REVIEW

The Kelp Forest Challenge: A collaborative global movement to protect and restore 4 million hectares of kelp forests

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Abstract

Marine kelp forests cover 1/3 of our world's coastlines, are heralded as a nature-based solution to address socio-environmental issues, connect hundreds of millions of people with the ocean, and support a rich web of biodiversity throughout our oceans. But they are increasingly threatened with some areas reporting over 90% declines in kelp forest cover in living memory. Despite their importance and the threats they face, kelp forests are entirely absent from the international conservation dialogue. No international laws, policies, or targets focus on kelp forests and very few countries consider them in their national policy. The Kelp Forest Challenge addresses that gap. Together with 252 kelp experts, professionals, and citizens from 25 countries, the Kelp Forest Challenge was developed as a grassroots vision of what the world can achieve for kelp forest conservation. It is a global call to restore 1 million and protect 3 million hectares of kelp forests by 2040. This is a monumental challenge, that will require coordination across multiple levels of society and the mobilization of immense resources. Pledges may therefore include area for protection or restoration, enabling pledges which assist in conservation (funding, equipment, professional expertise, capacity building), or awareness-based pledges which increase awareness or education about kelp forests. Correspondingly, participants may be from government, scientific institutions, private sector, NGOs, community groups, or individuals. This challenge is the beginning of a 17-year mission to save our kelp forests and anyone and any organisation is invited to participate.

Why create a Kelp Challenge?

Across the globe, when issues threaten our cultures, biodiversity, economies, and institutions, coalitions form to enable and accelerate collective action. As a result, we

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have global treaties and ambitions for reducing greenhouse gas emissions (Paris Agreement 2015), limiting CFC production (Protocol 1987), protecting ancient buildings (Meskell 2014), and conserving nature in its various forms (Convention on Biological Diversity 2010). The largest and most recent nature-based policy initiative is the Kunming-Montreal Framework on Biodiversity, which requires that the world protect 30% of global ecosystems and restore 30% of degraded ecosystems by 2030 (Convention on Biological Diversity 2022). Prior to that, there have been initiatives to protect or restore forests (Dave et al. 2017), mangroves (Global Mangrove Alliance 2019), coral reefs (International Coral Reef Initiative 2021), and endangered species from pandas to salamanders (Vié et al. 2009).

These initiatives have been shown to increase awareness and understanding (Hulme 2016), increase funding and research (Schmidt-Traub and Shah 2015), and ultimately spark action to address the issue of concern (Le Blanc 2015; Biermann et al. 2017). For example, at the 2010 Convention on Biological Diversity (CBD), 193 nations agreed to protect at least 17% of their terrestrial area (Convention on Biological Diversity 2010) and by 2020, 17% of global land area was formally protected (Bingham et al. 2021). Similarly, in the 11 years since it was established in 2011, the Bonn Challenge has inspired regional initiatives and pledges to restore over 200 million hectares of forest landscapes (Saint-Laurent et al. 2020; Tedesco et al. 2023a). While terrestrial forests have received significant attention, underwater kelp forests, major marine ecosystems are missing from the current global coalitions to save our vanishing biodiversity and the essential services they provide to humanity (Pörtner et al. 2021).

Kelp forests cover over one-third of the world's coastlines (Jayathilake and Costello 2021) with nearly 750 million people living within 50 km of a kelp forest (Eger et al. 2023). This fact makes kelp forests among the most important marine biomes on the planet (Jayathilake and Costello 2021; Duarte et al. 2022). Across this distribution, kelp forests are ecosystems of high regional importance (Buschmann et al. 2014; Bennett et al. 2016; Blamey and Bolton 2018) and based on three services, fisheries production, carbon cycling, and nutrient cycling, have an annual economic value of 500 billion US$ (Eger et al. 2023). Beyond economic impacts, kelp forests have important cultural significance (Dillehay et al. 2008; Thurstan et al. 2018), are used in art (Vergés et al. 2020), form the basis of myths and lore (O'Connor 2017; Pérez-Lloréns et al. 2020), are places where people can interact with the ocean and thus have their own intrinsic value (Lucrezi 2021). Kelp forests are ecosystem engineers and locally increase pH, possibly altering impact of ocean acidification (Cornwall et al. 2013; Hirsh et al. 2020). By creating habitat, they are home to immense biodiversity and are habitat for over 1,500 species of animals (Eger et al.

2023; United Nations Environment Programme 2023) and numerous primary producers (Pinho et al. 2015). Given their ecological and social importance these ecosystems have sustained cultures and economies for generations (Anderson et al. 2007; Erlandson et al. 2007; Vásquez et al. 2014; Thurstan et al. 2018).

Concurrently, kelp forests are increasingly threatened by a combination of biological, physical, and chemical threats. The key threats to kelp forests include ocean warming (Smale 2020), marine heatwaves (Arafeh-Dalmau et al. 2020), increased grazing pressure due to range expansions (Vergés et al. 2014) and-or predator loss (Atwood and Hammill 2018), increased sedimentation due to land modification and coastal industrialization (Gorman and Connell 2009), and water pollution (Coleman et al. 2008), which has resulted in the degradation of 40–60% of kelp forests over the last 50 years (United Nations Environment Programme 2023) and the total disappearance of others (Moy and Christie 2012; Rilov et al. 2020; Rogers-Bennett and Catton 2019; Butler et al. 2020; Eger et al. 2022b; Tamburello et al. 2022). As with terrestrial forests, these declines are directly threatening the biodiversity and ecosystem services provided by kelp forests and the societies that they support.

Despite the convergence of their prevalence, importance, and increasing threats, there are currently no global treaties, laws, or initiatives to protect or restore kelp forests (Techera et al. 2023). While there are regional initiatives such as the Convention for the Protection of the Marine Environment of the North-East Atlantic (de Bettignies et al. 2021), Cystoseira s.l. protection via the Bern convention (Mangialajo et al. 2008), Washington State's 2022 Senate Bill 5619 (Washington State Legislature 2022), and Law N°20.925 in Chile (Biblioteca del Congreso Nacional de Chile 2020), there is a need for national and international attention and action. Without global initiatives, kelp forests around the world may not receive the needed interest and funding for research, restoration, and conservation activities, as has historically been the case (Filbee-Dexter et al. 2022).

The Kelp Forest Challenge is designed to fill the policy and action gap and increase the protection, recovery, and restoration of kelp forests and their associated biodiversity around the world. It is supported by a coalition of restorationists, knowledge holders, businesses, artists, community members, policy makers, and conservationists with the core objective of increasing awareness, funding, and collaboration for kelp forest conservation. The vision of the Kelp Forest Challenge is that by achieving these goals, we can ultimately increase the area, geographies, and ecosystem health of kelp forests, the ecosystem services they provide, and the wellbeing of the communities they are connected to. In this paper, we describe the process through which collaboration and a target to assist these goals has been developed through the Kelp Forest Challenge.

The Kelp Forest Challenge

The Kelp Forest Challenge was conceived by the Kelp Forest Alliance (The Alliance), a research-driven, not-for-profit, and global community of people and organizations working on or in kelp forests in 26 countries (Eger et al. 2022a, Fig. 1). The Alliance currently hosts an online repository of kelp restoration projects, people, and organizations (Fig. 1) and will expand to include protected areas and monitoring sites.

Given the benefit of the knowledge, connections, and lived experiences of the global kelp forest community, the Kelp Forest Challenge was created as a grassroots initiative with open feedback and consultation. The hope was that this process would result in a ground-up vision of what the global kelp community wanted the world to achieve for kelp forest ecosystem conservation. The Kelp Forest Challenge not only includes area-based targets but also highlights the diverse and numerous people and organizations working around the world to protect, restore, or raise awareness about the importance of marine kelp forests. This grassroots approach and progress of The Alliance and the Kelp Forest Challenge has since been recognized and endorsed by the International Union for the Conservation of Nature (IUCN), and the United Nations Decade for Ocean Science for Sustainable Development and Decade for Ecosystem Restoration.

Designing the community consultation

The spirit of The Alliance is to be open and collaborative, and that vision was intended to flow through to the Kelp Forest Challenge. Therefore, the Kelp Forest Challenge was created through broad-scale, open consultation with members of the global kelp forest community. Starting in August 2022, participants were recruited through invitations sent to The Alliance network, an open call on social media, and advertising on the website of the International Seaweed Symposium. Between November 2022 and February 2023, The Alliance convened at eight online workshops and one in-person meeting to discuss the need to set a target for kelp forests, how the target would be determined, what the principles of that target should be, and ultimately what the target values should be. Ultimately, 252 people were engaged with participants spanning 25 countries. There was representation from scientific institutions, businesses, governments, local communities, sea management groups, NGOs, and the arts and education sector. This collective group, as represented by the authors, are referred to as "we" throughout this article.

Defining Kelp Forests

The Alliance decided early on that the Kelp Forest Challenge would include conservation activities from orders of brown, habitat-forming intertidal and subtidal seaweeds, the two most dominant of which are the orders Laminariales and Fucales. This decision was made with the recognition that in many parts of the world, these groups are referred to as kelp (Fraser 2012; Coleman and Wernberg 2017), provide very similar ecosystem functions, and often overlap in their distribution and co-occur (Fragkopoulou et al. 2022). Namely, these seaweeds provide a unique complex three-dimensional habitat that is anchored to
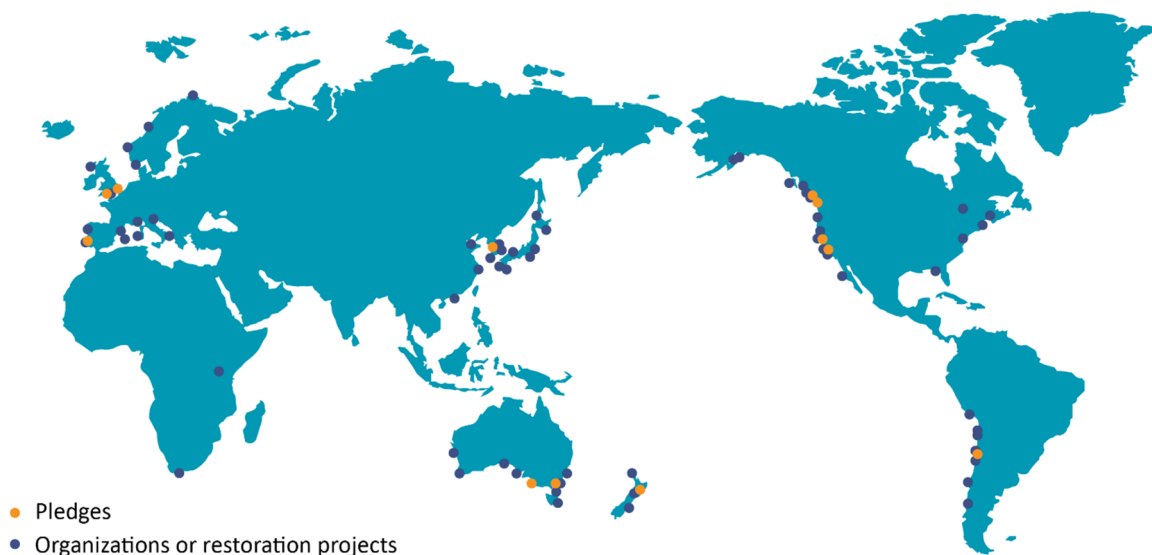

- Pledges
- Organizations or restoration projects

Fig. 1 Map of kelp restoration projects currently tracked on The Alliance website, organizations in The Alliance network (both in dark blue), and pledges to the Kelp Forest Challenge (orange) (Source: kelpforestalliance.com, accessed April 26, 2023). Projects are completed or ongoing restoration actions while pledges are commitments for future actions

rocky reef environments and supports biodiversity (Coleman and Wernberg 2017; Wernberg et al. 2019). As such, pelagic *Sargassum* which are not anchored to the seafloor would be excluded from this challenge, despite falling within the order Fucales. There are currently no known restoration activities related to species in the order Tilopteridales or Desmarestiales but they may also be included in the future if they meet the above criteria. These four orders contain 100 genera of kelp that fall within the scope of the Kelp Forest Challenge (Appendix 1).

How to set a target

We considered best available data and a wide suite of information to determine the target of the Kelp Forest Challenge, including how much kelp forest cover exists today, how much kelp forest has declined or degraded in the past 50 years (Krumhansl et al. 2016; Filbee-Dexter et al. 2022), what the current and future capacity for kelp forest restoration may be (Eger et al. 2022c), and available budgets and resources for conservation (Worldometer 2017; Eurostat 2023).

We compiled different scenarios using low vs. very high categories for each of the different approaches and generated a range of potential values for the target (Appendix 2). Estimating the historical and present global extent of kelp forests proved to be a particularly difficult task. We opted to use the most up to date estimates of observed kelp forest cover because estimates of modeled kelp forest typically reflect the potential kelp habitat, not the realized kelp distribution. We took an average estimation of 10 million hectares of kelp forests around the world based on the best available data and expert knowledge (Appendix 2, Pessarrodona et al. 2018; Mora-Soto et al. 2020; Eger et al. 2023, Pessarrodona et al. Unpublished).

Selecting a target

We then considered all information and scenarios and to understand which of the targets we thought were plausible, ambitious, or unrealistic (Appendix 2). The overarching considerations for setting the target values were: (i) that they should reflect what we thought the world should achieve for kelp forest conservation given the estimated extent of kelp forest, (ii) what will be possible with growing technology and capacity, and (iii) that the targets link to the Kunming-Montreal Protocol and the recently announced 30×30 targets (Convention on Biological Diversity 2022). Together, these considerations helped us generate aspirational targets. While the Global Biodiversity Target requires that 30% of habitat is protected and 30% of degraded habitat is restored by 2030, we opted for an ultimate end goal of 2040. The extended deadline reflects the fact that kelp forest restoration

has received much less research and investment than other ecosystems (Filbee-Dexter et al. 2022), can be more costly and difficult (Saunders et al. 2020), and requires new technological developments (Eger et al. 2022c). We also anticipate that, similar to other ecosystems (Saunders et al. 2020), the area under conservation will accelerate as these technologies and policies develop. Therefore the 2030 goal is a lower fraction (one fifth for restoration and one third for protection) of the final target.

The Kelp Forest Challenge is the beginning of a 17-year mission to create a global movement to protect and restore 4 million hectares of kelp forest by 2040. The target consists of a one-million-hectare target for restoration and a three million hectare target for protection of kelp forests by the year 2040, with sub-goals for the year 2030. The subgoal for 2030 is 200,000 hectares for restoration and 1,000,000 hectares for protection (Fig. 2). These values are aligned with the 30% values proposed by the Kunming-Montreal Protocol if we accept an average estimate of 10 million ha of current global kelp extent (Appendix 2) and an average estimate of 3 million hectares of lost kelp forest habitat (Filbee-Dexter et al 2022; United Nations Environment Programme 2023).

Pledges

Saving our kelp forests is not just a mission for governments and scientists. It is an inclusive goal in which anyone can participate. We invite pledges from all sectors of society. In addition to area-based pledges for protection and restoration, the Kelp Forest Challenge actively invites enabling, supporting, or awareness-based pledges. These pledges might not involve conservation directly, but they can help to support conservation programs or organizations to accelerate restoration and protection (Tedesco et al.
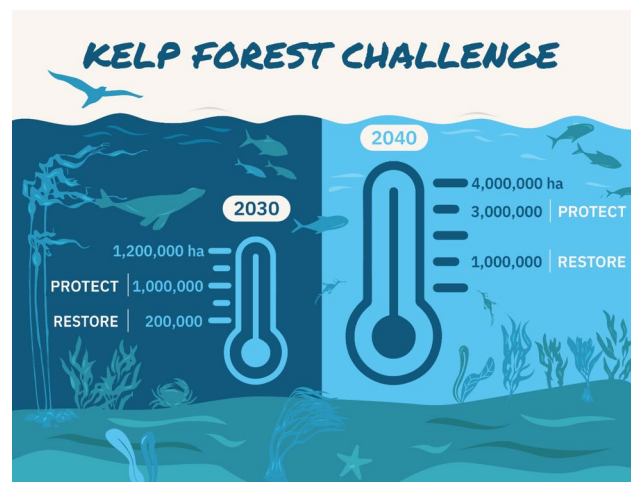

Fig. 2 Target values of the Kelp Forest Challenge

2023b). Alternatively, these pledges may work to increase awareness and understanding of kelp forests and communicate their importance to society. Examples of such types of pledges are researchers that improve restoration methods and reduce costs; businesses that loan equipment, technology, or software to help conservation; community groups assisting projects, professionals that volunteer their services such as legal, accounting, or marketing; artists, photographers, artists, or filmmakers that work to create pieces that communicate the beauty, diversity, or fragility of kelp forests; or organizations that provide funding to complete these projects (Fig. 3).

There was extensive discussion within The Alliance about the nature of the area-based pledges and whether they would be pledges to attempt restoration or commitments to achieve restoration. Ultimately, we decided, as a voluntary initiative, that it was best to encourage positive actions and attempts at protection or restoration while also holding those organizations accountable for reporting the outcomes of their work. Success may also be project specific and we want to give liberty to projects to define success as is appropriate for their local context (Waltham et al. 2020). Further, restoration is an iterative learning process and projects may learn important information from "failed" attempts (Fischer et al. 2021) and we did not want to discourage groups from trying. These cumulative learnings and small-scale, locally defined successes can indeed give rise to global progress in the field (McAfee et al. 2021). Therefore, the numbers in the Kelp Forest Challenge reflect pledges for areas under restoration and a commitment to follow established conservation practices (Gann et al. 2019), including best practices set out in the Kelp Restoration Guidebook (Eger et al. 2022b). Future work will focus on creating standardized monitoring and reporting protocols, metrics of success, and regular reporting on pledge activities to try and ensure the best possible project outcomes.

In the spirit of inclusivity and highlighting the level of activity linked to kelp forests, we decided that pledges do not need to be exclusive or additional. This means that pledges do not need to be exclusive to the Kelp Forest Challenge and may count towards multiple initiatives such as other local, regional, national, or international targets. Similarly, pledges for existing initiatives may also be accepted providing they meet the criteria and principles of the Kelp Forest Challenge. This decision allows stakeholders from diverse backgrounds to participate. Pledges to the Kelp Forest Challenge will be reviewed by a panel of experts from The Alliance community before being formally accepted to ensure that they meet the criteria outlined in this document. Positions on the panel are voluntary and anyone interested in joining may contact The Alliance.

Definition of protection and restoration activities

The Kelp Forest Challenge places conservation actions into two categories: 1) restoration, where the outcome is to restore a population that was lost and 2) protection, activities that positively impact existing kelp populations. The suite of activities that fall under either category is outlined in our kelp forest conservation typology (Appendix 3) which was developed in collaboration with the IUCN and connects to the IUCN's Restoration Barometer for tracking restoration across ecosystems (Saint-Laurent et al. 2020) (Table 1).

Because the level of protection afforded by marine protected areas can vary, entries to the site, area, and habitat protection category are also graded based on its protection status. These levels of protection are established by the IUCN Protected Area Management Categories (Dudley and Stolton 2008) and range from full protection (level I) to different levels of partial protection (level II-VI). If a conservation

Fig. 3 Different types of pledges that may be submitted to the Kelp Forest Challenge

area contains different types of habitats, we will only consider the amount of area that covers the potential niche of kelp forests (e.g., an appropriate depth, substrate, and environmental conditions). The Kelp Forest Challenge will track the amount of kelp forest area protected prior to its launch but will only accept pledges for protected areas that were declared after its launch in February 2023. Restoration areas within protected areas would however be classified as restored pledges.

The global target also explicitly excludes activities that involve afforestation or the creation of kelp forest habitat in an area that previously never had, nor would ever have, a kelp forest. Examples include creating cultured floating arrays of kelp in pelagic habitats (Antoine de Ramon et al. 2012) or creating artificial structures populated by kelp forests across extensive sandy bottoms (Taniguchi et al. 2001). Both are excluded from the Kelp Forest Challenge global targets and the IUCN Restoration Intervention Typology, on the grounds that they are not remedying environmental issues or generating meaningful ecological benefits versus the status quo (Saint-Laurent et al. 2020; Forbes et al. 2022).

Measuring the benefits for society

Kelp forest ecosystems provide a wide array of benefits and functions for people and marine environments. Simple metrics such as area protected and restored do not capture the dynamism of these benefits and functions. They do, however, provide universal, globally-applicable, easy-to-track, and easy-to-report metrics for assessing success (Dave

et al. 2017). While the goal of the Kelp Forest Challenge may be to protect 3 million hectares and restore 1 million hectares, the extended impact of protecting and restoring kelp forests around the globe includes increasing their associated biodiversity, and improving the livelihoods of the people that depend on them. In recognition of the benefits that kelp forests provide, the Kelp Forest Challenge encourages all projects involved to report on and celebrate the ecological and social benefits of kelp forests. While the Kelp Forest Challenge does not set any universal targets for restoring levels of ecosystem function or benefit, Alliance members are able to create goals for specific metrics such as jobs created, cultural ties renewed, or fish and invertebrate species recovered in their local area or region. Participants also have the option to create regional area based targets which are important for global scale success (McAfee et al. 2021). These specific or regional targets would be promoted via the same channels as the Kelp Forest Challenge but would be tracked independently.

Creating a participatory platform

The KFA has an online, freely available data platform for viewing and uploading information about kelp forest conservation projects (see kelpforestalliance.com). This platform will be used to track and monitor the success and outcomes of the Kelp Forest Challenge. On the platform, users can create individual profiles, organizational profiles, restoration and conservation project locations and outcomes, and pledges to the Kelp Forest Challenge will be displayed on the same platform.

Table 1 List of protection and restoration activities that are eligible for the Kelp Forest Challenge

Activity	Example Reference
Natural Regeneration	
Eliminate reef mining	(Støttrup et al. 2017)
Eliminate kelp harvesting	(Steen et al. 2016)
Pollution remediation	(Peterson 2001)
Nutrient enrichment (if limiting)	(Agatsuma et al. 2014)
Reduction of unsustainable kelp harvesting	(Bularz et al. 2022)
Artificial Regeneration	
Restoration or enhancement via seeding or transplanting	(Serisawa et al. 2005; Vergés et al. 2020)
Genetic selection for general fitness, temperature tolerance, etc	(Wood et al. 2020)
Supplementing natural habitat (e.g., adding substrate on existing kelp habitat)	(Eger et al. 2020)
Supplementing existing artificial structures, e.g., seawalls	(Morris et al. 2018)
Land or Water Protection	
Site, area, or habitat protection	(Dudley and Stolton 2008; Arafeh-Dalmau et al. 2021)
Predator population protections	(Babcock et al. 2010)
Invasive or problematic species control	
Grazer management (e.g., sea urchin control)	(Miller and Shears 2023)
Competitor removal, e.g., invasive species	(Gorman and Connell 2009)

The platform tracks the amount of area pledged for protection and restoration as well as the self-reported area restored or protected. There will also be an emphasis for reporting relevant indicators such as the ecosystem services or benefits resulting from that conservation, the number of people involved in the kelp forest community, and non-area-based pledges such as the dollar value of those pledges, the number of person-hours contributed, or the audience reached by an activity. The platform will also serve as a repository of useful documents and resources that can promote kelp forest conservation.

Community of practice principles

Protecting and restoring kelp forest ecosystems is a challenging activity, far more complex than any single one or two goal numbers can capture. Accordingly, The Alliance developed and adopted a set of guiding principles of best practices to ensure ethical and inclusive participation in the Kelp Forest Challenge, and to which participants are expected to adhere. While not exhaustive, these principles provide a basic code of conduct that advocates for inclusive, equitable, and meaningful actions. When making pledges to the Kelp Forest Challenge, organizations and individuals are also asked to pledge to adhere to these principles. A detailed list of the principles is contained in Appendix 4 but they are summarized in Table 2.

Kelp Forest Challenge launch

The Kelp Forest Challenge was launched on February 19th, 2023, at a special event before the 23rd International Seaweed Symposium in Hobart, Tasmania, Australia (iss2023.net). The launch of the event was commemorated with the announcement of the founding pledges. The program was able to launch with 23 pledges from eight countries, tens of thousands of hectares of area for kelp forest restoration, professional photo libraries for communication, specially composed songs about kelp forests, technology companies getting involved in environmental monitoring, and marketing groups helping to communicate the importance of kelp forests (Table 3).

Following the launch of the Kelp Forest Challenge, The Alliance coordinated two parallel workshops, one in person and one online. For these workshops we had 44 participants in person and 36 online, working to determine the necessary actions to achieve the ambition of the Kelp Forest Challenge. The workshops asked participants to identify the key barriers to scaling-up kelp forest restoration, the solutions to those barriers, and the priorities and impact of those actions. This input is now being compiled into a roadmap document outlining the priority changes needed to enable global scale kelp forest conservation.

Grounded in science and the International Seaweed Symposium (ISS)

Science based decision making will remain an important philosophy within The Alliance and the Kelp Forest Challenge. To this end, The Alliance hosted two scientific symposia on kelp restoration during ISS. These symposia highlighted progress, breakthroughs, and future directions in kelp forest conservation across the globe and brought restoration into the discussion at ISS. The ten talks featured speakers from Australia, New Zealand, California, Washington State, Norway, Japan, Korea, the Mediterranean, and a global overview. We were also pleased to create the inaugural Kelp Forest Presentation Prize, or "Kelpie," to be given to the presentation which describes a project that best embodies the principles of the Kelp Forest Challenge and its mission to engage multiple segments of society to equitably protect and restore kelp forest ecosystems

Table 2 Summary description of the principles of the Kelp Forest Challenge

Principle
1. Participants treat each other with mutual respect
2. Participants commit to the open and free flow of information that may benefit other projects and accelerate our joint mission
3. Participants respect the intellectual contributions of other participants
4. Restoring and protecting kelp forests should not be used as a substitute for greenhouse gas reductions or the remediation of other human activities that threaten coastal environments
5. Projects will respect and uphold the territorial rights and custodianship of Traditional and Indigenous Peoples, and their knowledge and cultural values
6. Projects will engage a diversity of stakeholders, residents, and voices when developing projects and ensure that benefits of a healthy ecosystem are equitably distributed and accessible
7. Any restoration activities strive to achieve the standards set out by the Society for Ecological Restoration
8. Ecosystem restoration and ecosystem protection are often both necessary, but protection should be prioritized
9. The data needed for science-based decision making in kelp forest ecosystems is currently limited, this gap does not preclude the need to make decisions, but it does stipulate that the advice and recommendations may change in the future as more data are collected

Table 3 Summary of initial pledges to the Kelp Forest Challenge, launched in February 2023

Organization	Country	Sector	Pledge Type	Metric	Pledged Value	Year to achieve Pledge
Korean Fisheries Resources Agency	South Korea	Federal government	Area restored	hectares	30,000	2030
Cascais Municipality	Portugal	Municipal government	Area restored	hectares	1	2025
Ocean Wise	Canada	Not for profit	Area restored	hectares	10	2030
Ocean Wise	Chile	Not for profit	Area restored	hectares	3,000	2030
Department of Natural Resources Washington	United States of America	Regional government	Area restored	hectares	2,023	2040
Puget Sound Restoration Fund	United States of America	Not for profit	Area restored	hectares	1	2028
Giant giant kelp restoration project	United States of America	Not for profit	Area restored	hectares	800	2030
Eastern Zone Abalone Industry Association	Australia	Business	Area restored	hectares	110	2030
Fish Reef Goleta Bay	United States of America	Not for profit	Area restored	hectares	200	2040
The Nature Conservancy	Australia	Not for profit	Area restored	hectares	50	2030
Love Rimurimu	New Zealand	Not for profit	Area restored	hectares	1	2025
The Nature Conservancy-California	United States of America	Not for profit	Area restored	hectares	30	2030
The Kelp Rescue Initiative	Canada	Not for profit	Area restored	hectares	1	2023
Operation Crayweed	Australia	Not for profit	Area restored	hectares	100	2030
Hullbot	Australia	Business	Research and Development	dollars	70,000	2025
Ethicly	United Kingdom	Business	Professional Services	hours	200	2023
Cliona Molins	Australia	Artist	Communication and Outreach	audience	500	2023
Mossy Earth	United Kingdom	Not for profit	Enabling Restoration	dollars	70,000	2023
			Communication and Outreach	audience	400,000	
Kelp Forest Foundation	The Netherlands	Not for profit	Research and Development	dollars	30,000	2025
Jennifer Adler	United States of America	Artist	Communication and Outreach	hours	100	2023
University of Sussex	United Kingdom	University	Research and Development	hours	pending	2023

and the benefits they provide to society. The Alliance hopes to maintain these ties to the scientific community and present this award at future symposia.

Next steps

Launching the Kelp Challenge is the beginning of a global movement to protect and restore 4 million hectares of kelp forest. Achieving this goal will require significant investments but if it is successful the result will be richer ecosystems, empowered communities, and benefits for society into the future. Some of this work is currently actionable while other elements require new research and development. All this work will require considerable resources and support, far more than any one organization or indeed country can achieve on its own. Creating a global community through the Alliance and movement through the Kelp Forest Challenge will hopefully encourage its participants to share in this task, pool resources, work across cultural and professional boundaries, share information, and jointly work towards our shared goals. Specific next steps include the above-mentioned roadmap which summarizes the key strategies and actions that are required to scale up kelp forest conservation as well as new working groups to help address key concepts.

The Kelp Forest Challenge extends a broad invitation to add new local, regional, and national level pledges to the Kelp Forest Challenge. Many of the initial pledges received were for the restoration of kelp forests, but it is important that we expand this work to collect more pledges for the protection of kelp forests. Achieving this aim will require us to better connect with fishers, tourist operators, and environmental government agencies, which are often responsible for managing protected areas (Day and Dobbs 2013).

As the Kelp Forest Challenge progresses, it is important that the progress is openly and accurately monitored. Yearly progress updates are requested and they will be openly accessible on The Alliance website. We are also continuing

the development of monitoring and reporting standards for kelp ecosystems and associated ecosystem services. This work will be done in collaboration with the Kelp Forest Alliance community and will help ensure a gold standard of data collection and allow for better data aggregation and comparison. This standardized and aggregated data can then help guide future decision making, enable large scale synthesis, benefit researchers, and communicate the importance of kelp forests to the public (Adams and Sandbrook 2013). National pledges will also be included in the IUCN Restoration Barometer.

Conclusion

Kelp forests are one of the fastest declining coastal ecosystems on the planet (Krumhansl et al. 2016; Feehan et al. 2021), leading to economic, ecological and cultural losses (Grover et al. 2021; Hynes et al. 2021). Urgent actions are needed to prevent losses wherever possible while restoring areas that are unable to recover without assistance. While kelp forests have been historically underappreciated and have received less attention than other ecosystems (Arafeh-Dalmau et al. 2021; Filbee-Dexter et al. 2022), there is a growing momentum of activity and interest in kelp forests.

The Kelp Forest Challenge was created with the intention to direct the growing interest in kelp forests around the globe and generate positive conservation outcomes while also benefiting and enriching the people and organizations around the world who are involved in kelp protection and restoration. An international alliance and target can help reduce knowledge gaps, increase inclusivity, and strengthen collaborations between countries and their citizens. It is hoped that the Kelp Forest Challenge can help achieve the same types of successful outcomes that were sparked by other international initiatives and targets. While it is no longer possible to say there is no global initiative for kelp forests, there is a significant amount of work remaining. We are confident that with collective action, we can be successful in our goal to increase cultural appreciation for kelp forests, increase the area of kelp forests that are protected or restored, and ultimately elevate kelp forests in the global conservation narrative.

Declarations

References

Adams WM, Sandbrook C (2013) Conservation, evidence and policy. Oryx 47:329–335

Agatsuma Y, Endo H, Yoshida S, Ikemori C, Takeuchi Y, Fujishima H, Nakajima K, Sano M, Kanezaki N, Imai H (2014) Enhancement of *Saccharina* kelp production by nutrient supply in the Sea of Japan off southwestern Hokkaido, Japan. J Appl Phycol 26:1845–1852

Anderson RJ, Rand A, Rothman MD, Share A, Bolton JJ (2007) Mapping and quantifying the South African kelp resource. Afr J Mar Sci 29:369–378

Antoine de Ramon N, Chynoweth DP, Capron ME, Stewart JR, Hasan MA (2012) Negative carbon via ocean afforestation. Process Saf Environ Prot 90:467–474

Arafeh-Dalmau N, Schoeman DS, Montaño-Moctezuma G, Micheli F, Rogers-Bennett L, Olguin-Jacobson C, Possingham HP (2020) Marine heat waves threaten kelp forests. Science 367:635

Arafeh-Dalmau N, Cavanaugh KC, Possingham HP, Munguia-Vega A, Montaño-Moctezuma G, Bell TW, Cavanaugh K, Micheli F (2021) Southward decrease in the protection of persistent giant kelp forests in the northeast Pacific. Commun Earth Environ 2:119

Atwood TB, Hammill E (2018) The importance of marine predators in the provisioning of ecosystem services by coastal plant communities. Front Plant Sci 9:1289

Babcock RC, Shears NT, Alcala AC, Barrett NS, Edgar GJ, Lafferty KD, McClanahan TR, Russ GR (2010) Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects. Proc Nat Acad Sci 107:18256–18261

Bennett S, Wernberg T, Connell SD, Hobday AJ, Johnson CR, Poloczanska ES (2016) The 'Great Southern Reef': social, ecological

and economic value of Australia's neglected kelp forests. Mar Freshw Res 67:47–56

de Bettignies T, de Bettignies F, Bartsch I, Bekky T, Boiffin A, Casado de Amezúa P, Christie H, Edwards H, Fournier N, Garcia A (2021) Background Document for Kelp Forests habitat. OSPAR. https://epic.awi.de/id/eprint/55098/

Biblioteca del Congreso Nacional de Chile (2020) Crea Bonificacion Para El Repoblamiento Y Cultivo De Algas. Electronic file available at https://www.bcn.cl/leychile/navegar?idNorma=1091690 (Accessed August 25, 2023)

Biermann F, Kanie N, Kim RE (2017) Global governance by goalsetting: the novel approach of the UN Sustainable Development Goals. Curr Opin Environ Sustain 26:26–31

Bingham H, Lewis E, Belle E, Stewart J, Klimmek H, Wicander S, Bhola N, Bastin L (2021) Protected Planet Report 2020: Tracking progress towards global targets for protected and conserved areas. https://www.unep.org/resources/protected-planet-report-2020 (Accessed August 25, 2023)

Blamey LK, Bolton JJ (2018) The economic value of South African kelp forests and temperate reefs: Past, present and future. J Mar Syst 188:172–181

Le Blanc D (2015) Towards integration at last? The sustainable development goals as a network of targets. Sustain Dev 23:176–187

Bularz B, Fernández M, Subida MD, Wieters EA, Pérez-Matus A (2022) Effects of harvesting on subtidal kelp forests (*Lessonia trabeculata*) in central Chile. Ecosphere 13:e3958

Buschmann AH, Prescott S, Potin P, Faugeron S, Vasquez JA, Camus C, Infante J, Hernández-González MC, Gutierrez A, Varela DA (2014) The status of kelp exploitation and marine agronomy, with emphasis on *Macrocystis pyrifera*, in Chile. Adv Bot Res 71:161–188

Butler C, Lucieer VL, Wotherspoon SJ, Johnson CR (2020) Multi-decadal decline in cover of giant kelp *Macrocystis pyrifera* at the southern limit of its Australian range. Mar Ecol Prog Ser 653:1–18

Coleman MA, Kelaher BP, Steinberg PD, Millar AJK (2008) Absence of a large brown macroalga on urbanized rocky reefs around Sydney, Australia, and evidence for historical decline. J Phycol 44:897–901

Coleman MA, Wernberg T (2017) Forgotten underwater forests: The key role of fucoids on Australian temperate reefs. Ecol Evol 7:8406–8418

Convention on Biological Diversity (2010) Aichi biodiversity targets. In: COP 10 Decis. X2 Strateg. Plan Biodivers. 2011–2020. Secretariat of the Convention on Biological Diversity

Convention on Biological Diversity (2022) Kunming-Montreal Global biodiversity framework. In: Kunming-Montreal Global biodiversity framework Draft decision submitted by the President. Montreal, Canada - https://www.cbd.int/doc/c/e6d3/cd1d/daf663719a03902a9b116c34/cop-15-l-25-en.pdf

Cornwall CE, Hepburn CD, McGraw CM, Currie KI, Pilditch CA, Hunter KA, Boyd PW, Hurd CL (2013) Diurnal fluctuations in seawater pH influence the response of a calcifying macroalga to ocean acidification. Proc Roy Soc B 280:20132201

Dave R, Saint-Laurent C, Moraes M, Simonit S, Raes L, Karangwa C (2017) Bonn challenge barometer of progress: Spotlight report 2017. IUCN, Gland, Switzerland

Day JC, Dobbs K (2013) Effective governance of a large and complex cross-jurisdictional marine protected area: Australia's Great Barrier Reef. Mar Policy 41:14–24

Dillehay TD, Ramírez C, Pino M, Collins MB, Rossen J, Pino-Navarro JD (2008) Monte Verde: seaweed, food, medicine, and the peopling of South America. Science 80:784–786

Duarte CM, Gattuso J, Hancke K, Gundersen H, Filbee-Dexter K, Pedersen MF, Middelburg JJ, Burrows MT, Krumhansl KA, Wernberg T (2022) Global estimates of the extent and production of macroalgal forests. Glob Ecol Biogeogr 31:1422–1439

Dudley N, Stolton S (2008) Defining protected areas: an international conference in Almeria, Spain. IUCN, Gland

Eger AM, Eddy N, Gleason M, Layton C, McHugh T, Steinberg P, Vergés A (2022a) The Kelp Forest Alliance: A global community of practice to understand, advise, and motivate kelp forest conservation and restoration. Limnol Oceanogr 31:130–132

Eger AM, Layton C, McHugh TA, Gleason M, Eddy N (2022b) Kelp restoration guidebook: lessons learned from kelp projects around the world. The Nature Conservancy, Arlington, VA, USA

Eger AM, Marzinelli EM, Beas-Luna R, Blain CO, Blamey LK, Byrnes JEK, Carnell PE, Choi CG, Hessing-Lewis M, Kim KY, Kumagai NH, Lorda J, Moore P, Nakamura Y, Pérez-Matus A, Pontier O, Smale D, Steinberg PD, Vergés A (2023) The value of ecosystem services in global marine kelp forests. Nat Commun 14:1894

Eger AM, Marzinelli EM, Christie H, Fagerli CW, Fujita D, Gonzalez AP, Hong SW, Kim JH, Lee LC, McHugh TA (2022c) Global kelp forest restoration: past lessons, present status, and future directions. Biol Rev 97:1449–1475

Eger AM, Vergés A, Choi CG, Christie HC, Coleman MA, Fagerli CW, Fujita D, Hasegawa M, Kim JH, Mayer-Pinto M, Reed DC, Steinberg PD, Marzinelli EM (2020) Financial and institutional support are important for large-scale kelp forest restoration. Front Mar Sci 7:535277

Erlandson JM, Graham MH, Bourque BJ, Corbett D, Estes JA, Steneck RS (2007) The kelp highway hypothesis: marine ecology, the coastal migration theory, and the peopling of the Americas. J Isl Coast Archaeol 2:161–174

Eurostat (2023) Government expenditure on environmental protection. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Government_expenditure_on_environmental_protection. Accessed 22 Apr 2023

Feehan CJ, Filbee-Dexter K, Wernberg T (2021) Embrace kelp forests in the coming decade. Science 373:863

Filbee-Dexter K, Wernberg T, Barreiro R, Coleman MA, de Bettignies T, Feehan CJ, Franco JN, Hasler B, Louro I, Norderhaug KM (2022) Leveraging the blue economy to transform marine forest restoration. J Phycol 58:198–207

Fischer J, Riechers M, Loos J, Martin-Lopez B, Temperton VM (2021) Making the UN decade on ecosystem restoration a social-ecological endeavour. Trends Ecol Evol 36:20–28

Forbes H, Shelamoff V, Visch W, Layton C (2022) Farms and forests: evaluating the biodiversity benefits of kelp aquaculture. J Appl Phycol 34:3059–3067

Fragkopoulou E, Serrão EA, De Clerck O, Costello MJ, Araújo MB, Duarte CM, Krause-Jensen D, Assis J (2022) Global biodiversity patterns of marine forests of brown macroalgae. Glob Ecol Biogeogr 31:636–648

Fraser CI (2012) Is bull-kelp kelp? The role of common names in science. N Z J Mar Freshw Res 46:279–284

Gann GD, T. M, Walder B, Aronson J, Nelson CR, Jonson J, Hallet JG, Eisenberg C, Guarigata MR, Liu J, Hua F, Echeverría C, Gonzales E, Shaw N, Decleer K, Dixon KW (2019) International principles and standards for the practice of ecological restoration. Second edition. Restor Ecol 27:S1-S46

Global Mangrove Alliance (2019) Taking Action to Increase Global Mangrove Habitat by 20 percent by 2030: The Global Mangrove Alliance http://hdl.handle.net/20.500.11822/28817

Gorman D, Connell SD (2009) Recovering subtidal forests in human-dominated landscapes. J Appl Ecol 46:1258–1265

Grover IM, Tocock MS, Tinch DR, MacDonald DH (2021) Investigating public preferences for the management of native and invasive species in the context of kelp restoration. Mar Policy 132:104680

Hirsh HK, Nickols KJ, Takeshita Y, Traiger SB, Mucciarone DA, Monismith S, Dunbar RB (2020) Drivers of biogeochemical variability in a Central California kelp forest: Implications for local amelioration of ocean acidification. J Geophys Res Ocean 125:e2020JC016320

Hulme M (2016) 1.5 C and climate research after the Paris Agreement. Nat Clim Chang 6:222–224

Hynes S, Chen W, Vondolia K, Armstrong C, O'Connor E (2021) Valuing the ecosystem service benefits from kelp forest restoration: A choice experiment from Norway. Ecol Econ 179:106833

International Coral Reef Initiative (2021) Addendum to the ICRI Recommendation on the inclusion of coral reefs and related ecosystems within the CBD Post-2020 Global Biodiversity Framework. - https://icriforum.org/documents/recommendation-on-the-inclusion-of-coral-reefs-and-related-ecosystems-within-the-cbd-post-2020-global-biodiversity-framework/

Jayathilake DRM, Costello MJ (2021) Version 2 of the world map of laminarian kelp benefits from more Arctic data and makes it the largest marine biome. Biol Conserv 257:109099

Krumhansl KA, Okamoto DK, Rassweiler A, Novak M, Bolton JJ, Cavanaugh KC, Connell SD, Johnson CR, Konar B, Ling SD, Micheli F, Norderhaug KM, Pérez-Matus A, Sousa-Pinto I, Reed DC, Salomon AK, Shears NT, Wernberg T, Anderson RJ, Barrett NS, Buschmann AH, Carr MH, Caselle JE, Derrien-Courtel S, Edgar GJ, Edwards M, Estes JA, Goodwin C, Kenner MC, Kushner DJ, Moy FE, Nunn J, Steneck RS, Vásquez J, Watson J, Witman JD, Byrnes JEK (2016) Global patterns of kelp forest change over the past half-century. Proc Natl Acad Sci 113:13785–13790

Lucrezi S (2021) Characterising potential participants in kelp monitoring in the recreational diving community: A comparative study of South Africa and New Zealand. Glob Ecol Conserv 28:e01649

Mangialajo L, Gianni F, Airoldi L, Bartolini F, Francour P, Meinesz A, Ballesteros E (2008) Conservation and restoration of *Cystoseira* forests in the Mediterranean Sea: The role of marine protected areas. Rapp Comm Int Mer Mediterr 40:2013

McAfee D, Costanza R, Connell SD (2021) Valuing marine restoration beyond the 'too small and too expensive.' Trends Ecol Evol 36:968–971

Meskell L (2014) States of conservation: Protection, politics, and pacting within UNESCO's World Heritage Committee. Anthropol Q 87:217–243

Miller KI, Shears NT (2023) The efficiency and effectiveness of different sea urchin removal methods for kelp forest restoration. Restor Ecol 31:e13754

Mora-Soto A, Palacios M, Macaya EC, Gómez I, Huovinen P, Pérez-Matus A, Young M, Golding N, Toro M, Yaqub M (2020) A high-resolution global map of Giant kelp (*Macrocystis pyrifera*) forests and intertidal green algae (Ulvophyceae) with Sentinel-2 imagery. Remote Sens 12:694

Morris RL, Konlechner TM, Ghisalberti M, Swearer SE (2018) From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence. Glob Chang Biol 24:1827–1842

Moy FE, Christie H (2012) Large-scale shift from sugar kelp (*Saccharina latissima*) to ephemeral algae along the south and west coast of Norway. Mar Biol Res 8:309–321

O'Connor K (2017) Seaweed: a global history. Reaktion Books Ltd., London

Paris Agreement (2015) Paris agreement. In: Report of the Conference of the Parties to the United Nations Framework Convention on Climate Change (21st Session, 2015: Paris). https://unfccc.int/resource/docs/2015/cop21/eng/10.pdf. Retrieved December 2022

Pérez-Lloréns JL, Mouritsen OG, Rhatigan P, Cornish ML, Critchley AT (2020) Seaweeds in mythology, folklore, poetry, and life. J Appl Phycol 32:3157–3182

Pessarrodona A, Moore PJ, Sayer MDJ, Smale DA (2018) Carbon assimilation and transfer through kelp forests in the NE Atlantic is diminished under a warmer ocean climate. Glob Chang Biol 24:4386–4398

Peterson CH (2001) The "Exxon Valdez" oil spill in Alaska: acute, indirect and chronic effects on the ecosystem. Adv Mar Biol 39:1–103

Pinho D, Bertocci I, Arenas F, Franco JN, Jacinto D, Castro JJ, Vieira R, Sousa-Pinto I, Wernberg T, Tuya F (2015) Spatial and temporal variation of kelp forests and associated macroalgal assemblages along the Portuguese coast. Mar Freshw Res 67:113–122

Pörtner H-O, Scholes RJ, Agard J, Archer E, Arneth A, Bai X, Barnes D, Burrows M, Chan L, Cheung WL (2021) IPBES-IPCC co-sponsored workshop report on biodiversity and climate change. IPBES IPCC 28.

Protocol M (1987) Montreal protocol on substances that deplete the ozone layer. US Government Printing Office, Washington DC 26:128–136

Rilov G, Fraschetti S., Gissi E, Pipitone C, Badalamenti F, Tamburello L, Menini E, Goriup P, Mazaris AD, Garrabou J, Benedetti-Cecchi L (2020) A fast-moving target: achieving marine conservation goals under shifting climate and policies. Ecol Appl 30:e02009

Rogers-Bennett L, Catton CA (2019) Marine heat wave and multiple stressors tip bull kelp forest to sea urchin barrens. Sci Rep 9:15050

Saint-Laurent C, Begeladze S, Vidal A, Hingorani S (2020) The Bonn Challenge: building momentum on restoration. Unasylva 252:82–91

Saunders MI, Doropoulos C, Babcock RC, Bayraktarov E, Bustamante RH, Eger AM, Gilles C, Gorman D, Steven A, Vanderklift MA, Vozzo M, Silliman BR (2020) Bright spots in the emerging field of coastal marine ecosystem restoration. Curr Biol 30:R1500–R1510

Schmidt-Traub G, Shah A (2015) Investment needs to achieve the sustainable development goals. Sustainable Devevelopment Solutions Network. https://www.jstor.org/stable/pdf/resrep15864.pdf (Retrieved August 2023)

Serisawa Y, Imoto Z, Taino S, Choi CG, Ishikawa T, Ohno M, Hiraoka M (2005) Marine afforestation of *Ecklonia cava* by using a spore bag method at an Isoyake area in Tosa Bay, southern Japan. Jap J Phycol 53:19–24

Smale DA (2020) Impacts of ocean warming on kelp forest ecosystems. New Phytol 225:1447–1454

Steen H, Moy FE, Bodvin T, Husa V (2016) Regrowth after kelp harvesting in Nord-Trøndelag, Norway. ICES J Mar Sci 73:2708–2720

Støttrup JG, Dahl K, Niemann S, Stenberg C, Reker J, Stamphøj EM, Göke C, Svendsen JC (2017) Restoration of a boulder reef in temperate waters: Strategy, methodology and lessons learnt. Ecol Eng 102:468–482

Tamburello L, Chiarore A, Fabbrizzi E, Colletti A, Franzitta G, Grech D, Rindi F, Rizzo L, Savinelli B, Fraschetti S (2022) Can we preserve and restore overlooked macroalgal forests? Sci Total Environ 806:150855

Taniguchi K, Yamane H, Sasaki K, Agatsuma Y, Arakawa H (2001) Marine afforestation of the kelp *Eisenia bicyclis* in coralline flats by introduction of porous-concrete reefs. Nippon Suisan Gakkashi 67:858–865

Techera E, Valckenaere J, Platjouw FM, Gnanalingam G, Hepburn CD, Nelson W, Flack B, Sander G (2023) Kelp forests in law and policy. In: Into the Blue: Securing a Sustainable Future for Kelp Forests. United Nations Environment Program, Nairobi, p 12

Tedesco AM, Brancalion PHS, Hepburn MLH, Walji K, Wilson KA, Possingham HP, Dean AJ, Nugent N, Elias-Trostmann K, Perez-Hammerle K-V (2023a) The role of incentive

mechanisms in promoting forest restoration. Phil Trans Roy Soc B 378:20210088

Tedesco AM, López-Cubillos S, Chazdon R, Rhodes JR, Archibald CL, Pérez-Hämmerle K-V, Brancalion PHS, Wilson KA, Oliveira M, Correa DF (2023b) Beyond ecology: ecosystem restoration as a process for social-ecological transformation. Trends Ecol Evol 3217:11

Thurstan RH, Brittain Z, Jones DS, Cameron E, Dearnaley J, Bellgrove A (2018) Aboriginal uses of seaweeds in temperate Australia: an archival assessment. J Appl Phycol 30:1821–1832

United Nations Environment Programme (2023) Into the Blue: Securing a Sustainable Future for Kelp Forests. Nairobi, GRID-Arendal. Norway. Retrieved from https://policycommons.net/artifacts/3936672/into-the-blue/4743745/ on 14 April 2023

Vásquez JA, Zuñiga S, Tala F, Piaget N, Rodríguez DC, Vega JMA (2014) Economic valuation of kelp forests in northern Chile: values of goods and services of the ecosystem. J Appl Phycol 26:1081–1088

Vergés A, Campbell AH, Wood G, Kajlich L, Eger AM, Cruz DO, Langley M, Bolton D, Coleman MA, Turpin J, Crawford M, Coombes N, Camilleri A, Steinberg PD, Marzinelli EM (2020) Operation Crayweed – ecological and sociocultural aspects of restoring Sydney's underwater forests. Ecol Manag Restor 21:74–85

Vergés A, Steinberg PD, Hay ME, Poore AGB, Campbell AH, Ballesteros E, Heck KL, Booth DJ, Coleman MA, Feary DA, Figueira W, Langlois T, Marzinelli EM, Mizerek T, Mumby PJ, Nakamura Y, Roughan M, van Sebille E, Sen GA, Smale DA, Tomas F, Wernberg T, Wilson SK (2014) The tropicalization of temperate marine ecosystems: climate-mediated changes in herbivory and community phase shifts. Proc Roy Soc B 281:20140846

Vié J-C., Hilton-Taylor C, Stuart SN (eds) (2009). Wildlife in a Changing World – An Analysis of the 2008 IUCN Red List of Threatened Species. IUCN, Gland 180 pp

Waltham NJ, Elliott M, Lee SY, Lovelock C, Duarte CM, Buelow C, Simenstad C, Nagelkerken I, Claassens L, Wen CKC (2020) UN Decade on Ecosystem Restoration 2021–2030—What chance for success in restoring coastal ecosystems? Front Mar Sci 7:71

Washington State Legislature (2022) Conserving and restoring kelp forests and eelgrass meadows in Washington state. Senate Bill 5619

Wernberg T, Krumhansl K, Filbee-Dexter K, Pedersen MF (2019) Status and trends for the world's kelp forests. In: Sheppard C (ed) World seas: An environmental evaluation. Elsevier, Amsterdam, pp 57–78

Wood G, Marzinelli EM, Vergés A, Campbell AH, Steinberg PD, Coleman MA (2020) Using genomics to design and evaluate the performance of underwater forest restoration. J Appl Ecol 57:1988–1998

Worldometer (2017) GDP by Country. https://www.worldometers.info/gdp/gdp-by-country/. Accessed 27 Nov 2022

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