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**Author for correspondence:**
Kristy de Salas
e-mail: kristy.desalas@utas.edu.au



# The super wicked problem of ocean health: a socio-ecological and behavioural perspective

Kristy de Salas[1], Jennifer Louise Scott[1], Benjamin Schüz[2] and Kimberley Norris[1]

[1]University of Tasmania, Hobart, Tasmania 7001, Australia
[2]University of Bremen, Bremen, Bremen, Germany

KdS, 0000-0002-2552-5108; JLS, 0000-0002-6955-4015; BS, 0000-0002-0801-498X

We are dependent on our oceans for economic, health and social benefits; however, demands on our oceans are escalating, and the state of the oceans is deteriorating. Only 2% of countries are on track to achieve the desired outcomes for the sustainable development goal (SDG 14) for the oceans by 2030, and the changes needed to prevent further degradation, or limit the impact of existing degradation, are not being undertaken fast enough. This paper uses a socio-ecological lens to explore the nature of actors and behaviours for change at the local, community, state, national and international levels, and introduces the need for technology, information- and knowledge-sharing, and policy as interconnected mediators, that work both in concert, and independently, to address the 'super wicked' problem of ocean health and to promote resilience. We recommend the need to develop transformational teams and leaders, as well as transformative policies within a holistic and integrated system to ensure ocean health initiatives are greater than the sum of their parts and are actual, realistic, achievable and evidence-informed pathways to change.

This article is part of the theme issue 'Nurturing resilient marine ecosystems'.

## 1. Introduction and research context

### (a) Demands on our oceans

Human society is, and always has been, dependent on the oceans, and human well-being over the coming decades will continue to depend critically and directly on the health of the world's oceans [1,2]. The oceans provide a wide range of ecosystem services such as regulation of our climate and oxygen production, as well as provision of resources to underpin millions of jobs, and important industries like mining, fishing, tourism and shipping [3]. Moreover, oceans and coasts are vital to the livelihoods and culture of many traditional and Indigenous Peoples [4], particularly the almost 30 million coastal Indigenous Peoples of the world [5]. Further, the contribution of oceans to social-emotional health and quality of life for all societies is increasingly evident [6].

As the population of the planet increases to an estimated 8.5 billion by 2030 [7], demands on the ocean are also expected to escalate with wide-scale 'enthusiasm' for the projected growth of the blue economy [3], which is already equivalent to the seventh-largest economy on the planet, doubling in size per decade [8,9]. These growing demands on our oceans are occurring simultaneously with a suite of anthropogenic drivers that continue to negatively influence the state of the oceans, like climate change, pollution and habitat loss. Ocean health is deteriorating with only 2% of countries on track to achieve the desired outcomes for the sustainable development goal for the oceans, (SDG) 14, by 2030 [10]. Moreover, recent reports from the Intergovernmental



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Panel on Climate Change estimate that climate-induced declines in ocean health will cost the global economy US $428 billion *per year* by 2050 [11].

## (b) The need to restore our oceans

The United Nations (UN) proclaimed a Decade of Ocean Science for sustainable development (Ocean Decade; 2021–2030) that aims to restore ocean health, and in doing so prioritizes six societal goals: an ocean that is (i) safe, (ii) transparent and accessible, (iii) sustainable and productive, (iv) predicted, (v) healthy and resilient, and (vi) clean. The Ocean Decade also encourages us to think beyond 'business-as-usual' to urgently deliver to stakeholders and policymakers the science needed to effect ocean change to facilitate the identified goals. In a comprehensive 'roadmap' for using the UN Decade of Ocean Science to support the achievement of SDG 14, key technical, organizational and conceptual scientific barriers were identified that have prevented policy action [12]. Co-production of knowledge, incorporation of multiple knowledge systems, and strong political will were all recognized as essential for achieving any significant progress towards achieving the SDGs [12].

### (i) Knowledge to restore our oceans

The 'Science we need for the future we want' frames the Decade of Ocean Science. Translating existing knowledge to restore our oceans requires us to understand and solve a broad range of issues and (often confounding) processes, which has been described as a 'Sisyphean' challenge [13]; an archetypal 'wicked' problem. 'Wicked problems' are complex, multi-factorial and interconnected sets of social and environmental issues confronting society with inherent disconnection and conflict across and among stakeholder groups, that in turn escalate and drive solutions further from reach [14,15]. They persist because their solutions require complex transdisciplinary knowledge and skills, collectivist collaborations across disciplines, and transformative system-level approaches [15] that effectively integrate solutions across actors and groups. Ocean health has been referred to as a 'super wicked' problem [13,16], as it is intertwined, embedded and confounded by, and within, the super wicked problem of climate change and global warming, and requires collaboration on a global scale to address.

Notwithstanding this complexity, there have been increases in knowledge about our oceans. However, a science-policy gap not only remains but appears to be growing [17]. The availability of knowledge and required action does not directly translate into implementation. Reasons for this are complex but may include: limited communication between scientists, policymakers and citizens [18]; misalignment of values and outcome goals [19–21]; the speed with which scientific knowledge is integrated into the policy [22]; and reliance on top-down (i.e. imposed from those in power) as opposed to truly multi-sectoral, multi-cultural, integrative and participatory frameworks [19,23,24].

### (ii) A multi-dimensional approach to restoring our oceans

The complexity of the task to restore and sustain ocean health requires a multi-dimensional approach, that simultaneously addresses individual, organizational, cultural, societal and structural components, and which needs to be flexibly applied to realize tailored approaches and achieve necessary change.

Our focus in this paper is to drill down more deeply into the proposed high-level actions and desired outcomes to explore what types of change are required to achieve SDGs, and who are the actors required to perform these actions. In this paper, we take a systems-based perspective [25], useful for understanding the behavioural, social, economic, environmental, technological and regulatory changes at the level of the individual, and local and global communities that are needed to achieve ocean SDGs.

We draw on the example of the Future Seas (https://futureseas2030.org/) collaboration, an international multi-partner transdisciplinary programme that aims to address this complexity in the context of what is possible for sustainable futures. It is an example of the type of programme that is increasingly desired and supported by research funders and government bodies, but, as with other such collaborations, there is a need to understand 'what works' in practice. The challenges in translating the Future Seas findings into tangible actions are provided as an example that would also apply to other similar transdisciplinary endeavours.

Future Seas resulted in a special issue of Reviews in Fish Biology and Fisheries, with 12 journal articles each addressing a key challenge for the UN Ocean Sciences Decade, and two summary papers exploring the lessons learnt across the key challenges. Spearheaded by the Centre for Marine Socioecology, it represents a collaboration of over 100 researchers from the University of Tasmania (UTAS), the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and other institutions, with collaborators including psychologists, public health and education experts, philosophers, ecologists, oceanographers, climate modellers, economists, social and psychological scientists, engineers, information and communications technology researchers, and social scientists, as well as governance, law and policy experts, and Indigenous knowledge holders.

The papers in the Future Seas special issue each explored potential scenarios of sustainable futures that are theoretically achievable for a range of key challenges for a healthy ocean (and in line with achieving the SDGs) including issues relating to indigenous rights and access [4], climate change [26], biodiversity conservation [27] and species redistribution [28], food security [29], ocean literacy [30], pollution [31], feedbacks between human and ocean health [32], resource use [33,34], international relations [35] and ocean governance [36]. For each challenge, 'drivers'—factors that had the potential to impact on the challenge in question, in the context of the SDGs, over the Decade of Ocean Science—were identified that could be influenced to achieve desirable outcomes [32]. Examples of implementable actions were associated with each driver to provide a tractable way forward.

A summary of the Future Seas papers and the recommended actions therein is provided in Alexander *et al.* [37], table 1.

These 12 papers represent a significant contribution towards a macro-level understanding of the drivers and actions required to bring about the SDGs for resilient ecosystems. Collectively the papers recognize that major transformations are needed to create a sustainable future for the 'ocean we need for the future we want'. Moreover, they explicitly recognize that this requires scientists and decision-makers to identify *how* to bring about change towards sustainable goals across individual, local and global scales, and not to 'just' identify *what* needs to be done. In this paper, we aim at providing an

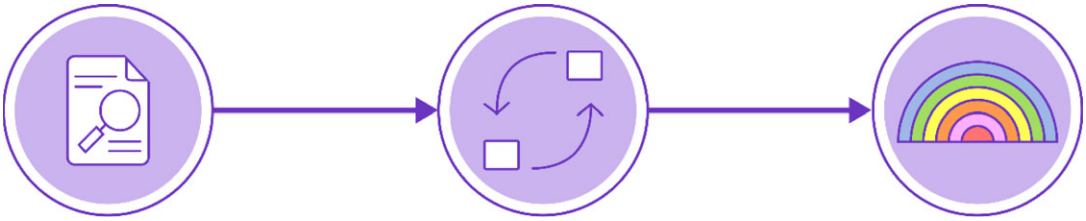
**Table 1.** Drivers and sample actions summary from the 12 Future Seas papers [37]. (Overview of data sample of papers analysed to assess outcome-based/distributive, process-oriented/procedural and concept/contextual dimensions of equity in the pathways required to move towards achieving sustainable futures for the ocean by 2030. Short titles (as referred to in-text) are in italics.)

| icon & reference | title | problem | drivers | sample actions |
|---|---|---|---|---|
| Trebilco *et al.* [26] | *Warming world, changing ocean*: mitigation and adaptation to support resilient marine systems | how to achieve a healthy, resilient, safe, sustainably harvested and biodiverse ocean | extreme events; human intervention to reduce climate change; appetite for climate action | creation and enhancement of economic incentives for climate mitigation and action; deploying marine-based renewable energy; deploying marine-based negative emissions technologies |
| Ward *et al.* [27] | *Safeguarding marine life*: conservation of biodiversity and ecosystems | how to safeguard marine ecosystem biodiversity, function and adaptive capacity while continuing to provide vital resources for the global population | financial mechanisms, sectoral stewardship, management and governance, societal impetus | upscale predictive capacity, expand and fund monitoring programmes, increase and enhance indigenous management and partnerships, streamline knowledge exchange |
| Farmery *et al.* [29] | *Food for all*: designing sustainable and secure future seafood systems | how can the ocean contribute to sustainably feeding the world's population | ecosystem change; ocean governance; influence of corporations; output and efficiency of seafood systems; consumer demand; focus on nutrition | diversification of production and consumption; co-management of marine resources; supply chain transparency; sustainable feed inputs; awareness-raising on nutritional value of seafood |
| Kelly *et al.* [38] | *Connecting to the oceans*: supporting ocean literacy and public engagement | how to improve societal connections to the ocean | education; cultural connections; technological developments; knowledge exchange and science-policy interconnections | ocean literacy targeted across society; develop programmes that are inclusive of local contexts and culture; maximize utility of technology; inclusive approaches |
| Willis *et al.* [39] | *Cleaner seas*: reducing marine pollution | how to reduce marine pollution | societal behaviours, equity and access to technologies; governance and policy | outreach and education campaigns; use of gross pollutant traps; recycling of fishing gear |
| Nash *et al.* [32] | *Oceans and Society*: feedbacks between ocean and human health | how to promote desirable and minimize undesirable interactions between ocean and human health | worldview, decision-making context, approach to behaviour change; power and agency; human development and industry; food system; lifestyle and connectedness to oceans | science and health communication upscaled and improved; knowledge exchange; changed incentives and rules and regulations to change behaviour; |
| Bax *et al.* [33] | *Ocean resource use*: building the coastal blue economy | how to manage sustainable development in future exploitation of both over-used and emergent coastal resources | conflict resolution | recognizing the problem and committing to action; co-management by multiple reliant groups; implement networks to maintain and enhance biodiversity |

(*Continued*.)

**Table 1.** (*Continued.*)

| icon & reference | title | problem | drivers | sample actions |
|---|---|---|---|---|
| Novaglio *et al*. [34] | *Deep aspirations*: towards a sustainable offshore blue economy | how to develop a sustainable offshore blue economy | governance, research and innovation; values of the ocean; partnership | a shift of societal values; sustainable and equitable financing; information sharing; improved legal and institutional mechanisms |
| Melbourne-Thomas *et al*. [28] | *Poleward bound*: adapting to dimate-driven species redistribution | how to manage and adapt to species redistributions and minimize negative impacts on ecosystems and human communities | monitoring and detection; managing at multiple scales; cooperation between jurisdictions; human adaptation | event-driven sampling; implementation of dynamic ocean management; improved communication and coordination between nations; knowledge co-production |
| Haas *et al*. [36] | the future of *ocean governance* | how to move towards more sustainable ocean governance aligning with SDGs | formal rules and institutions; evidence and knowledge-based decision-making; legitimacy; stakeholder engagement and participation; empowering communities | place-based management and planning; innovative marine business models; fair decision-making process; benefit sharing arrangements; capacity building; long-term cooperation |
| Smith *et al*. [35] | *Sharing our oceans fairly*: improving international relations around ocean issues | how to ensure international relations around oceans issues are fair | governance; value of oceans; politics; transparency; engagement; goals | high-level political commitments; changes to governance structure; participatory justice; clear transparent communication |
| Fischer *et al*. [4] | *Empowering her guardians* to nurture our oceans future | how to envisage a fair ocean future for indigenous and traditional peoples around the world | colonization and globalization | indigenous and traditional peoples to be handed power to make decisions over coastal and ocean spaces; scientists and practitioners to challenge processes, structures and strategies that do not include indigenous and traditional peoples voice |



step 1

content analysis of each Future Seas paper focusing on:

(i) each's specific challenge or problems to be addressed

(ii) the drivers for change to occur, and

(iii) example actions to bring about change

step 2

thematic analysis across all Future Seas papers to identify common themes and actions that were needed to effect the required changes as mentioned across the papers:

(*a*) additional research

(*b*) funding conditions

(*c*) international policy and law

(*d*) governance and management

(*e*) financial drivers

(*f*) indigenous partnerships

(*g*) knowledge and data sharing

(*h*) citizen science

(*i*) people and eduction

(*j*) technologies

step 3

mapping of Future Seas themes and example actions onto existing levels of the rainbow model

**Figure 1.** An overview of the three key steps underpinning the approach used to develop a socio-ecological perspective of behavioural change mapped onto a rainbow model of ocean health. (Online version in colour.)

overview of methods and approaches to facilitate such change on multiple levels.

## 2. Understanding the change needed to build 'the ocean we need for the future we want'

### (a) Research approach

We combined thematic analysis and literature review methods. Figure 2 outlines our approach to an analysis of the proposed drivers of change identified in each of the Future Seas papers.

We first applied a content analysis to each of the Future Seas papers, specifically recording each paper's specific challenge or the problems that were addressed. We identified the drivers that influenced the outcome for each paper and extracted example actions that were thought to bring about change (step 1, figure 1).

We then undertook a thematic analysis across all Future Seas papers to identify commonalities in the recommended change across people and society and categorized those into eight *domains* (step 2, figure 1).

While identifying 'what' needs to change, these domains do not provide information on the actors that are required to implement these changes, or whether and how these domains might be interrelated or hierarchically dependent. In step 3, we thus further reviewed the Future Seas papers to determine the actors needed to make the change happen for each domain. To do this, we adapted an existing socio-ecological approach (rainbow model of the determinants of health; [40]) that identifies multiple hierarchical layers and domains of social and environmental influences on health from the individual level up to a macro-level of societal and global influences.

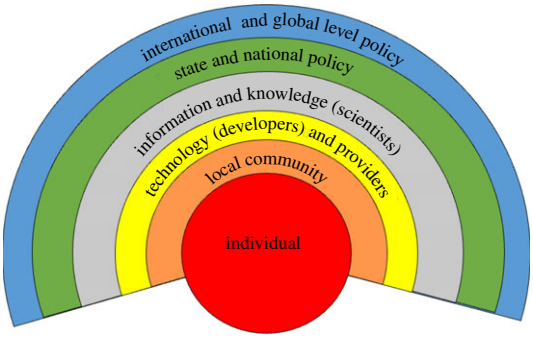



**Figure 2.** Rainbow model of ocean health with levels of actors from the inner core (individual) outwards representing great numbers of people, groups or societies. (Online version in colour.)

The rainbow model of the determinants of health [41] is a socio-ecological model, in which different areas of determinants of health and potential policy interventions are organized on five hierarchical levels, in ascending order: (i) age, sex and constitutional factors, (ii) individual lifestyle factors, (iii) social and community networks, (iv) living and working conditions, and (v) general socioeconomic, cultural and global environmental conditions. The higher the level, the larger the entity and group of individuals it encompasses. Further, the model allows for interactions between and within factors on the different levels. This hierarchical multi-level structure applies to a multitude of complex 'wicked' problems. Applying such a structure can thus help in identifying hierarchically layered determinants and domains relevant for ocean health [25].

Further in step 3, we then mapped the actors for change derived from our thematic analysis of the Future Seas papers on levels within a hierarchical structure.

**Table 2.** Thematic findings of the domains of change recommended in the Future Seas project papers.

| |
|---|
| change to research practice and support |
| support adaptation |
| develop technologies |
| support research collaborations and shared investment |
| change to International policies and laws |
| international laws, policies, frameworks and guidelines for ecosystem management |
| need political will and commitment |
| international, national and state-wide collaborations |
| change to governance and management |
| adaptive management plans and tools |
| sustainable pathways |
| supply chain transparency |
| co-management and empowerment of all stakeholders |
| measurable and achievable targets |
| fair and equitable distribution of resource use and benefits |
| change to financial drivers for sustainability |
| incentives to encourage sustainable practices and a circular economy |
| bans, taxes and fines to unsustainable behaviours |
| change to indigenous partnership practices |
| must include indigenous knowledge and work with knowledge-based institutions |
| change to data and knowledge-sharing |
| make access to data easy |
| make information transparent. |
| combine data sources to build knowledge |
| access real-time data for predictive knowledge |
| encourage knowledge and benefit sharing |
| change to education practices and people |
| need to encourage citizen science |
| develop ocean literacy goals, and links between ocean health and human health |
| educate about pollutions and contaminants, and how to collect and clean |
| teach that actions have consequences. |
| develop greater environmental consciousness |
| change supported by technologies |
| need to better use technologies for: information and data provision to support monitoring, detection, and predictions; educating stakeholders and building environmental consciousness; sustainable production across supply chains |

## 3. Domains of change for ocean health and levels of influence

In the second step in our research (figure 1), we identified eight domains of change across people and society for ocean health and sustainability. We detailed our findings in table 2.

There are a different number of changes identified for each of the themes.

Using the model developed by Dahlgren & Whitehead [41], we identified six levels of influence on which Future Seas objectives can be located. Our adapted rainbow model of ocean health contains the following six levels: (i) individual, (ii) local community, (iii) technology (developers and providers), (iv) science (information and knowledge), (v) state and national policy, and (vi) international and global level policy (figure 2).

To achieve change within the identified domains (table 2) on these six levels (figure 2), both objectives of change and targets of change need to be identified [42]. The intended outcomes need to be linked to the actions required to achieve such a change, and most importantly, actors responsible for implementing such change need to be identified. This may seem an oversimplification of change and interactions within and across complex systems. However, to be able to identify what exactly needs to change within complex systems, it is necessary to specify the links between change in systems and in the behaviours of those individuals who create, maintain and interact with others in these complex systems. This further allows narrowing in on the likely targets of change-oriented interventions (i.e. who needs to do what to achieve change; [43]).

The Future Seas papers discuss the challenges for achieving SDGs and outline change objectives to achieve the goal of improved ocean health. We therefore now discuss how a change in these domains and across these levels can best be achieved. In our final section, we present our rainbow model of ocean health (figure 3), explicitly illustrating the changes required, the actors responsible for leading the change and the interconnections between the levels of actors.

### (a) Level 1: individual level

At the core of the rainbow model of the ocean, health is the *individual*, encompassing peoples' socio-demographic characteristics (i.e. knowledge/awareness, attitudes and behaviours) [40]. There is considerable evidence, primarily from the field of public health, for the effectiveness of behavioural interventions for changing a range of individual behaviours [44–46].

In table 2, in particular, 'change to education and people' relates to individual behaviours—both to individual consumers and individuals directly interacting professionally with ocean environments such as fishers (seafood) farmers, or ocean-adjacent dwellers. There is a range of desirable behaviours on the individual level, from choosing to buy sustainable options to upgrading individual wastewater systems. The papers in Future Seas (among others) specify these behaviours, and to develop effective interventions, the desirable behaviours need to be related to the specific actors that need to portray this behaviour. Questions need to be answered such as: what behaviour do they need to do? where do they need to undertake this behaviour? and when should the behaviour be undertaken? The 'designs' for behaviour change need to be both rigorous and comprehensive.

Across the social and behavioural sciences, there are more than 80 theories outlining determinants of behaviour change [47]. A unified approach drawing across major theories such as the behaviour change techniques (BCTs) taxonomy and the related behaviour change wheel (BCW) [48] can help identify

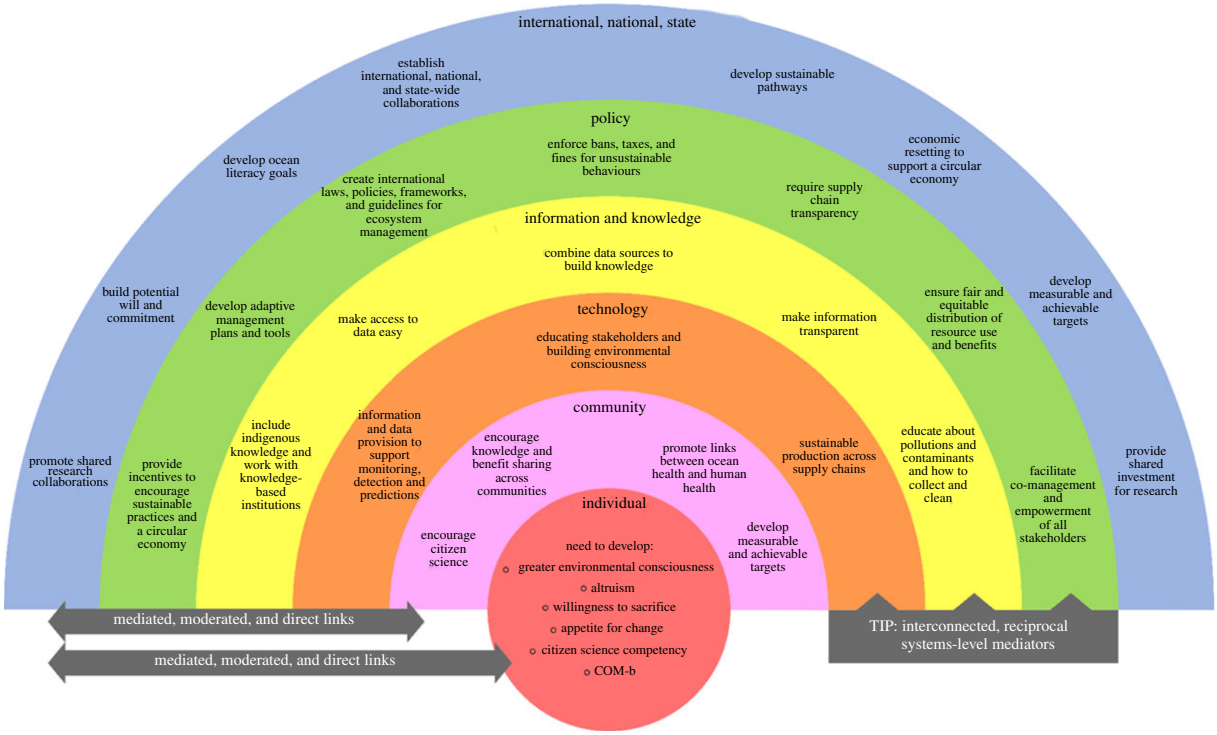



**Figure 3.** Rainbow model of ocean health—a framework identifying six socio-ecological levels and systems of influence for addressing ocean health and resilience (our adaption using thematic analysis of the Future Seas initiative, based on Dahlgren & Whitehead [40]). (Online version in colour.)

**Table 3.** The core determinants of behaviour change (adapted from the BCW COM-b model [48]).

**capability**

an individual's capacity to engage in the activity concerned can be psychological (comprehension, reasoning, etc.) or physical (strength, skills, etc.)

**opportunity**

all factors that lie outside the individual that prompt the behaviour or make it possible, can be physical or social (i.e. facilities or cultural and social acceptance)

**motivation**

all central nervous system processes that energize and direct behaviour, which can be conscious (e.g. goals, plans or conscious decision-making), or automatic (involving emotions, impulses, etc.)

common themes and avoid overlap. The BCW can guide intervention design and it has been used extensively in the health sciences [49]. The BCW can also help 'diagnose' the reasons an intervention may not have been successful in changing behaviour [48,50,51]. Central to the use of the BCW is a comprehensive analysis and understanding of the target population and the target-group specific determinants of behaviours. Within the BCW, the COM-b model (capability, opportunity, and motivation—table 3), which again builds on and contains processes implied in other theories is proposed to identify the core determinants of behaviour change [48,50].

According to the COM-b model, individuals are more likely to change their behaviours if they have the necessary skills and perceive they can do so, if their environment (physical as well as social) provides an opportunity to do so, and if they are motivated to achieve a particular endpoint through this behaviour, either through conscious decision-making or automatic processes, such as momentary cues.

Importantly, the core processes implied in the COM-b model can be linked to BCTs, such as promoting goal-setting, self-monitoring or providing feedback. To facilitate behaviour change based on an assessment using the COM-b model, these BCTs can then be delivered using different avenues for intervention: *education*, *persuasion*, *incentivization*, *coercion*, *training*, *restriction*, *environmental restructuring*, *modelling* and *enablement*.

In summary, we recommend that interventions and/or policy approach(es) for sustainable oceans, such as those recommended by the Future Seas papers should be mapped on to behavioural determinants, which then identifies the presence of strengths or deficiencies in the individual capabilities, opportunity and motivation or conditions identified of those implied in the targets—either individuals as targets of

**Table 4.** Core behaviour change targets in communities (CCC).

|  |  |  |
|---|---|---|
| **community connectedness** | **community capacity** | **communication and information** |
| the degree of community connected connectedness demonstrates a commitment to shared values. Higher levels of community belonging and connectedness are more likely to result in changing behaviour [55] and for this behaviour to align with community values, attitudes and norms | capacity and requisite resources are needed to engage in the required behaviour change strategies [56]. Community capacity requires the presence of (or willingness/ability to develop) relevant skills and knowledge, leadership, a sense of efficacy, trusting relationships and a culture of openness and learning [57,58] | communicating accurate, accessible, and timely information that is relevant to the target community, and that informs members about the processes and outcomes of action, is a core feature of successful community mobilization and behaviour change strategies [56,59,60] |

individual behaviour change or individuals within complex systems. Once behaviour change has been achieved there is a need to foster and maintain desirable behaviour change.

## (b) Level 2: change on a community level

Community-level interventions are not simply an aggregation of individual-level behavioural changes but are mobilized groups that leverage collective action. Changes in the *local community* (level 2—figure 2) encompasses both interpersonal and social psychological determinants. *The local community* encompasses social and neighbourhood networks and can be defined by shared values and features, not just where people live. Actions (e.g. citizen science projects, local management practices), feelings, values (e.g. connectedness to oceans, the realization of links between ocean health and human health) and social norms are embedded in and influenced by, local environments and social spheres that can transcend geographical boundaries. Targeting community-level change may enhance engagement and sustainability of pro-environmental behaviours in the longer term [52,53] through the development of new social norms [53]. To change such systems, changes in the determinants of the behaviour of individuals constituting and maintaining these systems is required—both via individual determinants as outlined above and via changes in the social norms, identity processes and values that constitute these networks.

Communities can extend beyond local geographical boundaries to encompass groups of people across states, nations or globally who are connected through shared beliefs, interests and/or actions. In this regard, we can also consider a change in the more distal levels (*international, national and state* scales: levels 5 and 6). The Future Seas papers identified goals that pertain to these levels of change, such as a reset of economies, with a shift to circular economies [31,32], natural capital factored into global accounting [32], cooperation and collaboration between countries and within nations [28,34]. Change in the practices of these communities relies on political will and commitment for change to achieve Future Seas goals [32,35]. There is a frequently expressed need for sharing behaviours and shared views to occur on a large scale, between countries and among large groups within a nation. This includes, for example, equality in sharing of resources [36] and benefits [33,34] sharing investments in research [29,34] and developing shared views of measurable and achievable sustainability targets [32].

There are few empirically supported models of community change based on targeted behavioural interventions. Drawing on insights from community resilience strategies and models [54], it is recommended that when designing interventions, it is important to first understand who the target community is, and to tailor interventions to meet their specific needs, characteristics, capabilities, opportunity and motivation. There are three core features often identified as targets for the implementation of behaviour change in communities: connectedness, capacity, and information and communication (CCC components shown in table 4). These core features interact with one another to influence the success of community-level behaviour change interventions. Contextually, the rapidity and ease of mobilizing communities to engage with behaviour change interventions may be a function of the extent they vary in CCC features and thus constitute invested, disengaged or diffuse communities [61,62].

*Invested* communities have high levels of all three CCC features. Invested communities are more likely to demonstrate an emphasis on bottom-up (i.e. community-initiated and led) approaches to behaviour change. If invested communities have resources available to them, shared experiences and successes that achieve successful and sustained outcomes will further reinforce community CCC. A *disengaged* community has low-to-moderate levels of CCC but can move towards mobilization. Disengaged communities are more likely to require a combination of top-down (e.g. policy and incentivization) and bottom-up approaches to support behaviour change. There may also be a role for behaviour change 'champions' who act as conduits between community members and policymakers. A *diffuse* community has low levels of CCC and a definable community has to be developed first to create opportunities. Top-down approaches (including the use of external reinforcers), along with an emphasis on information dissemination (communication), are important approaches.

Developing targeted community-level behaviour change interventions requires working closely with communities over time. Community needs assessments can ensure interventions are tailored appropriately. As this process unfolds, opportunities need to be facilitated to gain community

**Table 5.** Determinants of policy change.

|  |  |  |
|---|---|---|
| **multiple streams** | **social problems** | **'in all policies' approach** |
| three parallel streams of determinants of policy development: problems (topics and current affairs), politics (stream of decision processes), policy stream (potential solutions). Rapid changes in relationships between streams create 'windows of opportunity' for change | career of social problems from objective issues identified in research to the policy-defining issue can be facilitated through social processes such as problem framing and using this framing rather than a complex issue in communication | identify key issues as overarching themes that are required to be considered in all policy decisions, comparable to 'health in all policies' approaches—subsequent change and adaptation of all policy fields |



participation. Participation can strengthen trust and reciprocity among community groups and organizations and facilitate forums for community dialogue. The diffuse community can be shifted along the continuum of engagement, thereby enhancing the likelihood of success for behaviour change strategies. An important consideration and resultant challenge to overcome is the inherent diversity between community members in all types of communities. Moreover, communities change over time not only in the desired direction towards behavioural change but also away from this should tensions in CCC arise.

In summary, we recommend that community connectedness can be enhanced through processes such as repeated exposure (i.e. social learning through modelling; [63,64]), positive reinforcement (through enhanced self-esteem and social status), and access to community resources [55,60] which can elevate the behaviour to a 'discursive consciousness' [64].

## (c) Levels 3 and 4: changes in technology, information and knowledge, and policy (levels 5 and 6)

Change interventions often consider technology, information- and knowledge-sharing, and policy (TIP) in terms of the actors and decision-making that are the targets for change and that have direct impacts on individuals and communities. We argue that to enhance the design, implementation and maintenance of interventions to improve ocean health, the TIP spheres of influence, need to also be understood in terms of their important roles as mediators and moderators. They work across and within levels in the rainbow to influence actors' behaviours and actions, and this, in turn, influences the nature of the TIP, akin to a process in the field of information technology, called a task artefact cycle, that involves an iterative process of continuous mutually dependent development between task and artefact whereby each shapes the other [65]. Ultimately, TIP factors are tools for change that can cut across all levels in society to support coordinated and unified efforts in behaviour change (as depicted in figure 3).

*The technology* captures the consistent recognition across Future Seas papers of the role of technology innovations, systems and tools indirectly impacting the SDGs. Technology is seen as a potential transformative mediator to facilitate actions and communication across all levels in the model. *Information and knowledge* encompass not just knowledge content, such as marine-related data, science and ocean literacy, and the wisdom of traditional owners and first nation peoples, but also the need for enhanced processes for knowledge and information exchange. The most call common across the papers was for processes (frameworks/policy/management and practices) to streamline, synthesize, upscale and share information. Knowledge exchange processes are needed to involve qualities that facilitated coproduction and collaboration, and ensure transparency, clarity and accessibility. From this perspective, *information and knowledge* can be viewed as a sphere of influence that not only underpins behaviours and characteristics at both the *individual* and *technology* levels but is conceived as a mediator and conduit for communication and actions across all levels.

Technology has been recognized as underpinning the achievement of the SDGs by the Organization for Economic Co-operation and Development [66], and indeed, across our Future Seas papers, technologies of various types are recommended to support: monitoring, detection and predictions [26–28]; educating stakeholders and building environmental consciousness [30]; and sustainable production across supply chains [29]. Technology is conceptualized in and across the papers as both an outcome (such as recommendations to develop green and waste reduction technologies) and as a mediator for change (such as using social media tools to educate, inform and mobilize communities).

Furthermore, the papers model futures, where information and knowledge are shared [27,35], are easy to access [28], transparent [33] and informed by multiple stakeholders [29,34].

Core to the contributions of technology and information and knowledge-sharing towards the achievement of the SDGs is their roles as communication pathways that can create community identity, and a sense of connectedness between individuals and with their communities, and governments. For example, we know from seminal authors such as Rogers [67], that we need to gain an understanding of differences in user types—including their perceptions towards innovations, their gender, age and experiences. This helps us to understand the readiness and preparedness of the audience to accept and engage in change through technology adoption on a spectrum from early adopters to laggards.

Further, Davis *et al*. [68] and Venkatesh *et al*. [69] note the need to first identify an individual's level of readiness for

technology uptake; then enter co-production to ensure usefulness and ease of use enhance acceptance and adoption; and then consider and address end-user expectations about performance and effort, social influences and norms, that influence use.

While technologies are often a tool of dissemination and sharing of information, additional consideration of the attitudes and behaviours required by communities to build collaborations and the necessary sharing agreements is required for information and knowledge-sharing. Specifically, Moore *et al.* [15] note that co-produced knowledge is reliant on not just the availability of evidence and the collation of knowledge (as mirrored in the Future Seas recommendations) but is also reliant on working relationships and agreed objectives.

### (i) Policy

On the highest order levels, the Future Seas papers identify and recommend changes in policies (both state, national and international levels) and laws that govern and regulate ecosystem management and other actions. Again, the policy is both an outcome and a mediator in the TIP levels. Policy can directly influence ocean health behaviour change, either as a facilitator or an inhibitor. It can function independently to influence behaviour change or as part of the TIP system of interconnected mediators and moderators that operate in concert to 'TIP', or create contingencies for behaviour change in individual, local or global communities. As a result, if the linkages between TIP mediators are not well understood or used ineffectively, policy may have little impact on individual or community behaviour change or tip it towards negative consequences.

Recommendations for change included regulation through the implementation of international laws (e.g. Ward *et al.* [27] and Farmery *et al.* [29]—for ecosystem-based management; Haas *et al.* [36]—to protect marine life and resources), changes to governance/management approaches (Smith *et al.* [35]—implementing a multi-centric governance system with overarching binding instruments and laws) and shaping behaviours through financial drivers (e.g. Puskic *et al.* [31]—enforcing bans, taxes, fines for unsustainable behaviours and incentives). The Future Seas papers also outline that changes in *Policy* level determinants can also support actions across lower level spheres of influence, such as the *local community* level (Farmery *et al.* [29]—supporting domestic fisheries and supply changes; Nash *et al.* [32]—decentralization of management to local levels; Ward *et al.* [27]—ecosystem restoration), they are considered crucial for achieving outcomes at the top (6th) level *international, national and state* level determinants, table 5.

Policies can directly impact change on lower levels in the rainbow model by resourcing, regulating and reinforcing determinants that increase engagement with BCTs and through the creation of coordinated implementation components and pathways, within and across the community [70]. Policies related to ocean health and ecosystem resilience could originate from within a range of political portfolios such as economy, trade, environment, industry, foreign relations, or science and education.

While changes in policies on state, national and international levels are undoubtedly central, identifying determinants of change in policies is difficult—as, with any complex systems that derive policies, processes involve individuals, organizations and interactions on multiple levels [43]. Several approaches have been developed to facilitate changes in policies including the multiple streams approach (MSA) [71]. The MSA describes how particular topics reach the current political agenda and could thus influence change in legislation and speculates on why topics fail to be incorporated in policy. Policies can be particularly useful tools to enhance intervention uptake in disengaged or diffuse communities, where low motivation is the genesis for resistance to behaviour change. The MSA describes three parallel streams of determinants that impact policy development; problems (topics and current affairs), politics (stream of decision processes) and a policy stream (stream of potential solutions through policies, influenced by available technology and normative acceptance). While these streams are assumed to progress relatively independently, rapid policy changes can occur through the element of chance that influences the nature of the relationship between streams, creating a 'window of opportunity' for new policy creation or change. For example, the 2015 nuclear accident in Fukushima, Japan was a chance incident. This influenced discussion about nuclear energy in Germany and led to the hitherto low-priority policy agenda in Germany to enter the political stream. Ultimately, this chance event was linked to policies such as the closure of all nuclear power plants in Germany until 2022 [72]. On the other hand, political determinants or influential actors can engage in activities that can effectively close or defuse 'windows of opportunity'. For example, the international lobbying by the Australian government to remove the Great Barrier Reef from the UN's Educational, Scientific and Cultural Organization's 'in danger' list has been viewed by concerned groups as an action that moves reef rehabilitation and resilience interventions further from policy agendas [73,74].

To open such windows of opportunity, problems need to become salient and relevant to policymakers. This 'career' of problems—for the Future Seas SDGs the career from an issue identified through research towards a policy-defining issue is essentially a social process, which means that in addition to the 'objective' characteristics of the issue, it needs to become something that is seen to be desirable and worthy of change by a substantial and vocal segment of the population (e.g. [75]). This further requires the issue to be associated with a range of well-communicable and easily understandable attributes such that in addition to the—more complex—underlying issue, the more easily accessible attributes are communicated and shared in public (for a more nuanced discussion of this career pathway of social problems, see [76]).

There are few examples of policy development approaches that are so overarching that they aim to strategically influence determinants for a given social or environmental problem that exists across multiple layers of the 'rainbow'. One rare exception to this is the Pan American Health Organization's [77] *Health in All Policies*, a collaborative international approach across countries' ministries of health, international government, social and civil agencies, universities, community groups, and other partners that aims to improve health by incorporating health considerations into decision-making across all sectors and policy areas. All health-related policies of the European Union are now guided by this policy approach [78].

In summary, for TIP factors to work as mediators and moderators for change, they require connection to each other, to policy, and each of the human actors across the

levels. As tools of change, they are only as good as their inputs and their connectedness.

## 4. Achieving changes for ocean health: the rainbow model of ocean health

To summarize our 'rainbow' model, we have identified that by using behaviour change as a design guide (with individuals either as specific actors or as actors within and constituents of complex systems), applying community mobilization principles, developing national, international, and state initiatives and influencing TIP mediators, we can positively influence change in discrete behaviours on multiple levels.

However, most behaviour change requirements related to resilient oceans involve multiple sets of behaviours. The ability of individuals or communities to respond to SDG challenges is also dependent upon successful interactions, both within and between factors [79] at each of the levels of the 'rainbow'. This means that potential solutions or resources for effective or sustained behaviour change are often beyond the control of any one actor or community of action or practice.

Across the rainbow model of ocean health, there are multiple potential actors and complex determinates of behaviour change. Effective achievement of the SDGs for resilient oceans is influenced by psychological, socio-ecological, economic, political and TIP processes (see arrows in figure 3).

To address wicked problems, Moore *et al*. [15] advise change cannot be achieved with a focus simply on transitional or piecemeal actions. While these may be useful in developing capacity for change, they are unlikely to be at a sufficient scale and pace to meet current imperatives. The seminal work of Meadows *et al*. [80] considers possible targets for change of complex systems broadly from a systems analysis perspective. We concur with this premise and suggest that in addition, the achievement of radical and rapid shifts in infrastructural, behavioural and operational systems to meet ocean health, requires holistic consideration of transformational determinants, such as *relationships and cooperation; leadership qualities and champions; and strategies and opportunities*.

### (a) Transformative change

#### (i) Relationships: transdisciplinary perspectives and multi-agency cooperation

Wicked problems require multiple actors from across a broad range of discipline expertise working at a systems level to address issues or systemic processes within and/or across levels in the 'rainbow'. Team members may be geographically dispersed, come from different cultures and backgrounds, and vary in their capacity to engage in various levels of the teams' programmatic agenda. In short, the types of teams effective for wicked problems (known as transdisciplinary teams) can be very difficult to create, as the process of formation is a system process itself that needs to be understood [15].

An inherent feature of the wicked problem, and indeed ocean resilience, is that the actors seeking to bring about change hold disparate and sometimes disconnected perspectives and assumptions about the nature of the problem and the key objectives for collaboration. There can also be diversity across actors in their motivations for involvement in the team. It is therefore important to understand the characteristics of the transformative people, policies and windows of opportunity that are the essential ingredients for addressing wicked problems.

#### (ii) Policies and economics

There is a growing realization that the current approaches to policy, and policy implementation, are not fit-for-purpose to address wicked problems of ocean ill-health, and new approaches are needed to build transformative and rapid pathways for change [81].

Many experts call for fundamental change to the way that policies are conceptualized and developed. This includes 'mainstreaming' and prioritizing wicked problems into the considerations of public policy [82], particularly for economic policy such as creating transformations to the circular economy. Policies require a change to the world view of how we conceptualize profit and a new green lens [83]. The impetus for change to policies that focus on a circular economy may come, in part, from growing global social norms that pressure change, but more likely from the economic consequences for countries that do not adapt their policies and behaviours.

Further, the discourse around policies for wicked problems suggests that policymaking, and implementation, needs to be informed by an understanding of the systemic socio-ecological processes inherent in wicked problems. The behaviours of individuals in policymaking systems need to be considered.

As outlined above, developing and promoting ocean health policies are, according to the COM-b model, modifiable by attempting to change skills and perceived capabilities of policymakers (e.g. through providing clear links between the instalment of ocean health solutions and beneficial outcomes; see Alexander [37] for discussion of equitable outcomes), by providing opportunities or removing barriers towards behaviour (e.g. by providing public polling outlining that a majority would support such policies) and by attempting to change individual motivation (e.g. through outlining benefits and removing ideological barriers).

#### (iii) Entrepreneurs and multi-global champions for change

Wicked problems require multi-pronged approaches especially when political will is low. Understanding how issues such as ocean health become social problems—which then, in turn, can set the tone for 'windows of change' in policy is crucial. This suggests that systematic research on defining and tabling social problems is needed, as currently, approaches are focused on characteristics of individuals and organizations rather than modifiable processes and determinants. Transformative agencies and people, within and across countries, that come from non-government lobby groups, multi-national businesses, philanthropic groups and global collaborative networks serve as agents for change and may create, through sustained efforts, windows of opportunity for change across all levels of the 'rainbow' ([15,84]; see Meadows [80] for discussion of systems analysis for change).

Some of these 'policy entrepreneurs' and behaviour change champions operate at the international, national or state level of the 'rainbow', using their power, knowledge and networks to actively create and exploit opportunities to influence change [15,71]. Many are philanthropic, global non-profit or financial institution collaborations that primarily work to target specific socio-ecological issues. They aim to build capability, opportunity and motivation to address a specific aspect of the wicked problem through direct project

incentivization (e.g. Earthshot Prize, World Bank, World Resource Initiative, Rockefeller Foundation, KR Foundation). They may also support and grow champions within communities through leadership opportunities and co-produce community-level initiatives to increase engagement. These actions can serve as a platform to transition responsibility and power for ongoing behaviour change endeavours to community members. Well-crafted and targeted policy briefs submitted through multiple channels and integrated into grass-roots activities can serve the purpose to create momentum for change. More systematic research on how through such initiatives issues such as ocean health become salient social problems is needed.

Fundamentally these organizations are structured for flexibility and adaptation and their actions are not limited by needing policy change at the government level. They have organizational awareness and frameworks that consider many of the determinants in the 'rainbow'. These entities can bring diffuse or disengaged communities to a more engaged and resilient position through their efforts that provide opportunity and/or resourcing, and/or incentivization.

Some initiatives primarily take a bottom-up or grass-roots approach to empower action at local, community or global levels (e.g. The Climate Reality Project, Global Citizen, Surfrider Foundation, Sea Shepherd Conservation Society). Through these actions, they mobilize a community's sense of connection and are often embraced by communities that are highly invested.

For both types of transformative entities, intensive lobbying for climate action and continuing or increased grass-roots activities (e.g. 'Fridays for Future') might be constructive steps towards opening windows of opportunity. The process of public policy change is also dynamic and cyclical and subject to constant changes [70], and eventual changes in policies can be the product of constant and repeated endeavours.

### (iv) Moments and opportunities

In addition to transformative people and policies that lead deliberate actions for change, there are unplanned or unexpected events in time that lead to rapid transitions and change at a pace that sometimes outstrips policy and staged behaviour change. For example, the Blue Planet documentary programme, which depicted graphic scenes of the impact of plastics on marine life, has been credited with leading a global widespread approach to the discontinued use of single-use plastics [85].

Similarly, the Covid-19 pandemic has led to the rapid transformation of behaviour and policy [86]. Actors are now being required to think and act at a systems level to prepare and protect across the globe. Leaders are required to lead with clarity, compassion and hope in a time of great uncertainty and to develop policy to mandate action. Individuals and communities are being required to change their behaviour in response to policy mandates. Information and knowledge are being collated and shared to build insights into the virus and to develop new practices and countermeasures. Technologies are being developed to disseminate this new knowledge and to monitor and detect new threats to communities.

## 5. Conclusion

In this paper, we have developed and presented a socio-ecological model of ocean health that maps actors, systems and behaviours relevant to ocean health on multiple hierarchical layers. Actors and systems interact both within and between layers, and it is important to recognize that changes in the complex systems underlying super wicked problems, such as ocean health, require a change of practices and behaviours on multiple levels, involving complex feedback loops, coordination across and between levels, and transformative practice hinging on opportunities and policy windows.

A key recommendation stemming from the lens applied in this paper is that potential actors in ocean health must fully consider the socio-ecological and behavioural hierarchical context that impacts a target ocean health problem. One way to do this is to encourage and grow the development of cross-discipline teams that members with expertise in the relevant levels of the rainbow model of ocean health. A further recommendation pertains to improving our understanding of how issues, such as ocean health, become salient social problems that necessitate policy changes—and how to influence such changes in problem understanding. To our knowledge, this is the first paper to apply the rainbow model to ocean health and to articulate the pivotal role of TIP factors as mediators and moderators. A recommendation arising from this is that TIP factors need to be understood and strategically considered in the design and implementation of ocean health interventions in terms of their potential to bring about multifactorial change within and across systems that, in turn, enhance intervention success, impact and maintenance.

Using a convenience sample of high-quality studies (the Future Seas papers) outlining necessary changes on multiple levels, we have identified change objectives on multiple layers and have provided roadmaps to map these change objectives onto evidence-based determinants of change, both in individual and systems behaviour.

Such a socio-ecological model constitutes a paradigm shift in the ocean and climate health world views and practices aligned with our 'rainbow' model, coupled with transformational relationships, people and economies that ultimately move towards creating an impact that is greater than the sum of its parts.

Data accessibility. This article has no additional data.

Authors' contributions. K.d.S.: conceptualization, data curation, formal analysis, methodology, project administration, writing—original draft and writing—review and editing; J.L.S.: conceptualization, data curation, formal analysis, methodology, writing—original draft and writing—review and editing; B.S.: data curation, methodology, writing—original draft and writing—review and editing; K.N.: conceptualization, methodology and writing—original draft.

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