One Earth

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Commentary

State of the world's kelp forests

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Kelp forests, vital to global biodiversity and coastal economies, face degradation and underfunded conservation. The "State of the World's Kelp Forests" finds that 16% of the kelp biome is protected and 2% of the restoration target is met and provides a rallying call to meet global commitments for kelp forest conservation.

Forests of the sea

Kelp forests are one of the world's largest marine ecosystems, of immense ecological, cultural, and economic importance, yet they are declining worldwide and are often the forgotten forests of our planet.[1] While the Convention on Biological Diversity and the Kunming-Montreal Global Biodiversity Framework calls for protection of 30% of the world's ecosystems and restoration of 30% of degraded systems by 2030,[2] kelp forest ecosystems have largely been neglected in international conservation targets. The Kelp Forest Challenge aims to address this need and calls on governments and civil society to restore 200,000 ha by 2030 and 1 million ha by 2040, while also protecting 1 and 3 million ha of kelp forests by 2030 and 2040, respectively.[3] Still, progress in meeting these goals for kelp forests is behind other terrestrial and marine ecosystems. This lag presents a serious threat to ocean health as kelp forests are a dominant habitat in temperate and Arctic seas. As countries embrace this challenge, it is important that we accurately assess the starting point and track progress toward 30x30 and the Kelp Forest Challenge.

Humans are inextricably linked to kelp forests, and these ecosystems provide immense ecological, economic, and cultural value. Kelp forests cover more than a third of the world's coastlines, occur within 50 km of at least 740 million people, and represent a total value of over 500 billion USD every year.[4] In addition to their economic value, these underwater forests provide the foundational habitat and food for thousands of species, ranging from microscopic invertebrates up to the whales that forage around their canopy. Iconic species such as abalone, rock lobster, and rockfish are linked to kelp forests, and these underwater forests support billions of dollars of cultural and commercial fisheries worldwide.[4] The loss of kelp can have negative impacts on local fisheries. In California, the recreational red abalone fishery, once valued at $44 million USD annually, was closed in 2018 following an 80% decline in abalone populations. Among other factors, this decline was driven by the extreme loss of bull kelp.[5] Kelp forests are also key primary producers, with some species growing up to a 0.5 meter per day. Some of this primary production is sequestered long-term and ultimately removed from the atmosphere, with the latest estimates suggesting that kelp forests sequester at least 31 million tons of CO_2 annually.[6] Kelps are also used in a wide array of food, pharmaceutical, and biomedical products, with wild forests providing 771,000 tons of raw material while also acting as source material for 17.5M tons of kelp produced via aquaculture each year (https://www.fao.org/fishery/en/collection/global_production).

The health of kelp forests worldwide

Kelp forests are one of the most vulnerable marine ecosystems to climate change, second only to coral reefs.[7] While there is regional variation in the health of kelp forests, overall, they are declining at an average rate of 1.8% per year with an estimated 40%–60% of kelp forests degraded in the last fifty years[1] (Figure 1). Declines are most notable at warm range edges (e.g., Western Australia), driven by regional warming and extreme climate events like marine heatwaves, which lead to the replacement of kelps by more warm-adapted species, inhibiting recovery.[8] Abundant sea urchin populations are often linked to warming waters (or a lack of urchin predators) and the combination of the two stressors can result in extreme kelp forest losses.[5] Mid-latitude kelp forests exhibit variable trends depending on local climatic, ecological (e.g., overabundant sea urchins), and anthropogenic factors, with some showing resilience to extreme heat events.[9] Stability or growth in overall kelp cover is seen in regions with fewer heatwaves and cooling trends,[10] although shifts to warm-tolerant kelp species are sometimes observed, which can alter ecosystem functions.[11] Arctic kelp forests are generally stable or increasing, with future warming potentially expanding their range.[12] However, limited data

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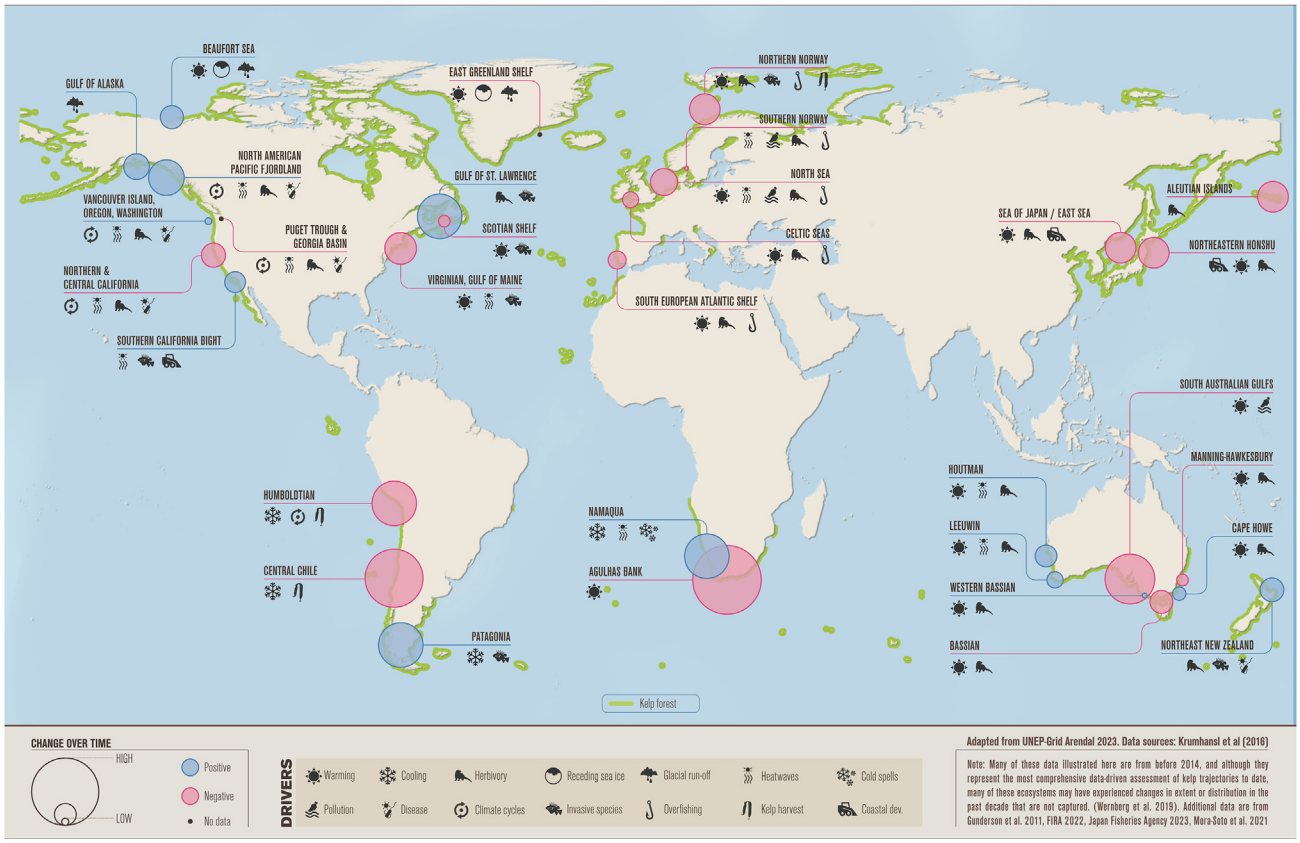

Figure 1. Global map of kelp forest distribution, population trends, and stressors

Regional variation and drivers or decline and increase for kelp forest populations around the world. Red bubbles indicate decreases, blues indicate increases, and the size of the bubble indicates the magnitude of change. Icons represent the drivers of change. Adapted from GRID-Arendal.[1]

collection hampers comprehensive understanding of Arctic kelp trends.

Despite supporting biodiversity and blue economies, kelp forests receive a fraction of the funding and attention received by coral reefs, mangroves, and seagrass ecosystems. In 2021, for every one instance a kelp forest was cited in international law and policy, mangroves were cited 43 times, coral reefs 38 times, salt marshes 20 times, and seagrass 8 times.[13] As a national example, in Australia (2015), kelp forests received 13 times less funding than coral reefs, despite covering a much larger fraction of the coastline and supporting more endemic animal life.[14] In the academic literature in 2020, for every one article on kelp conservation, there were ~7 on saltmarsh, 12 on oyster reefs, 14 on coral reefs, and 17 on mangroves.[15]

Despite so many people living near a kelp forest, there is a general lack of awareness among the public about their role and importance. This collective lack of understanding may potentially be related to the access barrier—most kelp forests are cold water ecosystems that live in cold, turbid, and often rough waters. As such, these ecosystems do not receive the same number of visitors and promotion as their better-known counterpart in the tropics, coral reefs. They are also, for the most part, subtidal, often too deep to see from the surface, and epitomize the concept of "out of sight, out of mind." The result is less public support for kelp forest management and fewer grassroots campaigns for their protection. Fewer dollars invested leads to fewer conservation outcomes achieved.

Yet, despite these challenges, we do not wish to suggest that there has been no work in kelp forest conservation. There is indeed a dedicated and highly capable kelp community of practice across the world. This community is rapidly evolving and highly supportive and is collectively working to move us toward reaching global targets. The "State of the World's Kelp Forests" is a global assessment of kelp conservation efforts and collects current progress toward protecting and restoring kelp forests globally (https://kelpforestalliance.com/state-of-the-worlds-kelp-report).

Kelp forest area protected

Kelp forest populations and ecosystems benefit from different forms of protection or sustainable management, including reduction or elimination of kelp harvest, fishing, pollution, or habitat destruction while also including traditional and sustainable uses by rightsholders. To achieve the best outcomes for kelp populations and local communities, kelp forests should be incorporated into the planning and management of marine protected areas (MPAs).[16] Importantly, MPAs alone are unlikely to buffer climate impacts, and society must reduce CO_2 emissions and incorporate additional climate strategies into kelp forest management.[17]

We estimated the amount of Laminarian kelp forest currently protected by

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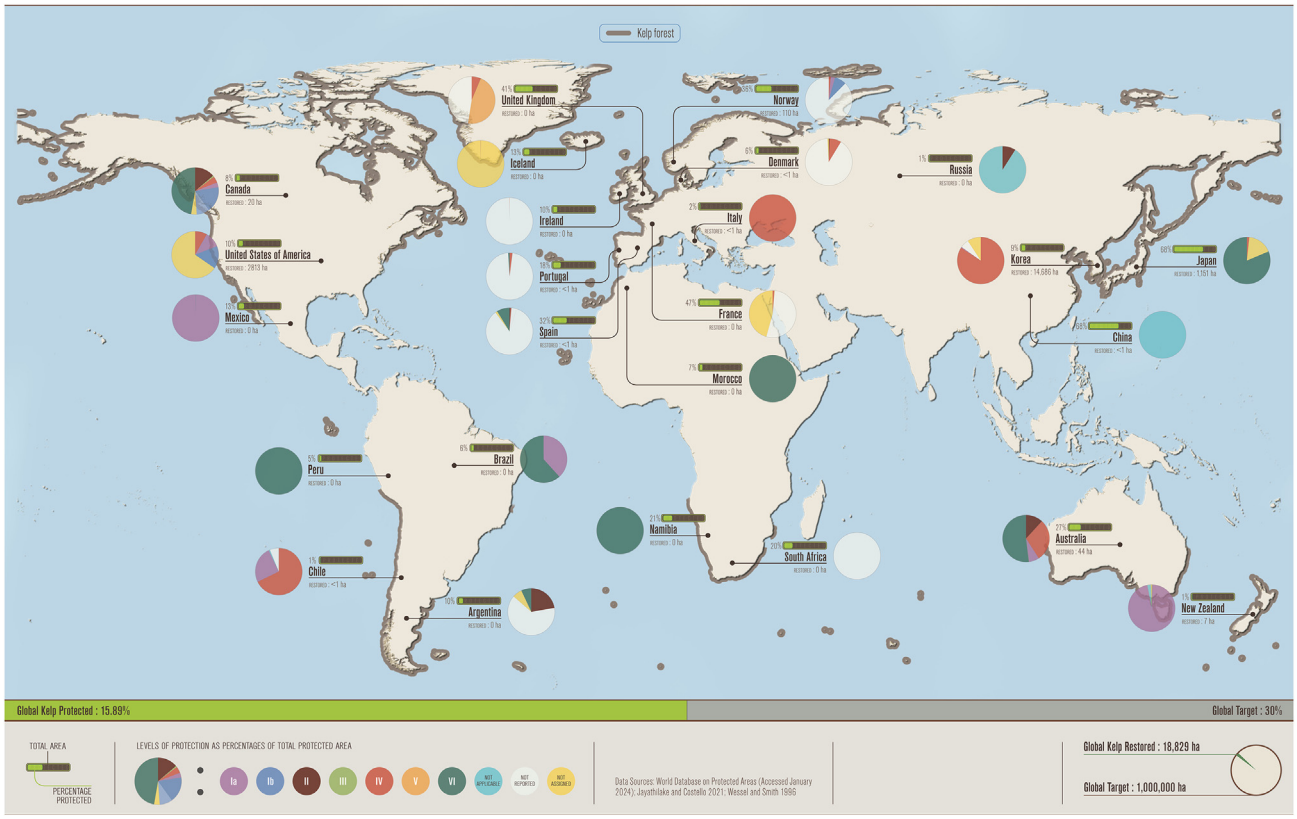

Figure 2. Global conservation status of kelp forests

World map of kelp forest area protected and restored. Restored refers to the amount of kelp forest area that projects have successfully restored since 1958 (hectares). Protected refers to the amount of kelp forest biome that is under some form of marine protection or management as of January 2024. Protection categories correspond to the scheme developed by the International Union for the Conservation of Nature.

overlaying the global distribution of MPAs categorized by their level of protection (/www.protectedplanet.net/en/thematic-areas/wdpa), onto the global kelp forest biome, which includes 147 kelp species.[18] Areas with "higher" levels of protection have more restrictions on activities that can occur in their boundaries (e.g., fishing or construction). While both datasets will be improved in the future (e.g., better kelp maps, better MPA classifications), this analysis provides estimates of the kelp forest area protected worldwide and countries can use these values to guide their targets.

There is currently an estimated 15.9% of kelp forests worldwide in some form of protected area (as of January 2024). Currently, only 1.6% of these areas are classified in IUCN protection categories Ia-III, the highest levels of protection. Approximately 4.2% of kelp forests are under the lowest form of protection (level VI). Further, a sizable portion of kelp forests under protection are in areas not currently categorized (6.8%, not reported, not assigned, not applicable, Figure 2). This lack of classification makes it unclear how effectively those areas protect kelp forests. Some of these areas might offer no protection at all, while others could be highly protected but not recognized as such.

Five countries (Japan, France, United Kingdom, Norway, and Spain) have potentially met their 30x30 targets for kelp forests. However, most of the kelp protected in France, United Kingdom, and Spain are in areas not classified in the IUCN protection schema. Therefore, it is unknown whether those areas provide effective protection for kelp forest habitat. Very little of the classified areas in these countries are highly protected (i.e., no-take areas where fishing is prohibited) (Japan - 0%, France - 0%, United Kingdom - <0.1%, Norway - 3.9%, Spain - 0.2%) the most effective type of MPA for biodiversity conservation.[19] Most countries (14) have protected 10% or less of their kelp forest habitat in some form of MPA. However, only one country, has potentially protected 10% of its kelp forest habitat in fully protected areas (IUCN Classification Ia-III).

Additionally, this analysis does not account for other critical factors affecting MPA effectiveness to protect kelp, such as fishing restrictions, proper implementation, enforcement, and funding.[17] Most MPAs do not report whether they limit fishing, even though many are labeled as fully protected under IUCN categories. Efforts are ongoing to better classify global protected areas (e.g., protected seas, MPA Atlas) to improve understanding of kelp forest protection and the effectiveness of different regulatory categories.

Despite most countries not meeting these targets, some sub-national regions in the USA and South Africa recently established networks of MPAs that currently fully protect more than 10% of their floating kelp forests.[20] These processes followed participatory approaches based on scientific guidelines.

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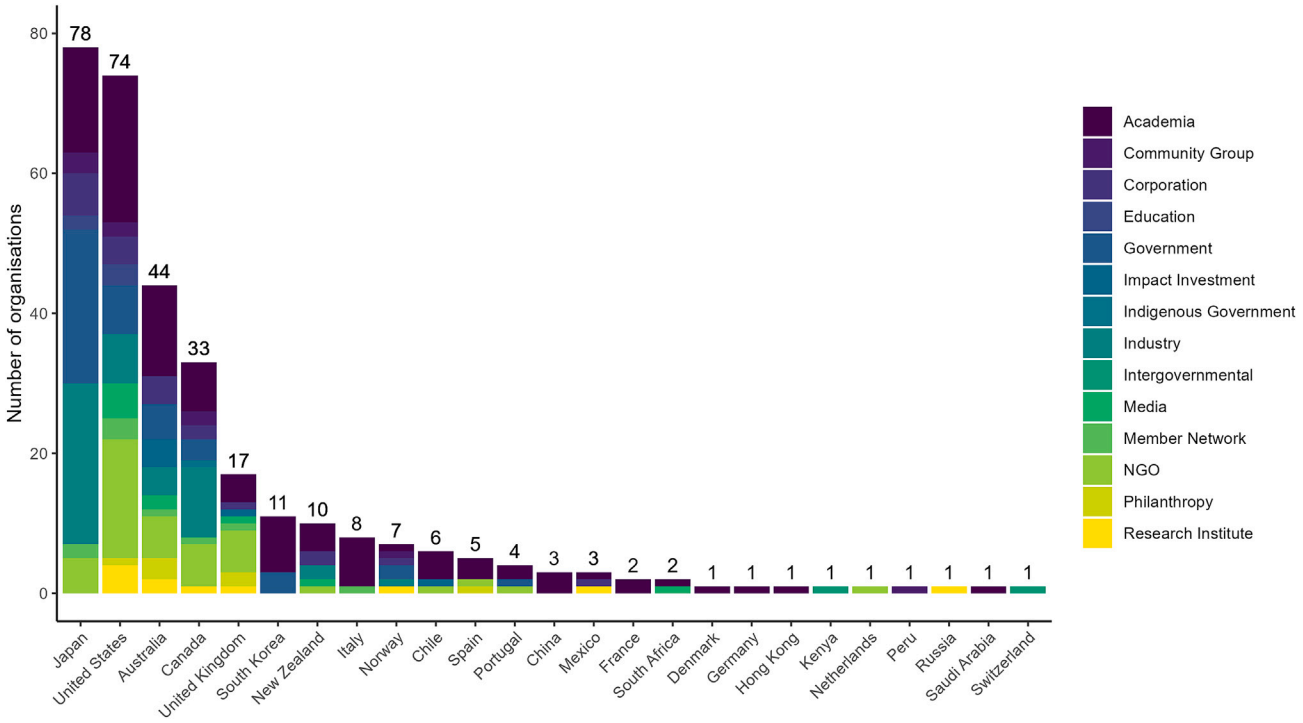

Figure 3. Global composition of kelp forest conservation community

Break down by sectors of the number of organizations involved in kelp forest conservation by country. The values are based on the Kelp Forest Alliance community database (https://kelpforestalliance.com/restoration-projects).

Kelp forest area restored

Globally, approximately 19,000 ha of kelp forests have been registered as restored since 1958. This value represents ~2% of the goal set by the Kelp Forest Challenge and relies on values registered in the Kelp Forest Alliance restoration database. This open database tracks global kelp restoration efforts and currently includes 238 projects (https://kelpforestalliance.com/restoration-projects). The platform allows users or administrators to upload project data and maintain a living database of global progress. While the database is inclusive, it is currently only available in English, and this creates bias in the recorded projects as a result.

Japan and South Korea have restored the most area, thereby contributing to the field over multiple decades.[21] This success has been achieved through a combination of political will, advanced systems for growing kelp, and reliable, long-term project funding. Elsewhere, kelp restoration work has been largely experimental with new methods still under development and is supported by limited funding and policy interest. These factors mean that many projects have only restored small areas. For example, the United States and Australia have recorded many individual projects over many years but have restored little total area in recent years.

To provide the best chance of large-scale restoration success, future projects should learn from past lessons while governments should model the stable and committed funding models found in Japan and Korea.

South Korea is home to the world's largest kelp restoration project. Starting in 2009, the federally run Korean Fisheries Resource Agency pledged to restore 54,000 ha of kelp forests by 2030 and has now placed 29,000 ha of kelp forests under restoration, with an approximate success rate of 50%. The project initially relied on artificial reefs and kelp transplantation but faced some opposition regarding eco-engineering and has since shifted toward restoring rocky reefs instead of creating new artificial habitat. Restorative techniques leverage the country's aquaculture expertise, including rearing kelp for planting and dispersing zoospores. Interest in managing sea urchin populations has grown, addressing their role in the failure of earlier restoration efforts and as urchin barren formation continues to be a prevalent inhibitor of kelp persistence in South Korea and globally (https://www.fira.or.kr/english/english_index.jsp).

Japan has trialed many different restoration methods over the years, with hundreds of projects in the last century. Their methodologies have included transplanting, seeding, urchin control, and artificial reef building. Similar to South Korea, kelp restoration in Japan is federally supported with multi-year and consistent funding. While records for many historic projects are difficult to access in English, there is evidence of the world's largest single restoration project using transplants in the Shizuoka prefecture, covering 870 ha.[22] New projects are now increasing as Japan launched J-Blue Credit, the world's only blue carbon kelp forest credit. Since 2022, ~600 ha of kelp forest has been restored under this initiative (https://www.blueeconomy.jp/credit/vandi/).

The Kelp Forest Challenge

Protecting and restoring kelp forests is possible and highly beneficial to coastal

ecosystems and communities. However, kelp is still poorly represented in international and national governmental targets. We now need far greater investment from most countries around the world to ensure that we meet the goals of the Global Biodiversity Framework and the Kelp Forest Challenge. This challenge is a grassroots, collaborative initiative that invites every part of society to work together, increase funding, increase awareness, and protect 3 million ha and restore 1 million ha of kelp forests by 2040. The Kelp Forest Challenge is supported by the Kelp Forest Alliance, a global community of purpose composed of 550 people from 320 organizations across 25 countries (Figure 3).

Governments and organizations may join the Alliance and the challenge by pledging to protect and restore kelp forest ecosystems in their home waters. Corporations and industry can pledge their financial resources, technical capability, or social capital to enable kelp conservation. Individuals can volunteer time and skills to their local kelp conservation project. This breadth of activity reflects the many ways people are connected to kelp forests and the many types of solutions needed to meet kelp restoration targets. To date, the challenge has received pledges for 55,000 ha of restoration. To reach the global target of restoring 1 million ha by 2040, countries need to substantially increase the number and scale of kelp restoration projects. Including kelp forests in action plans for the Global Biodiversity Framework can help achieve this goal.

While many nations have historically overlooked kelp forest conservation, there is a growing, grassroots capacity and eagerness to scale up kelp protection and recovery. The work of nations like South Korea, Japan, USA, and South Africa, their prioritization of kelp forest protection or restoration, indicates that with sustained investment and government support, countries can restore and protect kelp forests at large scales. As kelp forests experience accelerated losses globally, we call on governments to realize their commitments to the Global Biodiversity Framework and ensure that kelp forests are represented in that work. Working together, we can realize the potential of the Kelp Forest Challenge, help the kelp, and ensure healthy and resilient oceans for our future.

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AUTHOR CONTRIBUTIONS

A.M.E. conceptualized the manuscript; A.M.E., N.A.-D., A.G.O., and A.V. conducted formal analysis; A.M.E. wrote a first draft; all authors provided substantial comments and edits to the draft; A.M.E. designed the figures; and all authors read the final version prior to publication.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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