NORWEGIAN BLUE FORESTS NETWORK (NBFN)

TOP TEN TRENDS FROM 2022

A competence network established by the Norwegian Institute for Water Research, GRID-Arendal and the Institute of Marine Research

Norwegian Blue Forests Network

GRID ARENDAL

HAVFORSKNINGSINSTITUTTET

NIVA Norsk institutt for vannforskning

NBFN: TOP 10 TRENDS FROM 2022

2022 was a year of contrasts. On the one hand, there was growing interest in blue forests-related issues such as the blue economy, marine protection, and how the ocean can play a major role in lifting us out of the current climate and environmental crisis. On the other hand, 2022 was a record-breaking year, in a record-breaking decade, of climate catastrophes. Interest in nature-based solutions continued to rise – as did the recognition that protecting and restoring blue forest ecosystems (including mangroves, seagrasses, salt marshes and kelp ecosystems) is one such measure. Indeed, blue carbon has become a buzzword in the climate sector – hailed as a possible underused resource to help us keep to the much-needed promise of 1.5°C warming above pre-industrial temperature levels. In recognition of its importance, 2022 UN Climate Change Conference (COP 27) final declaration included, for the first time, a dedicated sub-section on the ocean. The text "encourages Parties to consider, as appropriate, ocean-based action in their national climate goals and in the implementation of these goals."

Yet blue forests can and do offer so much more, including economic opportunities, food security and support for biodiversity. In 2022 we saw academics, policymakers, and civil society make a case for why these vulnerable ecosystems are so valuable economically, environmentally, and culturally. The year culminated in the UN Convention on Biological Diversity (COP 15), where a new global biodiversity framework was agreed to. The first draft of this text used the term 'marine ecosystems'; the final text explicitly recognises coastal areas.

This paper presents a summary of the top ten trends of 2022 as seen by the Norwegian Blue Forest Network (NBFN), with the understanding that there are additional trends ongoing as well. It focuses on global and national trends seen from a Nordic perspective. We hope that by highlighting these trends, we can showcase areas of rising interest, as well as gaps for future research needs. We conclude by highlighting a selection of areas to watch in 2023 and beyond.

– **Norwegian Blue Forests Network**

Table of contents

BLUE CARBON

Blue carbon ecosystems such as blue forests capture and store organic carbon within their biomass and sediment. This carbon can remain sequestered for hundreds or even thousands of years, making blue forests a valuable asset for climate mitigation. While interest in blue forests' ability to sequester carbon continued to grow in 2022, there are still many questions about their carbon-storing potential that need to be answered. Interest in blue forests' many other ecosystem services was similarly on the rise.

#1. Beyond blue carbon: Increased acknowledgment of the wider ecosystem services blue forests provide.

In 2022, new research emphasised the connection between blue forests and the co-benefits they provide, such as increasing biodiversity, supporting fisheries through spawning and nursery grounds for juvenile fish, and filtering excess nutrients to improve water quality.[1 2 3 4 5] The Global Ecosystem services Assessment from Kelp forests (GEAK) network held its first workshop to comprehensively assess economic valuations of kelp in terms of fisheries and kelp harvest, as well as cultural values, carbon storage, nutrient filtration and biodiversity provision. The findings from this workshop will be finalised in a scientific paper in 2023. Expanding on this theme, in March the Norwegian Agency for Development (Norad) co-hosted a seminar on blue forests and poverty with NBFN,[6] touching upon topics such as food security, gender equality and livelihood generation. This event was followed by the Norwegian Ministry of Foreign Affairs and Norad's first annual ocean conference[7], where blue forests were mentioned throughout, not only for their carbon storage capacity, but also in the context of fisheries and poverty alleviation. The United Nations Decade of Ocean Science for Sustainable Development also launched the Global Ocean Decade Programme for Blue Carbon that aims to address Sustainable Development Goals (SDGs) 13 (climate action) and 17 (partnerships for the goals), alongside SDG 14 (life underwater) through enhanced scientific cooperation at all levels.[8]

Representative of the Gazi Women Boardwalk in Gazi Bay, Kenya. Rob Barnes, GRID-Arendal

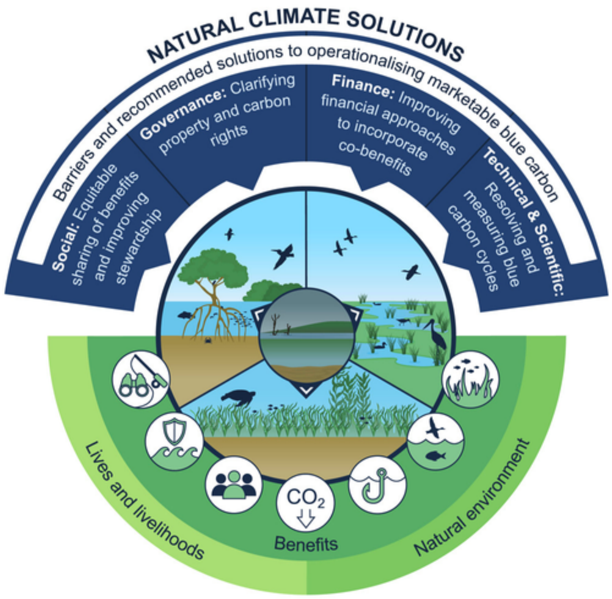
BLUE CARBON

#2. Blue carbon financing is on the rise, despite an opaque carbon market.

Over the past decade, blue carbon ecosystems like mangroves, saltmarshes and seagrass meadows have gained recognition as climate mitigation allies for their ability to sequester greenhouse gases up to 10 times more efficiently than terrestrial forests.[9] [10] [11] A demand for nature-based solutions has grown precipitously: the voluntary carbon market reached nearly $2 billion this year, quadrupling in market value from 2020.[12] This includes the voluntary market for blue carbon offsets, where one carbon credit represents one tonne of greenhouse gases that have been either avoided or removed from the atmosphere by coastal ecosystems. The few blue carbon projects that exist typically involve investment in ecosystem restoration where financial returns are provided to the communities who maintain these habitats.

Despite its great promise for ecosystem conservation and restoration, this emerging market is currently opaque and in need of transparency and verifiable evidence of community benefits to avoid reinforcing or exacerbating social inequities.[13] [14] One example is the Delta Blue Carbon, the world's largest blue carbon project to date. It aims to restore 350,000 hectares of mangroves in Sindh, Pakistan, and sold its first allotment of carbon credits on the market this year.[15]

Additionally, in September, the International Monetary Fund's Managing Director, Kristalina Georgieva, advocated that small island developing states should be able to repay their debts in the form of carbon credits.[16]



Barriers and recommended solutions for the blue carbon market[17]

As an example, Georgieva identified the Bahamas due to the nation's extreme climate vulnerability[18] and their immense carbon sinks, including an estimated $300 million worth of seagrass and mangrove carbon assets.[19] [20]

> ***"Nature-based solutions aren't a get-out-of-jail-free card for doing the hard work of decarbonising our economies" – Dan Friess, Centre for Nature-based Climate Solutions at the University of Singapore***[21]

Despite much enthusiasm for carbon credits as a nature-based solution, 2022 also saw pushback to this trend. India joined the likes of Papua New Guinea, Honduras, Indonesia and others to ban the export of their carbon credits on the international market.[2] [23] Market concerns include issues that terrestrial forestry carbon projects have faced, such as double counting and leakage[24] which blue carbon projects will also have to address.

BLUE CARBON

New research has also cast doubt on the cost-effectiveness and accounting issues related to coastal blue carbon ecosystem restoration for secure carbon removal[25], as well as the scalability of blue carbon projects that are not well adapted to local ecosystem dynamics, nor have buy-in from communities.[26] [27] A possible way forward is to expand blue carbon projects to better account for the many ecosystem services of blue forests – a topic discussed in trend one.

Mangroves in Indonesia. Steven Lutz, GRID-Arendal

#3. Is kelp a 'silver bullet' for climate change? The debate continues.

In 2022, we saw interesting debates within the kelp research community about the efficiency of wild kelp to store carbon, as well as the ethics of sinking cultivated kelp for carbon dioxide removal (CDR) purposes. An article published in April by Gallagher et al.[28] sparked a heated debate throughout the kelp community when the authors claimed seaweed ecosystems – which include sea squirts, shellfish and other phytoplankton-eating feeders in addition to seaweed – may actually release more carbon than they store.[29] This claim was quickly disputed by a group of kelp experts, including some of Norwegian Blue Forests Network's own experts, who penned a rebuttal article outlining potential flaws in Gallagher et al.'s conclusions which, they argue, may distort the global picture and risk further research motivations and initiatives to protect and restore seaweed forests.[30]

Their primary concern was that the study conflates very different seaweed ecosystems from a limited data set, resulting in net ecosystem production measures not being representative. More research is needed to fully understand the role of kelp and other seaweeds in climate mitigation. To this end, a number of academic articles on the ability kelp to sequester and store carbon were published in 2022.[31] [32] [33]

Nature-based solutions like ocean CDR are gaining attention, with specific focus on seaweed cultivation and subsequent sinking to the seafloor to sequester this carbon.[34] [35] However, the ecological impacts, as well as the effectiveness of this process, are largely

BLUE CARBON

unknown.[36] [37] [38] Initial research on the impacts of sinking seaweed show major potential negative side effects on marine ecosystems and their biogeochemistry, both at upper levels of the ocean where seaweed would be grown, and at depth.[39] [40] [41] This includes a potential reduction in phytoplankton production that could impact fisheries and the wider food web, the introduction of invasive species and spread of disease, and a reduction in oxygen levels on the seafloor that could lead to ocean acidification from an increased nutrient load. Ocean CDR strategies are not simple, and should be backed by sound research to prevent the development of practices with questionable benefits that may further harm the environment they are initially intended to protect.

"[T]he race to sink seaweed in the ocean is outpacing the rate of progress of the essential science to assess risks, surging past even perfunctory evaluation of the environmental impacts and social benefits"
– Ricart et al.[42]

Kelp forest off the coast of Lofoten, Norway. Janne K Gitmark, NIVA

BLUE CARBON

References

[1] Hagger, V., Waltham, N.J., Lovelock, C.E. (2022). Opportunities for coastal wetland restoration for blue carbon with co-benefits for biodiversity, coastal fisheries, and water quality. Ecosystem Services, Volume 55. https://doi.org/10.1016/j.ecoser.2022.101423

[2] Jankowska, E., Pelc, R., Alvarez, J., Frischmann, C.J. (2022). Climate benefits from establishing marine protected areas targeted at blue carbon solutions. PNAS, Volume 119: 23. https://doi.org/10.1073/pnas.2121705119

[3] Rodil, I.F., Lohrer, A.M., Attard, K. M., Thrush, S.F., and Norkko, A. (2022). Positive Contribution of Macrofaunal Biodiversity to Secondary Production and Seagrass Carbon Metabolism. Ecology 103: 4. https://doi.org/10.1002/ecy.3648

[4] Knutsen, H., Catarino, D., Rogers, L., Sodeland, M., Mattingsdal, M., et al (2022). Combining population genomics with demographic analyses highlights habitat patchiness and larval dispersal as determinants of connectivity in coastal fish species. Molecular Ecology, 31, 2562– 2577. https://doi.org/10.1111/mec.16415

[5] Hagger, V., Waltham, N.J., Lovelock, C.E. (2022). Opportunities for coastal wetland restoration for blue carbon with co-benefits for biodiversity, coastal fisheries, and water quality. Ecosystem Services, Volume 55. https://doi.org/10.1016/j.ecoser.2022.101423

[6] Norwegian Agency for Development (Norad) (2022). Blue forests: Valuable nature that contributes to food security and helps combat the climate crisis and poverty. Seminar. Recording available online.

[7] Norwegian Agency for Development (Norad) (2022). Power Meeting on Norway's International Maritime Investment. Recording available online.

[8] United Nations Decade of Ocean Science for Sustainable Development (2022). Global Ocean Decade Programme for Blue Carbon. Available online.

[9] Nellemann, Christian & Corcoran, Emily & Duarte, Carlos & Valdes, Luis & Young, Cassandra & Fonseca, Luis & Grimsditch, Gabriel. (2009). Blue Carbon – The Role of Healthy Oceans in Binding Carbon. Available online.

10] Mcleod, E., Chmura, G.L., Bouillon, S., Salm, R., Björk, M., Duarte, C.M., Lovelock, et al (2011), A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment, 9: 552-560. https://doi.org/10.1890/110004

[11] Lovelock, Catherine & Duarte, Carlos. (2019). Dimensions of Blue Carbon and emerging perspectives. Biology letters. 15. https://doi.org/10.1098/rsbl.2018.0781

[12] Ecosystems Marketplace (2021). VCM Reaches Towards $2 Billion in 2021: New Market Analysis. Ecosystem Marketplace. Available online.

[13] Macreadie, P.I., Robertson A.I., Spinks, B., Adams, M.P., Atchison, J.M., et al (2022). Operationalizing marketable blue carbon. One Earth, Volume 5, Issue 5: 485-492. https://doi.org/10.1016/j.oneear.2022.04.005

[14] World Ocean Initiative (2022). Are blue carbon markets becoming mainstream? Mangroves, tidal marshes and seagrass meadows are powerful nature-based net-zero solutions. World Ocean Initiative. Available online.

[15] Delta Blue Carbon (2022). The Delta Blue Carbon Project. Project website available online.

[16] McCartney, P. (2022). IMF managing director suggests carbon credits to pay off debt. The Nassau Guardian. Available online.

[17] Macreadie, P.I., Robertson A.I., Spinks, B., Adams, M.P., Atchison, J.M., et al (2022). Operationalizing marketable blue carbon. One Earth, Volume 5, Issue 5: 485-492. https://doi.org/10.1016/j.oneear.2022.04.005

[18] Cevik, S. (2022). Waiting for Godot? The Case for Climate Change Adaptation and Mitigation in Small Island States. International Monetary Fund. IMF Working Papers. Available online.

[19] Oxford Business Group (2022). Could Blue Carbon Credits be the Future of Sustainable Financing? Oil Price. Available online.

[20] Carbon Credits (2022). The Bahamas Intends to be the First Country to Sell Blue Carbon Credits. Carbon Credits. Available online.

[21] Howell, M. (2021). The unspoken challenges of blue carbon. The Fish Site. Available online.

[22] Mohanty, N. (2022). A ban on exporting carbon credits and its impact on the domestic carbon market. Ecosystem Marketplace. Available online.

[23] Hilmi, M. (2022). India's Ban On The Export Of Carbon Credits – What Are The Implications? Verdantix. Available online.

[24] Burkart, K. (2022). REDD+ ALERT: Are nature-based carbon offsets part of the climate problem? Climate and Capital Media. Available online.

[25] Williamson, P., Gattuso, J.-P. (2022). Carbon Removal Using Coastal Blue Carbon Ecosystems Is Uncertain and Unreliable, With Questionable Climatic Cost-Effectiveness. Frontiers in Climate, Vol. 4-2022. https://doi.org/10.3389/fclim.2022.853666

[26] Howell, M. (2021). The unspoken challenges of blue carbon. The Fish Site. Available online.

References

[27] Macreadie, P.I., Robertson A.I., Spinks, B., Adams, M.P., Atchison, J.M., et al (2022). Operationalizing marketable blue carbon. One Earth, Volume 5, Issue 5: 485-492. https://doi.org/10.1016/j.oneear.2022.04.005.

[28] Gallagher, J.B., Shelamoff, V., Layton, C. (2022). Seaweed ecosystems may not mitigate CO2 emissions, ICES Journal of Marine Science, Volume 79, Issue 3: 585–592. https://doi.org/10.1093/icesjms/fsac011

[29] Gallagher, J.B., Shelamoff, V., Layton, C. (2022). Seaweed ecosystems may not mitigate CO2 emissions, ICES Journal of Marine Science, Volume 79, Issue 3: 585–592. https://doi.org/10.1093/icesjms/fsac011

[30] Filbee-Dexter, K., Pessarrodona, A., Duarte, C., Krause-Jensen, D., Hancke, K., Smale, D., Wernberg, T. (2022). Seaweed forests are carbon sinks that can mitigate CO2 emissions. Preprint. http://doi.org/10.32942/osf.io/ya7wf

[31] Duarte, C. M., Gattuso, J.-P., Hancke, K., Gundersen, H., Filbee-Dexter, K., Pedersen, M. F., Middelburg, J. J., Burrows, M. T., Krumhansl, K. A., Wernberg, T., Moore, P., Pessarrodona, A., Ørberg, S. B., Pinto, I. S., Assis, J., Queirós, A. M., Smale, D. A., Bekkby, T., Serrão, E. A., & Krause-Jensen, D. (2022). Global estimates of the extent and production of macroalgal forests. Global Ecology and Biogeography, 31, 1422– 1439. https://doi.org/10.1111/geb.13515

[32] Pessarrodona, A., Filbee-Dexter, K., Krumhansl, K.A. et al. (2022). A global dataset of seaweed net primary productivity. Sci Data 9, 484. https://doi.org/10.1038/s41597-022-01554-5

[33] Filbee-Dexter K, Feehan CJ, Smale DA, Krumhansl KA, Augustine S, de Bettignies F, et al. (2022). Kelp carbon sink potential decreases with warming due to accelerating decomposition. PLoS Biol. 20(8):e3001702. https://doi.org/10.1371/journal.pbio.3001702

[34] Burns, W. (2022). Can Kelp Help? The Potential Role of "Ocean Afforestation". Illuminem. Available online.

[35] Jones, N. (2022). Kelp Gets on the Carbon-Credit Bandwagon. Hakai Magazine. Available online.

[36] Ricart, A.M., Krause-Jensen, D., Hancke, K., Price, N.N., Masqué, P., Duarte, C.M. (2022). Sinking seaweed in the deep ocean for carbon neutrality is ahead of science and beyond the ethics. Environmental Research Letters. Volume 17 081003. https://www.doi.org/10.1088/1748-9326/ac82ff

[37] Campbell, I., Macleod, A., Sahlmann. C., Neves, L., Funderud, J., Øverland, M., Hughes, A.D., Stanley, M. (2019). The Environmental Risks Associated With the Development of Seaweed Farming in Europe – Prioritizing Key Knowledge Gaps. Frontiers in Marine Science, Volume 6. https://www.doi.org/10.3389/fmars.2019.00107

[38] M. Troell, P. J. G. Henriksson, A. H. Buschmann, T. Chopin & S. Quahe (2022) Farming the Ocean – Seaweeds as a Quick Fix for the Climate?, Reviews in Fisheries Science & Aquaculture. https://doi.org/10.1080/23308249.2022.2048792

[39] Burns, W. (2022). Can Kelp Help? The Potential Role of "Ocean Afforestation". Illuminem. Available online.

[40] Wu, J., Keller, D.P., Oschlies, A. (2022). Carbon Dioxide Removal via Macroalgae Open-ocean Mariculture and Sinking: An Earth System Modeling Study. Earth System Dynamics, Preprint. https://doi.org/10.5194/esd-2021-104

[41] Campbell, I., Macleod, A., Sahlmann. C., Neves, L., Funderud, J., Øverland, M., Hughes, A.D., Stanley, M. (2019). The Environmental Risks Associated With the Development of Seaweed Farming in Europe – Prioritizing Key Knowledge Gaps. Frontiers in Marine Science, Volume 6. https://www.doi.org/10.3389/fmars.2019.00107

[42] Ricart, A.M., Krause-Jensen, D., Hancke, K., Price, N.N., Masqué, P., Duarte, C.M. (2022). Sinking seaweed in the deep ocean for carbon neutrality is ahead of science and beyond the ethics. Environmental Research Letters. Volume 17 081003. https://www.doi.org/10.1088/1748-9326/ac82ff

Further reading:
UNFCCC (2022). Sharm el-Sheikh Implementation Plan. Ch. 13, Ocean. Sharm el-Sheikh Climate Change Conference of the Parties (COP) 27. Available online.

Mangrove forests in the Gulf of Guayaquil, Ecuador. Jane Glavan, Distant Imagery

MONITORING AND RESTORATION

In order to conserve and protect blue forest ecosystems and their services, we need to know where they are, what their status is, and how they are threatened.

#4. The creation of better maps and models – both from the field and from afar.

Advances in satellite technology have meant that it is possible to model and estimate soil characterisation in mangrove forests as well as to evaluate changes over time. New remote sensing methodologies are being used to better understand the capacity of mangroves to store carbon.[1] [2] Newly discovered in 2022 was a unique type of mangrove in the Amazon delta that thrives in a freshwater environment.[3] [4] It is the first time that mangrove structures have been documented on deltas or coastal fringing mangroves with little to no salinity. It is significant because it expands the area of mapped mangroves in the Amazon delta by 20 per cent, and these mangroves will likely have unique ecosystem functions and support unique animal and plant species. The authors of the study on the mangrove further predict that these forests may hold the largest global carbon storage of coastal oceans, due to the presence of well-developed trees in an environment where they receive an abundance of fresh water and suspended sediments from the Amazon River plume. Such discoveries highlight the importance of continuing to fund on-the-ground field explorations of the world's natural habitats, as there are still many discoveries to be made. Seagrass beds are especially difficult to map, but Earth observation data methodologies, drones and machine learning are being established to provide at least a first overview of areas as diverse as the turbid Baltic Sea and the Great Barrier reef.[5] [6] [7] [8]

While these methodologies do not reduce the need for fieldwork and ground truthing, it does allow for the areas of interest to be identified faster and at a higher resolution, thus reducing the time and costs spent in the field, as exemplified by the Norwegian-based SeaBee infrastructure[9] for drone-based mapping, monitoring and scientific research. By using drone images and ground-truth observations to train a machine learning algorithm, researchers will be able to create habitat maps faster, more efficiently and more precisely than with more traditional methods. Having accurate maps of these ecosystems is vital for effective management planning, such as developing climate change mitigation plans, marine spatial planning and coastal zone management plans.

Drone mapping of kelp forests off the coast of Vega, Norway. SeaBee

MONITORING AND RESTORATION

#5. Efforts to restore blue forests surge.

Two years into the United Nations Decade of Ecosystem Restoration, there has been a marked increase in projects focusing on blue forests, with several large-scale restoration projects beginning in 2022 including large-scale seagrass restoration projects in New Zealand, the United Kingdom of Great Britain and Northern Ireland, and the Oslofjord in Norway, and a large-scale mangrove restoration project in Indonesia. [10] [11] [12] [13] While some restoration projects continue to fail despite best efforts, or are located in areas where the threats cannot be reversed, many ecosystems such as kelp and mangroves are enjoying high levels of success as more and more science-based methodologies such as ecosystem-based management (EBM) are utilised.[14] Kelp forest restoration projects can now benefit from the Kelp Restoration Guidebook: Lessons Learned from Kelp Restoration Projects Around the World.[15] This guidebook shares and distills lessons learned from kelp restoration efforts globally in an effort to help create more successful restoration projects. Additionally, with the growing focus on sustainable blue economy, there is the potential to better connect seaweed cultivation and the restoration industry in order to transform kelp forest restoration into a commercial-scale enterprise that can make a significant contribution to global restoration efforts.[16]

Shoots of eelgrass off the Norwegian coastline. Janne K Gitmark, NIVA

MONITORING AND RESTORATION

References

[1] Elmahdy, S.I.; Ali, T.A. (2022). Monitoring Changes and Soil Characterization in Mangrove Forests of the United Arab Emirates Using the Canonical Correlation Forest Model by Multitemporal of Landsat Data. Front. Remote Sens., https://doi.org/10.3389/frsen.2022.782869

[2] Zheng, Y.; Takeuchi, W. (2022). Estimating mangrove forest gross primary production by quantifying environmental stressors in the coastal area. Scientific Reports, 12 (1) https://doi.org/10.1038/s41598-022-06231-6

[3] Maiah, D. (2022). New Study: One of a kind freshwater mangrove forests discovered in the Amazon Delta. Available online.

[4] Bernardino, A.F.; Mazzuco, A.C.A.; Souza, F.M.; Santos, T.M.T.; Sanders, C.J.; Massone, C.G.; Costa, R.F.; Silva, A.E.B.; Ferreira, T.O.; Nóbrega, G.N.; et al. (2022). The Novel Mangrove Environment and Composition of the Amazon Delta. Curr. Biol. 32, 3636-3640.e2 https://doi.org/10.1016/j.cub.2022.06.071

[5] KuhwaldK.; Schneider von Deimling, J.; Schubert, P.; Oppelt, N. (2022). How can Sentinel-2 contribute to seagrass mapping in shallow, turbid Baltic Sea waters? Remote Sensing in Ecology and Conservation, 8(3):328–346 https://doi.org/10.1002/rse2.246609

6] McKenzie, L.J.; Langlois, L.A.; Roelfsema, C.M. (2022). Improving Approaches to Mapping Seagrass within the Great Barrier Reef: From Field to Spaceborne Earth Observation. Remote Sens. 14(11), 2604; https://doi.org/10.3390/rs14112604

[7] Carpenter, S.; Byfield, V.; Felgate, S.L.; Price, D.M.; Andrade, V.; Cobb, E.; Strong, J.; Lichtschlag, A.; Brittain, H.; Barry, C.; Fitch, A.; Young, A.; Sanders, R.; Evans, C. (2022). Using Unoccupied Aerial Vehicles (UAVs) to Map Seagrass Cover from Sentinel-2 Imagery. Remote Sens., 14, 477. https://doi.org/10.3390/rs14030477

8] Kovacs, E.M.; Roelfsema, C.; Udy, J.; Baltais, S.; Lyons, M.; Phinn, S. (2022). Cloud Processing for Simultaneous Mapping of Seagrass Meadows in Optically Complex and Varied Water. Remote Sens, 14, 609. https://doi.org/10.3390/rs14030609

[9] SeaBee (2022). SeaBee project. Project website available online.

[10] Cawthorn Institute (2022). Seagrass restoration project aims to help tackle climate change. Project website available online.

[11] British Broadcasting Corporation (2022). The UK's biggest seagrass restoration projects is to take place off the coast of Wales. Available online.

[12] Lie Pau, J.A. (2022). Vil få tilbake livet i Oslofjorden med ålegrasenger [Life will return to the Oslo Fjord with eelgrass beds]. KlimaOslo. Available online.

[13] The World Bank. (2022). New Project will Support Large-Scale Mangrove Conservation and Restoration in Indonesia. Available online.

[14] Hamilton S.L., Gleason M.G., Godoy N., Eddy N., Grorud-Colvert K. (2022). Ecosystem-based management for kelp forest ecosystems, Marine Policy, Vol 136, https://doi.org/10.1016/j.marpol.2021.104919

[15] Eger, A. M., Layton, C., McHugh, T. A, Gleason, M., and Eddy, N. (2022). Kelp Restoration Guidebook: Lessons Learned from Kelp Projects Around the World. The Nature Conservancy, Arlington, VA, USA. Available online.

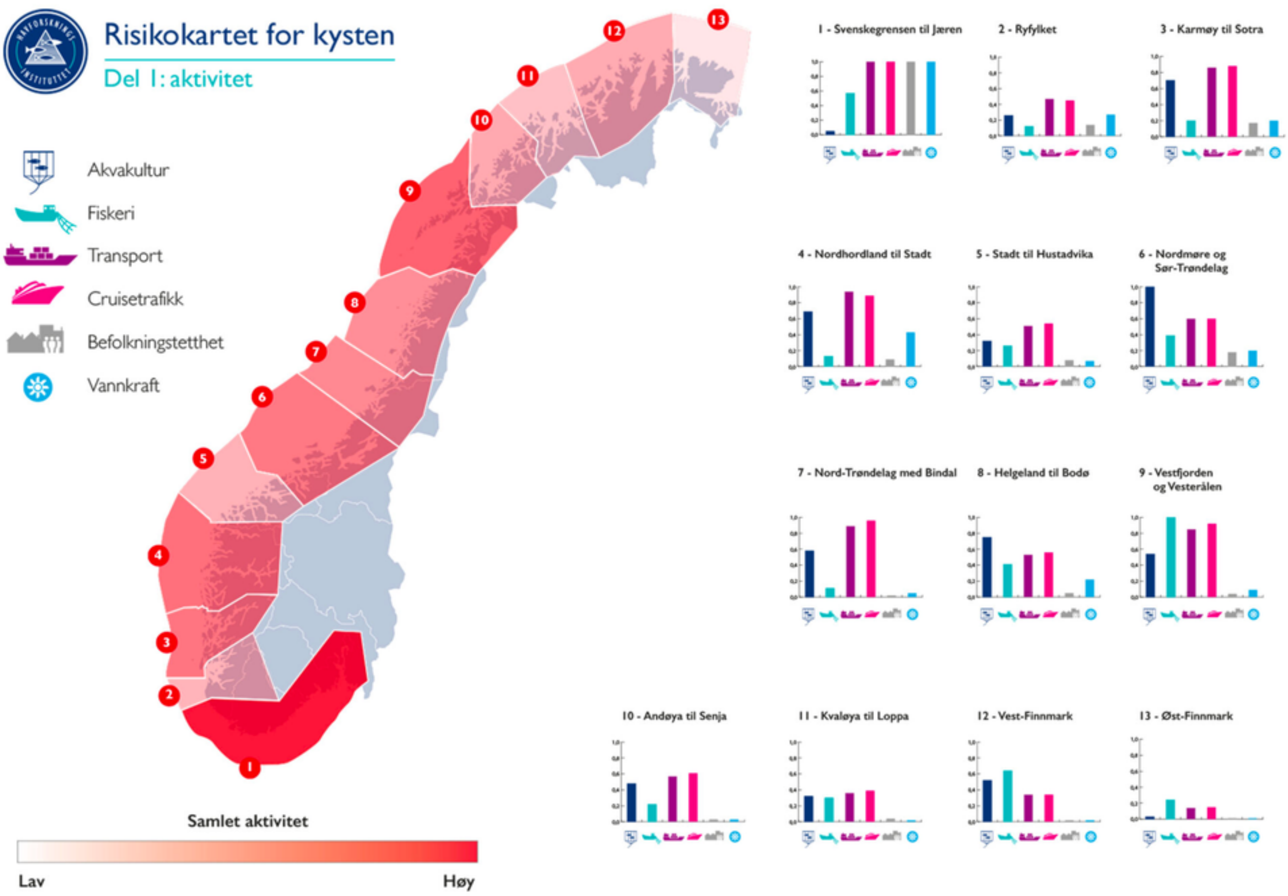
[16] Filbee-Dexter K., Wernberg T., Barreiro R., Coleman M.A., de Bettignies T., Feehan C.J., Franco J.N., Hasler B., Louro I., Norderhaug K.M., Staehr P.A.U., Tuya F., Verbeek J. (2022). Leveraging the blue economy to transform marine forest restoration. J Phycol 58(2):198-207. https://doi.org/10.1111/jpy.13239

NEW RESEARCH FRONTIERS

While the amount of knowledge on blue forests has grown exponentially over the past decade, there are still areas that require new research to help us deal with our changing world.

#6. The importance of ecosystem-based management is increasingly acknowledged yet understudied.

Ecosystem-based management (EBM) is becoming increasingly important as the focus on blue growth rises. EBM is a holistic approach that aims to ensure the cumulative effects of human impacts on an ecosystem do not exceed its critical limits. Yet the evidence base on what works, what does not work, and why, is limited. The first ever global synthesis report on kelp forests, to be launched in 2023 by the UN Environment Programme and the Norwegian Blue Forests Network, includes a chapter on how EBM can benefit kelp forest ecosystems, which policies are already in place, and how they can be improved.[1] This is a good start, but much more research is needed. A key component in EBM is to understand all the risks and how they interact. To this end, in 2022 the Institute of Marine Research launched a Coastal Risk Map of Norway ("Risikokartet for kysten"), which maps human activities that can put coastal ecosystems under pressure by sector and geographic area.[2] Thus far, the risk factors from 16 sectors have been identified. In the long run, such tools are very important for politicians and decision makers to implement EBM, especially when deciding to expand industrial activities in



Map outlining the primary activities impacting the Norwegian coastline[3] certain areas. While the evidence base for EBM is limited, governments are increasingly drawing upon its principles. In 2021, the Norwegian Government put forth a comprehensive action plan for a clean and rich Oslo fjord with active outdoor life ("Helhetlig tiltaksplan for en ren og rik Oslofjord med et aktivt friluftsliv"). In 2022, the first status update on the action plan was published.[4] The Norwegian Ministry of Climate and Environment also approved water management plans for 2022–2027. They are more ambitious than previous plans, including new waterways and increasing the environmental targets for them. In addition, the impact of farming has now been included in water management plans for the first time.[5] However, their focus on blue forests remains limited.

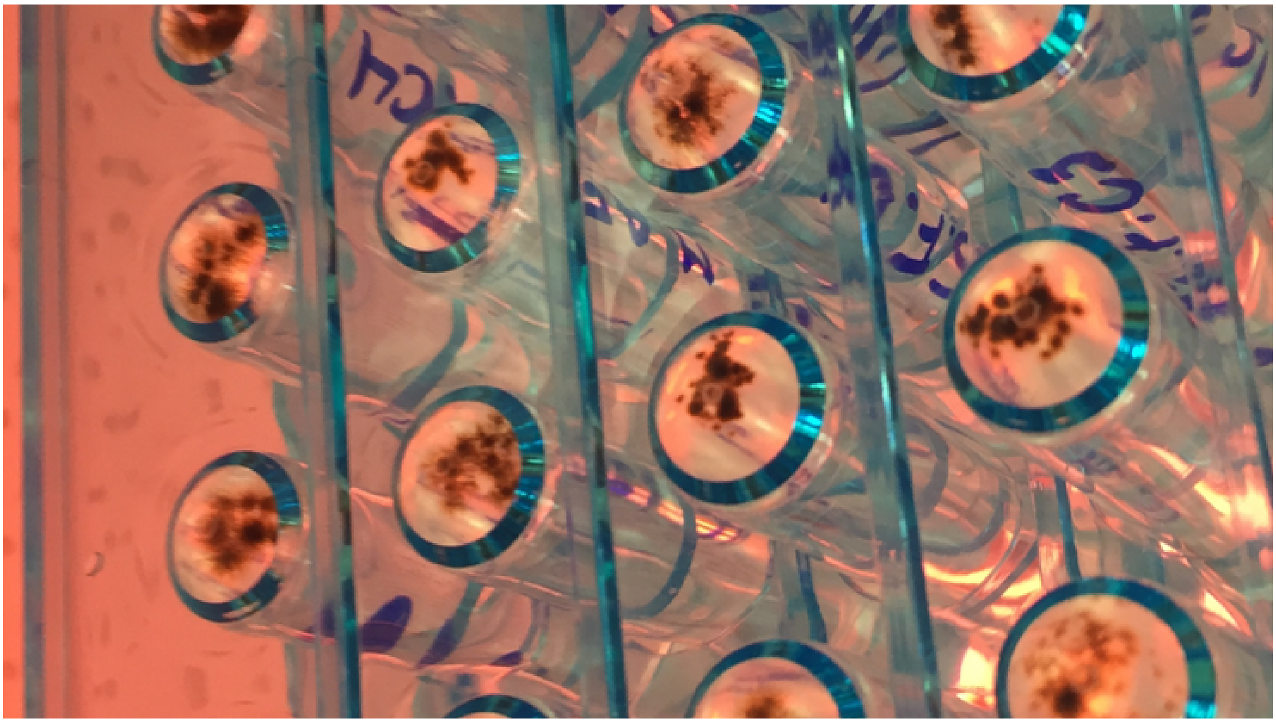
#7. Microbiomes essential for health and functioning of blue forests.

The role of microbiomes in blue forests are of growing interest to the scientific community. The functions of these relationships are only just being discovered, and could help explain how marine grasses and kelp thrive in nutrient-poor environments. Microbiomes play an important role in regulating nutrient and carbon cycles of terrestrial plants. For example, while nitrogen is essential in plant growth, most terrestrial plants cannot obtain nitrogen from the air themselves. Rather, nitrogen-fixing microorganisms hosted by plants do this job for them. Kelp have been described as "photosynthetic giants [that] host millions of microbial taxa whose functions are relatively unknown, despite their potential importance for host-microbe interactions and nutrient cycling in kelp forest ecosystems".[6]

In 2022, exciting discoveries in this field included genomic data, that suggests kelp-associated bacteria can provide their host kelp with vitamins[7]; imagery of dense microbial biofilms on kelp blades indicating that the kelp microbiomes could play a very important role in coastal ecosystems[8]; and the discovery that seagrasses rely on a new species of symbiotic bacteria in their roots to fix nitrogen, just like terrestrial plants.[9] Ongoing scientific discoveries in the critical role microbiomes play in host health and functioning will be essential in the conservation and restoration of blue forests ecosystems. Microbiomes may also play a role in resilience and pest management, and could be an important future management tool for the seaweed cultivation industry. They can be used as bioindicators to assess the health of populations or cultivation sites, or be manipulated to increase the adaptability of cultivars to different environmental conditions.

Kelp forest off the coast of Lofoten, Norway.
Janne K Gitmark, NIVA

NEW RESEARCH FRONTIERS



Bull kelp gametophytes stored in lab to preserve genetic diversity. California Sea Grant

#8. Mapping genes in kelp forests can help future-proof species for climate and industry.

High genetic diversity is essential for populations to adapt to future environmental changes, and is crucial in the conservation of species. Mapping genes in kelp forests ensures that ecotypes resistant to future climate changes, or that are better able to deter grazers, are identified and preserved. To counter the rapid loss of populations, several seed banks were created in 2022 to preserve the genetic material of different species.[10] [11] Advances in this field will not only be beneficial in ecosystem restoration when environmental changes occur, but will help inform industrial actors on which strains are best to cultivate. A new study has examined the genetic structure and gene flow in sugar kelp along the Norwegian coast, where the species is of great interest to seaweed cultivators.[12] The study shows the need to take into consideration what genetic material is used in cultivation, to prevent the loss of genetic diversity in wild populations. There are still many gaps in the knowledge of gene flow between populations, and intensive seaweed cultivation in Asia has already led to problems with invasive species and loss of native ecotypes. For example, cultivars from the intensely cultivated Saccharina japonica have escaped farms and established wild populations. The release of reproductive material that could cause gene flow into wild populations is one of the biggest concerns in developing the European seaweed cultivation sector. Research is also still lacking on how local adaptation of different populations to certain environmental conditions occurs and is maintained. Further research in this field will ensure that European stakeholders can make informed decisions as they strives to expand the sector.

NEW RESEARCH FRONTIERS

References

[1] UN Environment Programme (2023). Into the Blue: Securing a Sustainable Future for Kelp Forests. (unpublished)

[2] Muri, C. (2022). «Risikokartet for kysten» utvides med landbruk [The 'map of risks for the coast' expands with agriculture]. Institute for Marine Research. Available online.

[3] Muri, C. (2022). «Risikokartet for kysten» utvides med landbruk [The 'map of risks for the coast' expands with agriculture]. Institute for Marine Research. Available online.

[4] The Norwegian Environment Agency (2022). Gjennomføring av helhetlig tiltaksplan for Oslofjorden: Rapport for året 2021-2022 [Implementation of a comprehensive action plan for the Oslo Fjord: Report for the year 2021-2022]. Available online.

[5] Norwegian Ministry of Climate and Environment. (2022). Et stort skritt videre for å nå vannmiljømålene [One large step forward to reach the water environment goals]. Available online.

[6] Weigel, B.L.; Miranda, K.K.; Fogarty, E.C.; Watson, A.R.; Pfister, C.A. (2022). Functional Insights into the Kelp Microbiome from Metagenome-Assembled Genomes. Systems, 7, e01422-21. https://doi.org/10.1128/msystems.01422-21

[7] Ramírez-Puebla, S.T.; Weigel, B.L.; Jack, L.; Schlundt, C.; Pfister, C.A.; Mark Welch, J.L. (2022). Spatial Organization of the Kelp Microbiome at Micron Scales. Microbiome, 10, 52. https://doi.org/10.1186/s40168-022-01235-w

[8] Ramírez-Puebla, S.T.; Weigel, B.L.; Jack, L.; Schlundt, C.; Pfister, C.A.; Mark Welch, J.L. (2022). Spatial Organization of the Kelp Microbiome at Micron Scales. Microbiome, 10, 52. https://doi.org/10.1186/s40168-022-01235-w

[9] Gorman, R.M. (2022). Marine plant partners with microbes like terrestrial plants do. The Scientist, 2. Available online.

[10] Kieltyka, M. (2022). Simon Fraser University-led biobank aims to save West Coast kelp forests. Available online.

[11] Moskal, E. (2022). Scientists create a "seed bank" to preserve Bull Kelp. Available online.

[12] Ribeiro, P.A., Næss, T., Dahle, G., Asplin, L.; Meland, K.; Fredriksen, S., Sjøtun, K. (2022). Going with the flow – Population genetics of the kelp Saccharina Latissima (Phaeophyceae, Laminariales). Front. Mar. Sci., 9. https://doi.org/10.3389/fmars.2022.876420

An eelgrass meadow off the Norwegian coast. Janne K Gitmark, NIVA

INDUSTRY INVOLVEMENT

Healthy blue forests are vital for a sustainable blue economy. Harvested and cultivated blue forests are also a growing industry in their own right.

#9. The European seaweed industry is growing, but not yet soaring.

Governments, businesses, investors, and research institutes continue to bet on seaweed as a “new” green industry in Europe.[1] Macroalgae has been mechanically harvested for decades, but major upscaling requires seaweed cultivation. It is predicted that cultivated kelp production in Norway could reach 20 million tonnes a year by 2050.[2] But in 2021, seven years after the first license to cultivate kelp was issued, annual production had only grown to 249 tonnes.[3] 2022 levels have yet to be announced but are predicted to be similarly modest. Building a large and profitable industry will require major improvements along the entire value chain, from farming and processing to market demand and regulation. One avenue being explored is payment for ecosystem services. The Seaweed Carbon Solutions joint industry project, which started in April 2022, is testing the feasibility of large-scale seaweed production for long-term carbon capture – a controversial approach[4] (see trend #3). Meanwhile, the Norwegian Seaweed Association is in the early stages of exploring how to monetise seaweed’s contribution to water quality. The sector is also increasingly looking towards the open ocean for new farm grounds and co-use opportunities with wind farms.

Seaweed can be found in hundreds of products, from medicines and cosmetics to ice cream and sushi. The products that reduce the climate and environmental footprint of our food, fertiliser and fuel generally garner the most political and public interest.

Seaweed-based bioplastic packaging from the 2022 Earthshot Prize winning firm Notpla. Notpla

At the fifth United Nations Environment Assembly in March 2022, United Nations Member States committed to developing a legally binding plastic pollution agreement by 2024.[5] The agreement could further fuel interest in seaweed as a bioplastic. Indeed, the British seaweed bioplastics firm Notpla was one of five winners of the 2022 Earthshot Prize.[6]

Europe is in a unique position to develop its seaweed cultivation industry alongside research, taking into consideration the well-documented mistakes that have been made in other regions, as well as the fish aquaculture industry at home. While the environmental impact of seaweed cultivation at its current levels in Europe is largely positive, there will be a tipping point, with one of the biggest risks being the potential spreading of species and genes (see trend #8).

INDUSTRY INVOLVEMENT

#10. Seaweed will likely be defined as seafood in Norway.

In 2022, the Norwegian Ministry of Trade, Industry and Fisheries initiated the process of changing regulations to define macroalgae as seafood,[7] with the objective to increase human consumption of macroalgae both at home and abroad. Establishment of an export fee for seaweed and kelp ensures that the Norwegian Seafood Council can include this within their marketing portfolio, and give the industry access to funding from the Norwegian Seafood Research Fund. Both would be achieved by levelling a tax on seaweed exports. This tax, which would generate just less than 90,000 kroner with current levels of seaweed exports, is quite small in comparison to the combined income stream of the Norwegian Seafood Council and Norwegian Seafood Research Fund, which amounts to 821 million kroner. Nevertheless, if levied, this tax amount will increase as the industry grows. It would support research and increased industrial activity linked to seaweed, which in turn could accelerate the growth of the sector.

Edible seaweed used in culinary practice. Seaweed Energy Solutions AS

INDUSTRY INVOLVEMENT

References

[1] Seaweed for Europe (2021). The case for seaweed investment in Europe (Executive summary). Available online.

[2] Norwegian Ministry of Trade, Industry and Fisheries (2022). Høringsnotat om endringer i fiskeeksportloven og tilhørende forskrifter [Consultation note on changes to the Fish Export Act and related regulations]. Available online.

[3] Christie, H., Hancke, K. (2020). Taredyrking er i ferd med å bli stor industri. Er vi forberedt? [Kelp farming is becoming a major industry. Are we prepared?]. Aftenposten. Available online.

[4] Seaweed Carbon Solutions (2022). JIP Seaweed Carbon Solutions Project. SINTEF. Project website available online.

[5] UN Environment Programme (2022). Historic day in the campaign to beat plastic pollution: Nations commit to develop a legally binding agreement. Available online.

[6] The Earthshot Prize (2022). 6.3bn tonnes of untreated plastic waste currently litter our streets and fill our seas. NOTPLA shows us that the future is not plastic, it's seaweed. Available online.

|7] Norwegian Ministry of Trade, Industry and Fisheries (2022). Høringsnotat om endringer i fiskeeksportloven og tilhørende forskrifter [Consultation note on changes to the Fish Export Act and related regulations]. Available online.

Further reading:

- Lorentzen, E.A. (2022). HI skal leie stort EU-prosjekt om å dyrke blåskjel og tare i havvindparkar [IMR will lease a large EU project to cultivate blue mussels and kelp in offshore wind farms]. Institute of Marine Research. Available online.
- Norderhaug, K.M., Hansen, P.K., Fredriksen, S., Grøsvik, B.E., Naustvol, L-J., Steen, H., Moy, F. (2021). Miljøpåvirkning fra dyrking av makroalger: Risikovurdering for norske farvann [Environmental impacts from macroalgal cultivation: Risk assessment for Norwegian waters]. Institute of Marine Research. Available online.
- Norderhaug, K.M., Skjermo, J., Kolstad, K, Broch, O.J., Ergon, Å., Handå, A., Horn, S.J., Lock, E-J., Øverland, M. (2020). Mot en ny havnæring for tare? Muligheter og utfordringer for dyrking av alger i Norge [Towards a new marine industry for kelp? Potential and cha lenges for culturing algae in Norway]. Institute of Marine Research. Available online.
- Norwegian Institute for Water Research [Norsk institutt for vannforskning] (2021). Miljøpåvirkninger av taredyrking og forslag til utvikling av overvåkingsprogram [Environmental impacts of kelp cultivation and proposals for the development of a monitoring programme]. Available online.
- OLAMUR (Offshore Low-trophic Aquaculture in Multi-Use scenario Realisation) Project. Global Climate Forum. Project website available online.
- Seaweed: A Revolution to Achieve Goal 14 and More: Side Event – UN Ocean Conference 2022. Available online.
- Steinhagen, S. (2022). Innovation Off-Shore-Ulva. Seagriculture (11th International Seaweed Conference EU). Available online.
- van den Burg, S.W.K., Röckmann, C., Banach, J.L., van Hoof, L. (2020). Governing Risks of Multi-Use: Seaweed Aquaculture at Offshore Wind Farms. Front. Mar. Sci. https://doi.org/10.3389/fmars.2020.00060
- Vazquez Calderon, F., Sanchez Lopez, J. (2022). An overview of the algae industry in Europe. Publications Office of the European Union, Luxembourg. https://doi.org/10.2760/813113.

AREAS TO WATCH IN 2023

The following topics continue to rise in prominence, and may be set to surge in importance over the coming year.

A saltmarsh in Ytre Hvaler National Park, Norway. Hege Gundersen, NIVA

The visibility and value of saltmarshes

Around 50 per cent of the world's saltmarshes have disappeared. Many of those that remain are severely degraded and have lost some of their ecosystem functions. With the launch of the NORDSalt project in 2021, the recognition of this largely understudied ecosystem as both a carbon sink and as providing climate and coastal protection services to society is on the rise.

Food and nutrient security: The potential role of macroalgae

The world is increasingly looking to the ocean as a source of food and nutrient security. As highlighted in trends 9 and 10, there is a growing European interest in macroalgae as food. However, there are also concerns. To this end, the European Union and the Codex Alimentarius Commission are both expected to issue better standards and guidelines for the seaweed industry, and the European Food Safety Authority will undertake a comprehensive risk assessment of unwanted substances in macroalgae. These combined efforts should result in better data and guidelines on which kinds of seaweed are optimal for consumption, what levels are safe to eat, and what processing and cooking methods are optimal. In 2022, the Food and Agriculture Organization of the United Nations and the World Health Organization published a report synthesising available information on food safety in seaweed.

The competition for space and the pressure on coastal ecosystems

Even large coastlines are finite. With coastal and offshore areas being used more and more, including by wind farms, it will be interesting to follow marine spatial planning processes. The "race for space" is less intense in Norway than in some other regions, but still poses a challenge. We will be following Norway's

AREAS TO WATCH IN 2023

forthcoming integrated ocean management and business plans to see whether they will have a greater focus on protecting coastal ecosystems and supporting (and regulating) the growing seaweed industry. As input for the integrated ocean plan, the 2023 budget ("tildelingsbrev") for the Norwegian Environment Agency includes a post to obtain and compile data on the coastal zone.

Protecting blue carbon in Norway

The Norwegian Government is developing a strategy for increased carbon capture through natural carbon sinks in order to achieve carbon neutrality by 2050. A number of Norwegian Environment Agency-commissioned studies were carried out in 2022 to determine whether we have the evidence base needed to better manage blue carbon ecosystems and possibly include them in future carbon mitigation plans. These studies include a synthesis report on marine areas that are important for carbon capture and a synthesis report on human activities that disrupt carbon stored in the ocean. The Norwegian Environment Agency is also in the early stages of assessing the legal changes required to make climate change a marine protection objective

Eelgrass meadow. Eli Rinde, NIVA

Better marine protection

The new global biodiversity framework commits members to, *"Ensure and enable that by 2030 at least 30 per cent of terrestrial, inland water, and of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures [...] while ensuring that any sustainable use, where appropriate in such areas, is fully consistent with conservation outcomes."*

A key debate in the run-up to the United Nations Convention on Biological Diversity was whether Norway's marine protected areas (MPAs) achieve conservation targets or whether they are MPAs primarily in name only. A 2021 governmental white paper announced a plan to establish a pilot project in connection with one or more marine national parks in Skagerrak-Oslo fjord, in order to restore the ecosystem and build knowledge on the effects of such measures. The pilot is being developed by the Directorate of Fisheries and the Environment Agency. In 2022, the Institute of Marine Research provided scientific advice on the initial process. The government has set a deadline of June 2024 for an independent synthesis report on the effects of MPAs, as well as a deadline of March 2023 to review and analyse its international marine protection reporting practices.

AREAS TO WATCH IN 2023

References

The visibility and value of saltmarshes:

- NordSalt (2021). NordSalt Project. SINTEF. Project website available online.
- Norwegian Blue Forests Network (2021). Protecting and restoring blue forests: An important solution to reduce biodiversity decline. Available online.

Food and nutrient security: The potential role of macroalgae:

- Environmental Defence Fund (2022). The Aquatic Blue Food Coalition formally launches at the UN Ocean Conference. Available online.
- FAO and WHO (2022). Report of the expert meeting on food safety for seaweed – Current status and future perspectives. Rome, 28–29 0ctober 2021. Food Safety and Quality Series No. 13. Rome. https://doi.org/10.4060/cc0846en
- Nagelsen, V,, Boge, L.M. (2022). Dette vet forskerne om jod i tang og tare [This is what scientists know about iodine in seaweed and kelp]. Institute of Marine Research. Available online.

The competition for space and the pressure on coastal ecosystems:

- The Norwegian Government (2022). Vil innføre tiltak for å sikre bærekraftige hav [Will introduce measures to ensure sustainable oceans]. Press release. Available online.
- The Norwegian Government (2022). Vil ha innspill til næringsplaner til havs - regjeringen.no. Available online.
- Norwegian Ministry of Climate and Environment (2023). Tildelingsbrev 2023 for Miljødirektoratet [2023 Budget for the Norwegian Environment Agency]. Available online.

Protecting blue carbon in Norway:

- Hancke K., Andersen G.S., Gundersen H., Kvile K.Ø., Trannum H.C., Borgersen G. (2022). Kunnskapsoppsummering om marine områder som er viktige for karbonlagring [Knowledge summary on marine areas important for carbon storage]. NIVA [Norwegian Institute for Water Research] report no. 7788-2022.
- Hjermann D.Ø., Rudjord Z.C., Borgersen G., Gundersen H., Hancke K. (2023). Kunnskapsoppsummering om aktiviteter som forstyrrer karbonlagre i havet. NIVA [Norwegian Institute for Water Research] report
- Hurdalsplattformen [The Hurdal platform] 2021-2015 (2021). Hudalsplattformen: For en regjering utgått fra arbeiderpartiet og senterpartiet [The Hurdal Platform: For a government based on the Labor Party and the Center Party]. Ch. 4, Klima og miljø: En rettferdig klimapolitikk [Climate and the environment: A fair climate policy]. Available online.
- Norwegian Ministry of Climate and Environment (2022). Tildelingsbrev 2022 for Miljødirektoratet [2022 Budget for the Norwegian Environment Agency]. Ch. 3.2.2, Oppdragsliste 2022 innen resultatområde naturmangfold [Task list 2022 within the result area of biodiversity]. Available online.
- Norwegian Ministry of Climate and Environment (2020). Meldingar til Stortinget 29. Heilskapleg nasjonal plan for bevaring av viktige område for marin natur [Messages to the Norwegian Parliament no. 29. Healthy national plan for the conservation of important areas for marine nature]. Ch. 5.5, Marine bevaringsområde som tiltak for karbonbinding [Marine conservation area as a measure for carbon sequestration]. Available online.
- Seaweed: A Revolution to Achieve Goal 14 and More: Side Event – UN Ocean Conference 2022. Available online.
- WWF Norway (2022). Klimapolitikk 2.0: naturlig karbonlagring [Climate policy 2.0: natural carbon storage]. Video [11:45-37:19]. Available online.

Better marine protection:

- Convention on Biological Diversity (2022). COP 15: Nations adopt four goals, 23 targets for 2030 in landmark UN Biodiversity Agreement. Press release. Available online.
- Norwegian Ministry of Climate and Environment (2020). Meldingar til Stortinget 29. Heilskapleg nasjonal plan for bevaring av viktige område for marin natur [Messages to the Norwegian Parliament no. 29. Healthy national plan for the conservation of important areas for marine nature]. Ch. 5.6, Bevaringsprosjekt for naturmangfald og auka biologisk produksjon [Conservation project for natural diversity and increased biological production]. Available online.
- Norwegian Ministry of Climate and Environment (2022). Tildelingsbrev 2022 for Miljødirektoratet [2022 Budget for the Norwegian Environment Agency]. Ch. 3.2.2, Oppdragsliste 2022 innen resultatområde naturmangfold [Task list 2022 within the result area of biodiversity]. Available online.
- Norwegian Ministry of Climate and Environment (2023). Tildelingsbrev 2023 for Miljødirektoratet [2023 Budget for the Norwegian Environment Agency]. Available online.
- Norwegian Ministry of Trade, Industry, and Fisheries (2022). Tildelingsbrev 2022 for Fiskereridirektoratet [2022 Budget for the Norwegian Fisheries Agency]. Available online.
- Bergens Tidene [The Bergen Times] (2022). Hvordan kan norge lykkes med marint vern [How can Norway succeed with marine protection]. Available online.
- Fjeld, I. E. (2022). Slik motarbeider Norge vern av havet [This is how Norway opposes the protection of the sea]. NRK. Available online.

Norwegian Blue Forests Network

https://www.nbfn.no/ttt-22

Contributing authors:
Tanya Bryan, GRID-Arendal; Cecilie Wathne, Norwegian Blue Forests Network; Karen A. Martinez-Swatson, Institute of Marine Research; Olivia Polkinghorne, GRID-Arendal; Steven J. Lutz, GRID-Arendal

GRID ARENDAL
HAVFORSKNINGSINSTITUTTET
NIVA Norsk institutt for vannforskning