



**KELP FOREST
ALLIANCE**

State of the World's Kelp Forests Report 2026

2ND EDITION

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The Kelp Forest Alliance is the global home for kelp forest conservation. We bring together researchers, practitioners, Indigenous and coastal communities, governments and partners to share knowledge, build connections and help turn knowledge and passion into coordinated action for kelp forests around the world.

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yaʔyaʔnəŋ u cxʷ?

(Are you listening?)

Julianna Sullivan – Port Gamble S'Klallam Tribe



Some of my earliest memories are sitting cross-legged on the floor of my preschool classroom, quietly watching as the grandmothers sang us our songs. In their hands was a rattle made from bull kelp, its rhythm carrying our language, our teachings, and the voices of those who came before us. Though we were taught to listen with respect and intention, there

was something about the sound of the kelp rattle and the grandmothers' voices that drew us in. Even as young children, we knew those moments held something sacred.

Years later, kelp would carry me far beyond my own shoreline.

Kelp introduced me to Indigenous relatives from coastlines I had never walked, whose languages I do not speak, yet whose hearts recognised something familiar in my own. Although our languages, traditions, and coastlines are beautifully distinct, something remarkable happened when we gathered. In every story, every laugh, every song, and every teaching, we found reflections of our own relationships with kelp. What once felt like isolated experiences became part of a much larger story—one that has been unfolding along coastlines around the world since time immemorial.

Each gathering felt like drawing water from a deep well. Every person arrived carrying teachings from their own homeland, entrusted to them by their ancestors and communities. As those teachings were shared with humility and received with gratitude, the well grew deeper and purer. No one left with less. Somehow, we all left carrying more.

Mi'kmaq Elder Albert Marshall's teaching of *Etuaptmumk*, or *Two-Eyed Seeing*, became a guiding light for our journey. One eye recognises the strengths of our Indigenous ways of knowing, the other the strengths of Western science. It is only with both eyes open that we can better understand our kelp forests and find ways to better care for the world around us.

As kelp forests face unprecedented challenges, this growing circle of Indigenous kelp stewards reminds us that we are not alone. Across oceans, we are reconnecting to share knowledge, strengthen one another, and remember what the tides have always known—that the ocean connects us all.

My hope is that this spirit ripples outward, inspiring us to approach this work with curiosity, humility, and relationships rooted in respect, reciprocity, and care for the living world.

w'yaʔyaʔnəŋ cn.

(Yes, I am listening.)





Craig Foster – Sea Change

I'm at the tip of Africa in the Great African Seaforest. I watch in awe. A female pyjama shark is attempting to attach one of her eggs to a kelp holdfast by rotating her body around and around to weave the egg case thread into the kelp. Then something happened that I could never have imagined. A male pyjama shark appeared and repeatedly placed his body as protection between the female and any threat. As far as I know, this kind of protective behaviour is unknown in sharks.

Once the egg case was safely attached, both sharks moved away. Now the tiny shark would feed on the yolk inside the egg for at least six months before hatching, vulnerable to predation from starfish and whelks. I stared at the newly laid egg and felt a deep vulnerability in myself, because something told me that the survival of

this species was woven into my own survival. We feel separate, but that's not actually the case, as biodiversity health and human health are fundamentally linked.

Our future survival depends on our relationship with Mother Nature. Nurturing that relationship is the most important single thing we can do to support life and the coming lives of the next generation.

Kelp forests are places on Earth Mother's body that have great wealth and density of species. They represent reservoirs of hope. They are amongst the most fragile and critical places to look after. Each act of caring and protection is an act of self-care. All our lives, animal and human, rest in her arms.





Welcome to Kelp Forests



Authors: Kira Krumhansl, Thomas Wernberg, Karen Filbee-Dexter, Adriana Vergés, Aaron Eger

KEY TAKEAWAYS

- Kelp forests cover **one-third of our world's coastlines**.
- Areas within 50 km of a kelp forest are home to **950 million people** and account for **18% of global GDP**.
- **40–60% of these systems have declined in the last 50 years.**

1.1 KELP FORESTS

Simply put, kelp forests are the forests of the sea.

Kelp forests sit at a striking ecological and social crossroads. Kelp forests occur along a third of the world's coastlines (Figure 1.1), and more than 950 million people live within 50 km of one¹. These giant seaweed forests are among the most productive ecosystems on Earth.

Collectively, they generate an estimated US\$500 billion in potential value each year². They also support an extraordinary range of life, from microscopic bacteria to sharks and whales. People are equally connected to

these underwater forests through the food, livelihoods, cultural values, coastal protection, and other benefits they provide.

Yet despite their scale and importance, kelp forests remain poorly recognised in many parts of the world. They are often absent from public awareness, overlooked in environmental planning, and inconsistently defined in policy and regulation. In most countries, only a very small share of environmental funding is directed towards kelp forests. As a result, they are generally less well mapped, studied, monitored, managed, and protected than terrestrial forests, coral reefs, mangroves, or seagrass meadows.

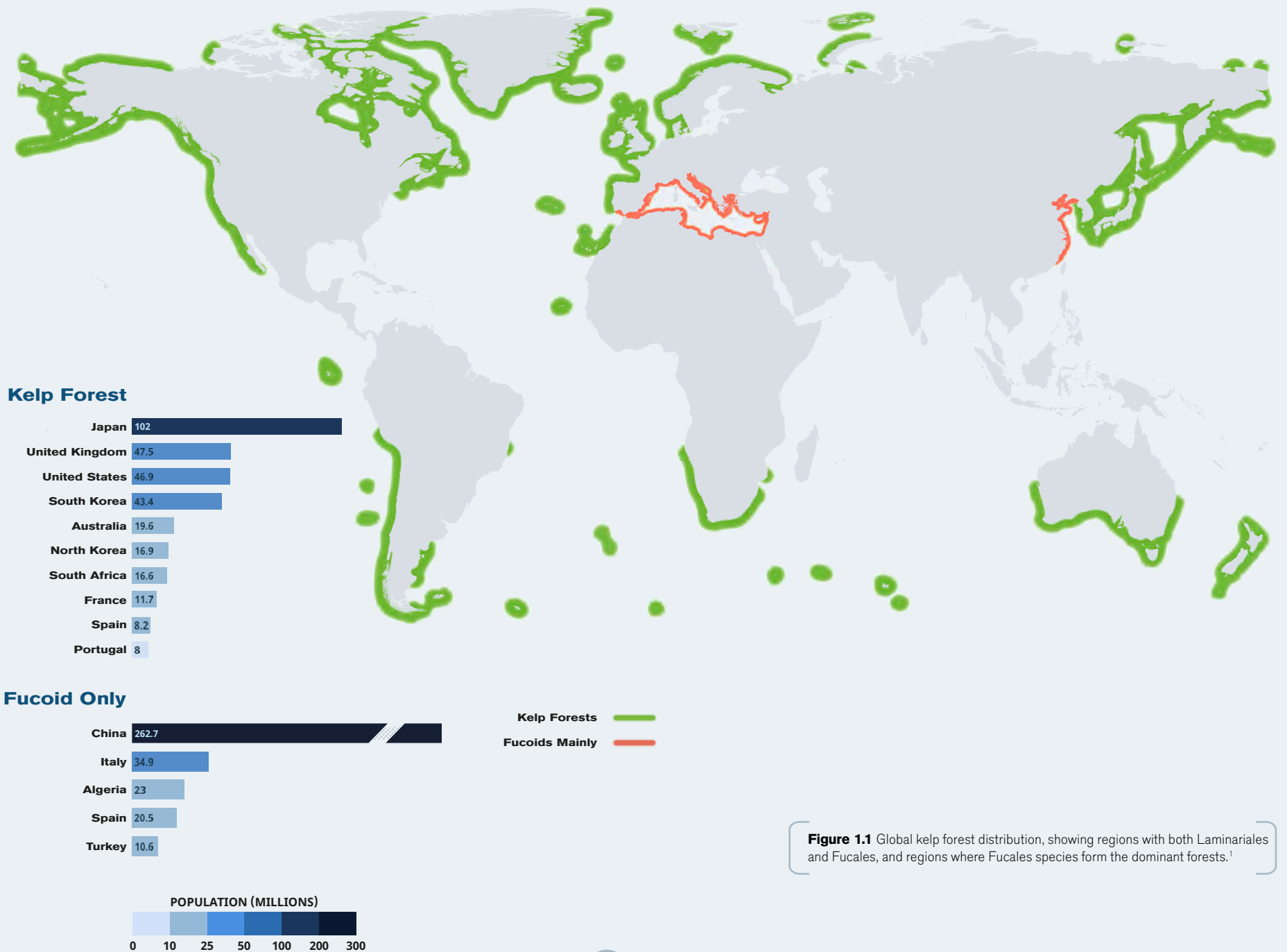


Figure 1.1 Global kelp forest distribution, showing regions with both Laminariales and Fucales, and regions where Fucales species form the dominant forests.¹

This situation is, however, beginning to change. Kelp forest protection, sustainable management, and restoration are expanding, supported by a growing funding pool and a broader network of practitioners, communities, governments, and researchers. Public awareness is also increasing, helping kelp forests move from relative obscurity towards a more prominent place in conversations about ocean health.

This momentum comes at an important time. Global interest is growing in approaches such as nature-positive development, blue carbon, and biodiversity credits. These emerging policy, finance, and market frameworks could create significant opportunities for kelp forests, but only if they are recognised clearly and represented credibly. The challenge now is to ensure that greater visibility translates into sustained investment, stronger policy, better knowledge, and effective conservation.

1.1.1 WHAT IS KELP?

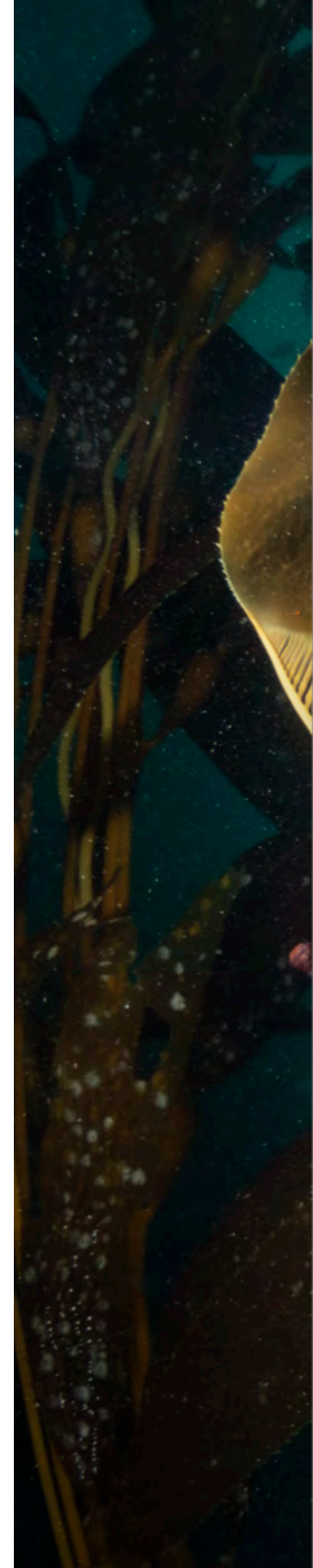
Kelp is both an organism and a habitat. As an organism, kelp is a structurally complex brown seaweed (see full list here⁸) that creates a canopy. Most kelp belong to the taxonomic orders Laminariales and Fucales and are referred to as macroalgae: large, visible algae or seaweeds.

All kelps are a type of seaweed, but not all seaweeds are a type of kelp.

Kelps are attached to the seafloor, grow vertically, create a leafy structure and canopy, absorb carbon and produce oxygen, and cycle nutrients. Several kelp together create a kelp forest, although the term 'kelp forest' does not have a strict definition. Kelps create unique, complex homes for animals in their blades ("leaves"), stipes ("trunks", "stems"), and holdfasts ("roots"), and their very presence defines the ecosystem (Figure 1.2).

1.1.2 DISTRIBUTION AND DEPTH

Kelp forests are mostly subtidal (always under water), extending from the water's edge down to 15–25 metres, within sunlight's reach. In particularly clear waters, they can live at depths of up to 40–60 metres and, in very rare instances, all the way down to 200 metres. Kelp forests are cold-water (approximately 0–25 °C) ecosystems and are distributed on every continent from the subtropics to the poles. The only kelp forests in the tropics are in very deep waters, and they occupy a very small area.







1.1.3 MEET THE KELP



SURFACE CANOPY

These species are over 10 metres tall from the seafloor to the surface. They have a strong holdfast gripping them to the seafloor, flexible stipes, and dense canopies that float on the surface, where they can often be seen from shore or by satellite.



MID-WATER CANOPY

These kelps have stiff, trunk-like stipes that grow upright in the water with leaves growing from the top. They live only beneath the waves and do not break the surface.



SEAFLOOR CANOPY

These kelps have big leafy branches that grow from the top of the stipe down to the seafloor. This creates a dense canopy that you have to brush aside to swim through.



INTERTIDAL CANOPY

These kelps straddle the line between land and sea and form dense mats on the seafloor, where they are often exposed to the air at low tide.

INTERTIDAL CANOPY



SURFACE CANOPY

MID-WATER CANOPY

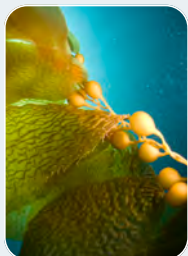
SEAFLOOR CANOPY

Kelp species come in many shapes and sizes, ranging from tens of centimetres to tens of metres tall.

Figure 1.2 Kelp growth forms and examples of forest-forming species.

Several species have captured public attention, either for their ecological and economic significance or simply because of their striking appearance.

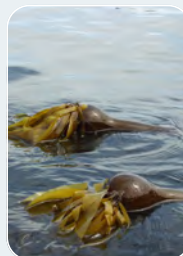
GIANT KELP



Giant kelp (*Macrocystis pyrifera*) is one of the most iconic species of kelp, recognised for its dense, towering forests that are vital to marine biodiversity. It is a perennial species, present all year round, and commonly found along the eastern Pacific from Alaska to Mexico. Further south, it is well distributed along the west and south coasts of South America, with populations also in New Zealand, southern Australia, and many oceanic islands in the Southern Ocean.



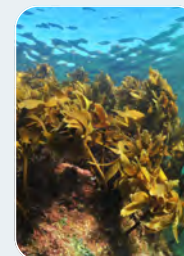
BULL KELP



Bull kelp (*Nereocystis luetkeana*) is found predominantly along the west coast of North America, beginning in central California and extending to the Aleutian Archipelago and further into Russia. Bull kelp is an annual species with cycles of growth, reproduction, and senescence (ageing and decline) each year. It gets its common name from its bullwhip-like form and has been an important part of Indigenous cultures in North America for millennia.



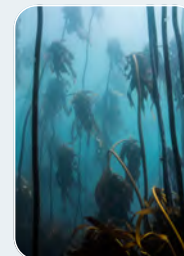
GOLDEN KELP



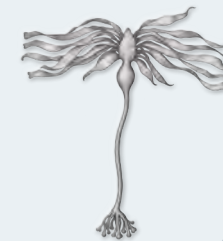
Golden kelp (*Ecklonia radiata*) forms extensive forests in the Western Pacific and is the key component of the Great Southern Reef on the southern half of Australia.



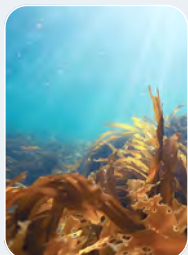
BAMBOO KELP



Bamboo kelp (*Ecklonia maxima*) is found only off the coast of Southern Africa, and sharks weave through its towering trunks. It was recently featured in the Oscar-winning documentary, My Octopus Teacher.



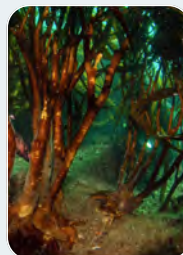
LAMINARIA AND SACCHARINA



Laminaria and *Saccharina* are known for the big, broad leaves of many of their species. These species are well known for their use in food (known as kombu in Japan), are often grown for aquaculture, and have many important medical and chemical derivatives. They are widespread across the Pacific and North Atlantic.



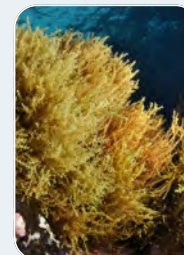
LESSONIA



Lessonia species are native to the southern Pacific Ocean. As they are often intertidal and subtidal, they provide critical connectivity habitat in coastal zones. Lessonia support one of the largest wild harvests of kelp on the planet.



CYSTOSEIRA



The *Cystoseira* furoid kelps create shorter, dense meadows of kelp habitat along rocky seashores but are also found in subtidal regions.



1.2 THREATS AND STRESSORS

Threats to kelp forests fall into three main categories.

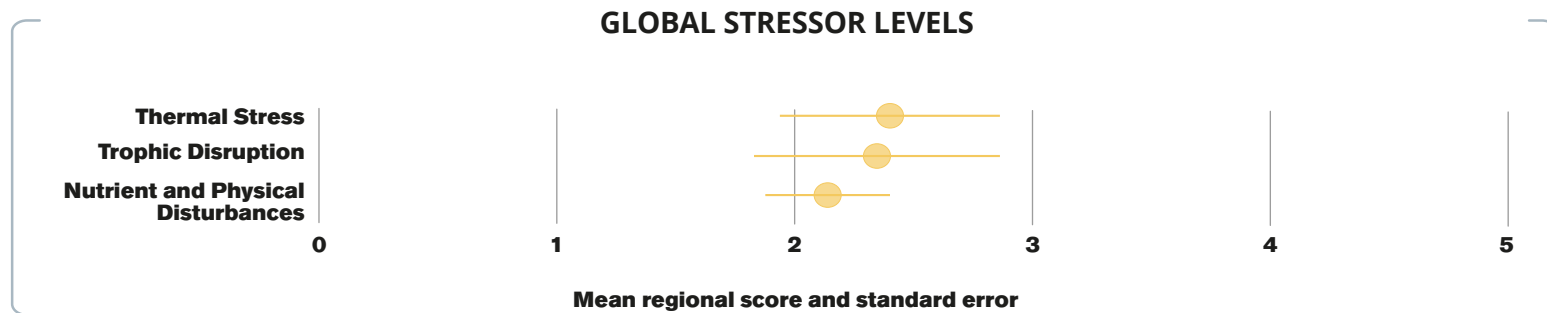
Ocean warming: Short-lived marine heatwaves or prolonged periods of elevated water temperature can push kelp beyond their biological limits and interfere with growth, reproduction, and survival, while also amplifying the impacts of overgrazing.

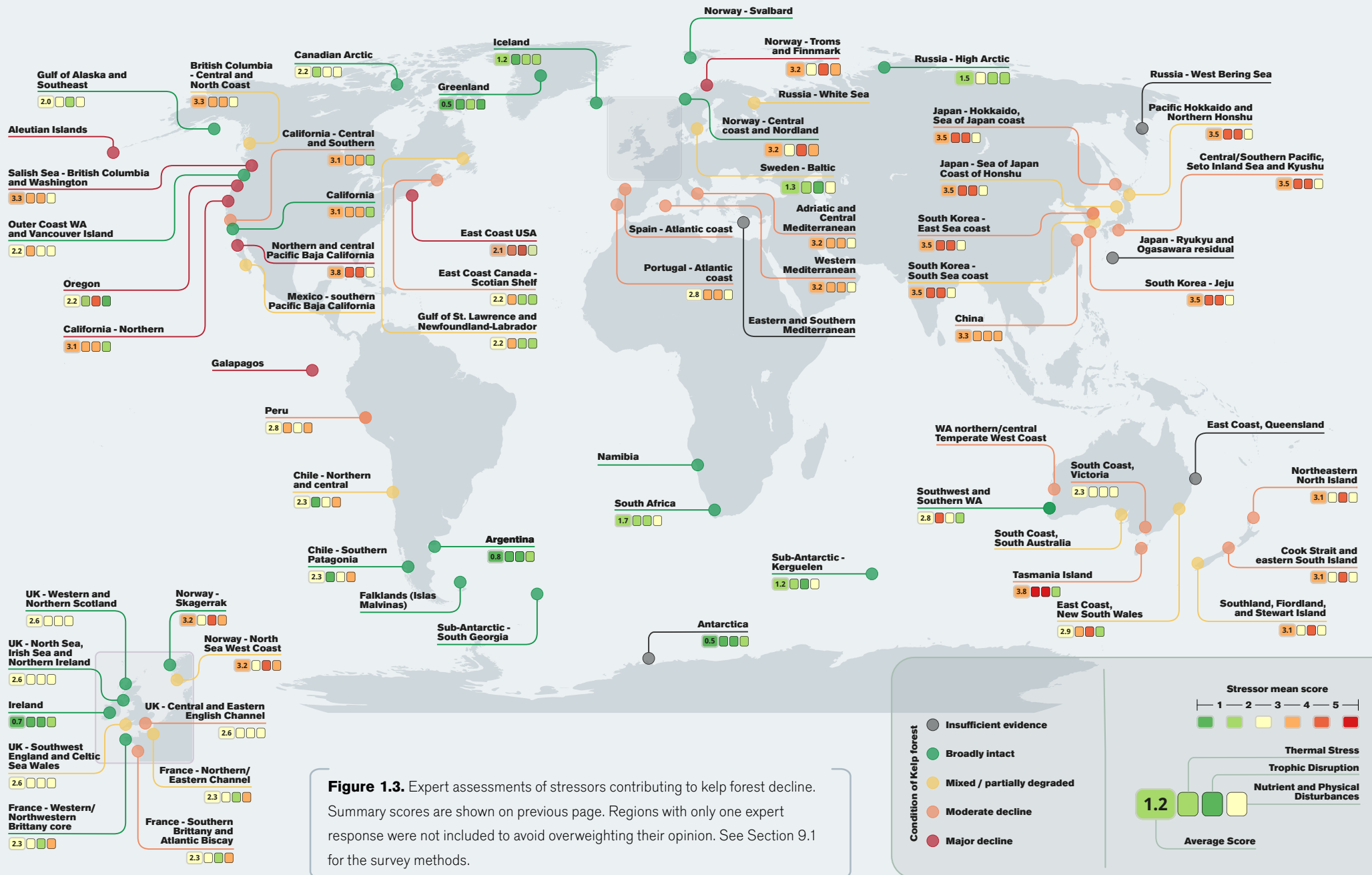
Overgrazing: An overabundance of animals that eat kelp forests, often linked to ecological imbalance such as predator loss (sea otters, sunflower sea stars, wolffish, lobsters, and predatory fish) or range expansions of grazers.

Nutrient and physical disturbances: Activities that physically destroy kelp or disrupt part of its life cycle. Examples include removal for harvest or development, light limitation (excess sedimentation or nutrients), sediment scouring of kelp spores from the seafloor, or a lack of nutrients needed for growth.

While we focus on the three key drivers described above, additional reasons for local kelp decline include invasive species, freshwater outflows, ice scouring, or diseases.

At the global scale, experts rank warming as the greatest threat, followed by overgrazing, and then physical disturbances. The effects of these stressors vary locally, regionally, and globally (Figure 1.3).





1.3 KELP FOREST HEALTH

The broad global pattern is one of decline, although kelp forest condition varies considerably among regions (Figure 1.3). Long-term datasets indicate that roughly 40–60% of kelp forests have experienced reductions in abundance globally.³ The kelp forests which have experienced the greatest losses are concentrated near the warm edges of kelp distributions, where marine heatwaves compound ongoing ocean warming and can drive rapid, large-scale collapse. In some of these locations, kelp forests are replaced by other seaweeds and species better adapted to warmer conditions, making natural recovery and restoration more difficult.

Across temperate, mid-latitude regions, kelp forests are more commonly stable. If degraded, losses are usually less severe than in warm-edge populations. The state of kelp health depends on how local temperature trends interact with other pressures, including harvesting and intense grazing by sea urchins. These populations often show greater capacity to persist through, or recover from, extreme heat than kelp forests already living near their upper thermal limits.

At higher latitudes and in cool-water refuges, kelp forests are generally stable or expanding. In some regions, heat-tolerant species are replacing cooler-water kelps,

maintaining overall cover but altering ecosystem structure and function. In the Arctic, limited evidence suggests kelp forests are largely stable or increasing, with potential for further expansion as waters warm in some areas. However, melting of glaciers, permafrost, and other ice stores may increase sedimentation and lower salinity, potentially offsetting these gains.

1.4 THE RACE TO HELP OUR KELP

December 2022 marked the launch of the Kunming-Montreal Biodiversity Framework. This landmark agreement was adopted by 196 countries and agreed to the effective protection of 30% of the world's ecosystems and the restoration of 30% of the world's degraded ecosystems by 2030 (often called 30x30).⁴ The agreement specifies that these gains should be representative of the ecosystems in each country's jurisdiction. As such, national targets for the protection and restoration of coastal ecosystems must be adaptive and ensure that all critical habitats are quantified and represented in these international discussions and target setting. Yet, this global conservation agenda was advancing against a backdrop where kelp forests remained consistently underrepresented. For example, a 2023 study⁵ showed that for every mention of kelp forests in international

policy documents, seagrass, salt marsh, coral reefs, and mangroves were referenced 8–43 times as often.

Most importantly, there was no flagship global agenda for kelp forests, in contrast to seagrass, salt marsh, coral reefs, and mangroves.

The Kelp Forest Challenge was launched in February 2023⁶ to address the critical gap in representation of kelp forests in international targets, policies, and agreements, and to ensure their inclusion in local and global marine management decisions. The Challenge is a collaboratively developed mission to save and enhance kelp forests around the world and is at the intersection of local projects and global initiatives such as 30x30.

The Challenge provides an open, participatory, pledge-based system to incentivise kelp conservation and raise awareness. The Challenge intentionally encourages any sector of society to participate, including businesses, governments, communities, universities, and individuals. The Kelp Forest Challenge is hosted by the Kelp Forest Alliance, a global home for kelp forests that brings together people and information to help our kelp.

The Kelp Forest Challenge calls for holistic management of kelp forests, which requires a combination of strategies. These can include marine protected areas (MPAs), improved fisheries management, habitat

restoration, and controlling invasive or overabundant species. This management will depend on collaborative efforts between local communities, governments, and conservation organisations, and management decisions should be grounded in scientific research, respect cultural contexts, and consider socio-economic activities to ensure sustainable and equitable outcomes for both people and marine ecosystems.

THE KELP FOREST CHALLENGE CALLS FOR:

The protection of 3 million hectares of kelp forests by 2040

The restoration of 1 million hectares of kelp forests by 2040

Increased awareness and appreciation of kelp forests

US\$14 billion raised to support these activities by 2040.



PLEDGE SPOTLIGHT

Hyundai is supporting kelp forest restoration and recognition through partnerships with government agencies and local organisations.

Since 2023, Hyundai has worked with South Korea's Ministry of Oceans and Fisheries and the Korea Fisheries Resources Agency to support sea forest restoration along the coast of Ulsan. The initiative has included the formal naming of restored sea forests in Ulsan and the recognition of a natural sea forest near Ulleungdo.

This work has since expanded through Forests Without Names,⁷ an initiative focused on giving previously unnamed sea forests clear, place-based identities. Sea forests in Australia and Argentina have now been named through the initiative.

Many sea forests remain unnamed and poorly recognised, limiting their visibility to communities, managers, and decision-makers. Naming these ecosystems can strengthen public recognition, communication, and long-term stewardship.

The initiative illustrates how businesses can support the Kelp Forest Challenge through targeted partnerships and place-based conservation action.

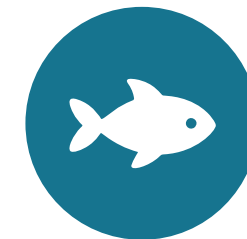
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Benefits of Kelp Forests



Authors: Albert Pessarrodona, Maria Cristina Piñeiro-Corbeira, Johanna Zimmerhackel, Karen Filbee-Dexter, Thomas Wernberg

KEY TAKEAWAYS

- Kelp forests provide a wide range of economic and cultural services to over **950 million people around the world**.
- The potential economic value of ecosystem services in kelp forests is **over US\$500 billion per year**.
- Kelp forest fisheries (lobster, abalone, fish) **generate tens of millions to billions for national economies each year**.
- Nearly **600,000 tonnes of wild kelp** are harvested each year.
- Kelp forests are estimated to sequester approximately **32 million tonnes of CO2 annually**.

2.1 SERVICES PROVIDED BY KELP FORESTS

Kelp forests provide some unique benefits, they are a habitat, a livelihood, a cuisine, and also a culture.

They support biodiversity and fisheries, contribute to cultural connections and recreation, provide opportunities for wild harvest, and may help capture and store carbon, remove nutrient pollution, or reduce coastal exposure in some locations. But these benefits are not equally strong or equally widespread.

Across our global expert assessment (see Section 9.1), biodiversity support and contributions to fisheries were the most consistently recognised benefits of kelp forests. Other benefits were important in specific regions, but varied more depending on local ecology, culture, livelihoods, and the available evidence. Kelp forests should therefore not be valued through a single benefit alone. Their importance comes from the combination of benefits they provide.

2.2 ECONOMIC VALUE OF KELP FORESTS

The economic value of kelp forests is impressive. The three major market services provided by kelp forests (coastal fisheries, nutrient cycling, and carbon removal) have been estimated to generate more than US\$500 billion in potential value each year.¹ Estimates also vary according to the methods, assumptions, and definitions applied. They should therefore be interpreted as indicators of potential value rather than as realised revenue. Economic valuation helps communicate the scale of kelp forests' contribution to people and economies, but it captures only part of their importance. Cultural relationships, biodiversity, identity, recreation, and many other non-market benefits are difficult to express in monetary terms.

2.3 WILD HARVEST

Kelp forests have supplied food, fertiliser, medicines, and materials to coastal communities for thousands of years. Here, wild harvest refers to kelp collected directly from naturally occurring populations, rather than kelp cultivated through aquaculture.

Across 14 countries, an estimated 600,000 tonnes of wild kelp are harvested each year. Over the most recent five-

year reporting period, Chile recorded more than one million tonnes of wild harvest. Norway, Japan, France, and Peru reported approximately 762,001 tonnes, 204,359 tonnes, 273,176 tonnes, and 198,896 tonnes, respectively (Figure 2.2).²

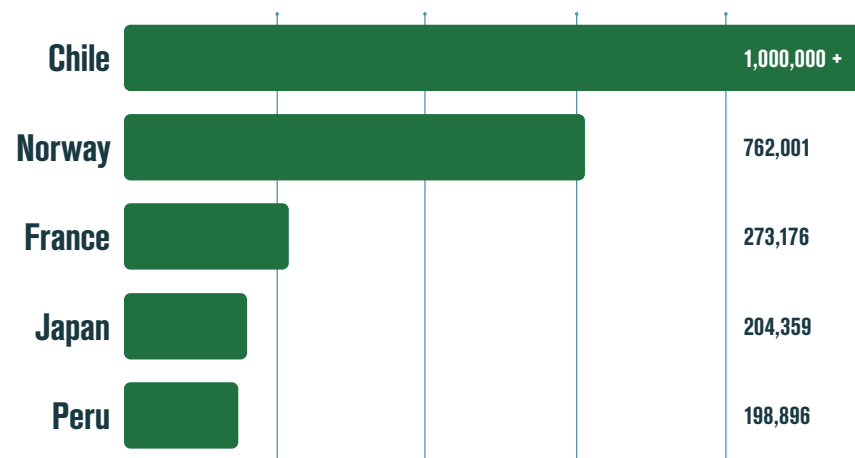


Figure 2.2 Wild kelp harvest in selected countries. Bars show cumulative reported harvest, in tonnes, over the five-year period described in the text.

Wild harvest can support livelihoods, local economies, and culturally important practices. Its ecological effects, however, depend on the species harvested, the methods used, the intensity and frequency of removal, and the effectiveness of local management. Well-designed harvest regulations can allow continued use while maintaining the ecological structure and productivity of kelp forests.



2.4 FISHERIES

Kelp forests are also critical habitats for many commercially and culturally important species, including abalone, lobsters, and fish. It has been estimated that each hectare of kelp supports an average of 904 kg of harvested fish and seafood annually.¹

Lobster and abalone fisheries are particularly important in kelp forest ecosystems. In Australia, annual catches of approximately 10,770 tonnes of rock lobster and 1,965 tonnes of abalone generate an estimated US\$396 million.³ Kelp-associated fisheries are also important elsewhere. At least nine fisheries have been linked to kelp forests in the United States.⁴ In the United Kingdom, seven fisheries are associated with kelp habitat,⁵ including a European lobster fishery valued at approximately US\$65 million annually.⁶ Approximately 2,945 tonnes of abalone⁷ and rock lobster⁸ are captured and cultured annually in South Africa, with an estimated economic value of US\$57 million per year (2024). In total, 38 species with economic value linked to kelp forests are found in South Africa.⁵

In Spain, 32 harvested species occur in kelp forest areas and generate approximately US\$18 million in annual revenue,⁹ while in neighbouring Portugal, 44 harvested species had an economic value of US\$1.83 million.¹⁰

These figures demonstrate the importance of kelp habitat to coastal economies, but they do not represent the total value of kelp-associated fisheries. Estimates differ in geographic coverage, methodology, and the strength of the ecological link established between individual fisheries and kelp forests.

Gross Value of Production (GVP) is the value of fishery production at the point of first sale, before accounting for production costs or downstream processing and retail.

**904 kg
fish &
seafood
per hectare**
supported for harvest
every year

	SOUTH AFRICA	AUSTRALIA	UNITED STATES	UNITED KINGDOM	SPAIN
					
Species with economic value linked to kelp forests 	38 species ⁵		At least 9 fisheries ⁴	7 fisheries ⁵	32 species ⁹
Key fisheries associated with kelp forests 	Approx 2,945 tonnes of abalone ⁷ and rock lobsters ⁸	10,770 tonnes rock lobster, and 1,965 tonnes of abalone ³	At least 9 fisheries ⁴	Including a European lobster fishery ⁶	32 fished species ⁹
Estimated economic value (USD per year) 	\$57 million ⁵	\$396 million ³		\$65 million ⁶ (European lobster fishery)	\$18 million ⁹

Figure 2.3 Examples of kelp-associated fisheries and their economic value. The comparison summarises selected species, fisheries, harvest quantities, and annual values reported in the accompanying text.

2.5 KELP AND CARBON CAPTURE

Kelps have high carbon-fixation rates and an extensive distribution, and are increasingly being viewed as a tool for carbon dioxide removal to help mitigate climate change. Kelp forests were recently shown to transfer significant quantities of carbon to the deep ocean, where it can remain stored for more than 100 years. These estimates suggest that a square metre of kelp forest may sequester between 5 and 30 grams of carbon in the deep ocean every year.¹¹ Globally, kelp forests are thought to sequester 8.6 million tonnes (range: 2.6–14.7 million tonnes) of carbon every year (32 million tonnes of CO₂) in the deep ocean, with forests in Australia, the USA, New Zealand, Chile, and Peru having the greatest sequestration potential. These estimates show that it is feasible, although technically complex, to link

management actions such as protection and restoration to specific amounts of CO₂ sequestered from the atmosphere. If done correctly, these methods can provide the basis for carbon credits in kelp forest ecosystems. It is important to stress that preventing the loss of kelp forests is the most cost-effective strategy to avoid losing their carbon removal capacity, as well as safeguarding the numerous other benefits they provide.¹²



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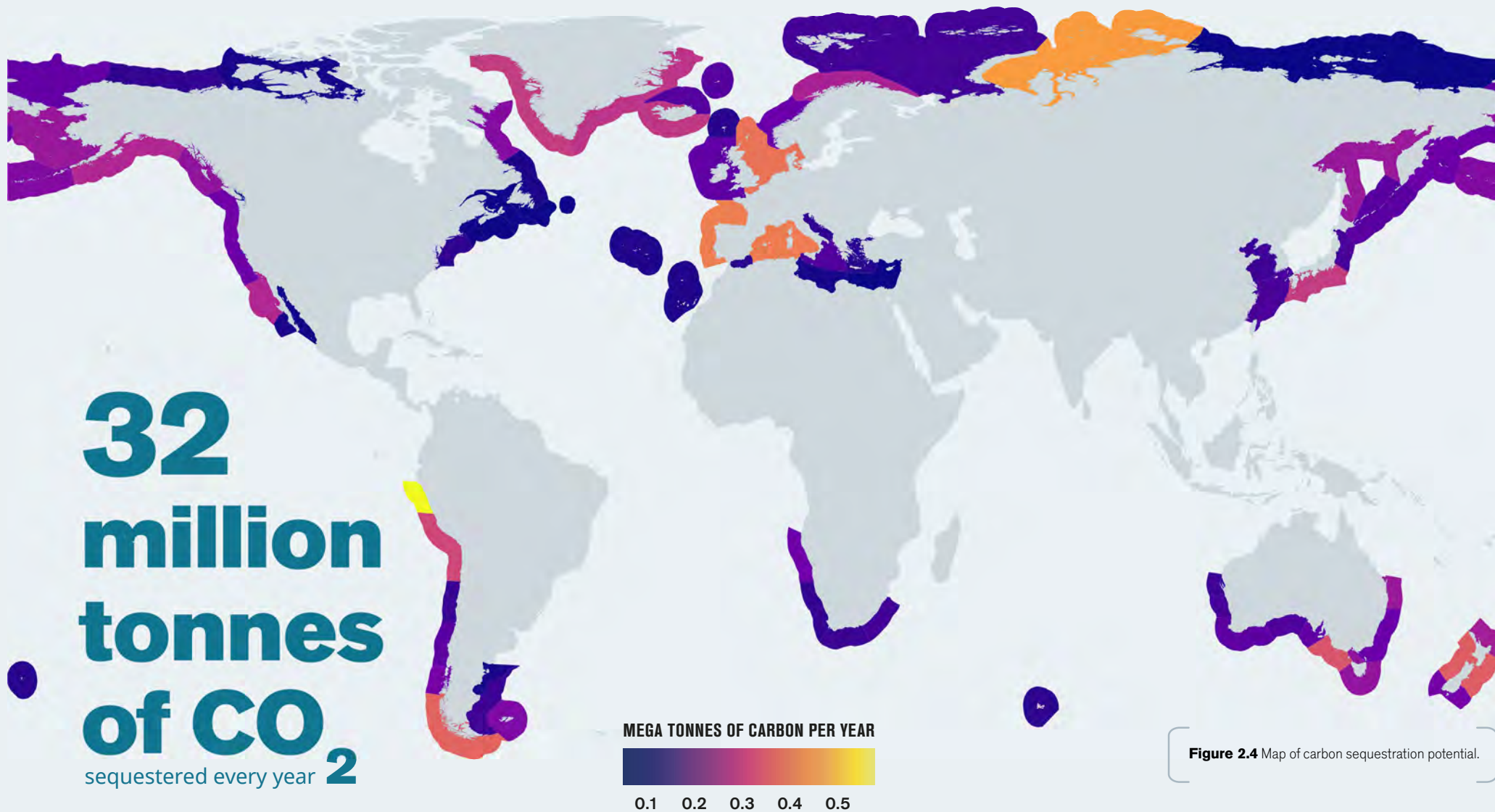


Figure 2.4 Map of carbon sequestration potential.



Conservation Actions and Priorities

Authors: Aaron Eger, Tristin McHugh, Peter Steinberg, Adriana Vergés

KEY TAKEAWAYS

- As the **threats facing kelp forests are diverse**, so are the methods for conserving, protecting, and managing these ecosystems. There is no universal approach, and conservation must be adapted to the local context.
- Monitoring is the most common type of kelp conservation used across regions.
- Communities are increasingly involved in kelp conservation projects.
- Indigenous stewardship, based on deep connections to local kelp forests, provides a complementary model for kelp conservation.

3.1 CONSERVATION ACTIONS IN KELP FORESTS

Marine protected areas (MPAs) can reduce direct pressures such as fishing, harvesting, and habitat disturbance. They are most effective when they are well designed, enforced, and aligned with the main local stressors, and protected in accordance with international standards such as IUCN or ProtectedSeas. MPAs can support kelp resilience, but they cannot directly prevent impacts such as marine heatwaves or land-based pollution.

Harvest management regulates the removal of kelp through tools such as quotas, seasonal closures, size limits, licensing, and spatial restrictions. Its role is to keep extraction within sustainable limits and avoid disrupting the ecological relationships that maintain healthy kelp forests. Regulation is only relevant in areas with active kelp harvest (see Figure 2.2).

Monitoring tracks changes in kelp extent, condition, biodiversity, and key stressors over time. It provides the evidence needed to detect decline, assess whether management is working, and adapt interventions as conditions change.

Community-led efforts involve local communities, Indigenous peoples, fishers, and other coastal groups in

stewardship, monitoring, restoration, and decision-making. These approaches can strengthen legitimacy, draw on local knowledge, and improve the long-term continuity of conservation action.

Policy reform and design create the legal, institutional, and financial conditions needed for sustained management. This can include recognising kelp forests in biodiversity plans, setting protection or restoration targets, improving permitting, coordinating agencies, and establishing long-term funding mechanisms.

Restoration: see Chapter 5.

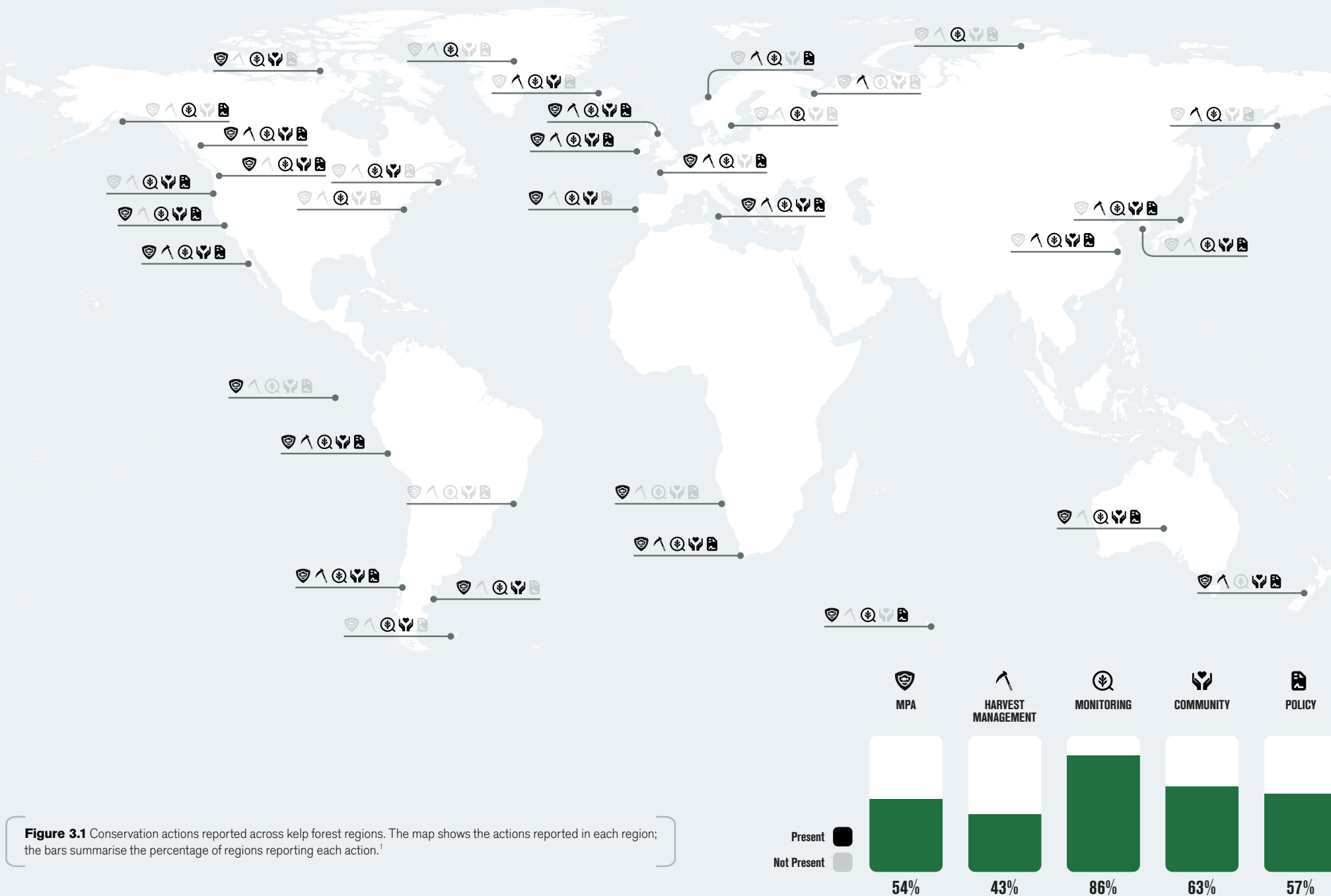


3.2 WHAT IS HAPPENING NOW

Ecosystem monitoring is the most common form of kelp forest conservation and management. Eighty-six per cent of regions reported long-term monitoring programmes (e.g., Reef Check, PISCO, and Reef Life Survey).

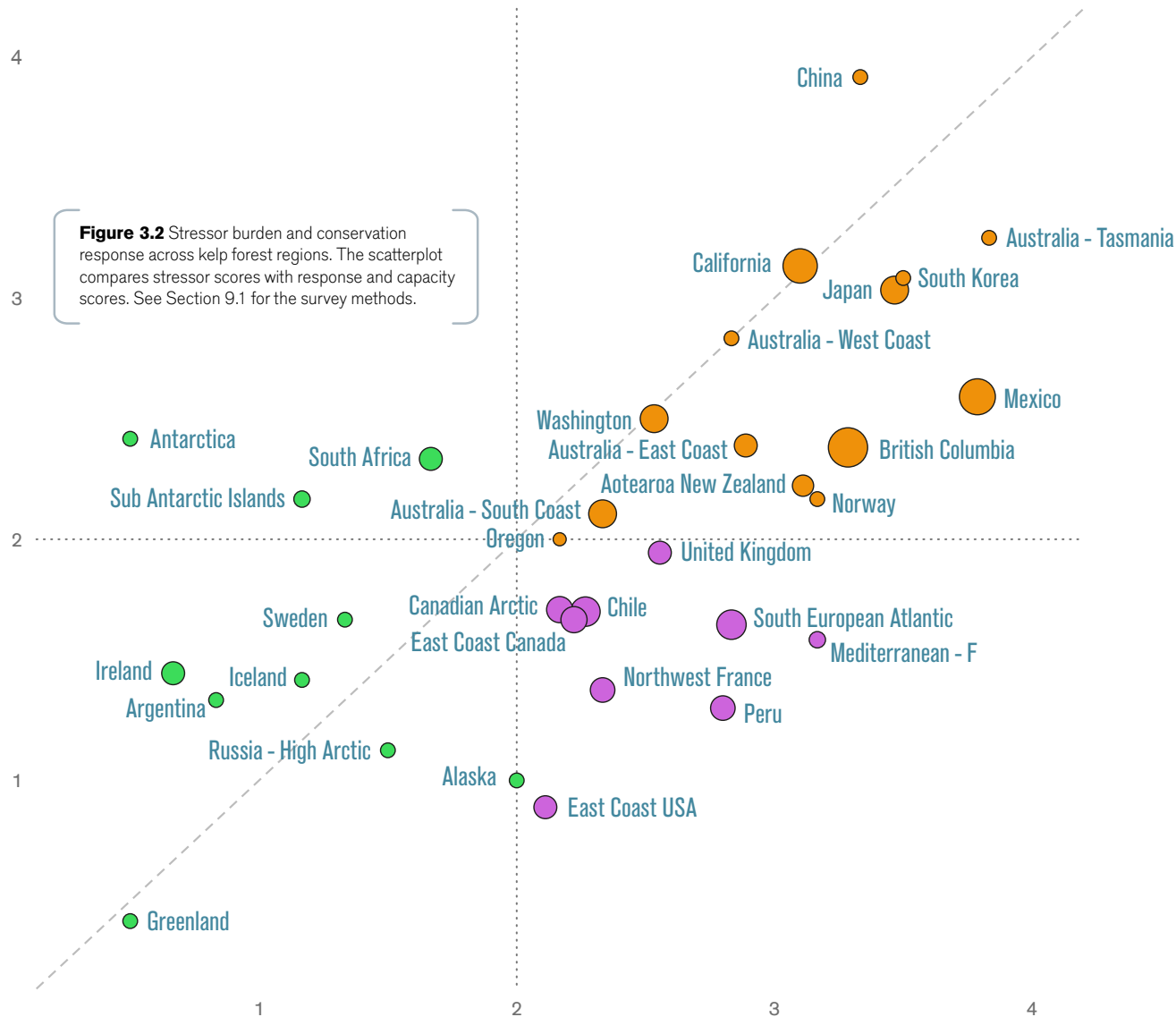
Communities were also heavily involved in kelp forest conservation with 63% of regions reporting community-led or community-linked conservation efforts. Policy planning and marine protected area planning specific to kelp forests are less common but still reported in approximately 50% of regions. The least common method for kelp conservation is harvest management (43%), though only a limited number of countries (e.g., Japan, Korea, France, Norway, Australia, and Chile) have active harvest industries to manage.







Mean response and capacity score



- Lower stressor burden
- High stressors, stronger management
- High stressors, low response



3.3 CONSERVATION GAPS

Not all kelp forests need management interventions, and not all kelp systems that need conservation receive the needed response. Our expert survey revealed areas where the capacity to respond outpaced the need (green zones, 10/31, e.g., Ireland, Argentina, and the Arctic), areas where the response was roughly proportional to the need (yellow zones, 13/31, e.g., California, Australia, and Japan), and areas where the stressor was greater than the response (pink zones, 8/31, e.g., the east coast of the USA, Peru, and the Mediterranean).

3.4 INDIGENOUS STEWARDSHIP OF KELP FORESTS

Authors: Makena Rush, Alejandra Paola González Vásquez, Loyiso Dunga, Betsy Peabody, Julianna Sullivan, Kelly Ferrier, Lineekela Kandjengo, Lynn C. Lee, Mairead Norton, Gwiisihlgaa Daniel McNeill, Marsha Mills, Mitchell Gibbs, Natalio Godoy, Shelley Estes, Tristin McHugh, Veronica C. Mills, Angelo Villagomez, Adriana Vergés, Aaron Eger

Across our world's oceans, many Indigenous communities hold invaluable reciprocal relationships with kelp forests: long-standing connections rooted in

stewardship, culture, and sustenance that span millennia. Many Indigenous communities continue to maintain intricate and dynamic relationships with kelp forests through harvesting their traditional foods, practising stewardship, transmitting knowledge across generations, crafting, sharing stories, and taking care of these ecosystems to sustain their ancestral connections to their lands and waters in daily life. These relationships persist despite the systemic impacts of settler colonialism and Indigenous dispossession.² When a foundational species such as kelp faces decline, it can lead to well-documented ecological loss and less-recognised cultural, social, and economic loss.^{3,4} This issue is compounded by historical and ongoing marginalisation and exclusion from conservation decision-making processes.⁵ Indigenous relationships with and access to kelp forests can play a major role in addressing kelp decline, yet Indigenous peoples in many regions of the world are not given the support that is needed to lead in efforts to address this challenge. Ecological stewardship, restoration, and conservation can be profoundly transformed when Indigenous worldviews, governance, and knowledge systems are recognised, respected, and uplifted.³

In recognition of the indelible relationships that Indigenous communities have had with kelp forests for centuries across the globe, we have established the

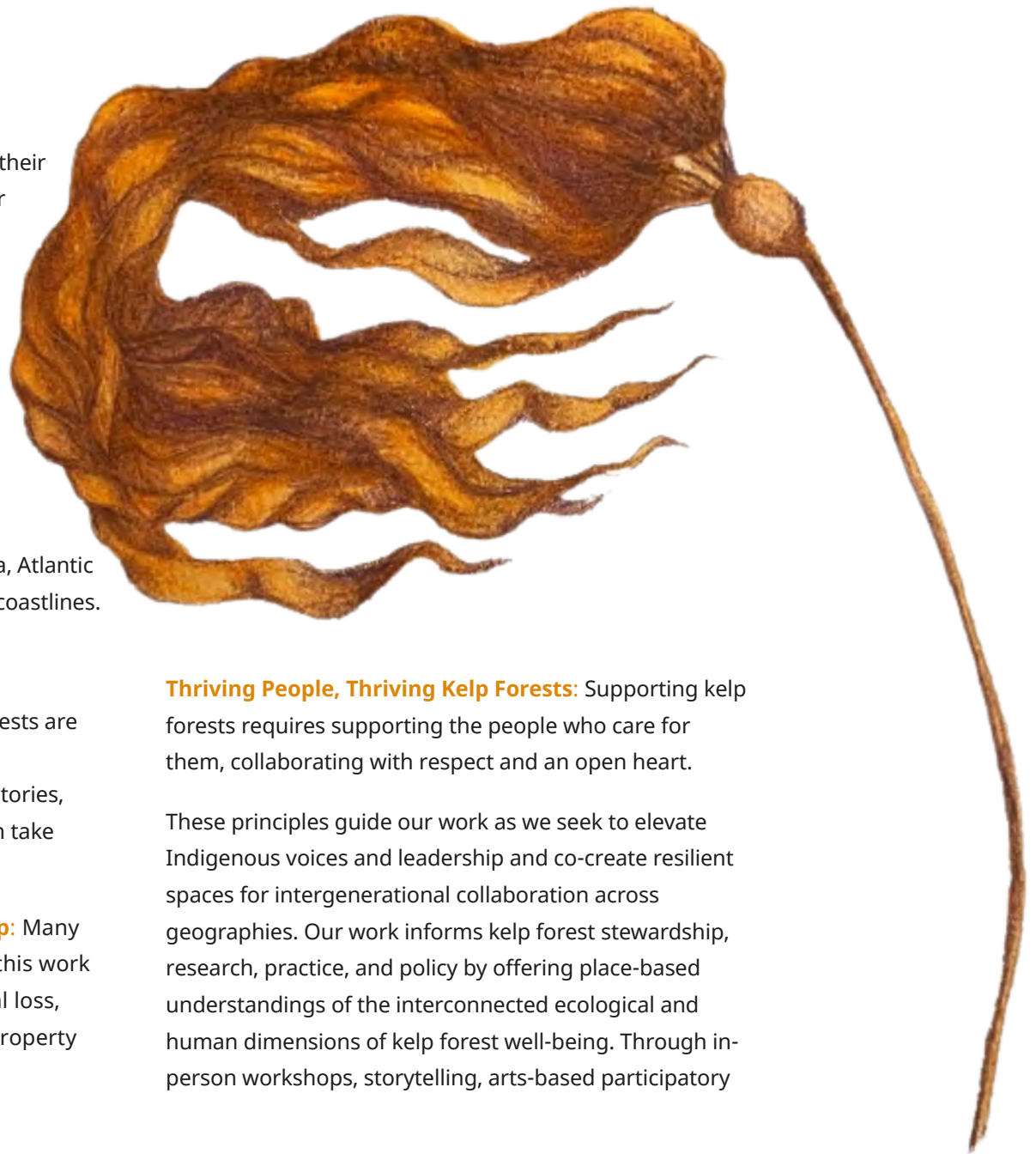
Indigenous Kelp Forest Stewards Community

Our members include Indigenous stewards and their allies from eight countries around the world. Our overarching goal is to raise the voices of Indigenous communities in their efforts to steward kelp forests, which is more important now than ever in the face of increasing human impacts and a changing global climate. We aim to build solidarity and capacity locally and globally by developing a worldwide network of communications and collaborations. Our membership currently spans the eastern Pacific, Aotearoa New Zealand, Australia, southern Africa, Atlantic Canada, South America, and other kelp-bearing coastlines.

Together, we acknowledge three key principles:

Celebrating Reciprocal Relationships: Kelp forests are taken care of and restored by people who carry relationships, responsibilities, memories, skills, stories, and obligations to place. In turn, kelp forests can take care of those who depend on them.

Recognising the Hidden Costs of Stewardship: Many of the people caring for kelp forests are doing this work with limited support while navigating ecological loss, institutional barriers, cultural and intellectual property risks, and the burden of explaining why their



Thriving People, Thriving Kelp Forests: Supporting kelp forests requires supporting the people who care for them, collaborating with respect and an open heart.

These principles guide our work as we seek to elevate Indigenous voices and leadership and co-create resilient spaces for intergenerational collaboration across geographies. Our work informs kelp forest stewardship, research, practice, and policy by offering place-based understandings of the interconnected ecological and human dimensions of kelp forest well-being. Through in-person workshops, storytelling, arts-based participatory

engagement, and co-production of community resources, this network supports biocultural conservation and creates important opportunities for future partnerships. We seek to create a vital stepping stone and a holistic model towards achieving reparative environmental justice and equity in kelp forest stewardship.

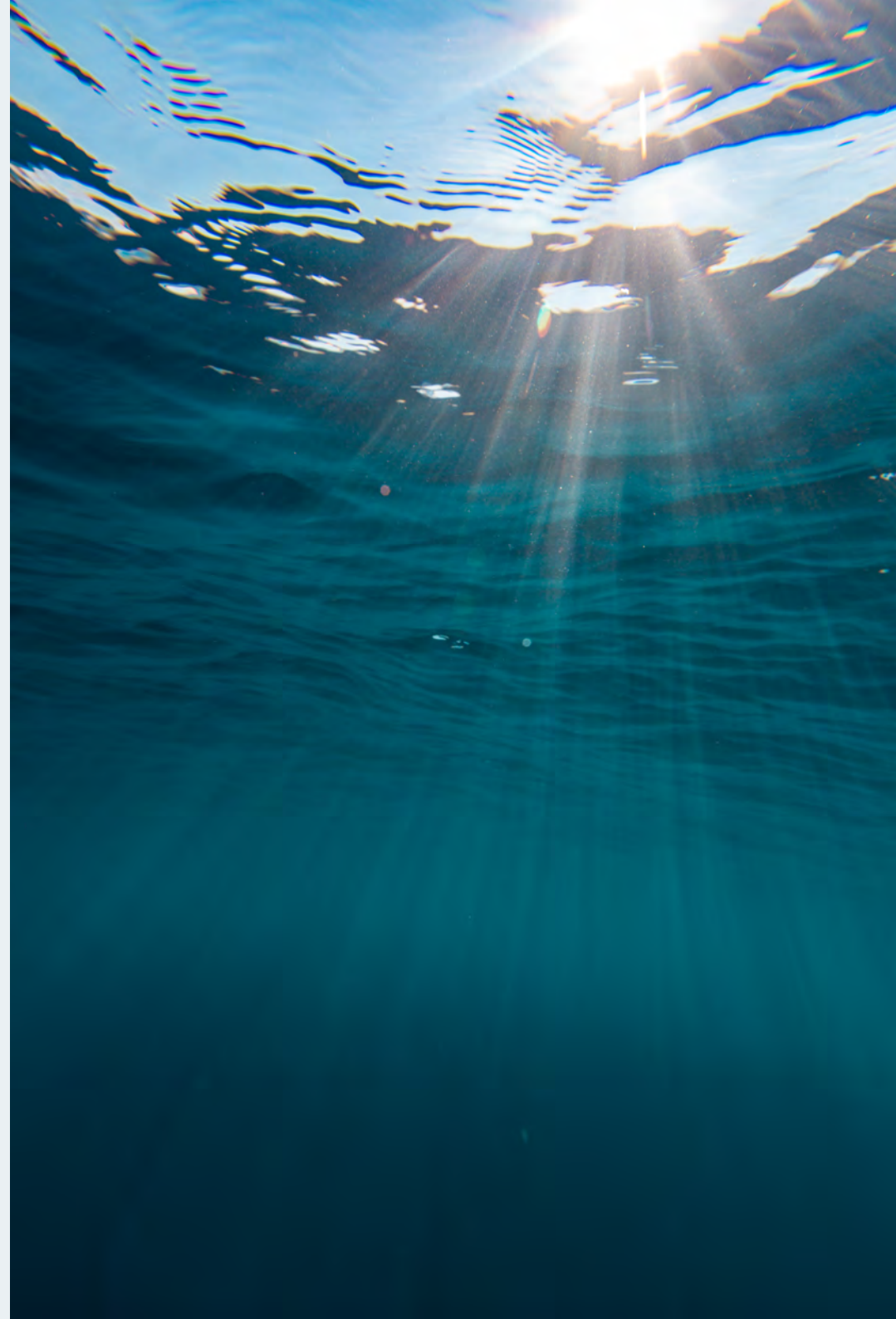
The concept of **Two-Eyed Seeing** (*Etuaptmumk*, in Mi'kmaq), in its many forms, guides our work through the transformative embrace of Indigenous Knowledge and Western knowledge equally for the benefit of all.⁶ Community members lead with **relational accountability**: conducting stewardship and collaboration with respect, reciprocity, and ongoing responsibility. This approach holds individuals responsible for their actions based on their mutual relationships with people, communities, and environments.⁷

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**Indigenous Voices in
Kelp Forest Stewardship
- A Global StoryMap**





Protected Areas



Authors: Aaron Eger, Anita Giraldo-Ospina, Jenn Caselle, Nur Arafeh-Dalmau

KEY TAKEAWAYS

- Around **23% of the global kelp biome** overlaps with a **protected area** – an increase from **16% in 2024**.
- **Thirteen regions have more than 30% of their kelp biome within protected areas**, while 23 regions remain below this level.
- Protected-area coverage is highest in regions including the Sub-Antarctic Islands, Atlantic France, Japan, South Australia, Atlantic Spain and Portugal, the Mediterranean, California, the United Kingdom, Ireland, Argentina, Western Australia, Washington, and Chile.
- Strong protection of kelp forest ecosystems is very rare. **Only 1.2% of the global kelp biome** can currently be confidently **identified as highly protected**, with an additional **1.86%** identified as moderately protected.
- Several regions remain particularly under-protected, including Aotearoa New Zealand, the Russian and Canadian Arctic, eastern Canada, China, and Tasmania.

4.1 PROTECTION OF KELP FORESTS

There is clear progress in the effort to create protected areas around the world's kelp forests. In two years, there has been a seven-percentage-point increase in protected-area coverage of kelp forests,¹ and 13 of 36 regions have *potentially* met their 30x30 targets for kelp ecosystems, although the level of protection is low and validation of actual habitat distribution is required (Figure 4.2).

However, upon closer inspection, the effectiveness of these protection measures remains unclear. For roughly one-third of kelp habitat within protected areas, the level of protection is currently unknown. The headline coverage estimate should therefore be interpreted cautiously: most kelp habitat within protected areas either has relatively weak protection or lacks sufficient information to assess protection strength confidently.

The protection level of one-third of global kelp forests in protected areas is currently unknown.

Thirteen regions have more than 30% of their kelp biome within protected areas. A further 23 regions remain below the target, with particularly low coverage in Aotearoa New Zealand, the Arctic, Peru, eastern Canada, China, and Tasmania.

High-quality protection is even more geographically concentrated. The Sub-Antarctic Islands, South Africa, and South Australia stand out as relative bright spots for the proportion of their kelp biome (>10%) within highly protected areas. These examples demonstrate that stronger protection is achievable, but they remain exceptions within a global system still dominated by weakly protected, poorly classified, or insufficiently reported areas.



Plant number	Total Length (cm)	Grazing (0-3)	Grazing (%)
1	2	0 = NO grazing marks	0%
2	2	1 = Minimal grazing	10-25%
3	2	2 = A few chunks through	25-50%
4	2	3 = Heavy grazing hole	50-75%
			>75%

4.2 WHY WE LOOK AT PROTECTED AREAS

Marine protected areas (MPAs) are essential spatial management tools for supporting marine biodiversity by managing human activities that impact marine life. As a result, the amount of the ocean protected has increased in the past decades. The level of protection varies among individual MPAs, with some fully restricting activities like fishing, while others allow a broader array of uses (e.g., IUCN levels 4-7, LFP 1-3). Restricted MPAs provide the greatest benefit for biodiversity and can provide opportunities for local stakeholders and rights holders. However, combining multiple levels of protection is crucial to conserve kelp forests effectively while also accommodating the rights and needs of Indigenous peoples, local communities, and industries.

MPAs benefit kelp ecosystems by directly or indirectly protecting kelp populations, associated fish, invertebrates, birds, and marine mammals. Directly, they can regulate kelp harvesting (Figure 4.1) and limit development, while indirectly, they

protect species vital to kelp health. These include sea urchin predators, which help control urchin populations and promote kelp growth. Overall, MPAs have a positive impact on kelp populations and associated biodiversity, and can help maintain a diverse and healthy ecosystem, but are not a standalone solution for kelp management.²

Figure 4.1 Proposed pathways through which marine protected areas may support kelp forests.^{2,3}

	STRESSOR	PREVENTION	RESISTANCE	RECOVERY	EVIDENCE OF EFFECTIVENESS
	Biodiversity loss 	●	●	●	Strong
	Gradual warming 	○	●	●	Limited
	Marine Heatwaves 	○	●*	●	Limited – Moderate
	Overgrazing & overfishing 	●	●	●	Moderate
	Pollution 	●*	?	?	None
	Kelp harvest 	●	○	●	Strong
	Invasive species 	○	●	?	Limited

*Context-dependent or localised effects only. For MHWs, resistance benefits are indirect and strongest where MPAs maintain trophic interactions that suppress grazers. For pollution, benefits may be limited to nearshore coastlines.

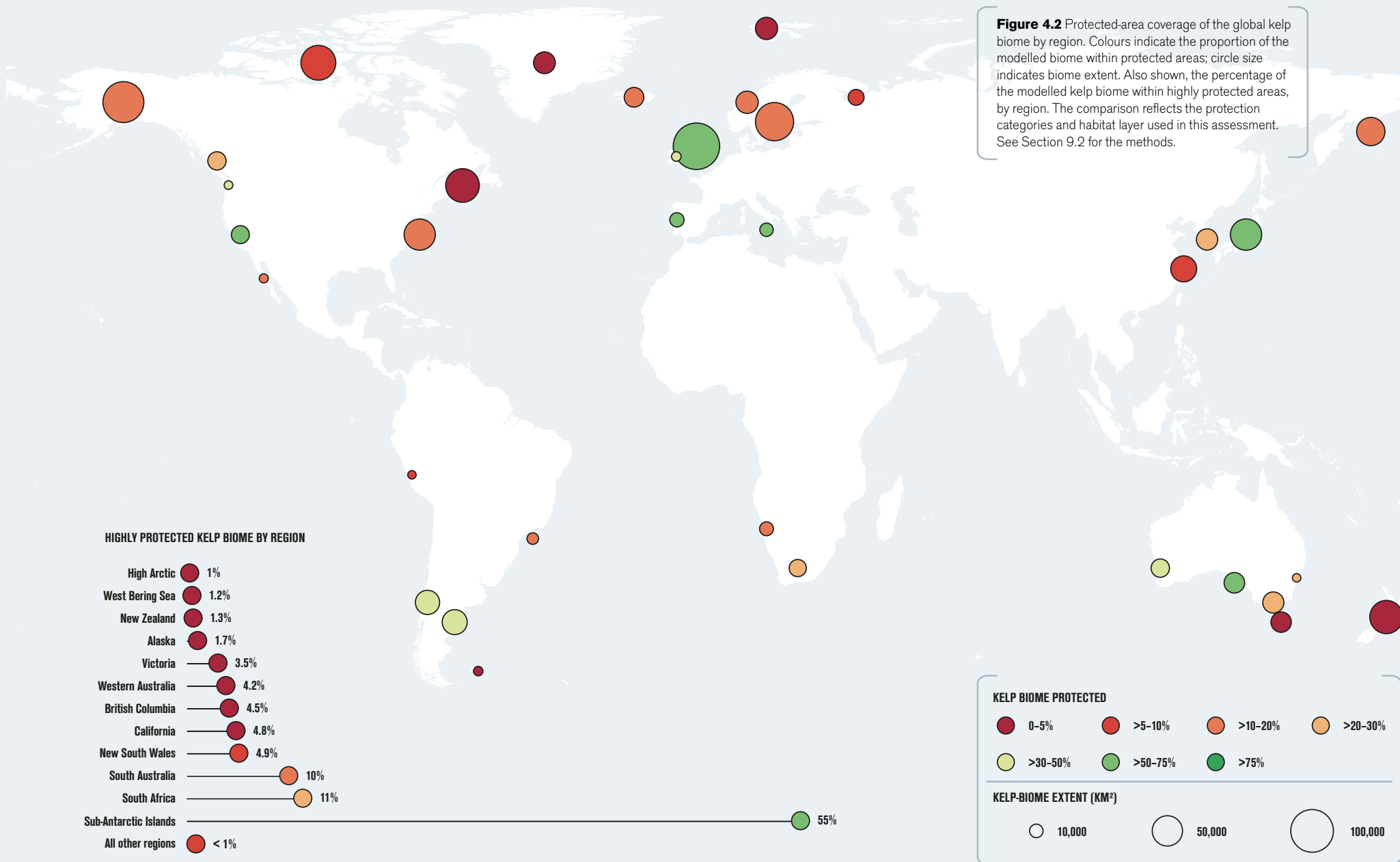


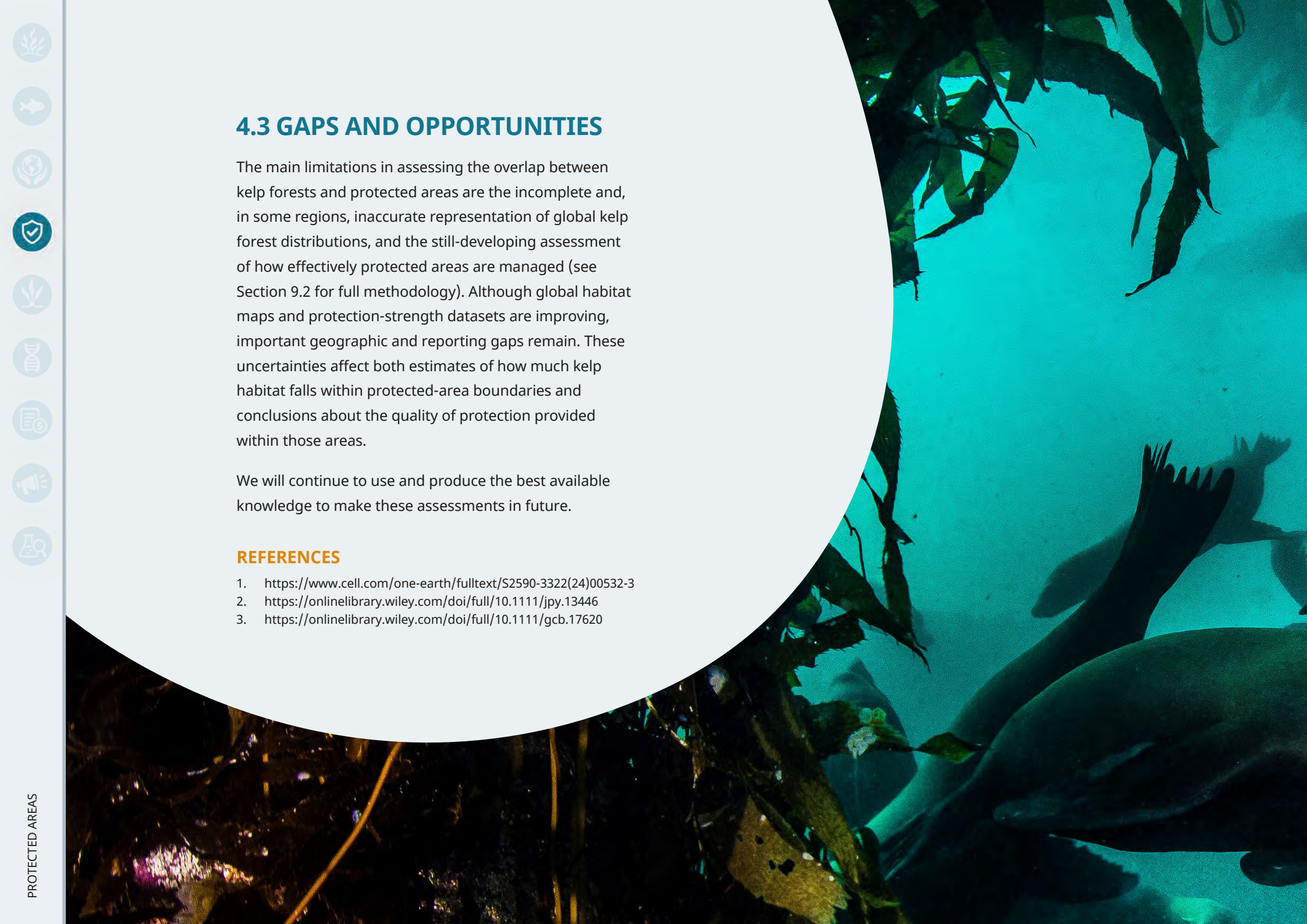
SUPPORTED



UNSUPPORTED

KELP AREA IMPACTED GLOBALLY





4.3 GAPS AND OPPORTUNITIES

The main limitations in assessing the overlap between kelp forests and protected areas are the incomplete and, in some regions, inaccurate representation of global kelp forest distributions, and the still-developing assessment of how effectively protected areas are managed (see Section 9.2 for full methodology). Although global habitat maps and protection-strength datasets are improving, important geographic and reporting gaps remain. These uncertainties affect both estimates of how much kelp habitat falls within protected-area boundaries and conclusions about the quality of protection provided within those areas.

We will continue to use and produce the best available knowledge to make these assessments in future.

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Restoration

CHAPTER AT A GLANCE

- **Restoration is expanding around the world, but progress remains uneven. A small number of larger programmes are showing that kelp forests can be restored at meaningful scales, while many projects remain small, experimental, or difficult to sustain and expand. Here, we highlight the main approaches being used and examine examples where restoration has succeeded at scale, focusing on the methods, partnerships, funding, and long-term management that have helped make recovery possible.**

5.1 WHERE IS RESTORATION HAPPENING?

The state of restoration varies significantly among regions. Some regions have not lost any kelp forests (often at higher latitudes) and therefore require no restoration. When restoration is required, the methods depend on why the kelp forests have declined, what resources are available, and local attitudes towards

restoration. The most common forms of restoration are kelp seeding (46% of regions), transplanting adults (31%), and sea urchin removal (29%). Substrate enhancement and future-proofing techniques are less common, with just 20% of regions reporting activity for either technique. Fifty-one percent of regions have no active restoration, though just six of those (Alaska, Peru, Galapagos, the eastern USA, eastern Canada, and Argentina) require restoration.

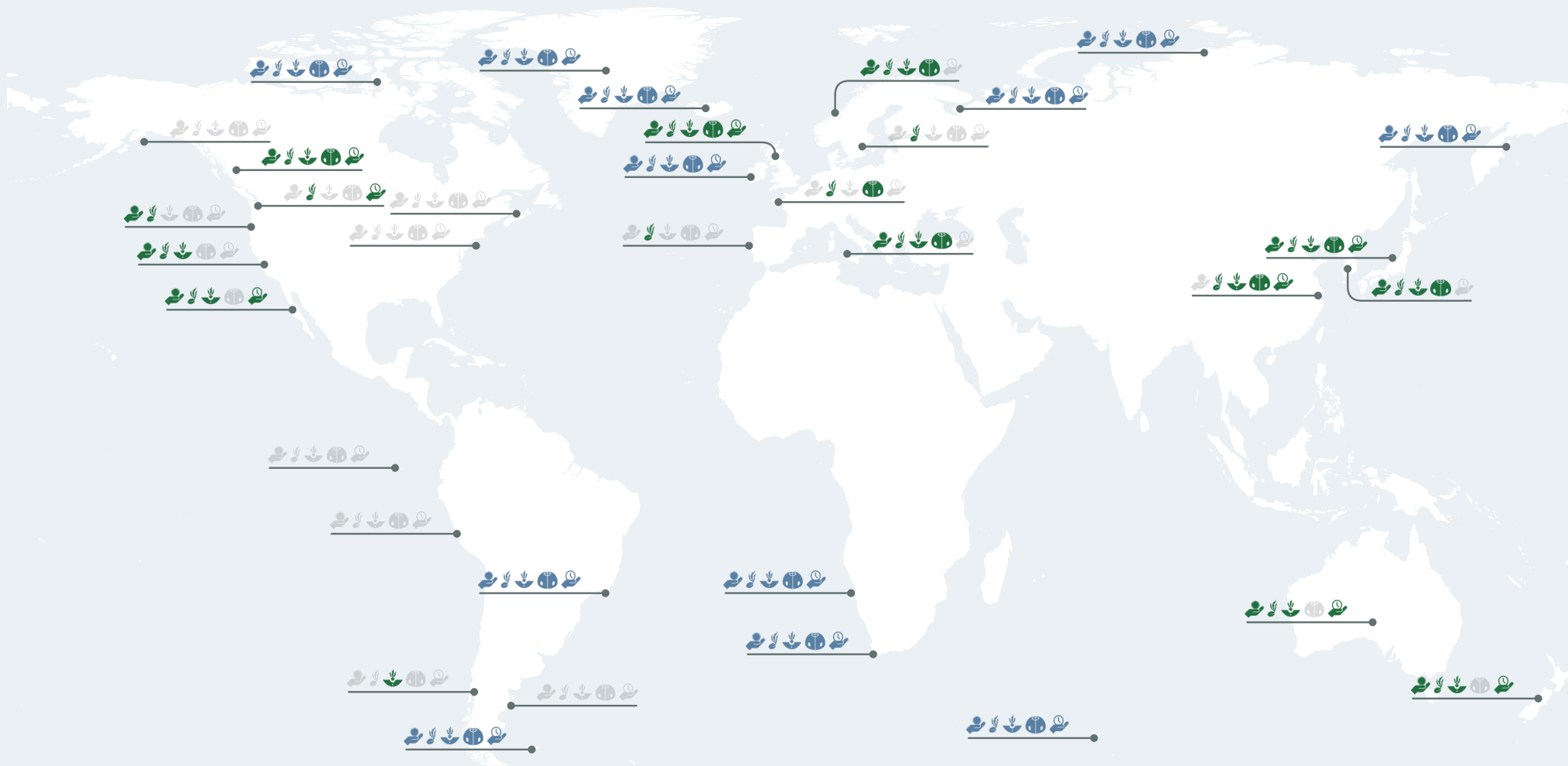
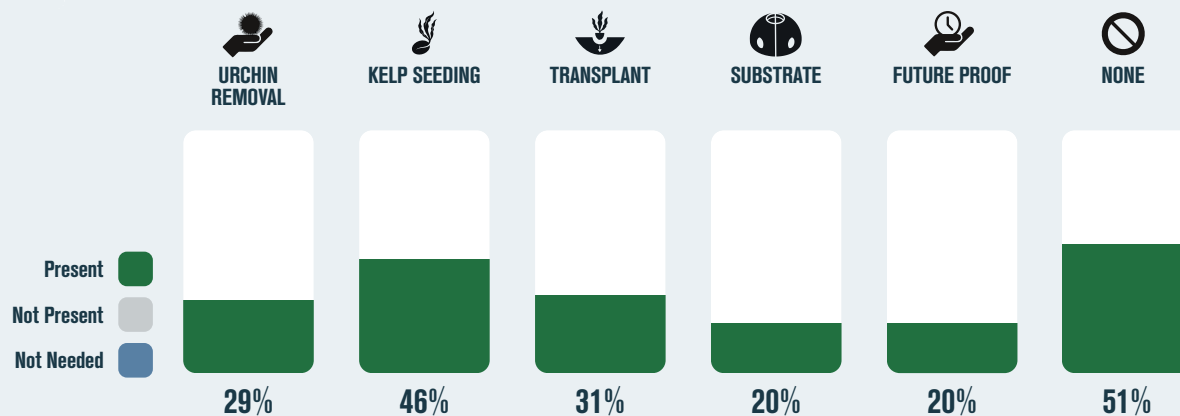


Figure 5.1 Restoration methods reported across kelp forest regions. The map shows regional activity, and the bars show the percentage of regions reporting each method or no active restoration.



5.2 HOW RESTORATION HAPPENS

Active restoration may be needed when reducing threats, improving management, or protecting an area is not sufficient to return a kelp forest to a healthy, self-sustaining state. Before restoration begins, it is essential to understand why the kelp forest declined and whether those pressures are still operating. If the underlying causes, such as poor water quality, excessive grazing, unsuitable substrate, or repeated marine heatwaves, are not addressed, restored kelp may fail to establish or persist.

Kelp forest restoration generally uses four main approaches: seeding, transplanting, grazer control, and substrate enhancement. Future-proofing can inform all four.

Restoration projects often combine several of these approaches. The most appropriate strategy depends on the cause of decline, the likelihood of natural recovery, local environmental conditions, the species being restored and the ecological, cultural, and social context of the site. Long-term monitoring is then needed to determine whether restored kelp survives, reproduces, and develops into a self-sustaining population.



Seeding



Seeding introduces kelp spores, microscopic life stages or juvenile kelp to suitable habitat. Seeded material may be deployed on lines, gravel, tiles or other attachment surfaces.

Transplanting



Transplanting moves juvenile or adult kelp from donor populations or cultivation facilities and attaches them directly to a restoration site.

Grazer control



Grazer control reduces or manages overabundant herbivores, particularly sea urchins, so that kelp can recover naturally or so that seeded and transplanted kelp have a greater chance of survival.

Substrate enhancement



Substrate enhancement adds, restores or modifies suitable attachment surfaces where the existing seabed does not support kelp recruitment or establishment.

Future-proofing



Future-proofing is an important consideration that can be incorporated into seeding and transplanting by accounting for the genetic diversity, origin and environmental suitability of the kelp being introduced. This can include maintaining broad genetic diversity, selecting source populations suited to local conditions and considering how restored populations may respond to future warming and other environmental change.

Figure 5.2 Approaches to kelp forest restoration: seeding, transplanting, grazer control, and substrate enhancement. Future-proofing can be incorporated into these approaches by considering genetic diversity and environmental suitability.

5.3 TRACKING GLOBAL RESTORATION ACTIVITY

The Kelp Forest Alliance maintains a global database of kelp forest restoration projects. It allows registered users to upload the outcomes of their restoration projects and contribute to the global tally. As of publication, 285 projects had been uploaded from 15 countries, and these entries were used to generate the reported figures. While the database is inclusive of project types and countries of origin, it is currently only available in English, and this biases the results. The database has tracked 19,071 ha of successful kelp restoration (Figure 5.3). Progress is geographically skewed, with over three-quarters of that restoration occurring in South Korea. There may be more restored area in South Korea than is reported in the database (see Section 5.5).

5.4 JAPAN: RESTORING KELP FORESTS THROUGH FISHERIES, CARBON FINANCE AND COASTAL PARTNERSHIPS

Tomohiro Kuwae

In Japan, kelp and other macroalgal forests are increasingly restored as working coastal systems that support fisheries, climate action, and regional

economies. This reflects the country's long coastline, its long history of seaweed use, and the dependence of many coastal communities on productive algal habitats. Where *isoyake* barren grounds have expanded, macroalgal loss has therefore become both an ecological problem and a threat to fisheries and livelihoods.

Two complementary policy mechanisms have helped make restoration more visible and attractive to investors. The voluntary J-Blue Credit scheme, administered by the Japan Blue Economy Association, certifies carbon dioxide removal generated through the creation, restoration, and management of marine vegetated ecosystems. By 2025, it had certified 61 projects and recorded 471 transactions; macroalgal beds represented 49.2% of projects and seaweed farming a further 18.0%. Japan also incorporated removals from seagrass meadows and macroalgal beds into its national greenhouse gas inventory in 2024. National accounting recognises macroalgal carbon removal in climate policy, while J-Blue Credit creates a pathway for private finance to support local action.¹

The fisheries benefits are particularly evident in Shakotan, Hokkaido, where fishers have restored macroalgal beds since 2009 in response to expanding barren grounds and declining sea urchin production. The project combines urchin-density management, deployment of fertile adult algae, and the reuse of



Figure 5.3 Global restoration progress. Top ten countries by reported successfully restored area, 4th Sept 2016 to 4th Sept 2026.

49.2% of projects certified through Japan's J-Blue Credit scheme involved macroalgal beds.

discarded sea urchin shells as restoration material. The restored habitat provides food for sea urchins, linking ecological recovery directly to harvest volume and product quality. The project estimated that restored beds could support about 390 kg of additional shucked sea urchin production, valued at approximately JPY 30.6 million, while also generating certified blue-carbon removals and supporting environmental education.²

These projects depend on partnerships. Across the J-Blue Credit portfolio, fishers, municipalities, companies, community groups, and academic institutions share responsibility for implementation, finance, monitoring, and long-term continuity.

Japan is also testing hybrid “green-grey” approaches, including steelmaking slag and other recycled or dredged materials as substrates for macroalgal-bed creation. In Hiroshima Bay, steel-slag substrates were used to establish *Sargassum* beds intended to support biodiversity and fishery recovery.³

The broader lesson is that restoration may be more durable when carbon is treated as one benefit among many. Fisheries, biodiversity, education, tourism, local identity, and infrastructure performance can be equally important to long-term success.

5.5 SOUTH KOREA: SCALING KELP RESTORATION INTO A NATIONAL PROGRAMME

Kyungsun Lee, Yejin Hyeon

South Korea has turned kelp restoration from a collection of local projects into a coordinated national programme. Seaweed barrens were first reported around Jeju Island and the southern coast in the 1980s and later spread to the East Sea. By 2025, a national aerial survey by the Korea Fisheries Resources Agency (FIRA) estimated that **34% of surveyed rocky seabed showed signs of seaweed barrens**, creating a strong need for restoration at scale.

The national response began taking shape in 2009, when the National Institute of Fisheries Science surveyed potential restoration areas. In 2011, FIRA was established as a dedicated organisation under the Ministry of Oceans and Fisheries, giving the country a permanent institution responsible for marine forest restoration. South Korea now aims to create **54,000 hectares of marine forests by 2030**. By 2025, **281 sites covering approximately 37,500 hectares** had been established, supported by annual investment of around **US\$20 million**.

FIRA manages the restoration process from site selection through implementation and monitoring. Projects

generally run for four years before being transferred to local governments for ongoing management. Restoration methods are adapted to local conditions and include controlling sea urchins and other grazers, installing artificial reefs, deploying underwater seed lines and spore bags, and cleaning rocky seabeds to create space for new seaweed to establish.

Early results suggest these interventions can rebuild more than kelp alone. Across 17 marine forest areas established in 2022, monitoring in 2025 recorded a

138% increase in seaweed biomass. Recovery of seaweed forests was also associated with increases in the diversity, abundance, and biomass of bottom-dwelling animals.

What makes South Korea distinctive is not any single restoration technique, but the infrastructure built around it. Long-term public funding, a dedicated national delivery agency, and standardised monitoring have allowed restoration to move beyond isolated experiments and operate across hundreds of sites.





The broader lesson is that restoring kelp at national scale requires institutions as much as ecology. South Korea shows how sustained investment, dedicated implementation capacity and consistent monitoring can turn restoration into a long-term component of coastal ecosystem management, supporting biodiversity, fisheries, and climate resilience.

5.6 NORWAY: URCHIN CONTROL USING QUICKLIME, SUPPORTED BY PREDATION

Hartvig Christie

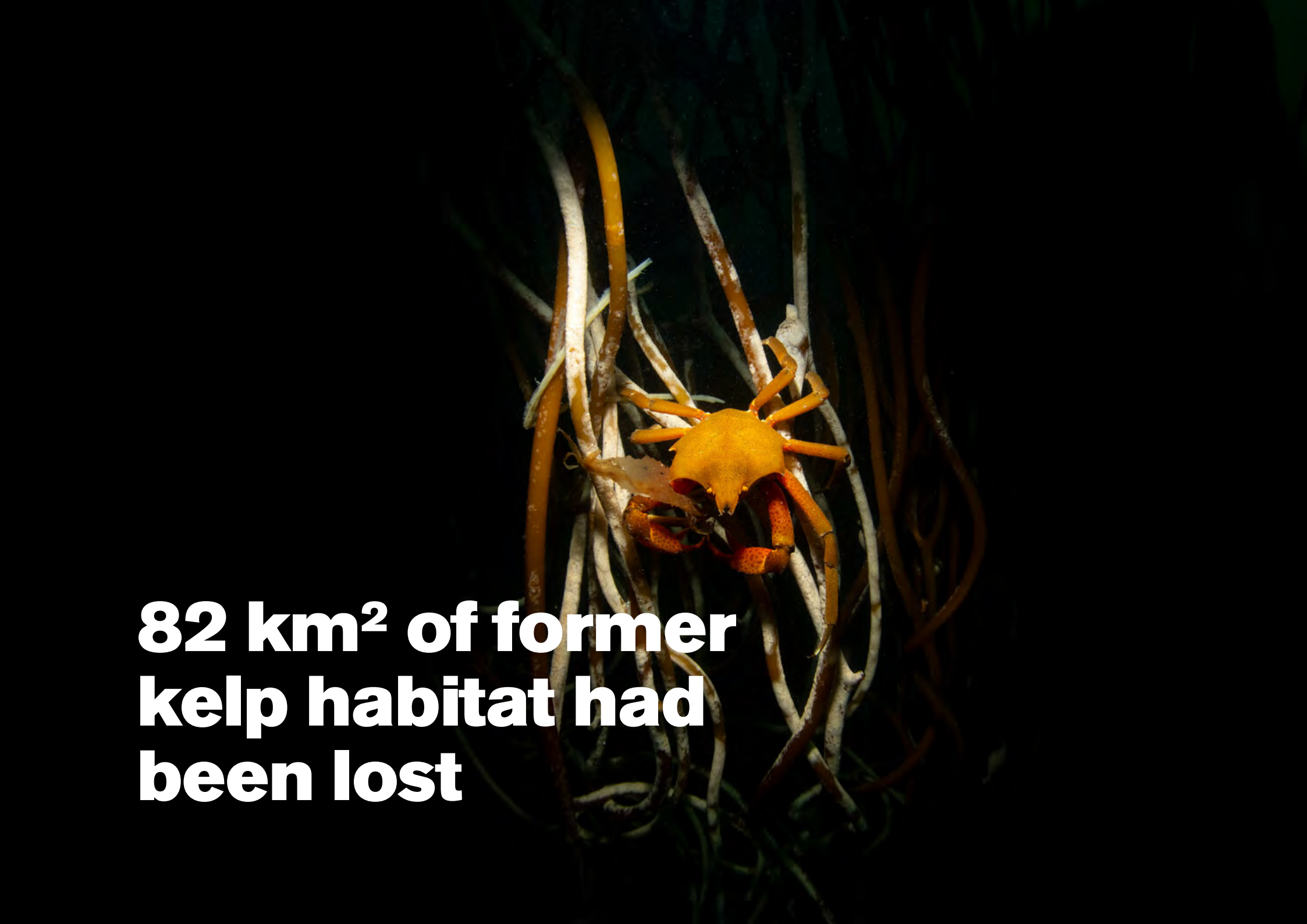
For more than four decades, large areas of northern Norway's coast remained trapped in a degraded state. Dense populations of green sea urchins had grazed kelp forests faster than they could recover, creating persistent barren grounds across thousands of square kilometres. In Porsangerfjord alone, around 82 km² of former kelp habitat had been lost. Continued grazing maintained these barrens by consuming new kelp and limiting the recovery of other reef organisms.

In 2013, researchers from the Norwegian Institute for Water Research and the Institute of Marine Research tested whether breaking this feedback could trigger recovery at scale. Around 200 tonnes of quicklime

(calcium oxide) were applied across 70 hectares of shallow rocky reef, roughly 100 football pitches, to rapidly reduce sea urchin densities. Quicklime allowed treatment at a scale that would have been difficult through manual removal. Because the quicklime was applied shortly before kelp released spores, it created an opportunity for natural recruitment.

200 tonnes of quicklime were applied across 70 hectares of shallow rocky reef, roughly 100 football pitches.

No kelp was planted or seeded. Instead, removing grazing pressure allowed more than 10 million kelp plants to establish in less than a year, dominated by sugar kelp alongside several other kelp species. The nearest known continuous sugar kelp forest was more than 400 km away, suggesting that small, previously undetected reproductive plants were probably present closer to the restoration site. Similar rapid recovery following urchin removal has occurred in smaller experiments in Norway and elsewhere, although the distance over which surviving kelp can reliably seed restoration remains uncertain.

A photograph of a bright orange crab, likely a rock crab, clinging to a bundle of dead, bleached kelp stalks. The background is a deep, solid black, which makes the orange crab and the light-colored kelp stand out. The crab is positioned in the center-right of the frame, facing towards the left. Its legs are spread out, gripping the kelp. The kelp stalks are thin, dry, and have a yellowish-white color, indicating they are dead. The overall composition is simple and focuses on the crab and its habitat.

**82 km² of former
kelp habitat had
been lost**

Removing grazing pressure allowed more than 10 million kelp plants to establish in less than a year.

Ecological recovery was substantial. Macroalgal biomass increased from almost zero to approximately 5–10 kg per square metre. By 2016, researchers had recorded 44 macroalgal species, together with an increasingly diverse kelp-associated fauna. Monitoring found no significant short-term decline in non-target bottom-dwelling animals. Instead, these communities increased as kelp habitat and food production developed. Juvenile cod and red king crabs were also frequently observed within the recovering forest. Follow-up observations indicate that the restored kelp forest remained present in 2025, more than 12 years after treatment.

Quicklime can be highly effective and cost-efficient, but it is not a universal solution. Its effectiveness depends partly on seabed structure because urchins can shelter among stones and gravel, and treatment does not prevent future recruitment. In Porsangerfjord, expanding red king crab populations subsequently helped suppress urchins and supported kelp recovery beyond the treated areas.

Quicklime can be highly effective and cost-efficient, but it is not a universal solution.

The broader lesson is that large-scale grazer removal can unlock rapid natural recovery where grazing is the main barrier. Long-term success depends on effective initial treatment, suitable substrate, continued monitoring and grazer control, and enough reproductive kelp within the surrounding ecosystem to support natural recruitment.⁴

5.7 TASMANIA: URCHIN CONTROL BY HARVEST

John P. Keane

In eastern Tasmania, commercial harvest of the range-extending long-spined sea urchin, *Centrostephanus rodgersii*, has increasingly been used to protect kelp forests and abalone habitat. Assisted by ocean warming and the strengthening East Australian Current, the species expanded southwards from mainland Australia and was first reported in Tasmania in 1978. By 2017, its population was estimated at approximately 20 million, with barrens covering around 15% of eastern reef habitat and threatening biodiversity and productive abalone fishing grounds.⁵

Commercial harvesting began in 2009 but remained below 100 tonnes annually during its first nine years. In response to expanding barrens, the Tasmanian Abalone Council introduced harvest subsidies in 2016–17, initially providing A\$0.75 per kilogram to supplement processor payments to commercial divers. State Government involvement



expanded through the Abalone Industry Reinvestment Fund (AIRF) in 2018, with an initial A\$5.1 million committed over five years to abalone sustainability and productivity initiatives, including urchin control. The programme brought together government, industry, divers, processors and researchers around the objectives of preventing new barrens, limiting expansion of existing barrens and promoting reef recovery.^{6,7}

A key refinement was the introduction of spatially differentiated payments in 2019. Uniform subsidies had concentrated fishing on dense, accessible northern populations, where returns were highest. Higher payments in priority areas redirected effort towards valuable abalone reefs where urchin densities were lower

but increasing. By 2025, five zones offered payments of A\$0.00 to A\$3.50 per kilogram, with approximately A\$300,000 in incentive funding applied across subsidised zones in 2024–25⁷. Rates and boundaries are reviewed annually as ecological priorities, fishing patterns and available funding change.^{6,8}

Together with investment in processing facilities and markets for urchin roe, these incentives accelerated development of the fishery. By 2025, approximately 3,760 tonnes had been harvested, including 3,139 tonnes over the previous seven seasons. Modelling estimated that fishing reduced urchin biomass density by approximately 50% around St Helens and 15–30% further south relative to scenarios without fishing, showing that targeted harvest can substantially suppress urchin populations and associated grazing pressure.⁸

However, population control is not always sufficient to restore established barrens. Commercial divers preferentially harvest larger urchins with marketable roe, while smaller animals can maintain grazing pressure. The 2023–24 Restoration by Harvest Pilot Program at Fortescue Bay therefore tested a ‘take-all’ approach along approximately 5 km of coastline, removing all accessible size classes. Kelp recovered where urchin biomass was reduced below approximately 71 g m⁻², whereas barrens persisted or expanded where biomass remained above this threshold.⁶

Tasmania illustrates how fisheries policy and ecological restoration can operate together. Commercial harvest can provide sustained population control, differential subsidies can redirect effort towards reefs where ecological benefits are greatest, and intensive take-all removal can be used where recovery requires grazing pressure to fall below a critical threshold. The broader lesson is that profitable harvest and ecological restoration do not necessarily target the same animals or places. Effective programmes therefore need economic incentives linked to ecological objectives, monitoring of habitat outcomes and continued intervention where urchin recruitment persists.

5.8 GWAII HAANAS: COLLABORATIVE AND CULTURALLY CONNECTED RESTORATION

Lynn Lee, Daniel McNeill, Vanessa Bellis

Haida Gwaii, an archipelago off northern British Columbia, is the traditional territory of the Haida Nation and home to kelp forests, sea urchins, abalone, and other interconnected species. The ecological loss of sea otters during the maritime fur trade disrupted these relationships, contributing to high abundances of kelp-grazing sea urchins and long-term reductions in kelp

forests. Since then, kelp distribution has fluctuated in response to urchin grazing, ocean conditions, and other environmental pressures.

The Chiixuu TII iinasdII—Nurturing Kelp Forests to Grow project was initiated in 2017 and co-led by the Council of the Haida Nation and Parks Canada Gwaii Haanas. Over five years, we aimed to restore kelp habitat, productivity, and biodiversity along approximately 3 km of coastline within Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site. Equally important were cultural goals: strengthening relationships with traditional foods and bringing knowledge of guuding.naay, or red sea urchin, and kelp ecosystems into Haida Gwaii communities and schools.

Equally important were cultural goals

We brought together collaborators from the Council of the Haida Nation, Parks Canada, Fisheries and Oceans Canada, the Pacific Urchin Harvesters Association and researchers from four universities. After two years of baseline surveys, commercial fishery and Haida Fisheries divers reduced red sea urchin densities by more than 90% through fishing and in situ cracking. No kelp was planted or seeded because natural kelp sources were present and grazing pressure was identified as the main barrier to recovery.

Bull kelp canopy area and depth increased rapidly following urchin removal, although kelp abundance and understory diversity fluctuated in later years, likely in response to renewed grazing and increased ocean temperatures. Annual maintenance and monitoring continued after the initial funding ended in 2022, supported by strong partnerships and shared stewardship goals. Urchins removed during site maintenance and an associated commercial fishery have continued to provide Haida traditional food for local communities, and the commercial fishery contributes an economic dimension to the restoration effort.

The project shows that restoration can deliver ecological, cultural, and social benefits simultaneously when it is grounded in Indigenous governance and long-term relationships. Its central lesson is that sustained recovery depends not only on reducing grazing pressure, but on cooperative management, continued restoration maintenance and monitoring, local food systems, and the values of the people responsible for caring for the place.

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New Technologies

CHAPTER AT A GLANCE

- **Technology has an important role to play in making kelp forest conservation more effective and more efficient. While the field has received little dedicated research and development compared to terrestrial and coral systems, we are seeing the emergence of innovative approaches and creative applications of technologies developed for other settings to improve kelp forest health. Here we highlight some emerging and established technologies that will help drive the future of kelp forest conservation.**

6.1 USING UNDERWATER ROBOTICS AND AI TO MONITOR KELP FORESTS

Arie J. P. Spyksma, Kelsey I. Miller, Shahrokh Heidari, Kelham Rawlinson, Katerina Taškova

Kelp forest management requires large-scale monitoring that is robust and up to date. Without it, we won't be

able to understand how kelp forests are changing or how well restoration or protection interventions are working. Currently, collecting these data is limited by the slow, expensive, and spatially limited nature of traditional marine monitoring methods and data analysis techniques. Future kelp forest management will therefore rely more heavily on technologies that enhance spatial coverage, increase automation, and reduce costs.

This problem is particularly pronounced for subsurface kelp forests, which require in-water data collection methods. Traditional methods are often costly, and slow, and require intensive diver time and data processing. Innovations in underwater image collection and automated robotics are, however, helping to solve this problem. By generating cost-effective, large-scale, georeferenced image datasets, autonomous and non-autonomous camera systems are beginning to significantly reduce the burden on divers. However, classifying these images manually requires many hours

of work and delays the sharing and use of information, effectively limiting their full potential. Recent advances in machine learning (ML) capabilities are providing key opportunities to automate underwater image analysis, reducing bottlenecks and making better use of these large-scale datasets.¹

***AI image-processing tools are
24 times faster than manual
processing.***

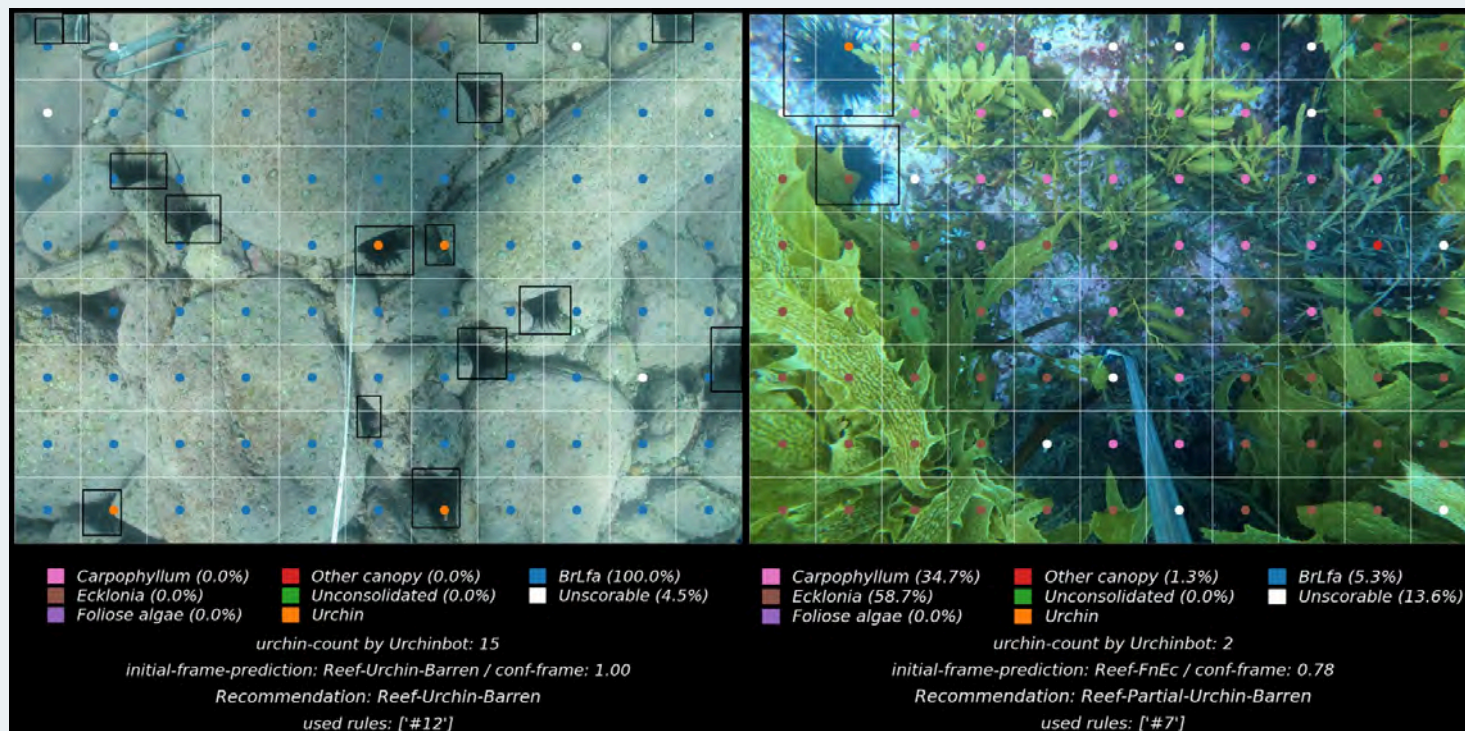


Figure 6.1 Urchinbot and Habibot AI toolkit in action. Together, these tools can rapidly identify urchin species (black boxes), provide patch-level habitat classifications (coloured points) and provide a whole-frame habitat prediction from images sourced from a range of camera platforms used across northeastern New Zealand and southeastern Australia.



We use two of these new tools, Urchinbot and Habibot, to detect sea urchins² and kelp habitat³ in northeastern Aotearoa New Zealand and southeastern Australia. AI image-processing tools are 24 times faster than manual processing and enable rapid, accurate detection of kelp loss and sea urchin abundance.

Importantly, they also provide measures of detection confidence and can incorporate human verification where desired.

It is important to note that underwater imagery relies on visual information that can be obscured by low image resolution, poor water clarity, uneven lighting, and motion blur.⁴ Future technological advances and integration with other sensor types can help reduce but never entirely eliminate these issues. Collectively, these tools and others like them hold considerable promise for future conservation efforts, but communication and standardisation across workflows and platforms will be important to maximise their benefits. These approaches will therefore likely be a useful component of the kelp forest monitoring toolbox but not a complete substitute for traditional methods.

6.2 GENETIC PRESERVATION OF KELP THROUGH CRYO- AND BIOBANKING

Cintia Iha, Wouter Visch, Anusuya Willis

As kelp forest populations and their genetic diversity are being lost, biobanks play a key role in supporting kelp conservation. These facilities allow the long-term storage of the genetic material needed to conserve kelp populations for years. Importantly, kelp biobanks can preserve a wide variety of strains, safeguard genetic resources, support selective breeding, and provide a reliable, readily available source of kelp tissue for research, cultivation, and restoration.

To establish a valuable biobank, it is essential that the strains are strategically collected across their geographic range and genetically characterised to assess levels of diversity and differentiation among populations. This information is fundamental for designing safe and successful restoration programmes. Genetic screening can also detect markers associated with adaptive traits, such as heat tolerance, providing valuable information for conservation.

Kelp biobanking uses two approaches: maintaining living cultures and cryopreservation.

Living gametophyte cultures: Laminarian kelps have two stages in their life cycle, including a microscopic gametophyte. These gametophytes provide a continuous source of reproductive material that can be maintained for many years under stable laboratory conditions (low temperature, stable nutrients, and red light). Maintaining living gametophyte cultures successfully requires dedicated facilities and regular maintenance, as cultures decline in quality when maintained for many years. As a result, adequate infrastructure and skilled technicians are needed to sustain biobanks and their benefits over the long term.

Cryopreservation: A complementary approach to living kelp biobanking is cryopreservation, which enables the long-term storage of kelp genetic resources at ultra-low temperatures (typically in liquid nitrogen at -196 °C). Kelp gametophytes are particularly suitable for cryobanking because they can be recovered and cultured after thawing, eliminating the need for continuous maintenance and reducing risks associated with contamination, genetic drift, or equipment failure. While such longevity is beneficial, substantial resources are needed to maintain these biobanks indefinitely.

Cryobanking is now also being developed for fucoid kelps, which lack a gametophyte life-history stage. For these species, cryobanking instead relies on preserving

gametes or germings.⁵ Advances in biobanking, genomic sequencing, and cryopreservation are expected to transform kelp conservation from simple strain preservation to strategic management of adaptive genetic diversity. Future biobanks will likely integrate genomic information with cryobanked collections, enabling the identification, preservation, and use of populations with desirable traits and enhanced restoration potential.

Nationally and internationally coordinated kelp biobanking networks could provide a global safeguard against biodiversity loss while supporting conservation and restoration.

Kelp cryobanking and biobanks are essential to safeguarding the future of kelp forests. Effective biobanks require strategically collected samples and genetic and physiological characterisation to establish a beneficial, viable, and fit-for-purpose collection.

6.3 GENETIC SELECTION AND MANIPULATION IN KELP SPECIES

Brandon Vong, Kelly DeWeese, Jaycee Lanza, Sergey Nuzhdin

Genetic tools are opening new possibilities for how kelp forests might be restored and managed in a changing ocean. Kelp researchers now have access to reference genomes⁶ and increasingly detailed information about the genes associated with growth, reproduction, and environmental tolerance. However, the practical tools needed to deliberately alter kelp genetics are still at an early stage.

In the near term, the most likely application is selective breeding informed by genomics. Researchers can identify naturally occurring genetic variation associated with desirable traits, such as faster growth or greater tolerance to heat, and use this information to guide which individuals are crossed.⁷ Because this approach works with genetic variation already present within kelp populations, it does not require direct modification of DNA.

More targeted approaches, including CRISPR-based gene editing, could eventually allow researchers to alter specific traits directly. Proof-of-concept genetic engineering tools have been demonstrated in kelps, but practical applications remain limited.⁸ Potential uses

include improving thermal tolerance, increasing productivity, or developing sterile or sporeless cultivars that could reduce the risk of genes spreading into wild populations.⁹

These technologies may become increasingly relevant as restoration confronts climate change. Restoring a kelp population to the conditions in which it historically existed will not be enough if those conditions are rapidly changing. Selective breeding, assisted adaptation, and, potentially, gene editing could help produce kelp better able to survive future temperatures and other environmental pressures.^{7,10}

However, greater ability to modify kelp also brings greater responsibility. Introducing genetically modified kelp into the ocean raises questions about gene flow, ecological interactions, reversibility, and appropriate scales of use. Robust monitoring and clear safeguards would be needed before such approaches could move from experimental systems into open ecosystems.

The key question is therefore not simply whether kelp can be genetically modified, but when and where genetic intervention might be justified. Researchers, restoration practitioners, Indigenous peoples, communities, regulators and policymakers will need to determine acceptable uses and risks together. Genetics could become an important part of the restoration toolbox, but

its role should be guided by clear conservation goals, ecological evidence, and appropriate governance.

6.4 KELPWATCH: MAPPING KELP BY SATELLITE

Tom Bell

Kelp forests form incredible, structurally complex, and rich ecosystems. And while these forests are extensive, they are also dynamic. Species like bull kelp (*Nereocystis luetkeana*) can form dense canopies within a single season, and those canopies can disappear even faster after a disturbance. Observations have typically lagged behind this rapid pace of change, as field surveys generate precise data but cover limited areas and are collected intermittently. As a result, managers are routinely asked to detect and respond to ecosystem changes months or years after the changes have occurred.

Kelpwatch (www.kelpwatch.org) addresses these issues for kelp forests that form visible surface canopies. Created in partnership with The Nature Conservancy, the Woods Hole Oceanographic Institution, UCLA, and UC Santa Barbara, the platform processes over four decades of Landsat imagery into open-access, seasonal data on emergent kelp canopy that can be freely visualised, queried, and downloaded. Importantly, the data are

relevant at multiple scales, from a single bay to continental coastlines. Coverage has expanded from the west coast of North America to Alaska, Peru, Argentina, the Falkland Islands, South Africa, and Namibia.

These data are a valuable tool for resource management. The California Department of Fish and Wildlife incorporated the canopy record into its Enhanced Status Report for giant kelp and bull kelp and has used it to screen candidate restoration sites. More broadly, the satellite archive provides the historical baselines upon which conservation decisions depend. Declines in kelp canopy are difficult to interpret without knowledge of prior conditions, and for most of the world's coastline, no field survey records exist.

For most of the world's coastline, no field survey records exist.

While these near real-time canopy data are useful, important limitations remain. For example, subsurface and understorey kelps are not visible, and canopy area alone provides no information on associated animals or whether the kelp is reproductively healthy. The current resolution misses narrow fringing beds, and cloud cover can obscure observations when and where they are most needed. Satellite monitoring therefore complements,

rather than replaces, field surveys, which remain essential for science and management.

Newer satellite systems such as Sentinel-2 and commercial constellations (e.g., Planet) will improve spatial and temporal resolution. Hyperspectral sensors such as NASA's EMIT and planned missions such as NASA's EAGLE programme and ESA's CHIME offer the potential to detect species composition and habitat condition in addition to canopy cover.

6.5 SELECTIVE BREEDING FOR CLIMATE-RESILIENT KELP FOREST RESTORATION

Cecilia Biancacci

As ocean conditions continue to change, there is hope that selective kelp breeding can help restored populations adapt to new environmental conditions. Selective breeding has substantially improved the cultivation of kelp, particularly in Asia, where controlled crossing and selection have enhanced production traits.¹¹ However, its application to kelp forest restoration remains experimental. Current initiatives focus on identifying naturally resilient individuals, crossing genotypes, or propagating selected material, while long-term, multi-generation breeding programmes have yet to be established.¹²



Restoration objectives are more complex than producing kelp that survives transplantation. They aim to establish genetically diverse, self-sustaining populations that reproduce, recruit new generations, and persist under future conditions. Achieving this will depend on using natural variation within kelp populations to identify traits that support long-term resilience, including thermal tolerance, growth, reproductive performance, and disease resistance.^{11,12}

In the wild, we hope to find natural genetic variations that are beneficial for new populations. Experimental studies have identified kelp family lines with enhanced tolerance to warming, but this tolerance is not reliably predicted by temperatures in their native habitat.¹³ Evidence for local adaptation varies with genetic background, environment, and ecological pressures.¹⁴ As a result, we need further research to understand what reliably predicts adaptability or tolerance in kelp forests.

Experimental studies have identified kelp family lines with enhanced tolerance to warming, but this tolerance is not reliably predicted by temperatures in their native habitat.

Once we do find a desirable population, we must still make sure that tolerance can be validated across multiple sites, environments, and generations. We should not measure success only by early survival and growth, but also by how that kelp functions in its natural environment (reproduction, natural recruitment, genetic diversity, and the recovery of broader ecosystem functions).^{12,14}

While selective breeding could provide real benefits, we must exercise significant caution as well. Even one generation of nursery propagation can reduce genetic diversity, increase inbreeding, and favour traits suited to artificial conditions rather than the wild.¹⁵ Responsible implementation will require genetically diverse broodstock, replicated field trials, long-term monitoring, strong biosecurity, and clear governance. As we are altering the genetic composition of our ocean ecosystems, any decision-making must involve Indigenous peoples, local communities, scientists, and stakeholders.^{12,16}

By increasing survival, reproductive success and long-term persistence, selective breeding could become a valuable tool for improving restoration outcomes as ocean warming intensifies. However, it should complement rather than replace efforts to protect existing kelp forests, restore habitats, and address the underlying drivers of decline.^{12,16}

6.6 REWILDING MARINE FOOD WEBS WITH PREDATOR REINTRODUCTIONS

Marianne Frantzen, Casey Benkwitt, Jono Wilson

Rewilding is emerging as a promising approach to kelp forest restoration. Rather than restoring habitat alone, it seeks to rebuild the species interactions and ecological processes that help ecosystems regulate themselves.

This is particularly relevant where predator losses have contributed to sea urchin population increases and persistent barrens. Human-led urchin removal can trigger rapid kelp regrowth, but sustained recovery may remain difficult if the underlying food-web imbalance persists.

In northern Norway, declines in predatory fish contributed to an ecosystem shift in the 1970s, when extensive kelp forests were transformed into urchin

barrens that persist in many areas today.¹⁷ The BlueRewilding project is testing whether rebuilding populations of Atlantic wolffish (*Anarhichas lupus*), a native sea urchin predator, could help maintain restored kelp forests. It is developing techniques for future pilot releases while testing whether predator recovery can reduce reliance on repeated grazer removal.

A parallel effort is underway on the west coast of North America. Predatory sunflower sea stars (*Pycnopodia helianthoides*) declined by more than 90% across much of their range following sea star wasting disease beginning in 2013.¹⁸ In northern California, their loss coincided with severe ocean warming events and contributed to expanding urchin populations and subsequent kelp declines. Modelling suggests sunflower sea star recovery could help control urchins and complement interventions such as urchin removal and kelp seeding.^{19,20} The Pycnopodia Recovery Working Group is coordinating efforts to advance disease research, captive rearing, and small-scale experimental reintroductions; see Roadmap to Recovery.²¹

Predator reintroduction also carries risks. Released animals may fail to survive or remain in target areas, and restored predators could affect non-target species. Ecological responses may also vary among locations, meaning predator restoration cannot be assumed to recreate historical food webs automatically.

For these reasons, the field is moving cautiously from **predator recovery as a conservation goal towards predator recovery as an ecosystem-restoration tool**. The next step is replicated trials that test survival, movement, predation, disease risk, and ecosystem responses alongside conventional kelp-restoration approaches.

As we seek to restore kelp forests, it is important that we consider not only how we restore associated biodiversity but how that biodiversity may enable restoration itself.

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Policy and Funding Advances

CHAPTER AT A GLANCE

- **Policy and funding can determine whether kelp conservation remains a collection of local projects or grows into coordinated, long-term action. Around the world, governments and partners are beginning to set clearer targets, strengthen regulation, build dedicated coordination structures, and invest in restoration and monitoring. Here, we highlight examples of how policy, funding, and governance are creating the conditions needed to support kelp conservation at meaningful scales.**

7.1 CALIFORNIA: ADAPTIVE ECOSYSTEM-BASED MANAGEMENT OF KELP

Tristin McHugh, Pike Spector, Kristen Elsmore

Over the past decade, California's response to widespread kelp forest decline has evolved from a collection of local recovery efforts into a statewide

approach focused on ecosystem conservation, restoration, and management. Driven by growing concern over large-scale kelp forest loss and lack of natural recovery, the State of California has invested more than US\$11 million in monitoring, research, restoration, and community engagement to better understand the drivers of decline, identify pathways for recovery, and initiate restoration efforts.



This transformation has been enabled by a series of interconnected policy and funding milestones. Guided by the state's groundbreaking Kelp Action Plan, released in 2021,¹ targeted investments such as the collaborative Kelp Recovery Research Program and Accelerating Kelp Research Program,² launched through the California Ocean Protection Council (OPC) and California Sea Grant, in coordination with the California Department of Fish and Wildlife (CDFW), have expanded scientific understanding, restoration capacity, and innovative experimental recovery efforts across the state to protect and restore kelp ecosystems.

In 2023, CDFW, in partnership with OPC, began developing a statewide, ecosystem-based, adaptive Kelp Restoration and Management Plan (KRMP)³ for giant kelp, *Macrocystis pyrifera*, and bull kelp, *Nereocystis luetkeana*. The KRMP is California's first comprehensive framework for kelp conservation, restoration, harvest management, and adaptive stewardship. By integrating ecosystem-based management, restoration planning, Tribal engagement, science, and permitting considerations into a single strategy, the KRMP aims to provide a framework for meaningful restoration and support the long-term management of these iconic ecosystems.

This proactive policy environment has accelerated innovation throughout the state. Tribally led monitoring, management, and restoration initiatives are playing an increasingly important role in ecosystem recovery while supporting Indigenous stewardship and sovereignty. At the same time, researchers, practitioners, agencies, and community partners are evaluating a growing suite of restoration approaches, including native purple sea urchin population control, kelp cultivation and outplanting, habitat enhancement, and emerging approaches (e.g., Array to Recover Kelp Ecosystem Vegetation (ARKEVs),⁴ drift supplementation). These efforts are supported by long-term ecological monitoring programmes, advances in kelp canopy mapping, and



strong community engagement, creating a foundation for adaptive management and a learn-by-doing approach built on the best available science.

While significant challenges remain and kelp loss continues to outpace restoration in many regions, California's leadership demonstrates how policy can help create conditions necessary for ecosystem recovery. The State's most notable achievement is not a single

restoration technique, but the deliberate alignment of public support, scientific investment, funding mechanisms, and management frameworks around a shared vision for kelp forest recovery. California offers an example of how governance can move beyond isolated restoration projects and meaningfully embed ecosystem recovery within broader biodiversity, climate resilience, and ocean stewardship agendas.

7.2 CANADA: NKELPA AND THE LAUNCH OF THE FIRST NATIONAL KELP ALLIANCE

Hannah Solway, Margot Hessing Lewis, Marianne Fish

NKELPA, the National Kelp Ecosystem Learning and Practice Alliance, spans Canada's Pacific, Atlantic, and Arctic coasts. It is the first national working group linked to the Kelp Forest Challenge and is collaboratively led by a coordination team comprising the Hakai Institute, WWF-Canada's Coastal Habitats Hub, and the Kelp Forest Alliance. Together, they support a steering committee of approximately 30 members and a community of practice of more than 100 people from over 50 organisations.

Importantly, NKELPA brings together people from a wide range of backgrounds, including research, Indigenous communities, government, industry, and non-profit organisations. Together, they are guiding the development of a national Kelp Action Plan that is grounded in regional realities and prioritises locally relevant action.

NKELPA is building a knowledge-to-action framework to support the future of Canadian kelp ecosystems. The process begins with metadata. Using a standardised template, NKELPA is cataloguing what kelp data, information, and knowledge already exist across the

country, where they are held, and who holds them. This inventory will feed into a national State of Kelp Report, which will synthesise the broader picture and use a readiness assessment to help identify priority objectives and enable action.

From there, the action-planning process will support the development of regional plans that identify opportunities to work across coasts and set practical priorities based on the available evidence, community needs, and remaining knowledge gaps.

Steering committee discussions have surfaced consistent priorities:

- **Enhancing collaboration and coordination**
- **Mapping where kelp forests are**
- **Making decisions with incomplete knowledge**
- **Making Indigenous and community leadership central rather than consultative**
- **Researching standardised assessment methods, aquaculture techniques, and ecosystem services provided by kelp forests**

The ambition is for NKELPA to become a model for similar regional and national alliances elsewhere. By developing a compatible and adaptable approach to cataloguing kelp knowledge and translating it into regional action plans, NKELPA aims to create a framework that can be transferred across jurisdictions.

Working alongside the Kelp Forest Alliance and other international partners, the longer-term vision is for countries and regions to coordinate more closely in pursuit of shared kelp conservation goals.

7.3 NORWAY: 5,000 KM² OF KELP LOST AND A NATIONAL KELP RESTORATION PLAN

Kjell Magnus Norderhaug, Thomas Wernberg, Karen Filbee-Dexter, Johanna Zimmerhackel, Cecilie Wathne

In June 2024, the Norwegian Parliament adopted Parliamentary Resolution 789, requesting the Government to develop a plan to systematically restore kelp forests along the Norwegian coast. The resolution followed consideration of Norway's integrated ocean management plans and is being progressed by the Ministry of Trade, Industry and Fisheries together with the Ministry of Climate and Environment. The Institute of Marine Research (IMR) was tasked with developing the scientific basis for the plan and published its first assessment in 2025.⁵ In 2026, the plan is being developed further with the Directorate of Fisheries and the Norwegian Environment Agency.

The 2025 assessment concluded that more than 5,000 km² of kelp forest has been lost and identified climate

change and marine heatwaves, eutrophication and runoff, and overfishing and associated changes in food webs as major drivers.^{6,7} It also identified scaling, financing, and governance as key barriers to national restoration.⁵

The next phase evaluates a business-as-usual scenario against a range of restoration and management options, including sea urchin removal and harvesting, quicklime treatment, artificial reefs, marine protection, predator deployment, and kelp transplantation and seeding. These measures are being compared according to their expected ecological effects, spatial applicability, costs, scalability, and uncertainty, alongside socioeconomic, regulatory, and institutional considerations. The plan also draws on restoration experience from Norway and internationally.⁸ The national plan is expected to be presented in 2027.

Importantly, the Parliamentary resolution did not include dedicated funding for national-scale implementation. Financing therefore remains a central challenge rather than a secured delivery mechanism.⁵

A major strength of the Norwegian process is the connection between political mandate, scientific assessment, socioeconomic analysis, and the agencies responsible for implementation. Its main limitation is also instructive internationally: political ambition

currently exceeds both demonstrated restoration capacity at large spatial scales and available financing.

Several transferable lessons emerge. National restoration planning should establish ecological baselines before selecting interventions, address the causes of degradation rather than only replacing lost habitat, compare active restoration with passive recovery and protection, and consider costs, regulation, and scalability from the outset. Pilot projects, long-term monitoring, and adaptive management are also essential before committing to large-scale deployment. Norway illustrates that national restoration planning is not simply about choosing technologies, but about linking ecological recovery with governance, finance, and long-term ecosystem management.

7.4 WASHINGTON: COORDINATED PARTNER ENGAGEMENT ADVANCES KELP CONSERVATION POLICY AND FUNDING

Jeff Whitty, Bree Turner, Cynthia Harbison, Tom Mumford

Washington's kelp story is fundamentally one of collaboration and coordination. In parts of Puget Sound, kelp forests have declined substantially, but the response

has increasingly brought together Tribes, community groups, agencies, non-profits, universities, and policymakers around a shared approach to recovery.

Washington's kelp story is fundamentally one of collaboration and coordination.

A major step came in 2020, when more than 40 partners co-created the Puget Sound Kelp Conservation and Recovery Plan.⁹ Rather than focusing on a single intervention, the plan established shared priorities across research, monitoring, policy, restoration, education, and outreach. This collaborative approach gained further momentum in 2022, when the Washington State Legislature directed the Department of Natural Resources to conserve or recover more than 4,000 hectares of kelp and eelgrass by 2040.¹⁰ The resulting statewide framework is being developed with Tribal co-stewards and other partners, and approximately 1,200 hectares of protection zones have already been established.

Washington has also begun turning these plans into stronger policy. A statewide Kelp Policy Advisory Group developed recommendations to improve mapping, management guidance, and regulatory protection. Kelp partners are working with the Department of Ecology to strengthen consideration of kelp through updates to the

rules in the Shoreline Management Act.¹¹ In 2025, bull kelp (*Nereocystis luetkeana*) was designated Washington's official state marine forest, following advocacy involving students and Tribal and non-Tribal community representatives. The designation is symbolic, but it also reflects how far kelp has moved into the state's public and political conversation.

Progress has been supported by investment from state, federal, and private funders in monitoring, research, advancing restoration techniques, coordination, and public engagement. In 2026, the Puget Sound Marine Vegetation Implementation Strategy¹² was released to support accelerated recovery of kelp and seagrass by providing strategic planning support and a framework for funding regional and local projects. Maintaining Washington's kelp conservation and recovery momentum will depend on continued funding for ongoing programmes rather than short-term project cycles alone.

What makes Washington distinctive is Tribal leadership, partner collaboration, community support, and how policy, funding, and research increasingly reinforce one another. Instead of relying on isolated restoration projects, Washington has developed shared targets and working groups, and implemented long-term planning that strengthens policy, regulations, and programmes needed to conserve and recover kelp forests across the region.

The broader lesson is that kelp revitalisation is not only an ecological challenge. It is also a coordination challenge. Washington shows what becomes possible when long-term targets, investment and Tribal and community leadership are built into the way kelp forests are managed.

7.5 EU: NATURE RESTORATION REGULATION

Cristina Piñeiro-Corbeira

The European Union Nature Restoration Regulation (NRR) establishes the first legally binding EU-wide targets for restoring degraded terrestrial, freshwater, coastal, marine, and urban ecosystems. Adopted in June 2024 after negotiation between the European Commission, Council, and European Parliament, it required all Member States to submit their draft national restoration plans by 1 September 2026. The Regulation supports implementation of the Kunming–Montreal Global Biodiversity Framework, particularly Target 2, and aligns with the EU Green Deal and 2030 Biodiversity Strategy.^{13,14}

Member States must restore at least 30% of habitat areas in poor condition by 2030, 60% by 2040, and 90% by 2050. Equivalent targets apply where habitats must be re-established to reach their favourable reference area (FRA).



**In 2025, bull kelp
(*Nereocystis luetkeana*) was
designated Washington's
official state marine forest**

The NRR also requires continued improvement in habitat condition, stronger non-deterioration safeguards, and progressive closure of knowledge gaps, including assessment of 50% of habitat areas by 2030 and all areas by 2040.

Its practical impact will depend on the quality, ambition, and financing of national restoration plans, which remain under development. Marine implementation presents particular challenges because historical baselines are uncertain, monitoring is incomplete, and data outside Natura 2000 sites are limited. Establishing credible FRAs and defining “good condition” will therefore require substantial investment in marine observation, harmonised indicators, and more detailed monitoring than is currently available under many existing directives.^{15,16,17}

The Regulation does not create a dedicated funding mechanism. Instead, implementation is expected to draw on programmes such as LIFE, Horizon Europe, regional funds and the European Maritime, Fisheries and Aquaculture Fund, alongside national and private finance.

For kelp forests, the NRR provides an important opportunity to move European policy beyond protection towards active, accountable ecosystem recovery. Its planning, reporting, and transparency requirements could strengthen the recognition of kelp forests within

marine governance. However, effective implementation will require coordination beyond EU waters, particularly across the Atlantic Arc and North Atlantic, where kelp ecosystems extend into the United Kingdom, Norway, and Iceland. Shared monitoring protocols, compatible definitions of ecological condition, and cross-border restoration planning will be essential for managing these transboundary ecosystems coherently.¹⁸

7.6 CAN KELP FORESTS BE INCLUDED IN A COUNTRY'S CARBON ACCOUNTS?

Brian Takeda and Tomohiro Kuwae

The Paris Agreement (2016) has 194 national parties and is the global framework for keeping climate warming below an average of 2°C. Within that, the Nationally Determined Contributions (NDCs) are the national climate commitments which are submitted by each party and form the basis for national targets and sectoral policies related to CO₂ emissions.

Nature conservation has been included in many countries' NDCs, either through terrestrial carbon sink habitats (e.g., forests) or later, via “blue carbon” in marine habitats such as mangroves, saltmarsh, and seagrass.¹⁹ Indeed, at least 45 countries have included

these habitats in their national inventories and as part of their climate mitigation strategy.²⁰ Although seaweeds are major carbon-fixing marine habitats, they were originally excluded as their carbon is largely exported and stored offsite (as detritus or dissolved organic carbon) rather than fixed in sediment beneath the plant.

While there has been increasing discussion about including seaweeds as official blue carbon habitats, very little was official until the 63rd session of the Intergovernmental Panel on Climate Change (IPCC, October 2025 in Lima, Peru).²¹ Here, parties approved an outline that creates a pathway for coastal wetland systems such as tidal flats and seaweeds in the forthcoming 2027 Carbon Dioxide Removal Methodology Report. If finalised, this methodology will make it easier for Parties to assess and include seaweed ecosystems in their NDCs.

Japan is an exception and has moved in advance of an international consensus. In 2020, the Japanese government co-launched the J-Blue Credit, the world's first government-approved, voluntary blue carbon credit system, which extended eligibility to wild and farmed seaweeds alongside mangroves and seagrass. Importantly, the Japanese methodology focuses heavily on co-benefits and emphasises the ecological, social, and economic benefits that also occur with seaweed and kelp

conservation. As an additional step, the scheme also allows for private investment and support for marine conservation projects.

In 2024, Japan became the first country to report carbon removal from seaweed beds in its national Greenhouse Gas (GHG) inventory. Japan subsequently included these ecosystems within the scope of its 2035/2040 NDCs submitted in 2025. Japan is now pushing a step further, by building on its voluntary blue credit experience to launch compliance-grade blue credits. The Plan for Global Warming Countermeasures, adopted by Cabinet decision on 18 February 2025 as the government's comprehensive implementation roadmap for its NDC, explicitly designates blue carbon as a priority removal pathway, signalling the government's intent to move blue carbon credits from a purely voluntary instrument towards formal integration into national compliance policy.

With further international collaboration and standard setting, there is a clear pathway to include seaweeds, including kelp forests, in NDCs and country-level climate strategies. These strategies also have the opportunity to go beyond carbon and focus on the whole-ecosystem benefits provided by protecting and restoring these ecosystems.

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Communities and Communications

CHAPTER AT A GLANCE

- **Protecting and restoring kelp forests is as much about connecting people to these systems as it is about science and policy. People have expressed their connection to and the importance of kelp forests in many forms, from paint to poetry to podcasts. Here, we highlight some of our favourite examples of artistic expression and communication about kelp forests.**

8.1 1001 SEAFOREST SPECIES

Jannes Landschoff

It is perhaps counterintuitive that one of the kelp forests most people are familiar with is also likely one of the least understood. But that is the case along the southwestern coast of Africa, where the Great African Seaforest, the subject of an Oscar-winning documentary viewed by millions, still contains so many mysteries.

1001 Seaforest Species,¹ developed by the Sea Change Project and supported by the Save Our Seas Foundation, is building a biodiversity knowledge platform for the Great African Seaforest. Inspired by *One Thousand and One Nights*, in which storytelling preserves life, 1001 applies this idea to biodiversity: each species represents a story to be discovered, documented, and shared, keeping the seaforest and its biodiversity alive in people's imaginations.

Each species represents a story to be discovered.

1001 brings together many types of knowledge, documenting observations, preserving visual records, and contributing to scientific research. As such, collaboration is central to its long-term vision as it aims to connect these different forms and sources of knowledge and enable wider participation. Together, the contributors are creating a shared and enduring resource that benefits many communities and serves different purposes – from taxonomy and research to education, conservation, and public engagement.

At the centre of this resource is the 1001 Species app, a growing “living catalogue” currently under development for public release in 2027. Conceived as “a seaforest in your pocket,” it brings together over 1,000 species across the tree of life, from seaweeds and invertebrates to fishes, birds, and mammals. Species accounts combine identification, biology, and distribution with comparisons to related taxa, placing each species within the wider diversity of the seaforest.



Figure 8.1 Kelp forest habitats and the 1001 Seaforest Species platform.

Keeping the seaforest and its biodiversity alive in people's imaginations.

Alongside this scientific foundation, photography, film, natural history, and immersive storytelling reveal the lives behind the species. Field observations capture



behaviour and ecological interactions that may be absent from formal publications, presenting species as fundamental components of a complex living ecosystem.

The underlying premise is simple: biodiversity cannot be effectively studied, monitored, or protected if it remains poorly known, inaccessible or invisible to society. By connecting people with kelp forest life through knowledge and storytelling, 1001 seeks to strengthen both the understanding and societal connection needed for long-term conservation.

8.2 OCEAN LITERACY IN ACTION: LESSONS FROM THE GREAT SOUTHERN REEF

**Prue Francis, Catia Jose Abreu de Freitas,
Stefan Andrews**

A decade ago, the Great Southern Reef was hiding in plain sight. Stretching more than 8,000 km along southern Australia, it supported distinctive species, communities, and economies, yet had little public identity of its own. Naming the reef in 2015 gave people a shared way to recognise, discuss, and care about it.

Since then, its profile has grown through a deliberately varied mix of education, storytelling, and public



engagement. Scientists, teachers, artists, filmmakers, community groups, and organisations such as the Great Southern Reef Foundation have each helped tell the reef's story in different ways. Direct references to the Great Southern Reef in online and print media rose from 34 stories in 2020 to 207 in 2025, alongside around 90 broadcast mentions in 2025. Federal research funding also increased from approximately A\$4 million in 2010–2015 to more than A\$8 million in 2022–2026.

The documentary *White Rock* illustrates how these efforts can reinforce one another. The film brought the story of kelp loss and long-spined sea urchins to a broad

audience, while curriculum-linked resources helped teachers take that story into classrooms. Art exhibitions, podcasts, community events, television, radio, and print media extended the conversation beyond formal education.

The strongest results may be the simplest. After participating in a place-based ocean education programme, students from coastlines along the Great Southern Reef moved from drawing mostly tropical marine animals to depicting kelp forests and

local invertebrates. Teachers also reported greater confidence in teaching ocean topics and connecting them across subjects.

The Great Southern Reef did not become visible through one campaign or one organisation. Its growing recognition came from many people repeating, adapting, and localising the story over time. The lesson is that ocean literacy works best when it feels relevant to people's own coastlines, identities, and experiences—and when education, media, art, and community engagement are treated as connected parts of conservation rather than optional extras.

8.3 FORESTS WITHOUT NAMES: WHY NAMING KELP FORESTS MATTERS

Claudia Santori, Amanda Schadeberg, Chanelle Webster, Adriana Vergés

What does your name tell others about who you are? For many places, a name conjures a living image: the Amazon Rainforest, the Nile River, or Mount Fuji. Already, you can place them on a map, see their colours, and imagine the life they sustain.

Kelp forests are not so lucky.

All along the Great Southern Reef² of Australia, kelp forests have been cared for and used by Aboriginal peoples for tens of thousands of years, yet they remain unnamed, or their names may have been lost through colonisation and displacement. Without a name, kelp forests can be harder to identify or form a relationship with. Before we can ask people to care for a place, it might help if we can first introduce them to it.

The *Forests Without Names*³ project is an international collaboration between Hyundai and the Kelp Forest Alliance. Operation Crayweed,⁴ which runs the programme in Australia, invited local communities to name two kelp forests at South Coogee and Freshwater

in Sydney, Australia. We hosted workshops where swimmers, surfers, divers, residents, scientists, and Aboriginal community members came together to learn about crayweed restoration, share their relationships with the coastline, and create a list of potential names. After consultation with local Aboriginal authorities to ensure the linguistic accuracy of the names that included Indigenous words, we put the two community shortlists to a public vote.



Figure 8.2 A restored crayweed (*Phyllospora comosa*) forest in Sydney's eastern suburbs. Photo: Tom Burd.



Figure 8.3 Attendees at the South Coogee workshop, which resulted in the naming of Yanggaa Kelp Forest.

More than 1,800 votes were cast.

At South Coogee, the community selected Yanggaa Kelp Forest, using the Dharawal word for the crayfish that make their homes in the kelp forest.

At Freshwater, the community chose Kadjung Kelp Forest, with *kadjung* meaning freshwater in Gomberee, a local Aboriginal language.

With formal approval from the Geographical Names Board⁵ of New South Wales, these could become the first officially named kelp forests in Australia.

Research suggests that names can carry ecological knowledge and cultural memory, and that cultural recognition of places can be associated with their conservation.⁶ That both communities chose Aboriginal-language names was meaningful, respecting the ongoing caring relationships between Indigenous peoples, language, and the environment.

The idea is catching on. *Forests Without Names* has named kelp forests in Argentina and Korea, and a third community workshop is planned for Sydney. Naming is an invitation to both notice and care, and Yanggaa and Kadjung Kelp Forests are one step closer to being on the map for communities and conservation.

8.4 STORYTELLING AND THE MYSTERIOUS WORLD OF BULL KELP

Josie Iselin, Marianna Leuschel

THE MYSTERIOUS WORLD OF **bull kelp**

Exploring the kelp forests of the North Pacific Coast

<https://bullkelp.info/>

The Magnificent World of **giant kelp**

Exploring the Kelp Cathedrals of the Eastern Pacific

<https://giantkelp.info/>

kelp!

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How do we create empathy for kelp?

How do we humans above connect with the ocean's kelp forests and their hidden abundance below? Kelp recovery and restoration are now a global enterprise, key to rebuilding healthy oceans. To support restoration, we must connect human communities to the kelp ecosystem by building empathy—engaging all the senses. Above/Below spearheads an ocean education campaign throughout the Eastern Pacific region that combines science, art, and storytelling.

Our initiatives include *The Mysterious World of Bull Kelp* webstory that connects kelp research with lyrical storytelling and compelling illustrations, photography and infographics. From this collaborative effort, events such as multimedia art exhibits, local festivals, films, talks, and dance performances arise with initiatives from a growing community of researchers, artists, and kelp enthusiasts. Public-facing communications for restoration projects and book publishing take the story of kelp to an even wider audience.

This is how the web of empathy grows into a resilient, interconnected "ecosystem" of support for kelp forests.

**ABOVE
BELOW**

Above/Below is a team of designers focused on promoting ocean literacy through creative storytelling about the kelp forests of the Eastern Pacific Ocean.

8.5 DEVELOPING A NETWORK OF KELP FOREST ECOSYSTEM MONITORING PROGRAMMES

Dillon Dolinar and Rodrigo Beas-Luna

“Observations provide the logical starting position from which to begin to propose explanations or theories.”⁷

Our understanding of kelp forests and the communities that they harbour has benefited immensely from the establishment and maintenance of long-term ecological and environmental monitoring programmes. These investments have captured and described profound ecological crises,⁸ identified why systems collapsed or shifted,⁹ and linked policy decisions to ecological and social outcomes.¹⁰ While these programmes can generate large amounts of useful information, that value cannot be fully realised if people are unable to locate, share, and use their data.

We are developing a tool that will enhance data sharing, collaboration, and understanding across kelp forest monitoring programmes around the world. This work will provide a centralised repository illustrating where long-term monitoring is occurring along rocky reefs and kelp forests, and equally importantly, where monitoring gaps remain.

The publicly available web platform will host information on the location, years surveyed, survey frequency, and methods

used by long-term monitoring programmes. Importantly, the platform will also guide users on how to access the data and will help reduce the duplication of monitoring efforts at the same location.

One of the most exciting elements of this work is that it will help combat “shifting baseline syndrome”, whereby younger observers see a degraded state and assume it is natural. By increasing access to data documenting how things once were, the programme can help guide decisions about what restoration outcomes should look like, or how much damage has been done to an ecosystem. The project will also enhance data sharing and help facilitate regional monitoring programmes and guide management and research in these systems.

The platform will be hosted on the Kelp Forest Alliance website and open to all. We expect a regional launch in early 2027 and global expansion by 2028. We invite researchers and monitoring organisations interested in collaborating on this project to reach out.

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Methods

9.1 EXPERT OPINION SURVEY

This assessment draws on a structured global survey of kelp forest experts, practitioners, and managers. Participants provided information only for regions where they had substantial knowledge or experience.

The survey assessed four aspects of kelp forest conservation: threats and stressors, current conservation action, capacity to respond, and ecosystem benefits. Sixteen indicators were scored using consistent criteria, allowing broad comparisons among regions.

Responses were combined to produce regional summaries and to identify places where conservation action and capacity may not be keeping pace with the pressures facing kelp forests.

The results represent expert-informed assessments rather than direct measurements of ecological condition or management effectiveness. The number of respondents and the availability of evidence varied among regions, so findings from areas with limited responses should be interpreted cautiously and alongside other available information.

9.2 KELP PROTECTION ANALYSIS

We estimated how much of the global kelp biome overlaps with marine protected areas and how strong that protection is likely to be.

The kelp biome was represented using a global model of potential kelp distribution¹, restricted to waters shallower than 60 metres. This captures the broad environmental range in which kelp forests may occur, but it is not a direct map of observed kelp. It may overestimate habitat because it does not account for the availability of rocky reef, while also underestimating kelp distribution in places that were inaccurately modelled.

We overlaid this biome layer with two complementary protected-area datasets. The World Database on Protected Areas was used to estimate the overall area of kelp habitat located within designated protected areas. ProtectedSeas' Level of Fishing Protection dataset was used to assess the strength of fishing restrictions within those areas, with a focus on moderately and highly protected sites.

Where protected areas overlapped, each location was assigned to the highest applicable protection category to avoid double-counting. These results indicate the spatial extent and likely regulatory strength of protection, but they do not directly measure enforcement, management effectiveness, or ecological outcomes.

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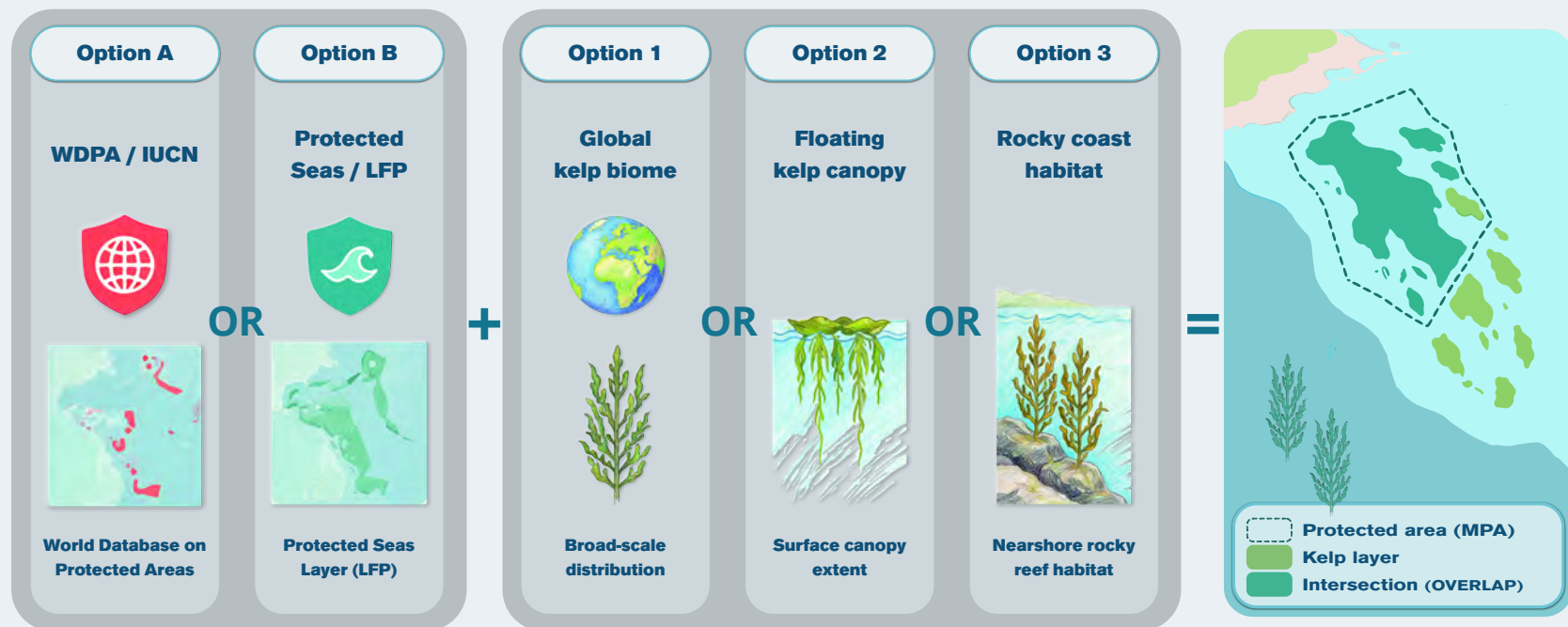


Figure 9.1 Overview of the kelp protection analysis. Habitat and protected-area layers are overlaid to estimate spatial overlap. See Section 9.2 for the habitat layer and protection datasets used in this report.

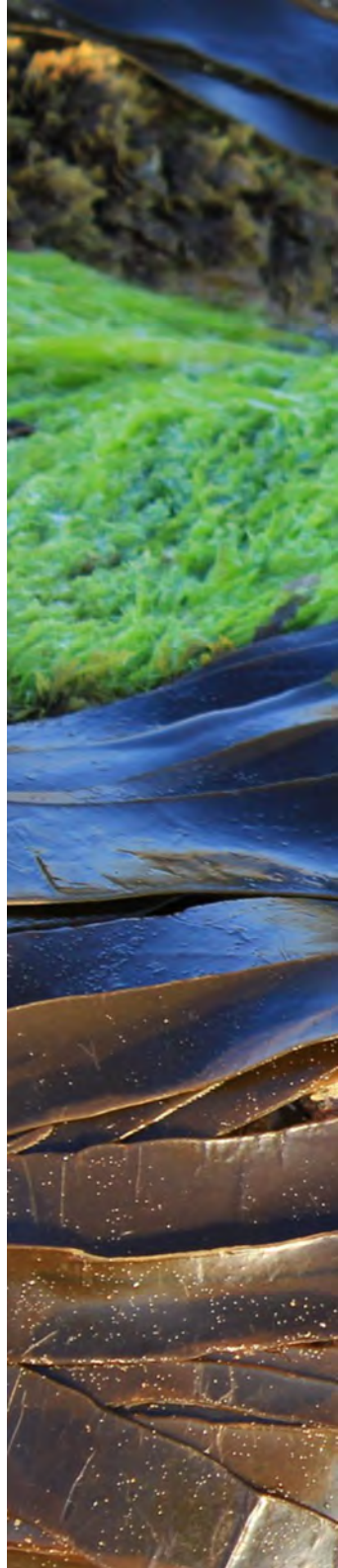


KELP FOREST ALLIANCE

Closing

The state of the world's kelp forests remains mixed. Kelp forests continue to be lost, oceans are warming, and overabundant grazers remain a major challenge. At the same time, more areas are being restored, new partnerships and collaborations are forming, and funding is increasing in some regions. The seeds for effective and ethical growth are there. But we must also consider what that growth looks like. For kelp conservation to grow in a way that realises its potential to benefit people and nature, it will need to expand not only the amount of knowledge and action, but also the types of knowledge, the types of action, the diversity of people working on this mission, and the connections between them.

The next report will show what those seeds have grown into: the third *State of the World's Kelp Forests* report.





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**When you pull
on the fronds
of a kelp forest,
you find it
attached to all
the depths of
the ocean.**

