data collection, for example targeted by the UN Decade of Ocean Science, and other approaches such as quantitative modelling. Furthermore, the mobilisation of transformative action requires an understanding of the potential to realise these futures through the development of action pathways.

Action pathways to alternate futures

Although the ultimate aim of the action pathways was to identify ways to achieve the More Sustainable futures in relation to each Key Challenge, the process of developing these pathways serves two further functions. First, identification of case studies of successful actions that are already in train, and which could be scaled up to have larger-scale impact, may be particularly important to address feelings of powerlessness that arise due to the magnitude of the challenges we face. Second, the development of normative 'More Sustainable' future scenarios, followed by backcasting made it possible to evaluate the feasibility of the imagined future against current knowledge of the global political, environmental, legal, social and economic context, and best practice in the behavioural sciences (de Salas et al. unpublished). Challenge teams were able to identify mismatches between current global policy and research effort, e.g. policy goals on biodiversity (SDG targets) and research on drivers of biodiversity loss are misaligned (Mazor et al. 2018). Such mismatches are discussed in the Key Challenge papers in this issue.

Potential misconceptions

Over the course of the plenary discussion at the workshops, a series of potential misconceptions associated with the alternate futures and action pathways came to light (Table 6). First, we want to clarify that the purpose of the narratives is to provide a vision of potential futures, rather than to predict the future. Leading on from this, we note that we are not presenting a universally 'shared' vision of the future. The futures detailed in this special issue are not intended to reflect all possible plausible futures. Furthermore, we acknowledge that there are a wide range of 'invisible' voices that have not been incorporated into our scenarios (Kaijser and Kronsell 2014; Pereira et al. 2019). One way we tried to address this significant concern is through the inclusion of Indigenous and Traditional knowledge holders in the Future Seas project (e.g. Fischer et al. 2020). Nevertheless, there is still much to do to in relation to increasing the diversity of participation to ensure futures research and the development of 'mobilizing narratives' reflects the values of those who are marginalised or often excluded from decision-making processes (Blythe et al. 2018). In light of this constraint, our goal was to highlight potential opportunities (and risks) associated with moving towards a more sustainable future, rather than providing an exhaustive exploration of options from all perspectives.

Next, we recognise that the drivers of change are not coherent across all the Key Challenges. We defined the drivers as those factors that may impact on the Key Challenge over the course of UN Decade of Ocean Science. Due to the contrasting foci of the different Challenge teams, something classified as a driver by one team may have been classified as an action in the action pathway of another Challenge team. We view this as an outcome of the diversity of possible approaches to addressing the challenges faced by the world's oceans, rather than as a weakness of our methodology. Finally, we wish to highlight that we are not advancing the use of narrative scenarios at the exclusion of other, quantitative approaches. Rather, we posit that these techniques are complementary and

Table 6 Potential misconceptions and clarifications regarding the methodology used in this special issue

Potential misconception	Clarification
The intention of this issue is to predict the future in relation to a series of Key Challenges facing the oceans	The development of narrative scenarios is not about predicting the future, rather it is a transparent method for helping to bring together different perspectives of the world and imagine potential futures
The 'Sustainable' future presents a value-free exploration of the future that aligns with the intent of the Sustainable Development Goals	Although the sustainable futures described in the Key Challenge papers are aligned with the intent of the Sustainable Development Goals, judgements made by participants over the course of developing the scenarios necessarily reflect their values and background and as such represent one set of plausible 'More Sustainable' futures
The action pathways presented in this special issue offer a definitive set of actions regarding society's potential to change the direction of the Key Challenges over the next decade	The action pathways presented in this special issue necessarily reflect the views and expertise of the participants, and as such provide only one set of views of how we might move towards a more sustainable future. Our goal is to highlight potential opportunities and risks associated with moving towards such a future, rather than providing an exhaustive exploration of options
Drivers of change are defined as those factors that may impact on a Key Challenge over the decade to 2030. As such, these drivers will be coherent across all the Key Challenges	Drivers of change are defined as those factors that may impact on a Key Challenge over the decade to 2030. As such, a factor classified as a driver in one challenge may have been classified as an action necessary to achieve a particular alternate future in another Key Challenge
Narrative scenarios should be used instead of more traditional quantitative modelling to explore social-ecological systems	Narrative scenarios complement quantitative modelling approaches. For example, the alternate futures developed can be used as a springboard for the development of numerical models focused on specific details or to explore tipping points in social-ecological systems. Similarly, narratives such as those developed in this special issue can be used to highlight gaps in quantitative models (Planque et al. 2019), or uncover assumptions in quantitative approaches that may be naive in relation to socio-economic and technological factors (Kloprogge et al. 2011)

should be used in concert to address the grand challenges of sustainable development.

Conclusions

The complex and uncertain nature of many key challenges facing the oceans and our society can lead to inertia and paralysis among private and public actors alike. It is our hope that presenting sustainable but realistic versions of the future, and highlighting that collectively we have the combination of knowledge, resources, and technology to respond constructively, may lead to greater action across all levels from individuals to governments. Society needs a vision of what the future could look like, beyond the 'doom and gloom' story that we must avert the 'inevitable' catastrophe. The earth is already undergoing significant transformations in the Anthropocene. Now we need to develop and disseminate tangible depictions of where we are headed but also where we *could* head if we actively chose to steer the transformation to a more sustainable future.

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