SHIFTING GEARS: ACHIEVING CLIMATE-SMART FISHERIES

Working together to promote sustainable fisheries and address the nature and climate crisis

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Content

TOWARDS CLIMATE-SMART FISHERIES

Executive summary

We are amidst a nature and climate emergency and evidence shows that ocean health is vital if we are to successfully address both. Industries operating in and around our oceans have a vital role to play in tackling climate change and contributing to the goal of net zero carbon emissions. Fisheries are no exception and present a complex problem. They are both vulnerable to the impacts of climate change whilst also contributing to anthropogenic driven climate change. Fisheries contribute to greenhouse gas (GHG) emissions through the disturbance of blue carbon habitats in marine systems, the extraction of fish, disruptions to ecosystem function and industry-wide fossil fuel use.

Blue carbon refers to the carbon captured and stored in coastal and marine ecosystems. This includes vegetated habitats such as seagrass meadows, saltmarshes, and seaweeds, as well as carbon stored in seabed sediment and the carbon sequestered by living organisms, including fish. If left undisturbed, significant volumes of blue carbon can remain stored in the marine environment for millennia, decreasing the volume of carbon in the atmosphere that contributes to climate change.

Fishing for mussels. @Pauleinerhand © Unsplash.com

Fisheries primarily impact blue carbon through the contact made between towed bottom fishing gears and the seabed. Heavy trawls and dredges towed across the ocean floor disturb, and in extreme cases, destroy blue carbon ecosystems. Disturbed carbon re-mineralizes into the water column and can eventually re-enter the atmosphere where is adds to global greenhouse gas levels. Experts estimate that as much as 1.02 billion tons of carbon dioxide (CO_2) are released into the water column annually from degraded coastal ecosystems of which fisheries contribute a significant part.

The fishing industry's extraction of fish above sustainable levels is also an extraction of blue carbon, further contributing to GHG emissions. Fisheries have significantly depleted some fish and shellfish stocks relative to pre-industrial levels, thereby removing large volumes of carbon in the form of marine organisms. These fish would otherwise eventually sink as carcasses and their carbon would become stored in deep ocean sediments. Overfishing practices further impact blue carbon by contributing to biodiversity loss and changes in ecosystem function. Fishing above sustainable levels can lead to the removal of enough fish biomass within certain trophic levels to unbalance food webs.

Powering fisheries requires significant fossil fuel use that results in a significant industrial carbon footprint by contributing to GHG emissions. In 2016, the equivalent CO_2 from 51 coal-fired power plants in one year was released into the atmosphere by global marine fishing vessels alone[77]. Inefficient fleet structures, government fuel subsidies and lack of incentives to decarbonise continues to stagnate the transition to low carbon capture methods, and instead contributes to significant GHG emissions across the industry.

The fishing industry's carbon footprint combined with its significant impacts on long-term carbon capture and storage in blue carbon habitats makes the industry an important consideration when designating GHG reduction and climate mitigation strategies. However, governments have generally been slow to acknowledge the fishing industry's impact on GHG emissions and blue carbon stores. Fisheries are commonly missed from assessments of GHGs, not considered in climate change mitigation strategies and are largely ignored during climate negotiations.

This report undertakes a comprehensive review of the existing knowledge around fisheries, climate change and blue carbon with a UK-focus, and clearly identifies the specific impacts of UK fisheries on blue carbon within UK waters. Practical recommendations highlight the essential elements that are needed to form a climate-smart strategy for UK fisheries management to help tackle the current climate crisis.

Climate-smart fisheries management will help futureproof fisheries and allow them to play their role in combatting climate change and help in the achievement of net zero. Such management means that fisheries must clearly acknowledge and mitigate their contribution to GHG emissions, whilst building resilience to climate change threats. At present, climate-smart fisheries approaches are evolving largely across developing countries and small island nations. This is likely because of the heightened awareness around early onset climate change threats in developing and island nations, bringing greater need for climate-smart action. Developed economies, however, appear to be slower to adopt climate-smart approaches to fisheries management, regardless of having more funds and capacity available for new technology development to support climate-smart fishery plans.

The UK is recognised as a leader in the drive for climate change adaptation through net-zero policy and legislation. Following the UK's departure from the European Union on January 1st, 2021, Prime Minister Boris Johnson declared the government's intention for the UK to become a leading, responsible, independent coastal state. However, to realistically achieve this, all governments of the UK must consider the fishing industry's role in combatting climate change.

In November 2020, the UK Fisheries Act (2020) was passed, which for the first time acknowledged climate change in UK fisheries policy, a world leading first. The Act presents the opportunity to steer fisheries policy reform in a climate-smart direction and means that the management of UK fisheries and the marine environment address fisheries impacts on national GHG emissions and blue carbon. Strategies should focus on the reduction of blue carbon disturbance and unsustainable extraction, whilst also taking steps to move the industry towards net-zero emissions. If successful, implementation of the Act could make the UK a major leader of climate-resilience that prioritises long-term sustainability, balanced with economic productivity of the fishing sector. It also has the potential to feed into international agreements that would influence people and the marine environment on a much larger, global scale.

In short UK fishing needs to rethink current practices and modernise to meet the challenge of climate change and net-zero. The report concludes that a climate-smart strategy should focus on six key actions that act as an intertwined system where stakeholders should actively seek to:

- Limit bottom towed fishing gear to protect and support recovery of blue carbon within current MPAs and in key areas outside of MPAs.

- Work to decarbonise the UK fleet including removing fuel subsidies and eliminate inefficient fleet structures.

Crated fish. @nklphoto © Unsplash.com

- Mandate Remote Electronic Monitoring (REM) with cameras that incorporate Vessel Monitoring Systems (VMS) across vessels fishing in UK waters to deliver increased transparency and traceability across the UK fishing industry to improve stock health and increase biomass.

- Reduce pressure from heavy, towed bottom fisheries gear and review the impact of passive gear use and whether incentives for gear changes are appropriate.

- Strengthen overall marine policy frameworks with a climate change lens such as the UK Marine Strategy, to make them fit for purpose in a bid to combat the climate crisis.

- Increase research and knowledge on blue carbon habitats, stocks, and the fishing sectors GHG emissions and blue carbon impact.

If such a strategy is adopted it should futureproof UK fisheries by bringing about the recovery of the oceans health and help meet the triple challenge of sustainably feeding a growing population, while staying on track to keep global warming below 1.5°C and reversing biodiversity loss.

1. Background on climate change and GHG emissions

1.1. The climate change emergency

Climate change is defined as the shift in climate patterns caused by greenhouse gas (GHG) emissions from natural processes and human activities[1]. The Earth's average global temperature is directly correlated to the concentration of GHGs in the Earth's atmosphere[2]. This is due to a naturally occurring process known as the GHG effect, which refers to atmospheric GHGs trapping solar radiation within the Earth's atmosphere[3]. Since the Industrial Revolution, there has been a clear increase in anthropogenic GHG emissions, along with a resulting steady mean global temperature rise, known as global warming[4]. Carbon dioxide (CO_2) accounts for two-thirds of GHG emissions and is largely the product of human activities that require the burning of fossil fuels (coal, oil, and gas) for the generation of power[2].

As of 2019, the average global temperature is approximately 1.2°C above pre-industrial levels (the period from 1850 to 1900)[5]. In recent years, research has shown that climate change is amplifying the frequency and intensity of extreme weather events such as deadly heatwaves, droughts, wildfires, and hurricanes as well as intense rainfall, flooding, storms, and landslides[6]. Increased levels of carbon emissions are increasing the impact of the GHG effect as more heat is trapped within the Earth's atmosphere[3]. This in turn is causing ocean warming, acidification, and oxygen loss, threatening entire marine ecosystems and human livelihoods[7,8]. As a result, ice sheets are thinning, glaciers are melting, and global mean sea-levels are expected to rise by between 25–123 cm by 2100[9]. This will have significant further consequences for Earth's climate system, and the 10% of the world's population living within 10 metres of sea level[10,11].

According to the emissions gap report prepared by the United Nations Environment Programme (UNEP) in 2019, total GHG emissions in 2018 reached the highest level on record at 55.3 $GtCO_2e$[12]. At the current rate, levels are expected to reach 56 $GtCO_2e$ by 2030, and global temperature rise is on track to increase by more than 3°C by 2100[13]. Without sufficient global commitments to reduce climate polluting emissions, this scenario is expected to cause significant ongoing problems for people and nature[14]. Increasing public pressure on governments to pursue more stringent cuts in GHG emissions following the release of the 2018 Intergovernmental Panel on Climate Change (IPCC) Report has resulted in many authorities acknowledging that current mitigation strategies are not enough. In many cases this has led to more formal communications through climate emergency declarations (CEDs)[15,16].

A Climate Emergency Declaration (CED) is the action taken by governments, councils or groups of scientists that acknowledges that humanity is in a state of climate emergency[15]. It declares that climate change is real and that the measures taken to mitigate its impacts have so far been insufficient[17]. As of the 23rd July 2021, there were 2,006 jurisdictions across 34 countries that have made CEDs (including the Europe Union) and 23 national CEDs[17].

Scientists predict that although serious global impacts will still occur, humanity can work to reduce the more severe impacts of global warming by limiting further global temperature rise to 1.5°C above pre-industrial levels[2]. To meet this crucial goal, scientific advice set out in the Intergovernmental Panel on Climate Change

Global climate change strike. @markusspiske © Unsplash.com

(IPCC) Special Report on 1.5°C Global Warming, urges all countries to work towards the goal of net-zero carbon by 2055-2080[2].

The goal of net-zero refers to achieving a state of carbon neutrality by 2050, mainly through emissions reduction[18]. This goal can be achieved in two ways which work in tandem:

- *Reduce existing CO_2 emissions production by reducing sources of GHG emissions as much as possible.*

- *Actively removing GHGs from the atmosphere[19].*

- *When a balance is achieved between the emissions produced and the volume removed from the atmosphere, a country will have become a net-zero emitter[20].*

Global efforts to mitigate climate change focus on the global reduction in GHG emissions[21]. This focus has underpinned global climate agreements, protocols, and legislation for the last 40 years. Increasingly higher emissions reduction commitments have been made over this period as international concern has increased[22]. The continued development of different climate agreements, protocols and legislation highlights that the journey of global understanding and increased action is well underway, but sufficient progress to reach the 1.5°C target has not yet been made.

1.5 Degrees Celsius. @mbaumi © Unsplash.com

1.2. Slow progress to date

The reduction in CO_2 emissions between 1999 and 2016 as a direct result of climate legislation amounted to 38 $GtCO_2$. This is equivalent to just one years' worth of global CO_2 output[23]. Some GHG reduction policies focus too heavily on reducing the GHG emissions of single industries, and as a result often fail to meet annual targets[24]. The development of climate change legislation has also historically been weak during times of economic difficulty. The COVID19 pandemic has therefore caused concerns regarding continued efforts to reduce GHG emissions[22]. Some, however, believe that the COVID19 pandemic provides a promising opportunity for radical change in emissions reduction through a post-pandemic green recovery[25]. The pandemic caused an unprecedented shutdown of large sectors of the global economy, requiring plans to re-build and strengthen these sectors as the world returns to some kind of 'normal'[13]. This 'rebuilding' provides an important opportunity to put countries on sustainable trajectories with the goal of net-zero at the centre[26]. Global recovery spending has at the time of writing this report, however, missed the opportunity for green investment[27]. According to an analysis of spending by leading economies, led by Oxford's Economic Recovery Project and UNEP, only 18% ($368bn out of $14.6tn) of COVID19-related fiscal rescue and recovery efforts has gone towards activities that will reduce GHG emissions[27]. As governments now move away from short-term rescue measures and begin to focus on long-term recovery, the opportunity to shift attention toward rebuilding economies through a framework that focuses on net-zero emissions and sustainable practices could see world emissions reduced to 44 $GtCO_2e$ by 2030[13]. This is predicted to result in a 25% reduction in the emissions expected from pre-COVID19 climate policies and would bring the world within range of emissions required to meet the 2°C limit (although greater action would be required to reach the goal of 1.5°C)[13].

1.3. Nature-based solutions to climate change

To achieve the 1.5°C target of the Paris Agreement, a proportion of the previously emitted CO_2 needs to be removed from the atmosphere[28]. It is therefore not enough to only reduce future emissions. Knowledge as to how this can be achieved is increasing, and many of the most promising solutions highlight that nature is the key[29]. Research has found that 37% of the carbon emissions reduction needed to meet the goals of the Paris Agreement by 2030, can be achieved by utilising nature's ability to sequester carbon[30]. Nature-based solutions have become a primary component of many Nationally Determined Contributions (NDCs) required by the Paris Agreement, with 66% of the signatories to the Paris Agreement having committed to include nature-based solutions in their climate change programs as of 2019[31]. Promisingly, legislation that focuses on the protection of the natural world increasingly notes the role of natural systems in reducing CO_2 emissions[32]. To date, however, much of the climate effort has been directed to the role of land-based sources of emissions and sinks, with natural climate solutions focused on the carbon sequestration ability of primary producers in terrestrial ecosystems such as forests and peatlands[33–36]. Efforts to meet the goal of net-zero have more recently revealed the importance of oceans and coastal habitats to capture and store more carbon per unit area than terrestrial ecosystems[37–40].

Research shows that 83% of global carbon is circulated through the ocean, with coastal ecosystems capturing amounts of carbon each year comparable to land-based ecosystems[41].

Of all carbon captured by plants through photosynthetic activity globally (marine and terrestrial), 55% is captured by marine organisms[41].

Furthermore, carbon stored in vegetated marine habitats below ground, is estimated to be up to 1000tC ha^{-1}, much higher than most terrestrial ecosystems[11]. Consequently, the oceans are becoming increasingly recognised as a major sink for anthropogenic CO_2 emissions[42].

Ocean Ripple. @matthardy © Unsplash.com

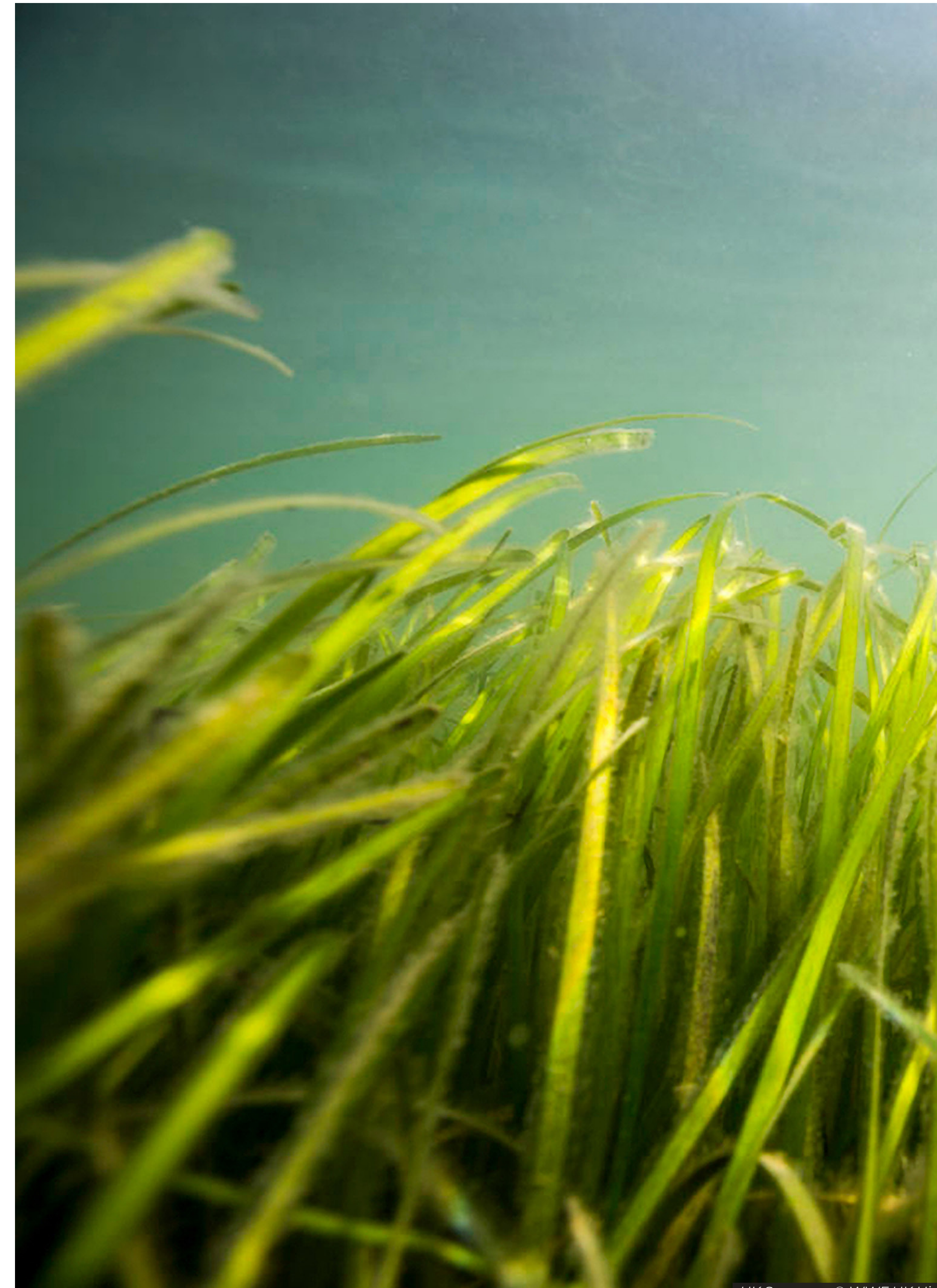
2. The role of carbon in the marine environment

2.1. What is blue carbon?

The oceans help regulate the climate by sequestering anthropogenic carbon in a similar way to terrestrial ecosystems such as forests and peatlands[39,41]. Carbon is removed from the atmosphere through biological and chemical processes which is then accumulated and stored in organic matter[38].

'Blue carbon' refers to the carbon captured and stored in coastal and marine ecosystems, particularly by vegetated habitats such as seagrass meadows, saltmarshes, wetlands, mangroves, and seaweed. Carbon is also stored in seabed sediment and sequestered by living organisms which also include calcifying organisms such as corals and molluscs[40].

If left undamaged, significant volumes of blue carbon remain stored in the marine environment for millennia, decreasing the volume of carbon in the atmosphere that contributes to climate change[40]. The carbon sequestration potential of shellfish and seaweed aquaculture has also recently been highlighted [43,44], again emphasising the significance of the marine environment in capturing and storing anthropogenic carbon emissions. Furthermore, coastal ecosystems provide numerous co-benefits and services that aid in climate change mitigation, such as improving critical habitats for biodiversity, enhancing local fisheries production and food security, as well as protecting coastal communities from sea level rise and increased storm events[40].


UK Seagrass. © WWF UK Hive

2.2. Blue carbon and anthropogenic CO_2 emissions

The global interest in blue carbon is rooted in its potential to mitigate climate change through long term carbon storage that decreases the volume of carbon in the atmosphere[40]. Between 1994 and 2007, the marine environment absorbed 34 gigatonnes of CO_2, or 31% of what humans put into the atmosphere during that time[45]. This is a fourfold increase of 2.6 billion metric tons per year when compared to the period starting from the Industrial Revolution in 1800 to 1994[45].

As of 2021, approximately 27% of emitted carbon each year is captured by the ocean[11].

Consequently, many countries are beginning to recognise the significant global emissions reduction capacity delivered by blue carbon ecosystems and their role in decarbonisation efforts[46]. Using the marine environment as a climate change mitigation strategy is steadily becoming a tactical consideration to enhance national climate ambitions and actions to ensure the goals of the Paris Agreement are met.

2.3. Blue carbon: A source of GHG emissions?

Despite their benefits and ecosystem services, coastal blue carbon ecosystems such as seagrass meadows, kelp forests and saltmarshes, are some of the most threatened ecosystems on Earth.

An estimated 340,000 to 980,000 hectares of coastal blue carbon ecosystems are being lost each year globally[47], due to the impacts of human activities and climate change.

Current research estimates that up to 1 billion tonnes of CO_2 is emitted each year following the destruction of blue carbon ecosystems caused by a combination of stressors[48].

Coastal ecosystems are threatened by numerous stressors linked to human activity including coastal infrastructure, tourism, aquaculture, dam development, pollution, and overfishing[49]. Coastal systems are further vulnerable to climate change impacts through increased storm surges, coastal flooding, and sea level rise. In the UK alone, research indicates that approximately 60 hectares of protected intertidal habitats will continue to be lost per year across the UK as a result of climate change, sea level rise and coastal squeeze, unless protective action is taken[50]. Deterioration of blue carbon ecosystems can cause the carbon once stored to be re-mineralised and potentially constrain the ability of seawater to absorb further atmospheric carbon[40].

Carbon released into the water column is understood to eventually make its way back into the atmosphere and contribute towards CO_2 emissions[51]. The exact pathway, however, is still currently unclear[42]. Nevertheless, blue carbon ecosystems are a significant source of carbon stores linked to global GHG emissions and therefore climate mitigation approaches[51].

Despite the known importance of blue carbon in the fight against climate change, legislation and policy still largely fail to reference the role that the marine environment can play in climate mitigation[52]. Therefore, successful implementations of measures to maintain and strengthen coastal blue carbon ecosystems are vital to ensure the ocean remains a long-term carbon sink and is increasingly acknowledged as a way for countries to reach emission targets towards the goal of net-zero[53].

Compass rose. Mirand P. © Pixabay.com

2.4. The objectives of this study

The specific objectives of this report are:

- To provide a review of knowledge around fisheries, climate change and blue carbon and how the management of fisheries might help tackle the current climate crisis - with a UK-focus.
- To describe how fisheries impact blue carbon and identify the specific impacts of fisheries on blue carbon within UK waters.
- To outline the UK landscape regarding climate change adaptation and mitigation policy, and legislation relating specifically to fisheries.
- To synthesise what a climate-smart strategy might entail for the UK fishing sector, including practical recommendations to improve climate change mitigation through fisheries management.

2.5. Overview of approach

A comprehensive literature review using a structured keyword search was conducted to find relevant, global literature pertaining to fisheries impacts on blue carbon, fisheries GHG emission contributions and to understand what is currently considered climate-smart practice in marine management. The 126 publications identified were used to develop an understanding of the current scientific knowledge surrounding the aforementioned topics. This knowledge was also used to inform practical recommendations that can be used to develop a climate-smart strategy for fisheries and marine management.

Sunrise Weymouth trawler. Tim Hill © Pixabay.com

3. Climate smart fisheries and blue carbon literature

What does the review of current literature tell us about climate-smart fisheries and blue carbon?

- There has been a significant increase in global research effort related to blue carbon from 2012 onwards. Awareness of the importance of carbon in the marine environment is growing.

- The subject area of climate-smart fisheries is still relatively new. Increased research on blue carbon and climate-smart fisheries has been driven by the push for net-zero emission commitments combined with the recognition of marine systems as a climate change mitigation "tool".

- Both globally and within the UK, government policy documentation relating to climate-smart fisheries and blue carbon is lacking. Although public-media and scientific literature on these topics has increased in recent years, government policy documents have seen a slower increase. This may indicate that government policy is not reacting with sufficient speed to new scientific understanding on fisheries impact on blue carbon and the idea of climate-smart fisheries.

- Most research on blue carbon and climate-smart fisheries appears to focus on either global or country scales. Current literature on climate-smart fisheries and fisheries impacts on blue carbon is not often undertaken at local management scales.

- An increase in EU-focused studies since 2019 could indicate that there has been a European drive for knowledge on climate-smart fisheries and fisheries impacts on blue carbon. This could help drive further attention and research from other major economies and could go some way to steer international fisheries policy in a climate-smart direction.

- In recent years, interest in less commonly studied blue carbon habitat types such as mussel beds, maerl beds and oyster reefs has grown significantly. This trend is likely linked to the growing recognition of the climate change mitigation potential of blue carbon. Increased research of lesser-known blue carbon habitats will likely aid in national climate change mitigation strategies. This is particularly important for the UK, where less understood blue carbon habitats such as flame shell, maerl and brittle star beds are abundant.

Crab pots, St Andrews, Scotland. @offeringofpie © Unsplash.com

4. Fisheries and blue carbon

To provide clear recommendations to UK governments and fisheries stakeholders on climate change mitigation through climate-smart fisheries, it is first important to understand the impacts that the fishing industry can have on blue carbon. The following sections outline the various impacts of fisheries on blue carbon in the marine environment.

4.1. Fisheries seabed and habitat disturbance

The primary way in which fisheries impact blue carbon habitats is through bottom towed fishing gear contact with the seabed[54]. Bottom trawling and dredging involve towing fishing gear across the ocean floor to capture target species. Whilst in many cases such gear allows fishermen to land high volumes of (often mixed) catch, they also cause extensive physical disturbance to seabed communities and sediments[55]. Considering marine sediments are home to the largest pool of organic carbon globally[56], such fishing activity can therefore have significant consequences for blue carbon stores and GHG emissions. This is because when fishing gears disturb and resuspend organic carbon stored in marine sediments, the carbon within them can be re-mineralized. This is thought to lead to increased ocean acidification and adds to the accumulation of atmospheric CO_2 through air-sea CO_2 flux[57,58]. Bottom towed fishing gears have similar, significant impacts on other blue carbon habitats through the destruction and removal of carbon stored in vegetated habitats like seagrass and kelp.

A 2021 study estimated that 1.3% (4.9 million km^2) of the global ocean is bottom trawled each year[42]. The authors estimated that this seabed disturbance results in 1.47Pg of aqueous CO_2 emissions in the first year following trawl events. The authors also estimated that after 9 years of continuous bottom trawling, emissions stabilise at roughly 40% of the first year's emissions (approx. 0.58Pg CO_2)[42]. To put this into perspective, 1.47Pg CO_2 represents only 0.2% of total marine carbon but is equivalent to 15-20% of atmospheric CO_2 absorbed by the ocean each year[42]. Although the fraction of the aqueous CO_2 released into the atmosphere is currently unknown, increased CO_2 in the water column is expected to have further unknown impacts on the marine carbon cycle, primary production, and biodiversity[42].

It is important to note that the disturbance of marine habitat is not limited only to towed bottom fishing gears. Other fishing gears can also disturb seafloor ecosystems, and thus blue carbon habitats. Examples include passive fishing gears such as demersal gillnets, seine nets, traps, and pots, among others. Considering that only 7% of the ocean is under some kind of protection from fishing[59], significant and long-lasting protection from damaging fishing activities on seabed carbon stores is urgently needed[60]. Further seabed impacts from fisheries (as well as other maritime sectors) on blue carbon habitats include anchor damage, trampling, wave wash from vessels traffic and water pollution, largely from contaminated vessel bilges and ship waste.

Combined with ongoing anthropogenic and climate-related stressors such as water pollution, sea level rise and deforestation practices, damage to the health of coastal blue carbon ecosystems such as seagrass, saltmarshes, and mangroves is considerable[61,62]. As with bottom towed fishing impacts on marine habitats, damage to coastal blue carbon habitats such as mudflats and saltmarshes can reduce their capacity to absorb carbon, and compromise sedimentary carbon which has otherwise been stored and remained largely undisturbed for millennia[63].

Experts estimate that as much as 1.02 billion tons of carbon dioxide is released annually from degraded coastal ecosystems, of which fisheries contribute a significant part[47].

Fisherman working on a large trawler net. @pauleinerhand © Unsplash.com

4.2. Removing fish is removing carbon

Marine organisms are carbon sinks. The fishing industry's extraction of fish can therefore also be considered an extraction of blue carbon that indirectly contributes to GHG emissions. If the dead bodies of marine organisms are not consumed by other predators or scavengers, they eventually sink to the bottom of the ocean and decompose[64]. Over the long-term, the carbon stored in the body tissues breaks down and is sequestered in sea bottom sediments[64].

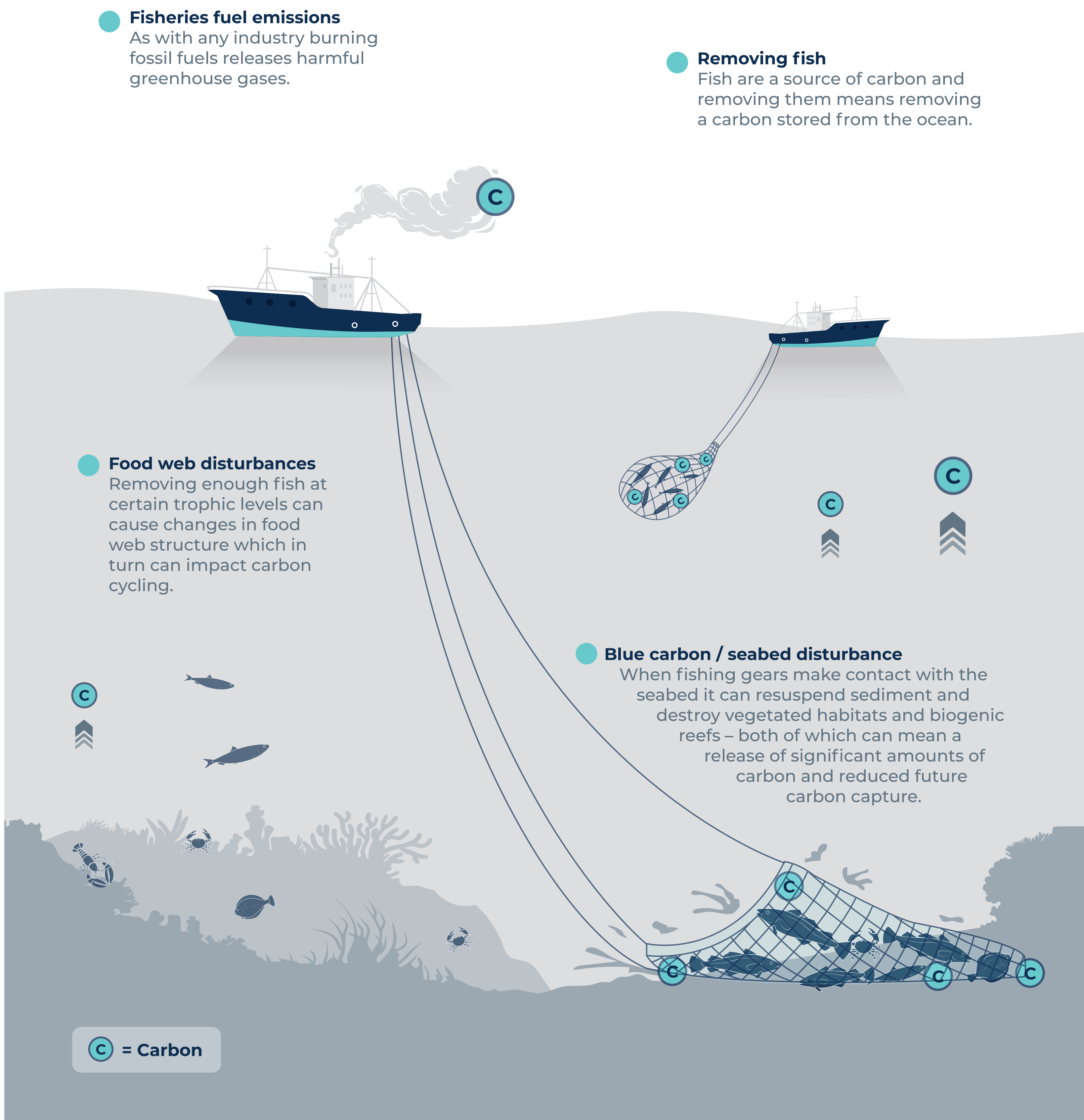
Many fish stocks are significantly depleted relative to preindustrial levels[65,66]. This removal of fish represents a large volume of carbon that has been extracted from the ocean[67]. Historical catch data shows that from 1950 to 2014, the global fishing fleet extracted 318.4 million tons of large fish[64]. Combined with fisheries fuel use, this is equivalent to 37.5 ± 7.4 million tonnes of carbon (MtC) released into the atmosphere[64].

4.3. Ecosystem imbalance

Overfishing practices further impact blue carbon by contributing to biodiversity loss. According to the Food and Agriculture Organization's (FAO) The State of World Fisheries and Aquaculture report published in 2020, over 90% of the world's fisheries are overfished or are maximally sustainably fished. Many of these fisheries continue to benefit from government subsidies that enable them to be profitable[65,68]. In 2019, 35.6% of audited UK fish stocks were healthy in terms of stock size relative to MSY reference points, whereas 20.2% were in a critical condition[69]. The sustainability of the remaining 44.2% cannot be determined, leaving them at greater risk of unsuitable management decisions.

In a healthy ocean of bountiful fish and marine habitats, the ocean can sequester large volumes of anthropogenic carbon[70]. However, fishing above sustainable levels largely due to the heavy use of intensive bottom and pelagic (midwater) fishing gear, can lead to the removal of enough fish biomass within certain trophic levels to unbalance food webs[42]. It is worth noting that fishing gears that target pelagic fish such as pelagic trawlers and purse seine nets often do not contact the seabed and therefore are not known to disturb blue carbon stored in sediments or damage vegetated marine ecosystems. They are, however, often associated with high fish biomass removal. Intensive bottom and pelagic fishing gear can therefore significantly impact blue carbon habitats. This is particularly so for systems in which the removal of predators results in trophic cascades[71], in which intermediate, herbivorous trophic levels are released from predation which in turn can lead to increased grazing pressure on blue carbon habitats and subsequent reductions in blue carbon stores[71,72].

Fisheries impacts on blue carbon



5. Fisheries fuel consumption

The fishing industry's reliance on burning fossil fuels clearly contributes to global GHG emissions[73]. Fuel use in fisheries occurs throughout the supply chain in many fisheries; from capture though to transportation, processing, and storage[74,75]. Fuel use and GHG emissions of global wild capture fisheries between 1990 to 2011 were estimated to contribute an average of 2.2kg of CO_2 emissions per kilogram (live weight) of landed fish and shellfish. This makes up approximately 4% of the emissions produced by the global food production sector, which alone contributes to 25% of anthropogenic GHG emissions globally[76].

Government-funded fuel subsidies have allowed many fishing fleets to travel vast distances, burning large amounts of fossil fuel to reach remote fishing grounds on the high seas[78]. Often these subsidies determine the profitability of fishing operations[68]. In some fisheries, this has resulted in the subsidisation of largely unsustainable fishing practices, inefficient fuel use, greater dependencies on fossil fuels and a substantial industrial carbon footprint from emissions. Energy costs are the largest overhead in the fishing industry[78]. Many fisheries are also reliant on effective and reliable refrigeration systems from the point of catch through to the point of landing. This requires a near constant supply of power that most often comes from the combustion of fuel by onboard generators.

Cooling systems also produce huge amounts of emissions from leaks in refrigerant gases that contain ammonia and other harmful compounds such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3)[79,80]. When released, these gases become significant contributors to GHG emissions due to their high CO_2 equivalence. For example, HFCs when compared to a CO_2 equivalent of 1, make a 13,000 times greater contribution to global warming[79]. Any malfunction of vessel cooling systems that cause them to leak is therefore extremely detrimental to the environment. Such leaks also pose important safety risks for fishing crews as inhalation of such gases can be fatal[81].

The energy intensive nature of fisheries capture, and seafood storage coupled with an increased demand for seafood has led to an increased amount of energy consumption resulting in growing amounts of GHG emissions from fisheries production globally. The fishing industry's carbon footprint, often driven by government fuel subsidies and potentially leaky refrigeration systems, therefore needs greater consideration when designing GHG reduction strategies. Integrating more sustainable forms of energy production will be essential to help fisheries rely less on fossil fuels and fuel subsidies for economic viability.

Petrol pump. @scottrodgerson © Unsplash.com

5.1. Fisheries and blue carbon summary

Fisheries have significant impacts on climate change through gear contact with blue carbon stores, carbon extraction in the form of marine organisms and by indirectly adding to global GHG emissions through the burning of fossil fuels. The impacts of the industry on long-term carbon capture and storage of blue carbon are therefore an important consideration regarding the design of climate change mitigation strategies. Nevertheless, the fishing industry's impact on blue carbon is commonly missed from global assessments of GHGs, not considered in marine management or climate change mitigation and largely ignored during climate negotiations[77]. The latest breakdown of global emissions by sector for example, only considers vessel fuel use of the global fishing industry in combination with agriculture (1.7% of total GHG emissions from industry) and is not calculated to a spatial resolution small enough to benefit local management decisions[83,84] . Furthermore, most research that combines climate change and fisheries to date has typically focused on the threats of climate change to fish stocks rather than the impacts of fisheries on climate change[73,85,86]. Global fisheries in their current state present the challenge of both being threatened by the impacts of climate change whilst also contributing to anthropogenic climate change. Climate-smart approaches to fisheries management are therefore needed across the fishing industry to ensure that GHG emissions are reduced, and ecological sustainability is achieved. This would help to strengthen the resilience of fish stocks and blue carbon as an important climate change mitigation tool, whilst building food security on a global scale. Nevertheless, balancing these objectives in an environment already susceptible to additional climate change impacts is no easy task[87].

Fishing vessel on the North Sea. @pauleinerhand © Unsplash.com

6. UK fisheries

6.1. UK blue carbon status

The UK's coastal habitats and territorial waters cover over 885 thousand square kilometres and comprise 2% of the global ocean shelf area[51]. There are currently 372 Marine Protected Areas (MPAs) in UK (offshore and inshore) waters. These include Marine Conservation Zones (MCZs), Special Areas of Conservation (SAC), Special Protection Areas (SPAs), and Nature Conservation MPAs (NC MPAs). These are all collectively referred to as MPAs herein[87]. UK MPAs cover a total of 338 thousand square kilometres, over 38% of the UK's territorial waters (delimited by the UK Exclusive Economic Zone (EEZ) and the UK Continental Shelf but not including British Overseas Territories)[87]. To date, estimates of UK blue carbon stores mostly focus on MPAs and well-studied blue carbon vegetated habitats such as seagrass meadows, saltmarshes, mudflats, and kelp forests[88]. Research on less understood blue carbon habitats such as biogenic reefs (oyster reefs, mussel beds, maerl beds and flame shell beds) has, however, increased in recent years yet data is currently lacking on their full UK extent and the blue carbon stores of each (Table 1).

To our knowledge, there are no estimates of total UK blue carbon that combine carbon stored within all known coastal ecosystems. However:

- *UK shelf sediment and saltmarsh and seagrass meadows hold approximately 220 Mt of blue carbon. 93% of this blue carbon is held within marine sediments[51].*

- *UK EEZ marine surface sediments (top 10cm) hold approximately 524 Mt of organic carbon and 2,582 Mt of inorganic carbon.*

- *Offshore UK benthic MPAs account for around 13% of UK shelf sediment habitats and approximately 26.53 Mt of blue carbon.*

In recent years, there has been an increase in efforts to expand knowledge on blue carbon extent across the UK so that its full potential and scope can be managed and protected[58]. To our knowledge, there has been no comprehensive survey or estimations made of the total volume of blue carbon within the coastal waters of England or Northern Ireland (Table 1). Pioneering work, however, has begun in Scotland and Wales, where initial blue carbon research has been undertaken, funded by the Scottish Government and the National Assembly for Wales (now Senedd Cymru) and Natural Resources Wales (NRW)[88,90,91].

The Scottish government identifies several key blue carbon vegetated habitats within Scottish waters including kelp forests, intertidal macroalgae, subcanopy algae, seagrass meadows, saltmarshes, and biogenic reefs[88]. Scotland's marine environment is estimated to store 9,636 Mt CO_2-equivalents collectively, which is more than the total carbon stores within Scotland's terrestrial environment (9, 546 Mt CO_2-eq) such as peatlands,


Oyster Festival, Whitstable, UK. Fred Moon © Unsplash.com

forestry, and soils[92]. This is perhaps unsurprising given that the total sea area around Scotland is six times greater than the total land area[92]. An estimated 9.4 Mt of organic carbon and 47.8 Mt of inorganic carbon is estimated to be held within Scottish SAC's and NC MPAs[88].

Welsh territorial waters, which cover 32,000 km^2, are home to several key blue carbon vegetated habitats - seagrass meadows, saltmarshes and mixed seaweed habitats. A recent study by NRW found that the Welsh marine habitats are estimated to sequester at least 26,100 tonnes of carbon (or 0.03 Mt C) every year, with saltmarshes and intertidal flats accounting for a large percentage of this value[90]. This equates to 95,900 t CO_2eq (or 0.096 Mt CO_2eq) and represents around 7 % of the amount sequestered by Welsh forests every year (around 21,000 ha of forest)[90]. Furthermore, in any given year, the Welsh marine waters hold at least another 48.7 Mt of carbon, mostly in the form of dissolved inorganic carbon and at least 113 Mt of carbon is estimated to be stored in the top 10 cm of Welsh marine sediments which represents almost 170 % of the carbon held in Welsh forests[90].

Nevertheless, the current loss of coastal habitats around the UK is estimated to be approximately 3% per year (the main habitats affected by such loss are saltmarshes and mudflats, seagrass, kelp and other seaweeds)[93]. If the current rate of habitat loss continues, it is expected to lead to the equivalent loss of over half the current UK marine habitat coverage by 2050, significantly reducing UK blue carbon stores[93]. Although the UK fishing industry is not the only driver of this habitat loss (climate change, pollution and land use among other factors also play significant roles), to meet the legal obligations of climate policy, it is important that the UK fishing industry moves towards climate-smart approaches that will help to manage and safeguard key UK blue carbon habitats. Conservation of these habitats will be of benefit to UK biodiversity, blue carbon stores, climate change mitigation, and fisheries productivity[39].


Seaweed on the surface. @Shanestagner © Unsplash.com


Vegetation on sea rocks. @_bunny_ © Unsplash.com

Habitat	Blue carbon importance	Area extent of blue carbon (km^2)	Threatened in UK waters?
Seagrass meadows	Capable of sequestering carbon 35 times faster than tropical rainforests[94]. If left undisturbed, seagrass soils persist for thousands of years acting as long-term / permanent carbon storage[94].	At least 85 km^2 UK-wide[94].	At least 44% of UK seagrasses have been lost since 1936, 39% since the 1980's. this loss may be as high as 92% over longer time spans[61].
Saltmarsh and mudflats	Saltmarsh ecosystems capture CO2 from both the water column and air through vegetation. They are able to continue sequestering carbon without ever reaching full capacity and will store carbon for millennia if left undisturbed[91].	England 324 km^2 [95] Scotland 70 km^2 [96] Wales 76 km^2 [90] Northern Ireland 2.15 km^2 [97]	85% of UK saltmarsh cover has been lost over the last century. Saltmarsh habitats are now listed as a UK Biodiversity Action Plan (BAP) Priority Habitat[91].
Kelp forests	Until recently, kelp was not considered an important blue carbon store due to its lack of sediment blue carbon (kelp forests grow attached to rock not the seafloor). New research into blue carbon stored in the biomass of kelp and the macroalgal carbon accumulation in the deep sea has meant that kelp is now recognised as an important blue carbon habitat. Macroalgal carbon accumulation occurs when seaweed becomes dislodged and eventually get deposited in coastal habitats, the deep sea or on land[98]. Approximately 90% of carbon sequestered by macroalgae is exported to the deep ocean, while the remaining 10% is stored in coastal sediments[98].	Approximately 67,340 km^2 UK-wide[99]	Driven mainly by climate change loss, the majority of UK kelp forests are predicted to completely disappear by 2100, unless more efforts are made to protect and restore them[100].
Biogenic reefs	Biogenic reefs (such as oyster reefs, blue mussel beds, maerl beds and flame shell beds), retain carbon in shell material during growth[88]. They form over centuries/ millennia, locking away large quantities of sequestered carbon if left undisturbed[88].	Full UK area extent currently unknown	There is little research on the current health of biogenic reefs across the UK.
Muddy sediment	Coastal muddy sediment (along with estuaries and fjords) has the largest carbon storage potential compared to other blue carbon habitats[89]. The burial of carbon in the seabed is higher in muddy than in sandy sediments, controlled by mixing processes (biological and physical) and the oxygenation of the seabed[101]. In mud, carbon is largely incorporated into the seabed by faunal feeding[101]. Research has identified that muddy sediments in the UK EEZ hold the greatest quantity of organic carbon, offering potentially valuable opportunities for targeted future management and protection of sedimentary carbon stores within the UK EEZ[89].	Approximately 51,775 km^2 in the UK EEZ (75% of all the muddy sediments within the UK EEZ seabed is located within Scottish waters)[89].	The most common threat to sediment habitats such as muddy sediment and associated carbon stores is seabed disturbance, most commonly by bottom trawling and dredging[89]. Disturbance of seabed sediments caused by bottom trawling remobilizes the top layer of sediment, exposing organic carbon to further remineralization. At present, only 5% of UK MPAs are protected from bottom fishing activity, leaving 93% of carbon stored in the UK's seafloor vulnerable to disturbance and remineralisation[57].

6.2. The UK fishing fleet

As of 2018, the UK fishing fleet was the 7th largest fleet in the EU in terms of vessel numbers, the 4th in terms of power (0.75 million kilowatts) and the 2nd largest in terms of total gross tonnage[102]. The UK fleet is made up of 5,911 fishing vessels (a reduction of 9% since 2009)[103]. As of 2019, 79% (4,675 vessels) of the UK fleet was recorded as <10 metres in length and 1,236 vessels (21% of the fleet) make up the >10 metre fleet[103]. Despite this, <10 metre vessels only accounted for 6% of catch by weight in 2019[102].

Of fish landed by UK vessels in 2019, approximately 87% was captured using a mixture of beam trawlers, demersal trawlers, dredgers, and demersal and pelagic seine nets[102].

In many cases this has important consequences for blue carbon sediments and some vegetated marine habitats.

It is worth noting that in 2019 UK pelagic landings by UK vessels dominated by volume (54%). The remaining 56% of landings was split almost equally between shellfish and demersal species. Both demersal and pelagic trawls require towing by one or two boats (known as pair trawling) when in use. The fuel use required to power these types of fishing gears is high and therefore an important contributor to industry GHG emissions.

6.2.1. UK fisheries and habitat disturbance

The UK fishing industry impacts UK blue carbon stores primarily through its use of bottom towed fishing gears. These gears can degrade vegetated blue carbon coastal ecosystems and release carbon from seabed sediments into the water column, and potentially the atmosphere where is adds to GHG emissions[102]. Extensive bottom trawling and dredging of UK seas is a threat to both sequestered blue carbon and the sequestration potential of marine habitats[51]. Bottom towed fishing gears are currently only restricted in 1.7% of UK seas[57,93] and of the 372 UK MPAs, only four, covering 25 km^2, are fully protected from fishing activities[104]. Furthermore, 71 of 73 offshore MPAs (included in the 372 UK MPAs, covering a total area of 245,000 km^2) are designed specifically to protect the UK seabed, yet none currently have management plans that restrict or exclude bottom towed fishing gears[57,105]. Regardless of MPA status, bottom fishing activities still occur widely within UK MPAs where important ecosystems, species and blue carbon stores are supposedly safeguarded[101].

Between 2015 and 2018, fishing vessels using demersal trawl, dredge, and seine gear fished a total of at least 89,894 hours within offshore UK MPAs, designated specifically for the protection of benthic features[57].

This equates to approximately 10 years' worth of continuous fishing activity in just 3 years, which is likely to significantly deplete carbon stored within seabed sediments in these areas. The UK fishing fleet was specifically responsible for 43% of the demersal fishing recorded within UK MPAs over this time frame (non-UK vessels were responsible for 57% of bottom fishing activity in UK MPAs)[57].

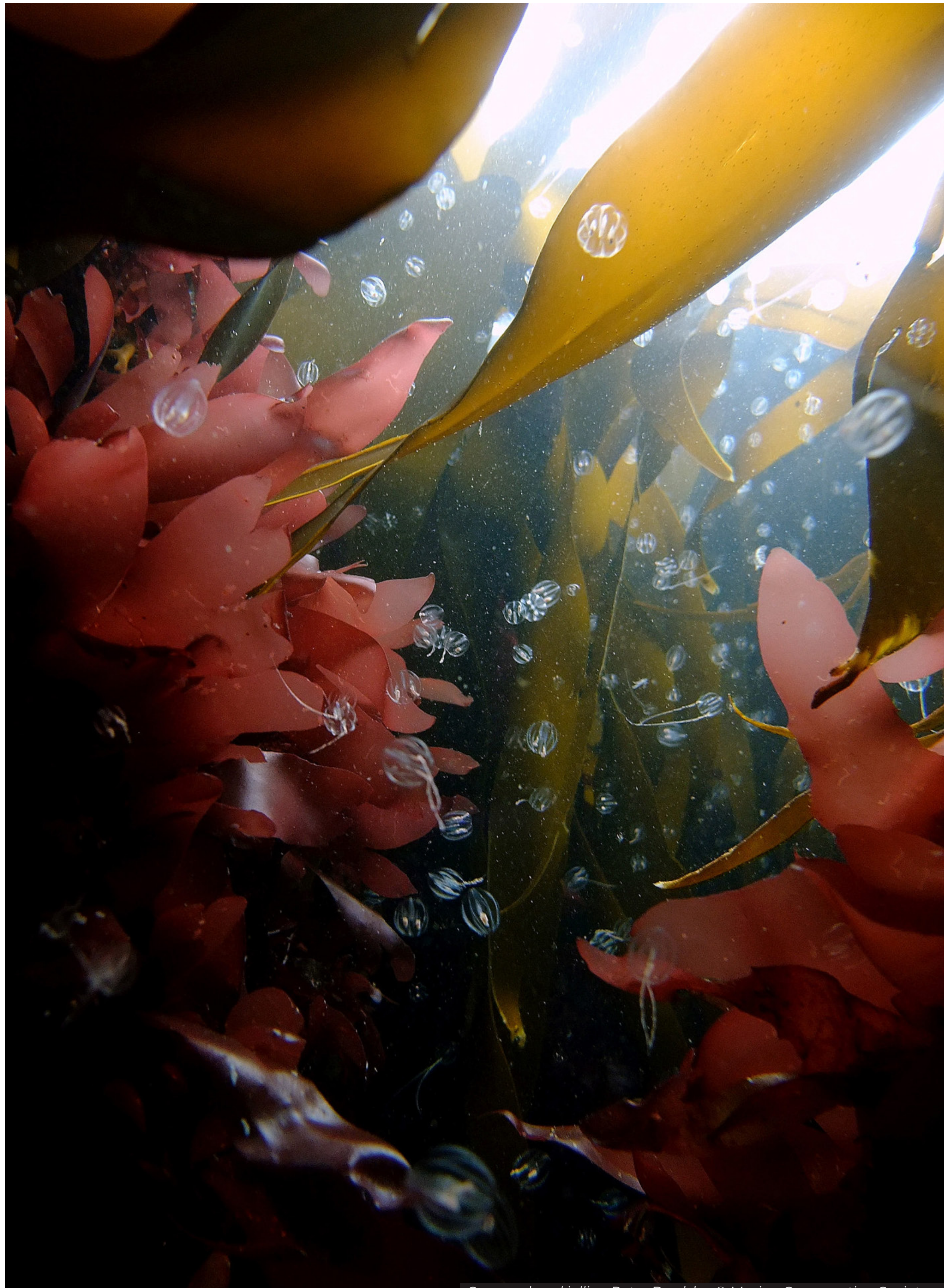
Continued disturbance of the blue carbon stored in the sediment of UK offshore MPAs alone, could cost the UK nearly £1 billion to mitigate over the next 25 years[57]. Measures to reduce the blue carbon impact of bottom towed fishing gear in UK waters are urgently needed. However, not all blue carbon resides within MPA's, and it will be important to identify key storage and sequestration habitats.

If bottom towed fishing activity is left unrestricted, the release of carbon across the entire UK continental shelf (from combined fishing impact and climate change disturbances) between 2016 and 2040 could cost up to £9 billion to mitigate by cutting emissions in other areas of the economy[57]. Damage to blue carbon caused by the UK fishing industry is, to some extent, hindering the UK's opportunity to utilise carbon in the marine environment as a climate change mitigation tool, and a means towards achieving net-zero emissions.

6.2.2. Removing UK fish is removing UK carbon

An evaluation of UK fisheries management highlighted that catch quotas have regularly been set above scientifically recommended sustainable yields, allowing overfishing practices to occur[107]. The UK fishing industry is therefore pushing some fish stocks towards critically low levels, which is likely impacting blue carbon through biodiversity loss and carbon extraction in the form of marine organisms (although on a much smaller scale than seabed disturbance). According to the first post-Brexit UK fish stock audit published at the start of 2021, only 3 of the UK's top ten fish populations are currently fished at or below maximum sustainable yield (mackerel (Scomber scombrus) in the north-east Atlantic, haddock (Melanogrammus aeglefinus) in the North Sea, and langoustines (Nephrops norvegicus in the west of Scotland)[69] . Many other species, including over 60% of UK shellfish stocks have unknown stock status in relation to management reference points[69]. The audit draws the conclusion that in 2019 almost 65% of commercial UK stocks were either in a critical state or had data limitations which meant that status could not be determined. Consequently, close monitoring of UK fish stock baselines and fisheries management approaches is needed to ensure UK fisheries do not fish at unsustainable levels, further imbalance marine systems, and negatively impact the UK's blue carbon habitats.

Habitat	Blue carbon impacts	Steps to reduce impacts
Seagrass meadows	The UK fishing industry impacts seagrass meadows in areas in which bottom disturbance occurs from the use of bottom towed fishing gear on the seabed (and other gear that makes contact with the seabed such as pots) as well as anchor damage[107]. Sediment disturbance and degradation of seagrass habitats leads to a reduction in natural carbon sink capacity, as carbon stored in the seagrass biomass and sediments of seagrass ecosystems is released back into the atmosphere when they are degraded, damaged, or destroyed[108].	• Seagrass restoration[109]; seagrass meadows can rebound and grow back if given the opportunity, therefore restoration of seagrass meadows will be an important part of addressing the interrelated crisis of biodiversity and carbon loss from both fishing and climate change impacts that have reduced the extent of UK seagrass meadows[107]. Projects such as the Seagrass Ocean Rescue project are already trying to replant millions of seagrass seeds across the Pembrokeshire seafloor in Wales[110]. • Restrictions on fisheries access to seagrass areas; needed to reduce damage to current seagrass meadows. This could take the form of MPAs with full protection from anchoring, bottom towed fishing gear and other fishing gears that make contact with the seabed.
Saltmarsh and mud flat habitats	Saltmarsh and mud flat habitats are at threat from erosion from multiple stressors in the UK, however, there is currently a lack of research on whether the UK fishing industry poses any significant threat[111]. Nevertheless, the UK fishing industry is highly dependent on saltmarshes specifically to serve as nurseries for many fishes and crustaceans[112]. Therefore, efforts by the fishing industry should still be made to conserve such key habitats.	• The reduction of erosion across all UK saltmarsh habitats[63]. • Setting maximum speed limits on vessels within habitat areas to reduce erosion from wave damage and vessel wash. More general marine management steps include: • Developing sedimentation fences and supplementation at sites highly vulnerable to erosion and sediment starvation[113]. Dredge material from the fishing activities could be utilised[63]. • Coastal realignment to protect remaining habitats where coastal squeeze is a problem.
Kelp	UK kelp forests have seen a decline in extent from a combination of storm damage and benthic disturbance following damaging fishing practices e.g. bottom towed fishing gear (causing comparatively greater damage than netting or potting) and the dumping of sediment by dredging boats[88,114].	• Kelp habitats are currently included in 77 UK MPA designations, yet are not protected from bottom towed fishing gear. Therefore, by restricting fishing access in these areas, disturbance of UK kelp forests will be reduced to some extent [114]. • Drastically decrease vessel time within MPA areas or restrict what fishing gear can be deployed. A change from bottom towed fishing gear to passive gear such as traps, pots and rod and reel fishing practices would reduce the intensity of seabed damage that impacts kelp forests (although some damage from contact may still persist)[57].
Biogenic reefs	Biogenic reefs are highly vulnerable to human activities that abrade, remove, or smother such ecosystems. UK fisheries impact can damage and destroy biogenic reefs through impact with bottom towed fishing gear (scallop dredging, potting etc.) which can eliminate carbon locked away for centuries or millennia, decreasing blue carbon stores and releasing stored carbon back into the water column and potentially the atmosphere[115,116]. The disturbance of sand and seabed sediment caused by fisheries disturbance of the seabed can also smother biogenic reefs, affecting reef regeneration and reducing blue carbon capacity[117].	• Fisheries restrictions: strict restrictions on gear that contacts the seabed of blue carbon sites of known importance, similar to the protection recently proposed for the protection of the Dogger Bank site[118]. • Restoration for stock enhancement: Once protection from fisheries is given, restoration techniques should focus on stock enhancement and substrate stabilisation, along with formulating a large-scale carbon storage assessment to provide accurate data[119]. • Aquaculture restoration: The installation of carbon (shell) banks to enhance aquaculture restoration[119].
Muddy sediment	Muddy coastal and shelf ecosystems are productive environments that occur in places with an accumulation of fine sediment, and often limited wave exposure. Offshore mud-rich shelf environments are particularly vulnerable to UK bottom towed fishing gear as they are often areas of abundant fish stocks[51]. In comparison to sandy sediment, mud has a higher sediment carbon concentration and is also more vulnerable to deeper fishing gear penetration[120]. A single trawl pass over muddy sediment in UK offshore waters is estimated to resuspend an average of 27.5kg of carbon/ha into the water column[51].	• Bottom towed fishing gear restrictions: • Reduce the number of new areas of seabed fished by bottom towed fishing gear. Aim to fish using bottom towed fishing gear in areas already fished using these methods to reduce fishing in new areas of undisturbed blue carbon stores. • Decrease the penetration depth of fishing gear types in muddy sediment areas to reduce the resuspension of deeper layers of carbon stock.



Seaweed and jellies. Peter Bardsley © Marine Conservation Society

6.3. Reducing UK fishing impacts on blue carbon

For the UK to move towards net zero emissions we must rethink practices and modernise to meet the climate change challenge. Steps should be taken to reduce the fishing industry's impact on important blue carbon stores - mainly the spatial extent of seabed and ecosystem disturbance from bottom towed fishing gears operating in UK waters (see Table 2). This could be achieved in several ways.

- *Reduce the UK dependence on bottom towed fishing gears by putting a greater focus on prioritising the use of well managed passive fishing gear over bottom towed fishing gear to reduce damage to blue carbon sediments and habitats.*
- *Refine bottom trawling sites to designated areas to actively reduce the disturbance of bottom trawling, and limit new areas of seabed available to bottom trawling.*
- *Develop, implement, and enforce new and existing MPA sites that are specifically designated for carbon storage protection[51,58].*
- *Increase policy recognition of the importance of blue carbon as a climate change mitigation tool. For example, in the UK marine strategy where climate impacts and mitigation are absent.*

Within MPA networks, banning bottom towed fishing gear for blue carbon protection, could conserve and help build carbon stores as part of UK efforts to curb climate change and help habitat conservation and marine wildlife recovery[101]. Furthermore, steps to reduce damage and extraction of blue carbon by unmonitored fisheries management practices could focus on improving the traceability and transparency of fishing in UK waters[101]. This would ensure that fisheries activities and management progress is more easily and efficiently measured, whilst holding those accountable that continue to cause damage to blue carbon stores. Increased accuracy in monitoring vessel behaviour and fishing activity would further ensure fisheries are compliant with sustainable catch limits. This in turn should help conserve carbon lost through overfishing practices that impact food webs through biodiversity and ecosystem function-related losses.

The installation of Remote Electronic Monitoring (REM) with closed circuit television cameras (CCTV) across vessels fishing in UK waters would make the bedrock of a comprehensive data collection and monitoring framework for both commercial and bycatch species. This would further help address the data poor status of many stocks and help improve the accuracy and speed at which management can respond to changes in stock status. Reluctance to install REM has been found across some industry segments. Therefore, a legal mandate to mainstream REM installation across all vessels fishing in UK waters may be needed if fisheries impacts are to be comprehensively monitored and protected[122]. REM systems usually include Global Positioning Systems (GPS) which allows greater monitoring of both vessel position and activity. This will be important when monitoring vessels within MPAs, known coastal blue carbon ecosystems or areas of extensive trawling activity. Position monitoring can be delivered by Vessel Monitoring Systems (VMS) but at present, only vessels >12 metres in length are legally required to be fitted with VMS, meaning that the UK fleet, 79% of which is made up of vessels <10 metres in length, is largely untracked[123]. A better alternative would be to make REM with cameras mandatory and adhere to specifications that meet governments needs and current VMS rules. This would mean using only one piece of combined equipment that would allow the capture of reliable evidence and additional data that can be used to support climate-smart UK fisheries.

REM camera system onboard vessel. © Lotte Kindt Larsen


Boat captain. @garrettpsystems © Unsplash.com

7. UK fisheries emissions

Powering the UK fishing industry requires significant fossil fuel use, that results in an industrial carbon footprint that contributed to the UK's total GHG emissions[102]. However, there are still significant holes in current knowledge surrounding the UK fishing industry's estimated CO_2 emissions and their contribution to total UK annual carbon emissions. UK emission inventories of the fishing industry are particularly sparse and annual fuel efficiency data is not readily available for all vessels, particularly for smaller vessel sizes[124]. Consequently, inventories have been heavily based on assumptions in UK fuel use from days at sea calculations rather than accurate vessel movement estimates. Nevertheless, using UK fishing vessel activity data, UK fisheries are estimated to have generated 295.7 kilotons of fuel and emitted 914.4 kilotons of CO_2 between May 2012 and May 2013[124]. The emissions emitted over this 1-year period is equivalent to 12,105 full gasoline tanker trucks, or the same as providing the annual energy use of over 110,000 homes[125]. When combined with the fact that over 50% of the UK fleet is around 30 years old (currently considered the life span of a typical fishing vessel[102]), the current fuel efficiency of the UK fleet may well benefit from investment, as older vessels are expected to be less fuel efficient and therefore contribute to greater GHG emissions than newer vessels[77]. Consequently, developing an up-to-date understanding of the UK fisheries GHG emissions from fuel use is vital if the industry is to work towards actively supporting national climate targets. Similar to many other industrialised fisheries, UK fisheries are heavily dependent on fridge and freezing systems, with studies estimating the total energy consumption and costs of cold stores and blast freezers to range from 10.9 to about 20.7 gigawatt hours (GWh) with an equivalent cost of £1.7–3.2 million per year for the UK[78]. Furthermore, like other countries, UK governments currently provide generous fuel subsides to any eligible UK vessel undertaking marine voyages (where at all times, the vessel is either within the limits of a port or at sea)[126]. Included in the list of eligible vessels are UK fishing vessels[126]. Vessel operators can claim fuel relief on heavy oils used such as gas or fuel oil, as well as light oil such as petrol. The most common gas oil used by the UK's fishing vessels is red diesel, a type of gas oil that has been chemically marked and dyed to enable law enforcement agencies to identify it as rebated fuel which must not be used in road vehicles[126]. Red diesel is currently entitled to a tax rebate of 46.81 pence per litre (PPL), giving it an effective duty rate of 11.14 PPL. This equates to an 80% tax subsidy approximately[127]. It can be found at quaysides, marinas and on inland waterways and its subsided price drives fuel use, overcapacity, and fuel hungry methods of fishing. It distorts relative prices in favour of the most carbon-intensive fishing methods such as scallop dredging and overall reduces the incentive to reduce CO_2 emissions[128]. In March 2021, policy changes made by UK governments meant that the entitlement to use red diesel and rebated biofuels will be restricted to certain sectors as of April 2022 to meet net-zero targets[127]. The fishing industry has, however, been granted entitlement to continue benefiting from the use of red diesel and fuel subsidies. Thus, highlighting how the fishing industry's emission contributions are typically not considered in national climate change mitigation plans[127].

UK fisheries are estimated to have generated 295.7 kilotons of fuel and emitted 914.4 kilotons of CO_2 between May 2012 and May 2013[124]. The emissions emitted over this 1-year period is equivalent to just over 12,100 full gasoline tanker trucks, or the same as providing the annual energy use of over 110,000 homes[125].

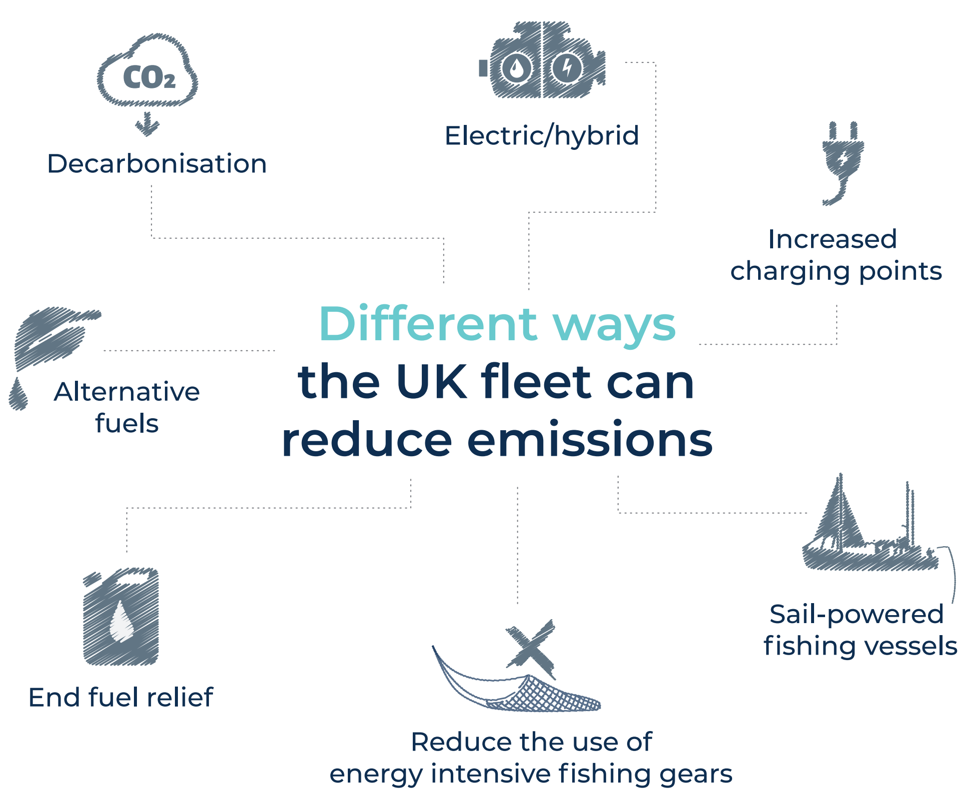
Fresh catch. @kmus07 © Unsplash.com

7.1. Reducing GHG emissions of UK fishing sector

7.1.1. Decarbonisation of the UK fishing industry

A significant step to enhance the decarbonisation of the UK fishing fleet is to remove current fuel subsidisation. This would increase fuel costs for fisheries which is expected to reduce overcapacity and actively help move UK fisheries away from fuel intensive fishing gear types such as bottom towed dredgers and trawlers, towards more low emission methods[128]. It is, however, worth noting that passive gears are not without problems such as bycatch of undersized and Endangered Threatened and Protected species (ETP) and, in some cases, habitat damage. Nevertheless, this move could result in greater motivation to decommission older diesel vessels and retrofit or invest in electric or hybrid vessels that generate significantly lower emissions and would rely less on subsidised fuel.

Up until recently, maritime industries such as fishing and shipping have been missed out of the debate on global GHG emissions[77]. However, in July 2019, the UK published the Clean Maritime Plan,



becoming one of the first countries to publish a national maritime action plan to work toward zero-emissions[129]. It identifies ways to tackle air pollutants and GHG emissions in parallel, while securing clean growth opportunities for the UK[129]. The plan builds on the International Maritime Organisation's 2018 strategy to reduce CO_2 emissions across international shipping by at least 40% by 2030 and 70% by 2050 (compared to 2008 figures)[130]. Although the UK government's Clean Maritime Plan appears to be focused largely on shipping, it does state that "By 2025, we expect that all vessels operating in UK waters are maximising the use of energy-efficient options. All new vessels being ordered for use in UK waters are being designed with zero-emission propulsion capability"[129]. With interest in shipping now increasing, it looks promising that the decarbonisation of the fishing industry could become the next big focus. Consequently, it is important that the UK focuses on innovations across marine industries which may help to reduce the UK fishing industry's carbon footprint.

Emission reductions of the UK fishing fleets could come through opportunities to decommission older vessels in the UK fleet, and increase fuel and catch efficiencies with the aim of reducing the amount of fuel burnt per unit of catch, whilst still fishing within ecological limits. Vessel upgrades could include investments in electric, hybrid, or hydrogen modified engines, as well as renewable alternatives for energy intensive cooling systems.

7.1.2. Electric and hybrid Vessels

Electric vessels have seen a recent revival with the increase in innovative emission reduction technologies. The possibility to eliminate fossil fuel power from the fishing industry altogether looks increasingly promising. The 11 meter Karoline M-82-H for example, (Figure 1) became one of the world's first hybrid electric fishing vessels in 2015[131]. The Karoline, built by Selfa Arctic for fisherman Bent Gabrielsen from North Norway (in collaboration with Siemens) is equipped with two battery packs that have a total capacity of 195 kWh, as well as a 500-litre diesel engine, which together power the boat for a full day of fishing in the Norwegian Sea[132]. Charged overnight by plugging into the port's power supply provides enough power to run for 10 hours on the battery alone. The Karoline's energy storage system onboard acts as a future investment, generating fuel savings of around 25%, whilst simultaneously reducing GHG emissions by 25-40%. Since the build of the Karoline, technology has continued to develop, with the introduction of larger fishing vessels such as The Spes Nova, (Figure 2) a 31-meter UK 205 fly-shooter/twinrigger vessel set to fish the North Sea.

Electric and hybrid vessel engine systems offer further benefits than just reduced GHG emissions and fuel efficiency. Electric engines are more compact, requiring less space onboard, they are much quieter, produce far less vibration which is better for both crew, marine noise pollution and longevity of vessel gears. Low emission technologies are a major win so far for the environment, but to ensure they remain efficient and that the benefits filter back to society and economies, adequate training must be given to skippers and engineers traditionally trained in the use of diesel engines. Furthermore, mainstreaming the installation of electric charging points in harbours is essential to enable a widespread vessel decarbonisation transition.

The Karoline M-82-H, one of the world's first hybrid electric fishing vessels (built in 2015). © Corvus Energy

The Spes Nova, a UK-205 fly-shooter/twin rigger vessel built at Damen Maaskant shipyards, Netherlands. © DAMEN

7.1.3. Alternative fuels and renewable energy

Alternative fuels include any fuel type other than conventional fossil fuels. Alternative fuels include biodiesel, bio-alcohol, gases like hydrogen or ammonia and even compressed air. Hydrogen as a fuel source emits zero carbon dioxide, zero sulphur dioxide and only negligible nitrogen oxide[131]. However, its use as a replacement for traditional diesel fuel still requires research and development, and there are still safety issues associated with storing hydrogen. Nevertheless, hydrogen gas is currently the most popular fuel alternative with many successful examples of its use in transport globally[133]. In the UK, Orkney has been coined the 'Hydrogen Islands ' and 'pioneers' by the press following several successful projects to turn local renewable energy into hydrogen[134,135].

Orkney, Scotland – Hydrogen power

Thanks to its location where the Atlantic meets the North Sea, Orkney is surrounded by abundant renewable energy resources. So much renewable energy is generated through both wave and wind turbines that there is a surplus supply. Consequently, a community project known as SURF 'N' TURF has become the first community energy project to take this surplus electrical energy generated on the island of Eday and convert it to hydrogen gas through a 500kW electrolyser[136]. Once compressed, the hydrogen is transported by road and sea to a fuel cell which is sited on Kirkwall Pier. This then provides electricity on demand for operations within the harbour. Major plans and testing are currently underway to decarbonise the local sea-going passenger and car ferry[137]. The ferry which operates on the route between Kirkwall and Shapinsay in Orkney, is being used to test whether hydrogen fuel cells can be successfully integrated with a marine hybrid electric drive system, along with the associated hydrogen storage and bunkering arrangements[137]. Fuel cells of this type are currently used in road transport and can be found in hundreds of hydrogen-fuelled buses across Europe[133]. If successful, the project will pave the way for the first seagoing vessel to use this fuel technology, becoming Europe's first hydrogen fuel cell-powered passenger ferry[138].

The SURF 'N' TURF project not only reduces the use of fossil fuels and subsequent carbon dioxide emissions, but it also helps communities and companies to harness locally sourced energy, reducing their community carbon footprint. Furthermore, to tackle the socioeconomic impacts of this new renewable venture, local prices for fuel are low to tackle fuel poverty, and hydrogen training will be available through Orkney College University of the Highlands and Islands[137]. The community project run by SURF 'N' TURF, successfully combines environmental and socioeconomic aspects of coastal community life to build climate resilience for the future.

Compressed hydrogen generated from excess energy from local tide and wind farms is transported by ship to a fuel cell in Kirkwall, UK. © Energyvoice.com

7.1.4. Low emission fishing ventures

A substantial growth in consumer purchasing power and interest in sustainably harvested seafood in recent years[139] could provide a unique opportunity for UK fisheries to further reduce GHG emissions and blue carbon impacts, whilst also balancing economic considerations. Low emission fishing ventures such as sail-powered fishing vessel opportunities, could command a premium price for low carbon or carbon neutral services. To date, a small number of independent fishing communities across the UK already venture in the zero carbon space, such as the Fal Oysters (and queen scallop) fishery in Falmouth, Cornwall[140]. This scallop fishery has become a marine pioneer in low emission fishing practices. The fishery is one of the few examples of commercial fishing ventures that has banned the use of engines and other power sources except sail, oar, and human muscle[140]. In addition, the selective and low impact nature of harvesting scallops using divers by some of the operators also ensures a premium price tag, whilst avoiding benthic disturbance common with industrial scallop dredgers[141].

Other independent companies within the marine sector are focusing on bringing trade to the UK via clean, sail-powered cargo ships[142–144]. Several are utilising new technology such as solar powered engines alongside traditional sailing masts to ensure that zero carbon shipping is both clean and commercially viable[145]. This marketing opportunity of low carbon footprints provided by other low emission ventures within the maritime industry could give the UK fishing industry the opportunity to gain higher market prices by focusing on reducing carbon in their supply chains.

The UK has the opportunity to combine its world leading stance on climate change mitigation with the heightened consumer interest in sustainable seafood by promoting new low emission fishing ventures.

Wind-powered (or a renewable hybrid combination) vessel could also give way to ecotourism opportunities, further strengthening the UK's plans to become a responsible and thriving coastal state. If a combination of the above measures is adopted, significant steps could be taken towards helping the UK move towards net-zero, limit future losses in blue carbon habitats and set a leading precedent in being the first major economy to implement climate-smart fisheries.

Lobsters. @kmackay276 © Unsplash.com

8. Climate change policy in the UK

The UK is recognised as a world leader on climate change in comparison to many other major economies as a result of the pioneering nature of its climate change adaptation strategies, research, and policy[146]. On the 1st of May 2019, the UK Parliament made a national environment and climate emergency declaration, closely following similar declarations by both Welsh and Scottish governments[147–149]. The UK's declarations demonstrate that UK governments and local authorities are willing to address the UK's role in climate change, yet the declarations do not legally compel them to act[150]. Consequently, legally binding climate legislation and Nationally Determined Contributions such as the those required by the Paris Agreement are essential to ensure the UK remains accountable for its role in anthropogenic climate change and actively works to reduce its contribution to global GHG emissions.

The UK became the first nation to pass legislation that set out targets to enable a country to become a net-zero emitter[151]. Current UK legislation and commitments include:

- The Climate Change Act 2008 (2050 Target Amendment) Order 2019[146], which amended the Climate Change Act 2008, requires UK governments to reduce net GHG emissions by 100% relative to 1990 levels, by 2050[152].

- The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 which amended the Climate Change (Scotland) Act 2009, commits Scotland to end all contributions to climate change by 2045 at the latest[151].

- The Climate Change (Wales) regulations 2021 commits Wales to net-zero emissions by 2050 with interim targets of emissions reductions of 63% and 89% against the baseline for 2030 and 2040, respectively[153].

- On the 12th of December 2020, the UK became one of only a few major economies to communicate its new NDCs under the Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC)[154]. The new NDC states that the UK has set a target to reduce GHG emissions by at least 68% by 2030, compared to 1990 levels[154].

These targets, however, do not include the potential contributions to GHG emissions from marine activities such as the fishing industry's impacts on blue carbon habitats. Furthermore, until the UK Fisheries Act of 2020, only 1 of the 31 UK marine legislations spanning the last five decades, makes specific reference to climate change; the Marine Act (Scotland) 2010 which places a duty on Scottish Ministers to protect and enhance the health of Scottish seas alongside a duty to manage Scotland seas to mitigate and adapt to climate change. Therefore, the UK Fisheries Act 2020 provides the first opportunity for the UK to integrate both climate change mitigation and fisheries management in legislation since the UK made its commitment to net-zero emissions by 2050.

8.1. The UK Fisheries Act 2020

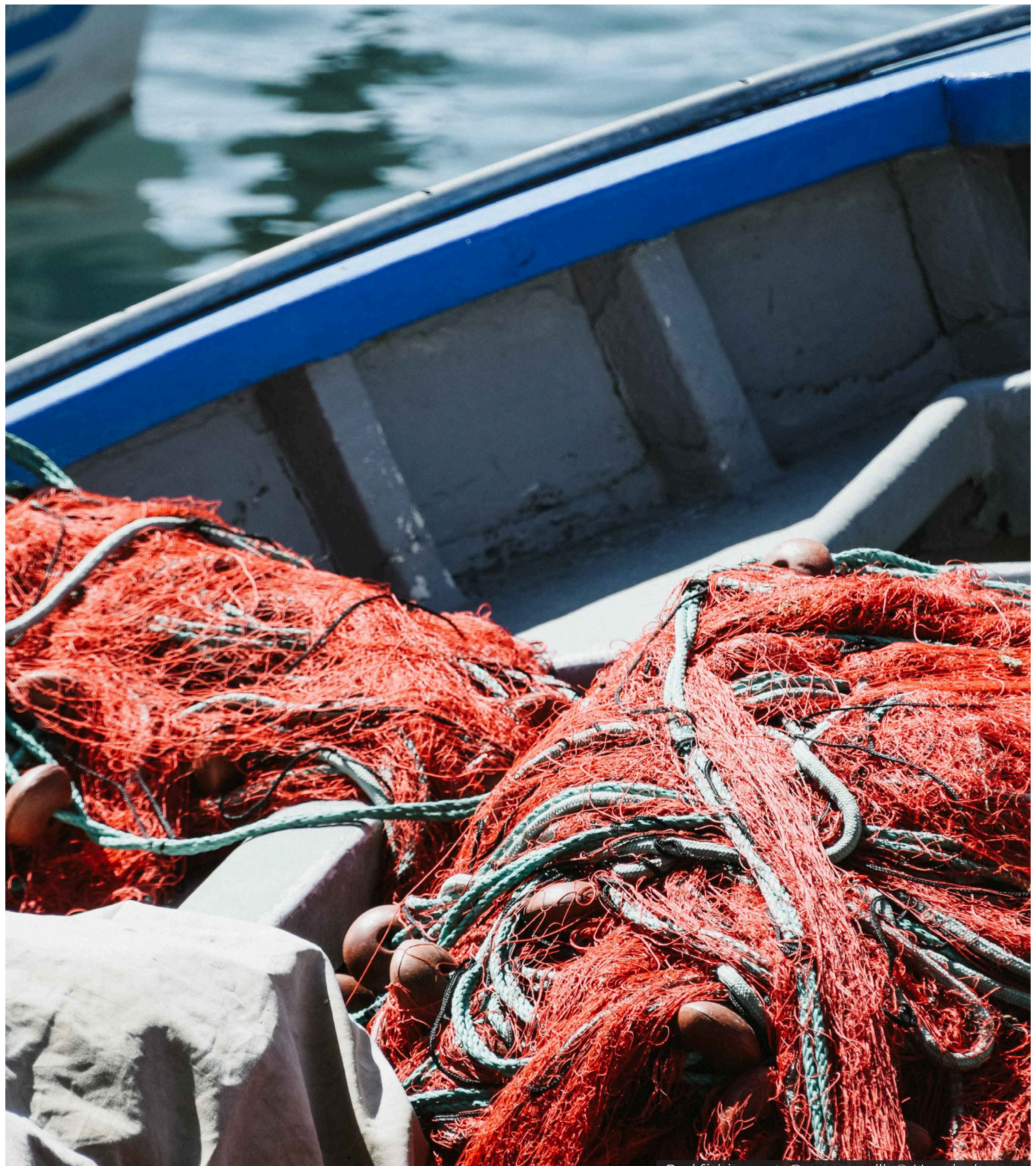
In 2020, UK Prime Minister Boris Johnson declared the government's intention for the UK to become a leading, responsible, independent coastal state following the UK's departure from the European Union on January 1st, 2021[155]. However, to realistically achieve this all governments of the UK must consider the UK fishing industry's role in climate change.

On the 23rd of November 2020, the UK Fisheries Act (2020) came into force, which gives the UK full control of territorial waters for the first time since 1973[156]. Under the act, each of the devolved administrations will have greater fisheries management powers, allowing the opportunity for tailored approaches to fisheries management, specific to the needs of each administration's marine industry and waters[157]. The Fisheries Act lists 8 key fisheries objectives which set out the overall aims of the Act; (1) Sustainability, (2) Precautionary, (3) Ecosystem, (4) Scientific Evidence, (5) Bycatch, (6) Equal Access, (7) National benefit and (8) Climate Change (see below)[158].

The UK Fisheries Act is the first major domestic fisheries legislation in almost 50 years, and the first to acknowledge the fishing industry's contribution to climate change. The climate change objective (number 8) of the Fisheries Act 2020 states that:

" (a) the adverse effect of fish and aquaculture activities on climate change is minimised, and (b) fish and aquaculture activities adapt to climate change"[156].

The Act, however, does not state how these objectives should be achieved[158]. Rather, it functions as a legal requirement for the four UK fisheries policy authorities (FPAs) to prepare and publish a document known as the Joint Fisheries Statement (JFS), detailing how they will achieve or contribute to the achievement of the fisheries objectives[156]. The FPAs have 2 years from the issue date of the Act (23rd of November 2020) to produce the JFS and must also report on the efforts and impacts of the JFS to relevant parliamentary power within the four nations of the UK every four years[156]. The framework for the JFS is currently being developed, yet there is a current lack of research on the issues relating to UK fisheries impact on marine carbon and GHG emissions. To meet the objective, a clear climate-smart strategy for the UK fishing industry needs to be developed to aid real climate change mitigation. Consequently, recommendations are needed to assist the UK FPAs in delivering a robust management plan that can produce measurable change towards appropriate climate-smart fisheries management, reducing GHG emissions and safeguarding UK blue carbon habitats.



Red fishing net. @meganedlh © Unsplash.com

8.2. How does the UK Fisheries Act 2020 compare globally

To date, few countries around the world have passed climate change legislation that specifically considers fisheries management or climate-smart strategies for the industry. Using the Grantham Research Institute on Climate Change and the Environment database of global climate laws, policies and litigation cases[159], 882 individual Acts and policies on climate change were identified. However, when searching specifically for reference to 'fisheries', the database only finds 5 action plans (and no specific legislation):

- National Action Plan Addressing Climate Change 2007 (Indonesia)[160].
- Climate Change Priorities Action Plan for Agriculture, Forestry and Fisheries Sector 2014-2018 (Cambodia)[161].
- Kiribati 20-year vision (2016)[162].
- National Adaptation Plan for Climate change Impacts 2016-2025 (Sri Lanka)[163].
- Climate Change Strategy and Action Plan (MCCSAP) 2016-2030 (Myanmar)[164].

All of the above climate change action plans advise the utilisation of climate-smart practices within the fishing industry. Each aims to enable industrial adaptation to the impacts of climate change on the fishing industry, and some identify mitigation of the industry's contribution to climate change (mostly through GHG emissions) as an important step. Nevertheless, it appears that climate change policy and legislation through a fisheries lens is currently addressed through national climate change action plans instead of legislation. This means that the UK Fisheries Act 2020 represents world-leading legislation on the issue.

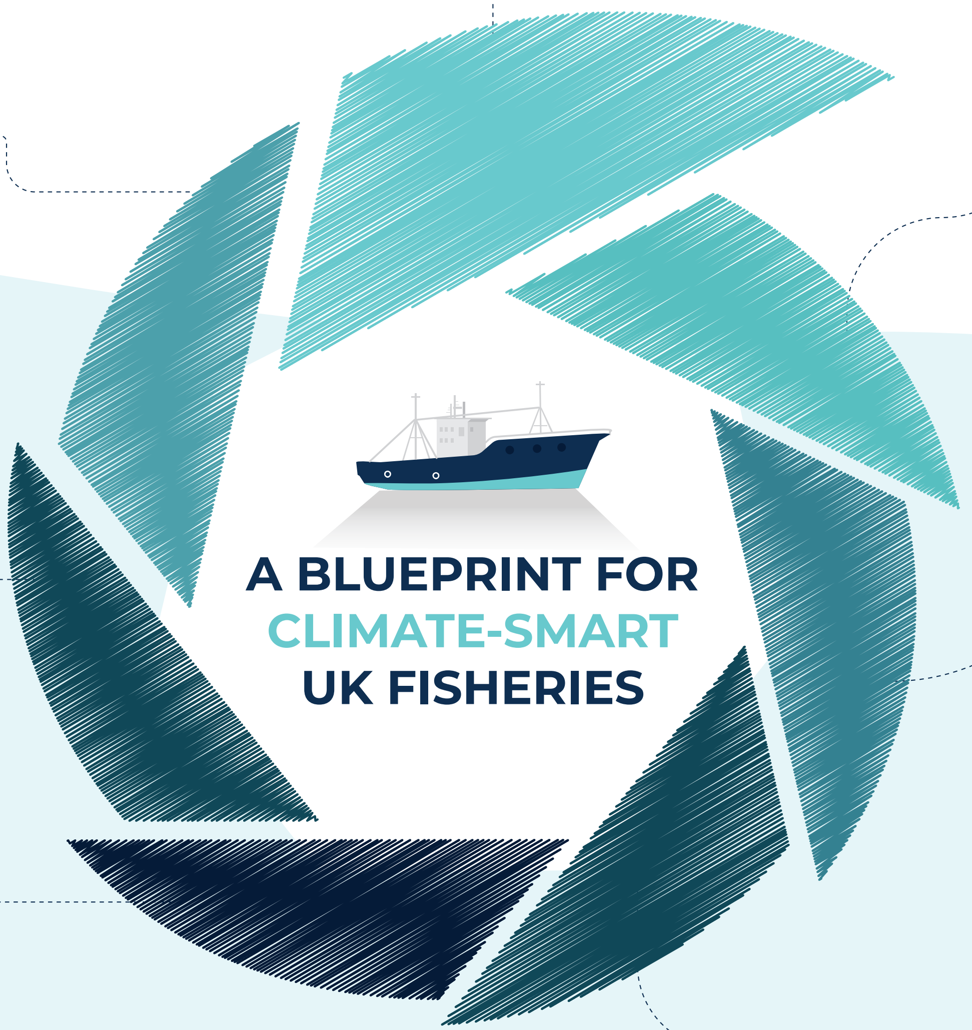
Global research and scientific understanding of fisheries blue carbon impacts and emissions has grown over the last decade yet is still in the early stages of development. It appears that climate-smart fisheries approaches are evolving largely across developing countries and small island nations, likely because of early onset climate change threats and stressors in those areas of the world. However, there appears to be no major economies other than the UK making concerted efforts to be climate-smart in fisheries management, even though there is an increasing interest in utilising marine systems as a climate change solution. Consequently, an international, united ocean-centric climate protocol is needed to be the most effective in protecting ocean resilience to climate change and aid in blue carbon sequestration. Globally, every nation can help drive change by setting precedents to address the contribution that fishing industries make to GHG emissions and damage to vital blue carbon stores.

The UK is recognised as a leader in the drive for climate change adaptation through net-zero policy and legislation. It also has a renewed opportunity to become a leading, responsible, coastal state with newly established, full control of its own waters. However, it is still to make efforts to address climate-smart fisheries approaches. The new UK Fisheries Act (2020), does, however, have the potential to influence real change and could act as a model to steer fisheries policy reform in a climate-smart direction, starting by addressing the UK fishing industry's impact on national GHG emissions through blue carbon impacts and the carbon footprint of the industry. On the 17th of December 2020, shortly after the passing of the UK Fisheries Act, Scotland set out a new policy for the future of Scottish fisheries; Future fisheries: management strategy - 2020 to 2030[165]. The policy's vision is for Scotland to be a world class fishing nation, delivering responsible and sustainable fisheries management[165]. It contains commitments to consider the contribution that the fishing sector itself makes to climate change and the need to reduce its impacts. It further discusses its aims for the Scottish fisheries to support the delivery of net zero emissions by 2045.

The UK Fisheries Act 2020 gives the UK governments the opportunity to develop and implement the climate-smart management of fisheries and the marine environment. If successful, implementation of the Act could make the UK a major leader of marine-focused climate-resilience that prioritises long-term sustainability, balanced with economic productivity of the fishing sector. The act has the potential to feed into international agreements that would influence policy and the marine systems on a global scale such as UNFCCC, the Sustainable Development Goals, and the Convention on Biological Diversity.

Abercastle, Haverfordwest, UK. @danielmorris © Unsplash.com

A BLUEPRINT FOR CLIMATE-SMART UK FISHERIES



Continue to increase knowledge and research around blue carbon and fisheries impacts.

- Build a clear understanding of UK blue carbon habitats and stock volume
- Improve understanding of UK towed gear activity and ability to monitor
- Increase research on climate stressors and UK fisheries impacts to fill knowledge gaps and build baseline data for climate-smart fisheries development

Increase transparency and traceability of UK fishing.

- Mandate Remote Electronic Monitoring (REM) with cameras that incorporate Vessel Monitoring Systems (VMS) across vessels fishing in UK waters (including vessels <12m)
- Evidence sustainable fisheries – fishing within biological limits and minimising ecosystem impacts

Reduce pressure from active fishing gear types.

- Incentivise the use of low impact and passive fishing gears
- Support and incentivise the development of less harmful gear modifications / technology

Work to decarbonise the UK fishing fleet and eliminate inefficient fleet segments.

- Track UK fisheries GHG emissions
- Set out the programme to replace older vessels with new energy efficient vessels and alternative fuel use
- Remove harmful fuel subsidies such as red diesel

Protect blue carbon already within MPAs.

- Prohibit bottom towed fishing gear and anchoring
- Impose speed restrictions
- Create buffers around sensitive features
- Restrict fishing within MPAs

Identify and protect key blue carbon in wider seas.

- Protect key stands of blue carbon such as muddy sediments or biogenic reefs from bottom towed gear
- Ensure fishing is within biological limits

Strengthen marine policy with a climate change lens.

- Increase climate change objectives within UK marine policy
- Include blue carbon within UK's Nationally Determined Contributions

9. A management blueprint for climate-smart UK fisheries


Boats at market dock. @pauleinerhand © Unsplash.com

9.1. Climate-smart strategy for UK fisheries management

Evidence shows that ocean health is vital and that industries operating across our seas have a role to play in tackling climate change. UK fishing needs to change and modernise to meet this challenge. The UK has a new, world leading legal objective for fisheries and aquaculture to help mitigate climate change. This report is calling on the governments of the UK and fisheries authorities to act with urgency to build and implement a climate-smart strategy for UK fisheries management. Below are some of the essential elements that need to form part of a climate-smart strategy for UK fisheries and how this can be achieved.

9.1.1. Practical fisheries recommendations

1. Protect blue carbon

a) Within MPAs that have sensitive blue carbon features, utilise management approaches such as: prohibiting all bottom towed fishing gear and anchoring; impose speed restrictions (to minimise wave damage); create buffers around sensitive features (to stop smothering from disturbed sediment) and restrict fishing within MPAs (using REM & VMS to track vessel activity and location). In some cases, it may be appropriate to allow well managed and marked passive gears such as longlines, and pots and traps to help reduce the negative economic impacts of reduced fishing activities. (Note that some still cause erosion of the seabed, however, the impact is far less intensive than bottom towed fishing gear).

b) Identify key stands of blue carbon outside of MPAs such as muddy sediments and biogenic reefs. Limit bottom towed fishing gear to protect and enable recovery of these important habitats in wider seas. Ensure connectivity and ecological coherence of the networks in the context of protecting the entirety of the ecosystem service provided by blue carbon habitats and associated features.

2. Work to decarbonise the fleet and eliminate inefficient fleet structures.

a) Replace older vessels (particularly those at the end of life - built before 1991) with decarbonised vessels to help reduce the industries carbon footprint. The UK governments and finance sector should set such decarbonisation as a condition for vessel upgrades. Funding should not be permitted where it will contribute to the over exploitation of a stock, or in sectors where overfishing is already an issue.

b) Develop a clear understanding of the UK fisheries GHG emissions from fuel use and actions to progressively reduce these.

c) Invest in hydrogen / fuel alternatives and support infrastructure to move away from fossil fuel dependence and towards net zero.

d) Remove current fuel subsidies for UK

vessels that drive overcapacity / overexploitation and use fuel intensive methods. This subsidy removal should be phased in for the most highly polluting vessels in the first instance.

e) Provide a just transition towards alternative forms of fishing / seafood harvesting.

3. Increase transparency and traceability across the UK fishing industry in support of improved management.

a) Mandate REM (with cameras) and VMS installation across vessels fishing in UK waters (including vessels <12m). This will provide data collection for both scientific and management purposes, allowing calculations of fisheries carbon footprints, better enforcement for protected areas and improved monitoring of bycatch, carbon removal and stock assessment information to improve stock health.

4. Reduce pressure from bottom towed fishing gears.

a) Change fishing gear dependence by developing incentives for fish caught via passive gear and / or restrict bottom towed fishing gears.

b) Support and incentivise the development of gear modifications / technology to make bottom towed fishing gear such as trawls and dredges less harmful and more efficient and selective.

5. Strengthen marine policy with a climate change focus.

a) Address the current lack of climate change objectives within UK marine policy such as the UK Marine Strategy, to make them fit for purpose in a bid to combat the climate crisis.

b) Consider blue carbon as a climate change mitigation tool within the UK's NDCs.

9.1.2. Research / knowledge recommendations

1. Build a clear understanding of UK blue carbon habitats and stock volume.

a) Increase the number and extent of UK blue carbon field surveys.

b) The UK would greatly benefit from a comprehensive study and monitoring program looking at UK wide blue carbon. This could work to build on existing blue carbon initiatives such as the Scottish Blue Carbon Forum research programme.

2. Increase research on UK fisheries impacts to help fill current knowledge gaps.

a) Increased scientific surveys of fishing impacts and climate stressors of the marine environment to build baseline data for climate-smart fisheries development.

b) To fill the knowledge gaps surrounding fisheries CO_2 emissions, it is recommended that emissions be tracked, calculated, and the information made transparent and publicly available. This should be combined with REM technologies and live CCTV to ensure accurate data collections.

Unloading fish boxes. @pauleinerhand © Unsplash.com

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