Marine Policy 154 (2023) 105672

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Sustainable use of ocean resources

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ARTICLE INFO

Keywords:
Sustainability
Policy
Conservation
Management
Philosophy
Ocean
Marine environment

ABSTRACT

Everyone agrees that the oceans should be used in a sustainable way, but there is no agreement on what this means, and this critically important concept has been devalued to the extent that it is typically a generic term for "greenness". Problems include the lack of clear criteria for ecological sustainability, and that the definitions used for fisheries and other ecosystem components differ.

The defining feature of "sustainability" as a concept is that it includes judgements about the future, as well as the present. Sustainable use can be assessed based on whether uses have impacts which would constrain future generations by preventing recovery of the environment, to a pre-use state, in a societally acceptable timescale. We present a practical approach to the assessment of ecological sustainability, based on its original roots in intergenerational equity, and which use the same criteria for all uses of the oceans.

1. Introduction

It is a truth universally acknowledged, that a country in possession of marine resources, must want to use them sustainably. "Sustainability" is a universal "good" and in present-day use can mean almost anything. As a result, it means nothing. This is an important problem, because "sustainability" is an incredibly important idea, rooted in intergenerational equity and essential to the fair and rational use of natural resources. The seas are the last area where most of our activities still use wild species and ecosystem services. The requirement that uses of marine systems be sustainable is written into national laws and international agreements, and universally agreed to be a key principle of ocean management. Specifically referring to the marine environment, UN Sustainable Development Goal 14 is to "*Conserve and sustainably use the oceans, seas and marine resources for sustainable development*". But what does "sustainable" mean in practice and how should it be assessed? Can we ever know whether an activity type and intensity level represent sustainable use before it is too late? It is the aim of this paper to explain a way of assessing sustainable use in a consistent way across different uses of the sea. Our core concept is that uses of the sea should not be considered sustainable if they have effects that are irreversible within a societally-acceptable timescale. We explore the logic behind the possible baselines, metrics, and timescales below, but first we need to go back a step, to the origins of the idea of sustainability.

The nearest to an official definition comes from the World Commission on Environment and Development (WCED), hereafter referred to as the "Brundtland definition" [2]: "*sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". Any process, which is to be labelled as "sustainable", must be able to demonstrate that it meets this clear definition. We argue that most statements about sustainability are unfounded, as they do not address the core of the concept – that uses today should not take opportunities away from future generations by leaving them an environment which can provide fewer services.

Present concepts of sustainability typically encompass issues such as equity and economics [3], adding enormously to the challenge of setting objective criteria. A wide range of metrics for these socio-economic factors already exist and are beyond the scope of this article, and there are no universal rules for what balance of social and economic value is right for all societies. Previous authors such as Kuhlman and Farrington [4] set out the historical development of sustainability concepts from simple persistence of renewable resources, through the splitting of sustainability into social, economic and environmental "dimensions". An important subsequent development was the consideration of "weak" and "strong" sustainability [5,6]. In strong sustainability, "the next generation should inherit a stock of environmental assets no less than the stock inherited by the previous generation", whereas weak sustainability allows consideration of "wealth, comprising man-made assets and environmental assets". Weak sustainability allows declines in environmental assets to be traded-off against

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https://doi.org/10.1016/j.marpol.2023.105672
Received 7 June 2022; Received in revised form 23 February 2023; Accepted 11 May 2023
Available online 19 May 2023

material gains. Difficulties arise when "Strong" sustainability is combined with a need to trade-off between the different dimensions, especially where there are no explicit rules for how the balance should be struck [6]. Kuhlman and Farrington [4] describe a need to separate "well-being" from "sustainability" to prevent "sustainability from becoming an empty phrase indistinguishable from 'goodness'". We completely agree with this assessment but seek to go further in terms of defining sustainability. We also argue that the "strong" sustainability concept of a "constancy of natural capital rule" (CNCR) [6] is unnecessarily strict, without accepting that permanent damage to the environment can be considered sustainable, whatever the economic and social benefits.

The current situation has been described as the "post-Brundtland quagmire" [7], and while we agree with their diagnosis, we would disagree with their cure, that we should "*…embrace a plurality of approaches to and perspectives on sustainability, accept multiple interpretations.*". Ecological sustainability can be defined in a universal way, and we should at least do this, even if socio-economic factors include more substantial value judgements.

2. A framework for thinking about the ecological dimension of sustainable use

Our proposed approach allows extractive and non-extractive industries to be compared fairly, and for sustainable use of fish stocks, the seabed and marine wildlife to be measured in the same units. The core principle (Table 1) is that uses of the marine environment should not have irreversible effects, such that cessation should allow ecosystems to return to a pre-use state within a societally acceptable time period. We consider the length of this time period in detail later on in the paper, but precedent in existing policy points to a range of 5–20 years [8,9]. Users of the marine environment do not have to demonstrate that the environment is currently in a natural state, or even close to it, for their uses to be sustainable. Users would, however, need to demonstrate that the system can return to a pre-use state. Such an approach allows for human-induced change but does not remove options from future generations.

Pre-use means different things for individual users and governments. A user would need to convince regulators that cessation of their use would allow the ecosystem to return to the state before their use began (which might not be a natural state if other impacts pre-dated the newer use). For governments seeking to say that their management of the entire system represented sustainable use, they would need to provide evidence that if all uses were removed, the entire system could return to a natural baseline (bearing in mind the climatic context). We describe below some of the experiments and other data sources available to help provide such evidence.

We argue that uses which have irreversible effects cannot be described as ecologically sustainable. If society deems the uses sufficiently important that they should proceed anyway, then the consequent impacts on future generations may be considered "acceptable" losses. The important thing is to be honest about the difference between "sustainable" and "acceptable".

Table 1
Core principles of our proposed approach to the assessment of environmental sustainability.

1) We do not know what future generations will need from the environment and so the onus should be on us to give them the maximum range of options. "*Conservation of options*" principle[1].
2) Uses with irreversible impacts remove options from future generations
3) At a user level, the end of a use should allow the area affected (and its ecosystem services) to return to its pre-use state.
4) At an ecosystem level, the end of use should allow the ecosystem affected to return to a natural state.
5) Sustainable uses are therefore those which do not affect the environment in ways which would prevent a future return to a natural state, or transformation to any other state desired by future generations. "*Conservation of equality*" when applied at an intergenerational level[1].
6) There is no requirement that the exploited environment be in a natural state, or even close to it, in order to demonstrate that the exploitation is sustainable, as long as principle 3 or 4 is met.

Most human uses of the natural environment are composed of many smaller activities. For instance, fin-fish aquaculture requires the provision of food for the fish, control of disease, transportation, the holding of fish during growth, and protection from predators. If even one of these individual activities has effects which cannot be reversed in a societally acceptable timescale the aquaculture operation as a whole cannot be considered sustainable.

In the context of marine systems, there are two broad categories of sustainable use – the maintenance of commercial stocks and the successful management of impacts on non-commercial species and the wider marine environment. Under the Marine Strategy Framework Directive [9], a use is considered sustainable if its effects are reversed if the use stops, allowing a "rapid" return to a "natural" state. Being in a state of sustainable use therefore does not necessarily imply that it is currently in a natural state, or even close to it. This criterion of reversibility is applicable to any use, allowing different uses to be compared in the same terms.

Similarly, the FAO guidelines on deep-sea fisheries management [8], the definition of Significant Adverse Impacts, includes criteria for whether the effects on productivity, habitat provision, species richness and ecosystem functions are "temporary". The concept of recovery as a criterion for assessing the effects of human activities in the sea is therefore within policies of both the EU and UN.

An approach based on the ability of systems to recover would allow the ecosystem effects of fishing to be considered in the same way as the yields of stocks. This is not typically how this has worked in the past, for instance in Marine Stewardship Council (MSC) certification, the scoring systems for stock sustainability and for the effects of fishing on ecosystems, used different methods [10]. While the sustainability of fishing on the stock has always been assessed using quantitative metrics such as MSY, the effects on biodiversity and the seabed were scored based on qualitative measures [10]. We argue that this is not necessary and that a system which seeks to recognise sustainable fisheries ought to measure whether impacts on non-target species and the environment are sustainable using the same criteria as are applied to the stock species. In a welcome development, the MSC's new standards move towards a system where at least Endangered, Threatened and Protected (ETP) species are treated more like stocks, with targets for the recovery of populations to "*50% of unimpacted levels within three generations or 100 years, whichever is shorter*" [11]. We would argue that this approach should be applied to seafloor integrity, biodiversity, and ecosystem functions, not just ETP species, but this is a welcome development. It is also more consistent with EU [9] and UN guidelines [8], helping build a consensus on recoverability as an essential metric.

Fisheries are an example where natural capital can decline over time without this being evidence of unsustainable fishing. This is contrary to the views of Ekins et al. [12] that "*…sustainability depends on the maintenance of the capital stock*". A decline in the size of a stock is a normal response to the start of fishing, and in fact considered necessary for Maximum Sustainable Yield (MSY). Whether a decline is evidence of unsustainable practices depends on its mechanism, rate and duration, and it is simplistic to conflate any decline with unsustainable use. For example, there could be a small but rapid decline associated with damage to habitats, compared to larger, slower decline without other damage. Are both unsustainable, and which is worse? The view that capital stocks must never change [12] is the root of the problem and the reason for the need for a "weak sustainability" concept as an escape. Fishing is impossible under any definition of "strong sustainability" where capital stocks cannot change. If we accept that under sustainable use the natural environment can change then the problem evaporates and the need to consider "substitution" of natural for financial capital is removed. Daly [13] allows for natural capital levels to vary, but all at their optimum level (preferring Maximum Economic Yield (MEY) over MSY). While this is a better position, it is unrealistic to expect all competing uses of a shared environment to have the resource they require at the optimum level at all times. Political judgements must be made about how resources and space should be shared, but imbalances between users do not imply that the resource is being used unsustainably from an environmental point of view.

Hilborn et al. [14] describe criteria for fisheries sustainability that include all three of the usual "pillars" and points out the conflicts between them. Examples given include "sustainable overexploitation", where harvesting can continue indefinitely at a level that would allow recovery, but that does not achieve the full economic value of the fishery. Other conflicts occur in decisions over quota allocation and concentration, where economic efficiency and social aims will often be in direct conflict [15–17]. In such cases there will often not be a "right" answer, because the best answer will differ greatly between cultures and political viewpoints. Neumann et al. [6] argue that these trade-offs are politically convenient, and often lead to weaker ecological protections on the basis of economic and social needs, while still claiming to be sustainable.

An example of this balancing act occurs in decisions about levels of fishing effort. The question of what the "optimum yield" of each stock should be has been a constant source of debate in the US, where this is part of the first "National Standard" of the Magnuson-Stevens Act [18,19]. Moving towards MEY (lower fishing effort, higher stock sizes and more efficient fishing) rather than MSY would appear to be a synergy between the economic and environmental dimensions of sustainability, but the higher profits by fishermen could be associated with reduced profits for processors who could suffer from the lower yields and higher unit prices. The effect of a change in management target could be quite different for different stakeholders and dependent on the spatial and temporal scale under consideration.

Hilborn et al. [14] are critical of the idea that "warm and fuzzy" feelings about fisheries should be incorporated into assessments of "sustainable seafood", and as they point out the many contradictions between ecologically sustainable fisheries and their socio-economic outcomes, they conclude that a return to the original concept based on persistence of stocks makes the most sense. We would argue that this type of approach can be easily extended to environmental impacts beyond the stock without weakening this concept.

3. Applying our approach to the assessment of sustainable use

We consider three main categories of marine resource use. Firstly, there are the targets of fisheries. Here, sustainability can be defined simply as the use of gears and levels of exploitation which do not reduce potential fishing opportunities for future fishers [10,14]. The political or social decisions about whether to maximise total yield or to maximise profits, and which sectors within the fisheries should benefit would be made separately.

Secondly there are uses which either cannot deplete the resource (marine renewable energy) or use a resource which is not replenished at relevant timescales (oil, gas, seabed minerals). The only decisions here are on when these resources will be used, based on market conditions. These market conditions might be influenced by environmental concerns if they affect demand. There is no sustainable level of use for these resources, it is either irrelevant (wind), or impossible (oil).

The third and most complex case is where the taxa or biotopes are not the target of any activity but the accidental victims of it. Damage to these components of the environment is a form of collateral damage, or economic externality. This category would include bycatch, effects on the seabed and benthic flora and fauna, foodweb effects (e.g. on higher predators). But can damage to non-target species and to the wider environment ever be considered sustainable? The answer to this question is yes. All activities in the marine environment have impacts and we cannot have fishing or energy industries without some effects.

An activity which affects the environment is considered to be sustainable if its method and intensity of use does not permanently preclude any future uses of that environment. It does not mean that there is no present impact and certainly not that the system is in a pristine state. An activity might cause a small change to a system and yet be unsustainable while another activity causes a large change but is sustainable. This is because an important part of the decision on whether the activity is sustainable is a judgement about the future and not just about the present. As described by Hollins [20], "instability" in a population does not demonstrate a lack of resilience, and in some cases may indicate the opposite. A pressure might have a large effect, but the removal of the pressure may result in an equally fast recovery [20].

Use of an ecosystem could be seen as operating within the "elastic limits" of the system and this concept underpins the notion of sustainable use. An ecosystem whose resources are being used might look quite different from its natural state, but the use would be sustainable if the system retained the capacity to recover to its pre-use state. This is clearly challenging, as we often do not have quantitative data about the pre-use state of ecosystems, where activities have been taking place for many years. But there are ways in which those who seek to claim sustainability can provide evidence. These include experiments in the present, as well as historical studies (see below).

For a proposed activity, a pilot phase, in which the use occurs and ceases, with data before and after (e.g. the Beyond-BACI approach [21]) would provide useful information to determine whether a novel activity is likely to be sustainable. Such pilot phases would be needed wherever there is inadequate experience with the type or intensity of a proposed activity, or it is an ecological context about which less is known.

At the level of the ecosystem as a whole the situation is more difficult and will usually require assessment in the absence of complete pre-use information, but many efforts have been made to identify such baselines and compare them to the present day [22–24]. There are, of course, challenges here. In restoration ecology, or "rewilding", there is the issue of what period in the past represents a suitable "target" state [25], and similar questions arise here. The climatic context has changed, making some previous states unreachable, and perfect knowledge of the past is impossible of course. But, many sources of information do exist, in fisheries data, stored otoliths, middens, and diaries which provide evidence of the past abundances, size frequencies, and occurrences of taxa which could be used as indicators (for a wider discussion see [24]). The difficulty of this task should not deter us from expecting governments to make their case and present their evidence if they wish to make statements about sustainability. Where evidence is more uncertain, a greater level of precaution will be required.

Spatial management and other fisheries measures can fortunately also provide a test of sustainable use because they provide an opportunity to assess the ability of the seabed and natural communities to recover where uses are removed or modified. Marine Protected Areas (MPAs) therefore do more than simply protect, they provide an opportunity to assess the wider sustainability of uses of the sea.

What the above sections should have demonstrated is that assessments of sustainability are judgements about the future. In many cases a "counter-factual" future which might never come about. Most of the seabed might not ever return to its pre-use state, but the whole area would be under sustainable use if it could return to this state if impacts were removed or reduced. There is no necessity for use to actually be stopped across the whole area, even if the seabed is measurably transformed from its natural state. Maybe future generations will stop these activities in order to meet different needs, we cannot know.

The most robust method for assessing sustainable use would be to assess change when all use is reduced or removed in appropriately sized and replicated trial areas representative of the wider area, compared to change within areas which remain under use. In many cases spatial management measures already exist which could be used as areas in which to test the sustainable use of the wider sea. Unfortunately, most

MPAs are chosen because they are special in some way and not because they are representative. There is also often insufficient replication and a lack of control areas, with notable exceptions such as the Californian MPA network [26]. At present the study of MPAs currently provide untapped opportunities to help us understand whether the uses to which we put the wider seas are sustainable. While protected areas may not have been fully exploited as tests of sustainable use, they retain their role in supporting the wider ecosystem. As sources of larvae and mobile adults they may increase the rate at which impacted areas can recover from pressures [27]. The evidence for beneficial effects outside MPAs, especially beyond the immediate “halo” where spillover is usually detected, is less certain that the evidence for change within MPAs. Even where good data exist, e.g. in California there is good evidence of local spillover of lobsters [26] but not for changes to wider fish populations [28]. In contrast, studies in New Zealand found that marine reserves made major contributions to wider snapper populations [29]. While MPAs have important roles, they clearly do not replace the need for controls over the types and intensities of human activities in the wider sea.

Our proposed way of thinking about sustainability links to the concept of “resilience”, in particular recovery rather than resistance [30]. If activities overwhelm the resilience of the system, such that it cannot “bounce back” even when pressures are reduced then the level of pressure was unsustainable. This might be the situation with the Scottish Firth of Clyde cod population, whose numbers failed to recover even after directed fishing for this species was completely banned [31]. While there are arguments over the roles of predators in preventing recovery, the evidence is that it was an unsustainable level of fishing which drove the fish population down to a level from which it is struggling to recover [31]. The extent to which fishing effects have really been removed remains highly contentious however, with some estimates of bycatch mortality being extremely high (M. Heath, personal communication), and protection of spawning aggregations being too weak[32].

Using a focus on the ability to recover as the core principle, the competing uses of the marine environment can be compared fairly. If an unsustainable activity was considered acceptable for other reasons, a clear distinction should be drawn between “acceptable” and “sustainable” uses of the marine environment.

4. Sustainable use for future generations

Using our concept of recoverability as the metric for sustainability still requires consideration of context and spatial and temporal scales. A new use of the sea might be sustainable if conducted for a short time, or over a small proportion of the seafloor, but not if continued for a long period or over a large area. While it is possible to come up with technical definitions of "natural" and statistical methods of detecting change towards such a state, there remains a critical societal decision. How quickly should a system be able to return to a natural state on cessation of the impacts which are thought to have altered it? Some definitions refer to a "rapid" recovery to a natural state, but give no actual timescale [9]. Some definitions allow for different rates of recovery depending on the taxon or process in question, e.g. the FAO allows “*5–20 years, taking into account the specific features of the populations and ecosystems*” [8]. Damage to cold water corals [33] or coralline algae beds [34] in temperate waters show little evidence of recovery after decades since the impact is thought to have occurred, but this is to be expected given the slow growth rates of the taxa involved. Should "rapid" recovery for such taxa be considered in decades or even centuries?

We would argue that timescales of greater than a decade stretch any common-sense definition of "rapid". Sustainable use should allow for changes in use over time, and it seems unreasonable that alternative users should have to wait more than 10 years before the effects of previous uses have gone. It is our contention that uses which damage systems to an extent from which they cannot recover within a decade, cannot be considered sustainable.

Such activities are now being considered in the deep ocean, where mining of polymetallic nodules is under consideration. Recent evidence suggests that there is no recovery of the biology of mined nodule fields after decades [35] and this might not be surprising given the biology of abyssal systems. It cannot be considered as a sustainable activity as the collateral damage to the biology of the area appears permanent on human timescales. Such activities might be considered "acceptable" and this returns us to a societal question of how much permanent damage we will allow.

Ultimately, sustainable use cannot be achieved unless we support the survival and prosperity of future generations. Current uses of the terms “sustainability” and “sustainable” obscure the real issue and we suggest that a definition which focuses on the future is needed. The unsustainable use of natural resources in past generations inflicts an inherited burden on children born today. The concept of environmental intergenerational equity is not new [1], but its growing presence in the collective public consciousness is evidenced by the Youth Strike Movement for Climate Action. There is a growing awareness of the unfairness of unsustainable use of Earth’s resources across generations. By focusing on the future availability of resources, our proposed approach and means of assessing sustainability inherently acknowledges intergenerational equity.

This proposed approach aligns with the UN report on “*Intergenerational solidarity and the needs of future generations*” [36] in that we agree “*the vision of sustainable development does not endorse the sacrifice of the legitimate aspirations of the poorest in the name of future generations*”. Our approach allows for human-induced change of ecosystems in the present generation but does not remove options from future generations. We do not need to identify these options, which would in itself be an impossible task, we need only demonstrate that we have not irrevocably damaged the ecosystem beyond the point of rapid recovery for a use to be sustainable. It will then be a societal judgement as to whether this generation pursues actions and uses that could incur large losses for future generations but in no way can this be deemed sustainable.

5. Conclusions

We have moral and legal obligations to ensure the wellbeing of future generations. We argue that current uses of the terms “sustainability” and “sustainable” obscure the real issue and that a return to a definition which focuses on the future is needed.

It is very difficult to meet “*…the needs of the present without compromising the ability of future generations to meet their own needs*”, but this should be the standard we aim for, and it is much more likely to be achieved if we stop allowing unsustainable activities to claim this standard.

As a society we continue to use marine systems and are continually discovering new uses for them. At the same time economic and social changes alter the balance of importance between existing uses. Future generations may have quite different aspirations for their seas than we do. While we cannot predict these future needs we can assess whether current uses of the sea will stop these future generations from being able to use the seas to their full potential.

Funding information

The ideas underpinning this paper were developed during the project “Seafloor Integrity in Scotland” funded by Scottish Environment LINK to DMB, which supported CRH.

CRediT authorship contribution statement

This work is based on extensive discussions between the authors, both of whom researched, read. wrote and edited.

Data availability

No data was used for the research described in the article.

Acknowledgements

The authors would like to thank their many colleagues and students for useful discussions about these ideas, and the reviewers for their helpful and difficult questions.

References

[1] E.B. Weiss, In Fairness to Future Generations: International Law, Common Patrimony, and Intergenerational Equity, United Nationa University,, New York, 2002.
[2] Anonymous, Report of the World Commission on Environment and Development: Our Common Future, World Commission on Environment and Development,, 1987, p. 383.
[3] Anonymous, Report of the World Summit on Sustainable Development, Johannesburg, South Afric, United Nations, New York, 2002.
[4] T. Kuhlman, J. Farrington, What is Sustainability?, (2010).
[5] D.W. Pearce, A. Markandya, E.P. Barbier, Blueprint for a Green Economy, Earthscan ublications,, London, 1989.
[6] B. Neumann, K. Ott, R. Kenchington, Strong sustainability in coastal areas: a conceptual interpretation of SDG 14, Sustain. Sci. 12 (6) (2017) 1019–1035.
[7] C. Sneddon, R.B. Howarth, R.B. Norgaard, Sustainable development in a post-Brundtland world, Ecol. Econ. 57 (2) (2006) 253–268.
[8] A. Food, Organization, International guidelines for the management of deep-sea fisheries in the high seas, FAO,, 2009.
[9] J. Rice, C. Arvanitidis, A. Borja, C. Frid, J.G. Hiddink, J. Krause, P. Lorance, S.Á. Ragnarsson, M. Sköld, B. Trabucco, L. Enserink, A. Norkko, Indicators for sea-floor integrity under the european marine strategy framework directive, Ecol. Indic. 12 (1) (2012) 174–184.
[10] Anonymous, Get Certified! Your guide to the MSC fishery assessment process, in: M.S. Council (Ed.) 2015.
[11] Anonymous, Clarifying best practice for reducing impacts on endangered species (ETP), 2022. 〈https://www.msc.org/standards-and-certification/developing-our-standards/the-fisheries-standard-review/projects/best-practice-reducing-impacts-on-endangered-species〉. (Accessed 21/01/23 2023).
[12] P. Ekins, S. Simon, L. Deutsch, C. Folke, R. De Groot, A framework for the practical application of the concepts of critical natural capital and strong sustainability, Ecol. Econ. 44 (2–3) (2003) 165–185.
[13] H.E. Daly, Toward some operational principles of sustainable development, Ecol. Econ. 2 (1) (1990) 1–6.
[14] R. Hilborn, E.A. Fulton, B.S. Green, K. Hartmann, S.R. Tracey, R.A. Watson, When is a fishery sustainable? Can. J. Fish. Aquat. Sci. 72 (9) (2015) 1433–1441.
[15] R. Hilborn, Defining success in fisheries and conflicts in objectives, Mar. Policy 31 (2) (2007) 153–158.
[16] G. Heal, W. Schlenker, Economics: sustainable fisheries, Nature 455 (7216) (2008) 1044–1045.
[17] E. Pinkerton, D.N. Edwards, The elephant in the room: The hidden costs of leasing individual transferable fishing quotas, Mar. Policy 33 (4) (2009) 707–713.
[18] Anonymous, Sustainable Fisheries Act of 1996, 2013. 〈http://www.nmfs.noaa.gov/sfa/laws_policies/msa/sfa.html〉. 2017).
[19] Anonymous, National Standard Guidelines, 2013. 〈http://www.nmfs.noaa.gov/sfa/laws_policies/national_standards/index.html〉. 2017).
[20] C.S. Holling, Resilience and stability of ecological systems, Annu. Rev. Ecol. Syst. 4 (1973) 1–23.
[21] A.J. Underwood, On Beyond BACI: sampling designs that might reliably detect environmental disturbances, Ecol. Appl. 4 (1) (1994) 3–15.
[22] A. Villnäs, A. Norkko, Benthic diversity gradients and shifting baselines: implications for assessing environmental status, Ecol. Appl. 21 (6) (2011) 2172–2186.
[23] E.S. Klein, R.H. Thurstan, Acknowledging long-term ecological change: the problem of shifting baselines, in: K. Schwerdtner Máñez, B. Poulsen (Eds.), Perspectives on Oceans Past, Springer, Netherlands, Dordrecht, 2016, pp. 11–29.
[24] J.N. Kittinger, L. McClenachan, K.B. Gedan, L.K. Blight, Marine Historical Ecology in Conservation: Applying the past to Manage for the Future, Univ of California Press,, 2015.
[25] K.B. Gedan, D.L. Breitburg, R.M. Grossinger, T.C. Rick, Historical information for ecological restoration in estuaries and coastal ecosystems, in: J.N. Kittinger, L. McClenachan, K.B. Gedan, L.K. Blight (Eds.), Marine Historical Ecology in Conservation, University of California Press, 2014, pp. 163–186.
[26] H.S. Lenihan, J.P. Gallagher, J.R. Peters, A.C. Stier, J.K.K. Hofmeister, D.C. Reed, Evidence that spillover from Marine Protected Areas benefits the spiny lobster (Panulirus interruptus) fishery in southern California, Sci. Rep. 11 (1) (2021) 2663.
[27] J.M. West, R.V. Salm, Resistance and resilience to coral bleaching: implications for coral reef conservation and management, Conserv. Biol. 17 (4) (2003) 956–967.
[28] D. Ovando, J.E. Caselle, C. Costello, O. Deschenes, S.D. Gaines, R. Hilborn, O. Liu, Assessing the population-level conservation effects of marine protected areas, Conserv. Biol. 35 (6) (2021) 1861–1870.
[29] Z. Qu, S. Thrush, D. Parsons, N. Lewis, Economic valuation of the snapper recruitment effect from a well-established temperate no-take marine reserve on adjacent fisheries, Mar. Policy 134 (2021), 104792.
[30] I.M. Côté, E.S. Darling, Rethinking ecosystem resilience in the face of climate change, PLOS Biol. 8 (7) (2010), e1000438.
[31] J. Clarke, D. Bailey, P. Wright, Evaluating the effectiveness of a seasonal spawning area closure, ICES J. Mar. Sci.: J. du Cons. 72 (9) (2015) 2627–2637.
[32] J. Clarke, D. Bailey, P. Wright, Evaluating the effectiveness of a seasonal spawning area closure, ICES J. Mar. Sci. 72 (9) (2015) 2627–2637.
[33] J.B. Jones, Environmental impact of trawling on the seabed: A review, N.Z. J. Mar. Freshw. Res. 26 (1) (1992) 59–67.
[34] J.M. Hall-Spencer, P.G. Moore, Scallop dredging has profound, long-term impacts on maerl habitats, ICES J. Mar. Sci. 57 (5) (2000) 1407–1415.
[35] D.O.B. Jones, S. Kaiser, A.K. Sweetman, C.R. Smith, L. Menot, A. Vink, D. Trueblood, J. Greinert, D.S.M. Billett, P.M. Arbizu, T. Radziejewska, R. Singh, B. Ingole, T. Stratmann, E. Simon-Lledó, J.M. Durden, M.R. Clark, Biological responses to disturbance from simulated deep-sea polymetallic nodule mining, PLoS One 12 (2) (2017), e0171750.
[36] Anonymous, Intergenerational solidarity and the needs of future generations, United Nations, 2006, p. 42.