frontiers | Frontiers in Marine Science

POLICY AND PRACTICE REVIEWS
published: 13 April 2022
doi: 10.3389/fmars.2022.800972

Reforming International Fisheries Law Can Increase Blue Carbon Sequestration

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The oceans are by far the largest carbon sink and are estimated to have absorbed roughly 40 percent of anthropogenic carbon dioxide emissions since the beginning of the industrial era. The climate services performed by the oceans can be described as an interaction between a physical and a biological carbon pump. Whereas the role of the physical carbon pump is well established, the full scale of the climate services provided by the biological carbon pump has only recently been understood. This pump is made up of services provided by different marine species, from microbes to marine mammals. Many of these species are managed under the international law of the sea and subject to the concept of Maximum Sustainable Yield (MSY). Although the MSY concept has developed since its inception, maximum generation of fish for human consumption remains the core objective according to the law of the sea. Under MSY based management, states are not required to consider the climate services represented by different marine organisms, making this regime unable to balance the interest of maximizing fish as a product against the oceans' role in carbon sequestration. In order to make optimal use of the carbon sequestering features of marine organisms, this perspective proposes five action points. Foremost, MSY should be complemented with a new management objective: maximum carbon sequestration (MCS). Although many aspects of climate-based fisheries management remain to be explored, it appears clear that this would imply allowing stocks to recover to maintain a larger amount of biomass, increasing conservation measures for species particularly efficient in providing negative emissions, differentiation of fisheries within species as well as a new approach to ecosystem management. Climate reforming international fisheries law could make an important contribution to the operationalization of the Paris Agreement on Climate Change, as well as the UN Sustainable Development Goals. As a first step, international guidelines should be developed on how to integrate the concept of maximum carbon sequestration in fisheries management.

Keywords: maximum climate mitigation, marine management, climate change, carbon sequestration, blue carbon, law of the sea, fisheries management, fisheries law

OPEN ACCESS

Edited by:
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Reviewed by:
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Tore Henriksen, UiT The Arctic University of Norway, Norway

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Specialty section:
This article was submitted to Marine Fisheries, Aquaculture and Living Resources, a section of the journal Frontiers in Marine Science

Received: *24 October 2021*
Accepted: *21 March 2022*
Published: *13 April 2022*

Citation:
Krabbe N, Langlet D, Belgrano A and Villasante S (2022) Reforming International Fisheries Law Can Increase Blue Carbon Sequestration. Front. Mar. Sci. 9:800972. doi: 10.3389/fmars.2022.800972

INTRODUCTION

The impact of climate change and ocean warming on the productivity of fish stocks has been subject to considerable scientific discussion and analysis (Free et al., 2019; Szuwalski, 2019). However, it has become increasingly evident that fish stocks also play a crucial role in the mitigation of climate change. Climate targets thus call for consideration of climate change mitigation effects in fisheries management. In the light of this insight, this perspective discusses how marine species, and in particular fish, have a mitigating impact on climate change and how the rules for managing fish stocks should be reformed to promote these climate services.

Globally applicable principles for the management of fisheries are found in the international law of the sea, and set out primarily in the UN Convention on the Law of the Sea (UNCLOS). At the core of UNCLOS' management regime for fisheries is the concept of Maximum Sustainable Yield (MSY). Although this concept has developed since the adoption of UNCLOS in the early 1980s, not least through the negotiation and adoption of the UN Fish Stocks Agreement (UNFSA) in the mid-1990s, maximum fish stock production for human consumption remains the core objective of international fisheries regulation.

The concept of MSY[1] does not require states to consider the challenges raised by climate change and the carbon sequestration potential of fish. While recent findings indicate that fish throughout their life cycles contribute to processes which sequester considerable amounts of carbon (Mariani et al., 2020), the objective of MSY based management is limited to promote optimal food production. Managing multispecies fisheries inevitably involves weighing various objectives, including biological and economic ones (Rindorf et al., 2017). States are increasingly undertaking to also include ecosystem considerations in catch decisions. Although this can make fisheries management more sustainable, current national processes to implement ecosystem-based fishery management (EBFM) indicate that it risks becoming a missed opportunity to also include climate considerations (Holsman et al., 2020)

Combining insights from natural sciences, law and economics, this article discusses the carbon sequestration effects of fishery resources and suggests that the international principles for fisheries management should be revised so as to also consider and promote the climate services provided by marine organisms. Considering the work in progress within the UN *decade of ocean science for sustainable development*, reforming fisheries management accordingly would not only be in line with the targets under SDG 13 Climate Action (Claudet et al., 2020). Our suggestion would also have the potential to support and guide the management of sustainable small-scale and industrial fisheries while promoting the restoration of biodiversity in line with SDG 2 Zero Hunger and SDG 14 Life Below Water (Folke et al., 2016; Sumaila et al., 2019; Friedman et al., 2020).

THE OCEANS AS CARBON SINKS

Covering over 70 per cent of our planet's surface, the oceans play a crucial role in oxygen production and weather patterns, as well as in the global carbon cycle (Denman and Brasseur, 2007).

In fact, the oceans are by far the largest carbon sink in the world and are estimated to have absorbed roughly 40 per cent of carbon dioxide emissions since the beginning of the industrial era (Sabine et al., 2004; Houghton, 2007; DeVries et al., 2017). In the period 1994 to 2007, the ocean's average uptake rate was estimated to be equivalent to 31 ± 4% of the global anthropogenic CO_2 emissions with regional variations (Gruber et al., 2019). About 93 per cent of the earth's carbon dioxide is stored and cycled through the oceans (Nellemann et al., 2009).

With the adoption of (The Paris Agreement in 2015), the importance of ensuring the integrity of all ecosystems, including marine ones, and the protection of biodiversity when taking action to address climate change was recognized (Rayfuse, 2019).[2] The Paris Agreement also calls for the conservation and enhancement of sinks and reservoirs of greenhouse gases.[3] The United Nations Sustainable Development Goals adopted the same year, recognize the central role of the oceans in counterbalancing the impact of climate change. Marine climate mitigation, also referred to as Blue Carbon, has since increasingly featured in the Nationally Determined Contributions submitted by countries according to the Paris Agreement, and been included in the accounting mechanisms of the United Nations Framework Convention on Climate Change[4] (Murray et al., 2012; Hoegh-Guldberg et al., 2013; Ullman et al., 2013). These contributions have, however, predominantly focused on coastal ecosystem habitats (mangroves, seagrasses, tidal marshes) while being less concerned with the role of marine fisheries (Beaumont et al., 2014).

The climate mitigation services provided by the oceans can be described as two pumps; the physical and the biological carbon pumps. *The physical carbon pump*, also known as the solubility pump, refers to the ocean's function to absorb large amounts of carbon dioxide, an effect which is particularly articulated in cold surface waters (Houghton, 2007). The cooling of surface waters at high latitudes favors their ability to dissolve atmospheric CO_2 (mainly by increasing the solubility of the gas) as well as increasing their density. These heavy surface waters plunge down to great depths, thereby keeping the CO_2 away from further contact with the atmosphere (Houghton, 2007; Bopp et al., 2019). This process is however not without side-effects: The chemical reaction of salt water and CO_2 generates carbonic acid, pushing down the pH of the oceans. Although the exact function and potential of this cycle

[1] The maximum sustainable yield (MSY) for a given fish stock means the highest possible annual catch that can be sustained over time, by keeping the stock at the level producing maximum growth. The MSY refers to a hypothetical equilibrium state between the exploited population and the fishing activity.

[2] The role of the oceans in climate systems had however been discussed also under previous schemes, such as the Kyoto agreement.

[3] See Article 5(1) of the Paris Agreement as well as Article 4(1)(d) of the United Nations Framework Convention on Climate Change (UNFCCC).

[4] Nationally Determined Contributions are provided based on Article 4 of the Paris Agreement.

is still not fully explored (DeVries et al., 2017), its importance for the climate system is well established. What has been given less attention in discussions about the climate mitigating effect of the oceans is that the physical carbon pump is complemented by a biological carbon pump. *The biological carbon pump* plays an important role in the transfer of CO2 fixed through photosynthesis at low trophic level, *via* complex biological-driven processes to the deep ocean (Cavan et al., 2019). In this context the role played by food web dynamics and trophic-cascade in pelagic ecosystem (Casini et al., 2009) linked to anthropogenic drivers such as climate change and fishing can have a major impact on carbon sink, and the dynamics underlying these processes are often non-linear and complex.

Top-down trophic cascade effects play an important role in regulating both food web dynamics and ecosystem functioning, as for example by removing top predators and their pressure on grazers resulting in an increase in algal biomass and changes in habitat characteristics. These effects will vary from case to case, site to site, time to time and ecosystem to ecosystem. For example, an increase in the abundance of small pelagics results in an increase in CO2 cycling through the ecosystem rather than sequestered into the deep. Generally, there is a need to better understand these trends, tradeoffs and temporal variability as CO2 equilibrium in the sea is variable over space and time.

In particular, as pointed out by Cavan and Hill (2021), carbon sink is largely dependent on plankton as much as fisheries across scales. Therefore, it must be better understood how the coupling of multi-trophic dynamics (from low to high trophic level) and fisheries exploitation, particularly in the small pelagics (such as anchovies and sardines), is linked to changes in carbon sink. The connection to management measures in the fisheries should also be further explored, as the top-down/bottom-up combined effects in regulating ecosystem functioning and CO2 regulation varies across ecosystem (Mariani et al., 2020). Marine plants are also key to consider when managing interactions between wild fishery resources and other marine organisms. Marine plants that contribute to this carbon sequestration, such as mangroves and seagrass, live in rich soil. Macroalgae such as kelp forest usually grow near the shore in rocky and eroding conditions where plant materials cannot get buried. Instead, bits of macroalgae get exported to the deep sea, where the carbon can be sequestered. The importance of macroalgae in sequestering away carbon has been overlooked until recently because it is difficult to precisely measure how much carbon is sequestered and exported to the deep sea. Krause-Jensen and Duarte (2016) recently estimated that around 200 Mt tons of carbon dioxide are being sequestered by macroalgae every year, highlighting the importance of protecting valuable coastal marine ecosystems such as kelp forests from environmental degradation. However, more assessments should also be made of the interaction with kelp, seaweed and mangroves, for which the carbon sequestration effects have been extensively described (Duarte et al., 2013a; Duarte et al., 2013b, Macreadie et al., 2019).

Analysis of carbon sequestration needs to also consider interactions between wild fishery resources and aquaculture to provide more comprehensive and integrated assessments of coastal ecosystems (Jones et al., 2022). For example, the Intergovernmental Panel on Climate Change (IPCC) has recommended macroalgal production as a research field for climate change mitigation (IPCC, 2019), an ocean-based climate change mitigation also suggested by the High-Level Panel for a Sustainable Ocean Economy (Stuchtey et al., 2020). In addition, the volume of valuable, carbon-rich shell waste from bivalve aquaculture is considerable, estimated at up to 11.9 Mt per year (Tokeshi et al., 2000). Also, and although returning bivalve shells to the marine environment will eventually release the stored carbon as shells dissolve, there are considerable positive benefits of bivalve reef restoration, including indirect carbon sequestration through enhancing blue carbon habitats (McAfee et al., 2020). These types of analysis of interactions enable policy makers to provide guidance on climate-friendly aquaculture practices that can reduce emissions or enhance marine carbon storage and to identify key knowledge gaps for future research.

It appears that carbon sequestration effects could be significantly increased not only in the management of wild fishery resources but also in aquaculture, where technological approaches have been proposed to promote such effects (Ahmed et al., 2017).

Generally, in relation to food provisioning for human consumption by wild catch fisheries and aquaculture in coastal and off-shore areas, it should be considered that there is a general need to consider how operations can be moved toward zero emission targets and a focus on low trophic level species that provide, like the small pelagics, low carbon footprint.

CLIMATE MITIGATION SERVICES, FISHERIES AND ECOSYSTEM SERVICES

Recent evidence on the carbon sinks performed and represented by marine organisms indicates that these climate mitigation services may be much higher than previously thought (Lutz and Martin, 2014; Bopp et al., 2019; Boyd et al., 2019). More than 55% of carbon captured by photosynthetic activity is captured by marine and coastal ecosystems as blue carbon (Mcleod et al., 2011).

Valuing carbon sequestration is key for policy makers in order to assess monetary and socio-cultural benefits to society and human well-being. Assessments of ecosystem services have generally been subject to an increasing scientific interest and acknowledgement as they illustrate the crucial role of nature for human well-being and sustainable economic development (De Groot et al., 2012; Costanza et al., 2014). In particular, ecosystem valuation can help to disentangle trade-offs between reversing the declining state of marine ecosystems and natural capital, and possible competing economic interests (Stefanski and Villasante, 2015; Villasante et al., 2015).[5] Various international frameworks have been developed to facilitate and support such analysis e.g.

[5] Marine ecosystem valuation is a powerful tool when used to answer clear policy questions. It requires analysis of the contribution of ecosystems to human well-being, both directly and indirectly. Ecosystem valuation can help to highlight the often-unrecognized benefits to society, such as recreation or carbon sequestration and their direct and indirect human health benefits.

by the Millennium Ecosystem Assessment (MEA); The Economics of Ecosystems and Biodiversity (TEEB); and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). To an increasing extent, the ecosystem service value of carbon sequestration has gained attention (De Groot et al., 2012; Pendleton et al., 2012; Camacho-Valdez et al., 2013; Beaumont et al., 2014; Melaku Canu et al., 2015; Zarate-Barrera and Maldonado, 2015; Cole and Moksnes, 2016; Ganguly et al., 2017; Himes-Cornell et al., 2018).[6] Building on predictions made by Stern and Stiglitz on the time evolution of carbon prices consistent with the Paris Agreement, subsequent studies have assessed the economic value of blue carbon services (Stern and Stiglitz, 2017; Norton et al., 2018; Santos, 2018).[7]

It is recognized that the carbon sinking potential of the oceans can be increased by developing mitigation and adaptation measures involving the conservation and enhancement of coastal and open ocean ecosystems and processes (Duarte et al., 2013; Wylie et al., 2016; Howard et al., 2017; Bindoff et al., 2019). A recent study by Mariani et al. (2020) on the role of fisheries in preventing blue carbon sequestration, showed that the global blue carbon extraction by fisheries between 1950 and 2014 was equivalent to 318.4 million metric tons (Mt) of large fish, corresponding to 37.5 ± 7.4 Mt of carbon (MtC) released to the atmosphere. This prevented the sequestration of 21.6 ± 4.4 MtC through the mechanism of fish carcasses sinking to the deep ocean after biomass consumption by predation. They have also diversified the extraction of carbon by fisheries in terms of industrial fisheries, artisanal fisheries, subsistence and recreational fisheries. These findings show how fisheries have reduced carbon sequestration by removing large individuals, and highlighted the importance of measures to promote the rebuilding of fish stocks, thereby increasing their capacity for carbon sequestration. More recently, Villasante et al. (2021) showed that society is not pricing the negative climate effects of fishing (Dasgupta, 2021) nor considering them in global fisheries management. The authors estimated the economic value of preventing the depletion of the oceans' carbon sequestration capacity by incorporating industrial fishing activities into the existing EU Emission Trading System (EU ETS) carbon market. They found that the EU ETS could help to reduce fishing activities which are socially negative in terms of obtaining marine protein and preventing marine carbon sequestration (e.g. trawling fishing). It would help to promote sustainable small-scale fisheries and more equitable distribution of fisheries resources globally, and it would also contribute to climate resilience by protecting vulnerable habitats.

More detailed assessments of the different carbon sinking effects of fish stocks and other marine organisms should be carried out. While at present a management regime for marine living resources aiming to promote carbon sequestration has not been fully explored in terms of its objectives and outcomes, preliminary observations can be drawn based on the findings of central climate services (Davison et al., 2013) (see **Figure 1**). Most obviously, a climate-based management of fisheries would not only call for recovery of fish stocks but for maintaining them at a maximal size, so as to bind as much carbon as possible in biomass (Costello et al., 2016). This goes beyond preventing overfishing and implies a shift of objectives in fisheries management. Reference levels for what represents desirable stock sizes should be set higher across species, so as to reflect maximum carbon sequestration levels instead of maximum regeneration levels. Keeping harvesting at a minimum not only until stocks are at viable population rates, but at maximum biomass levels within boundaries set by their role in ecosystems would both support ecological and climate perspectives. Moreover, in order to facilitate an adaptation of fisheries to fluctuating biomass across stocks, fisheries management should become more flexible. Less guidance in management decisions should be sought in allowable catch in previous years. Instead, quotas should be allowed to vary spatially more widely, in line with the dynamic development of stocks, which is expected to fluctuate increasingly as the result of climate change effects (Gaines et al., 2018). Needless to say, this calls for following scientific advice considering the carbon sequestration objective rather than merely socio-economic considerations or advice focusing on regeneration levels.

Generally, the knowledge of carbon sequestration effects of marine fish species provides strong arguments not only for biologically sustainable management in general, but for maximizing fish biomass as well as biodiversity (Lutz and Martin, 2014). But more than simply calling for promoting the recovery of stocks, findings from preliminary studies of climate services provided by fish stocks indicate that certain species and categories of fish are particularly valuable for carbon sequestration purposes. It appears to be little explored how this difference in climate mitigation services manifests across species (Mariani et al., 2020). Considering the wide differences in behavior relevant for central carbon sequestration effects identified, a robust and profound assessment of climate service differences between stocks is likely to yield important learnings on what species should be prioritized in management.

Promoting climate mitigation would call for adding new approaches to established fisheries management systems. In order to maintain healthy ecosystems and balanced trophic chains which can function as efficient biologic carbon pumps, it is vital to preserve top predator species (Atwood et al., 2015). Moreover, introducing maximum size limits in fisheries regulation should be considered in order to preserve the carbon sequestration effects of large individuals (Jørgensen et al., 2007; Froese et al., 2008; Mullon et al., 2011).

[6] Most studies were performed for developing countries and focusing on mangrove ecosystems. Little research about blue carbon ecosystems valuation has been developed for Europe.

[7] Under this scenario, Santos (2018) found that the estimated value of the current blue carbon stock for Portugal mainland prices amounts to 2.349.335€, of which approximately 2.291 million € are attributed to salt marshes; while Norton et al. (2018) also estimated that carbon absorption coastal services in Ireland are valued at €819 million. Beaumont et al. (2014) also valued the ecosystem service of blue carbon sequestration and storage in coastal margin habitats in the UK. The authors found that if coastal habitats are maintained at their current extent, their sequestration capacity over the period 2000–2060 is valued to be in the region of £1 billion UK sterling. However, if current trends of marine habitat loss continue, the capacity of the coastal habitats both to sequester and store CO_2 will be substantially reduced, with a reduction in value of around £0.25 billion UK sterling.

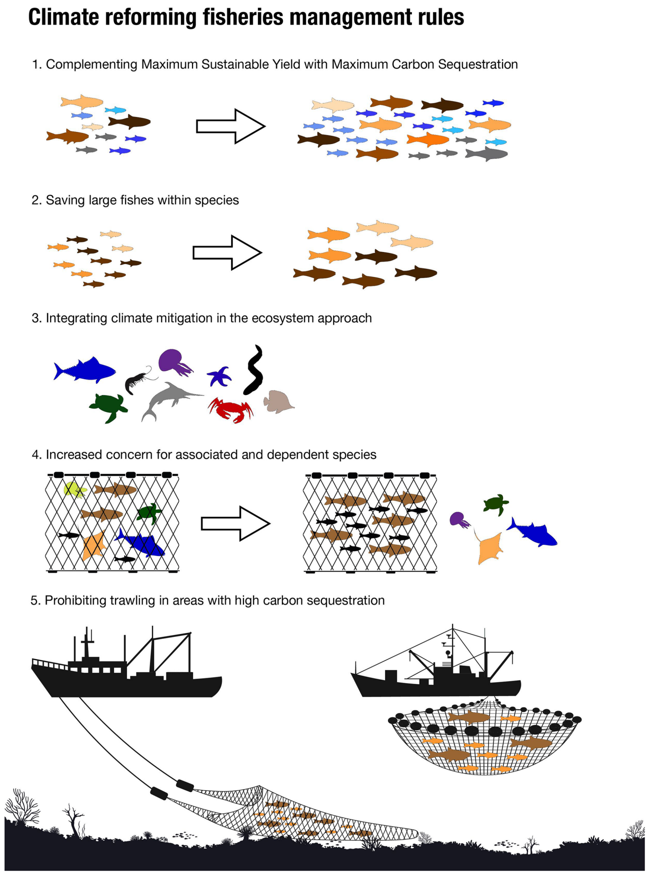

FIGURE 1 | Climate Reforming Fisheries Management Rules.

Moreover, from a climate perspective it is also critical to consider indirect effects of capture fisheries. A recent article by Sala et al. (2021) indicates that trawling has considerable climate effects by re-mineralizing sedimentary carbon to CO_2, increasing ocean acidification and reducing the buffering capacity of the ocean and increasing atmospheric CO_2. This can be effectively addressed by establishing marine protected areas where trawling is prevented. Considering the increasing exploitation of deep-sea fisheries, establishing such measures appears particularly important in deep-sea areas which have so far not been affected by trawling, where carbon has been sequestered for 100s of years (Norse et al., 2012). Declaring marine protected areas in coastal waters with high productive upwellings and carbon stocks has also been identified as key measures for climate mitigation. For example, Feijoo et al. (2021) have recently shown that marine protected areas are able to provide not only benefits in terms of increasing marine abundance of protected species but they are also more efficient in terms of energy return of marine protein. This result illustrates the importance of marine protected areas as relevant management measures for climate mitigation purposes.

To base fisheries management on climate mitigation concerns calls not only for allowing stocks to grow, but also to limit the catch of the species and individuals most valuable commercially. This represents a considerable challenge since it would go against established fisheries practices. Under the existing regime, seafood market prices promote fishing down the food chain (Pauly et al., 1998). However, climate concerns call for the opposite: Promoting the harvesting of small fish, further down the trophic chain. Moreover, it calls for decreasing trawling in general and in particular for protecting coastal waters where the carbon sequestration effects of fish stocks and sediments are particularly high.

Not only does it appear that taking these factors into consideration in fisheries management would increase the carbon sequestration effects of fish stocks. Undertaking relevant measures would also make marine ecosystems generally more resilient to the effects of climate change, thereby preventing depletion of stocks and marine ecosystem services expected under existing fisheries patterns (Karr et al., 2015; Free et al., 2019).

This emerging body of knowledge on the wasted potential of fisheries management in climate change mitigation is clearly a call for climate action. In the following sections we set out a reform agenda for international fisheries law that has the potential to transform it from an obstacle to a promoter of the integration of climate mitigation objectives in fisheries management and in the process also generate other social and ecological benefits.

THE CASE FOR LEGAL REFORM

Providing the basic framework for all uses of the seas, the 1982 UN Convention on the Law of the Sea (UNCLOS) has been heralded as one of the most remarkable achievements of international law. Not only are 168 states parties to the convention, substantial parts of it are generally considered to reflect norms of customary international law and thus binding also for non-parties like Colombia, Turkey and the USA (Tanaka, 2012). Among other things, UNCLOS sets out the fundamental rules for the management of all marine fisheries. In the exclusive economic zone (EEZ), i.e. the maritime zone normally covering the area between 12 nautical miles up to 200 nautical miles from the coast, coastal states have sovereign and exclusive rights to manage fish and other living resources.[8] This includes both conservation and utilization of such resources.[9] UNCLOS establishes a rather rigid legal framework for fisheries management, both in the EEZ of individual states and on the high seas, i.e. sea areas beyond the control of any coastal state.

This scheme comprises two countervailing objectives, which domestic regulation has to navigate between (United Nations, 1995). A primary ambition of UNCLOS is to ensure *optimum utilization* in all fisheries management. This is reflected in obligations calling for *utilizing* fish as a resource for the benefit of human purposes. This principle is formulated not only as a right but as *an obligation* of coastal states to promote the harvesting of fish stocks within their marine domains (Article 62). To the extent that a coastal state does not have the capacity or desire to harvest available fish, other states should be given access to the surplus. Accordingly, the exclusive rights of coastal states to manage organisms and ecosystems within their marine areas does not extend to letting fish stocks remain in their natural state. Instead, it in principle obliges them to promote the exploitation of such organisms although there may be ways for states to circumvent this obligation (Nordquist, 1985).

The same logic is reflected in the obligations aiming to ensure the *conservation* of fish stocks. Optimum utilization and the attendant total allowable catch should be determined according to MSY. This formula establishes that harvested species should be maintained or restored at levels which can generate the highest rate of reproduction, which (according to the logic of UNCLOS) would yield the highest future catch rates. The idea behind this concept is that regeneration of fish stocks is enhanced by harvesting up to, but not beyond, a certain level which can be scientifically assessed (Matz-Lück and Fuchs, 2015). The model has been severely criticized, in particular for oversimplifying the complexity of making stock assessments as well as for failing to take marine species interactions into account (Pauly and Froese, 2020). In particular, criticism has been voiced against the possibility of establishing the level of certainty called for in the scientific assessment provided for by the MSY concept (Finley and Oreskes, 2013). Practical difficulties in reducing fishing mortality to levels below those corresponding to MSY have also been shown in the US (Mace, 2001). Moreover, the logic of the MSY formula is also qualified by a number of environmental, economic and social factors acknowledged in UNCLOS. These provide a recourse in cases where policy makers want to avoid a strict scientific application of the MSY formula.[10] The central rule for the management of living resources under the law of the sea is thus dysfunctional, especially in the context of multispecies fisheries and ecosystem based fisheries management. It also allows states to derogate from its ecological rationale.

The focus on individual targeted fish stocks lacks a broader analysis of impact on other species. Although the effects on other species than those directly targeted in fisheries, i.e. so-called associated or dependent species, should be taken into consideration, that is only with a view to maintain such species above levels at which their reproduction may become *seriously threatened*.[11] Whereas targeted stocks should be maintained at the MSY level, non-targeted species can thus be put under considerably higher pressure (Melnychuk, 2017). This reflects a simplistic understanding of marine ecosystems and the trophic chain, as previously described. For carbon sequestration purposes, associated and dependent species may be of considerable importance.

The concept of MSY was developed to make single species stock assessments and estimation of stock status (Hilborn et al., 2021). Several studies (Larkin, 1977; Mace, 2001) have shown the difficulties of estimating MSY in a multi-species context, and set harvest strategies based on MSY that account for fish stock and predator-prey interactions, and climate driven processes. As suggested by Mariani et al. (2020), the MSY concept needs to be reformed to set biomass at a level above MSY; $>B_{msy}$, where $B_{msy,}$ is the biomass that would provide the highest long-term average catch. This would also contribute to the progress and implementation of an ecosystem approach to fisheries management (EAF) and support a move towards fisheries sustainability (Patrick and Link, 2015). Importantly, such a reform of the MSY concept would increase the blue carbon sequestration capacity of fisheries and ecosystems, thereby supporting climate mitigation.

However, it is not only the rigid management formulas that are ill-suited to promote climate mitigating effects of marine ecosystems. The rules in UNCLOS also have other shortcomings from a climate mitigation perspective. In particular, they fail to consider regional variations and lack a specific legal basis for protecting areas where stocks and sediments represent particularly high carbon sinks.

To some extent, these rules have been modified at the international level by the entry into force of the 2001 UN Fish Stocks Agreement (UNFSA), which functions as an implementing agreement, operationalizing the rules in UNCLOS for straddling and highly migratory stocks, as well as the 1995 FAO Code of Conduct for Responsible Fisheries (FAO Code of Conduct). These

[8] Articles 55-57 of UNCLOS.
[9] Articles 61-62 of UNCLOS.
[10] Article 61, paragraph 3, UNCLOS.
[11] Article 61, paragraph 4, UNCLOS.
[12] See Article 5 of the UNFSA as well as Articles 6 and 7 of the FAO Code of Conduct.

instruments introduced environmental principles such as protection of biodiversity which imply that also other interests than optimum utilization should be promoted.[12] The UNFSA also qualified the use of MSY as an objective, referring to it as a minimum standard for limit reference points.[13] It also strengthened enforcement rules, adopted a precautionary approach and considerations of ecosystem implications. The precautionary approach called for states to protect habitats of special concern and take into account uncertainties, including predicted oceanic, environmental and socio-economic conditions.[14] The adoption of the ecosystem approach in the general principles of the UNFSA[15] reflected a reform of fisheries management which had already started at domestic and regional levels, calling on all states to consider impacts on species belonging to the same ecosystems as the targeted stocks (Cadell and Molenaar, 2019). However, none of these provisions make reference to climate aspects; nor do they modify the basic principles for fisheries management. While representing important steps forward, these instruments did not alter the central status of the principles of optimum utilization and maximum sustainable yield.

Although domestic and regional fisheries management schemes exhibit considerable variation (Marchal et al., 2016), and the MSY concept of UNCLOS is not always decisive in management decisions (Mesnil, 2012), it still provides the global framework for fisheries management, and sends a strong signal to policy makers about what is currently prioritized. It also defines rights of access to fisheries based on the optimal utilization of these resources. Although with some variation, optimum utilization and maximum sustainable yield formulas remain the starting point for fisheries management in domestic settings.

Where states and regional fisheries management organizations have started to implement an ecosystem approach in fisheries management, it has the potential to enable better informed management decisions. Such advice is, however, seldom binding in the political decisions on fishing opportunities, although some countries have made scientifically defined standards binding for management (Marchal et al., 2016). For example, in the EU there has often been a considerable discrepancy between advice and ensuing management decisions (Borges, 2018). Moreover, even where management has been adapted based on ecosystem considerations, it has not implied the promotion of climate mitigating effects of fish. The success of fisheries management still tends to be judged by the conservation status of key fish stocks (Marchal et al., 2016). Evaluations of the implementation of ecosystem-based fisheries management tend to consider climate change only in terms of an external factor to which fisheries management has to adapt, not as a process that is and can be affected by fisheries management (Heenan et al., 2015; Townsend et al., 2019). Even recent scientific frameworks for comprehensive evaluation of fisheries systems mostly fail to include the sequestration of carbon as an objective (Stephenson et al., 2018; Belschner et al., 2019), thus indicating its low recognition as a factor under the current state-of-the art fisheries management.

This does not stand scrutiny when mounting scientific evidence indicates that fish stocks represent one of the most important climate mitigation services globally. Even if these effects have not been fully assessed and many unknowns remain, there is still reason not only for decreasing catch levels in many instances, but for reconsidering the basis of the framework, i.e. fisheries law. In essence, not even a successful implementation of the ecosystem approach as it is commonly understood would suffice to realize the climate mitigation potential of fish stocks. Promoting climate action in fisheries management requires rethinking the basis for existing management.

HOW TO REFORM INTERNATIONAL FISHERIES LAW

In several important regards, it appears that the obligation to harvest any surplus in fish stocks for human consumption is detrimental to the climate mitigation interest. In a revision of management rules, the perspective of fish as food needs to be balanced against the conception of fish and other living resources as blue carbon see (**Figure 2**). Such a revision should pursue potential synergies between these objectives and consider social and economic effects, in particular on small scale and subsistence fisheries.

Climate reform would involve a number of modifications to the rules in UNCLOS, or at least recognizing that UNCLOS is dated in important respects and that fisheries law needs to be supplemented with climate considerations. A climate adaptation of the optimum utilization concept would imply replacing or complementing the MSY formula with a new target, promoting climate services. This could be equally determinative as the MSY formula, and be referred to as the maximum carbon sequestration (MCS). MCS would in most cases imply increasing stock levels beyond MSY levels, to maintain the largest amount of biomass possible without risking the functioning of ecosystems. Larger stocks would not only put the carbon sequestration effects at a stable higher level. A period of dynamic stock increase would involve a dynamic sequestration of substantial amounts of carbon within a short period of time. At more specific levels, further assessments would have to be made to assess MCS of ecosystems and individual stocks and species. Where certain species are particularly valuable from a climate mitigation perspective, it follows naturally that they should be subject to special regard. Many states have diversified their fisheries management policies, and included more policy goals than optimum utilization and MSY. The increasing application of the ecosystem approach to fisheries is promising. However, fisheries management reform should not merely aim for the general recovery of fish stocks and consideration of the impact of other species of the ecosystem. In the transformation of policies, the particular climate aspects should also be considered (**Box 1**).

Taken together, a climate reform of the international fisheries regime could make a significant contribution to climate change mitigation, in line with undertakings within the Paris agreement. Moreover, it would better capture the full spectrum of the SDG agenda, including climate action and life below water in addition to food production. Not least would it send a strong signal about

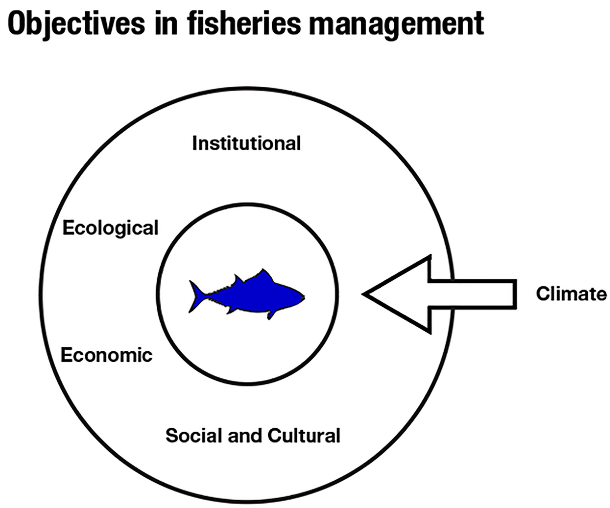

FIGURE 2 | Objectives in Fisheries Management.

Box 1 | Action Points

1. Maximum Carbon Sequestration

The mounting evidence of the climate mitigation effects of marine organisms calls for increased efforts to prepare for providing scientific advice based on the MCS concept and integrate a climate perspective through a reform of international fisheries law. Particularly at a time when the world is agreeing on the need for urgent measures to meet tight mitigation objectives, potentially significant contributions to climate change mitigation cannot be left untapped. As a first step, international guidelines should be developed on how to integrate the concept of maximum carbon sequestration in fisheries management.

2. Differentiate within species

All aspects of fisheries management, from rules in international law to allocation of quotas and development of gear ought to be differentiated not only between but within species, promoting the preservation and not catch of the older and bigger individuals (Belgrano and Fowler, 2013). This underlines the importance of limiting high-grading in fisheries. The destructive effects could be prevented by limiting quotas to specified maximum sizes, or providing incentives for limiting catch to smaller individuals in combination with developing more selective gears[16].

3. Climate integration in EAF

The Ecosystem Approach to Fisheries (EAF) should be further developed and operationalized to integrate climate aspects. Not only should the impact of fisheries on individual stocks as well as the role of keystone species in ecosystems be considered. The broader consequences of fisheries on carbon sequestration in connected ecosystems must also be taken into account (Culhane et al., 2020). In addition to fisheries management, this includes the protection of coastal and marine vegetation, such as mangroves, seagrass meadows, which promotes reproduction and binds carbon (Fourqurean et al., 2012; Alongi, 2014). It should thus be considered how fisheries can be managed so as to promote climate services not only in targeted species but throughout marine ecosystems.

4. Non-targeted species

The subordination of associated and dependent species should be replaced with equal concern for the restoration of these stocks. From a carbon sequestration perspective, indirect effects of fisheries on other species may be equally important as the impact on targeted stocks. This calls for a reform of the current total allowable catch-approach that includes more holistic perspectives, as well as renewed efforts at developing selective gears and preventing bycatch.

5. Climate relevant MPAs

Marine protected areas are able to provide not only benefits in terms of increasing marine abundance of protected species but they can also be more efficient in terms of energy return of marine protein (Feijoo et al., 2021). It is an important management measure for carbon sequestration purposes. Such areas, where sediments and fish stocks bind particularly high amounts of carbon should be closed to trawling. Currently, legal development is focused on developing high seas marine protected areas. For carbon sequestration purposes, it appears more important to compel coastal states to declare marine protected areas in coastal waters within their jurisdiction.

the potential of fisheries management to contribute positively to climate change mitigation. It would also remove legal impediments to climate focused management decisions. A new implementing agreement to UNCLOS could be one way to achieve this. However, even in the absence of such reform at the level of UNCLOS, there should still be room at regional and domestic levels for broadening the scope of ecosystems-based fisheries management to actively pursue management practices that not only benefit ecosystems and the long-term viability of stocks, but also realize the positive climate potential of fishing.

[16]Such incentives could be financial (e.g. price signals, tax credits/allowances), behavioral (nudging through default rules for cooperation), informational (reporting requirements) or regulatory (including catch share programs such as Individual Transferable Quotas and Territorial Use Rights in Fisheries).

AUTHOR CONTRIBUTIONS

We are a transdisciplinary group of four researchers, representing law, marine ecology, economics, and social sciences, working on challenges associated with reconciling international fisheries and climate change law in line with SDG 14 (Life below water) and SDG 13 (Climate action). Although NK came up with the idea and have coordinated the work, all authors have been involved in writing and contributed with analytical perspectives, in line with their respective disciplines and areas of expertise. These include law of the sea (NK), environmental law and marine management (DL), marine ecology (AB) and economics and ecosystem services (SV).

FUNDING

SV is supported by the EQUALSEA project, under the European Horizon 2020 Program, ERC Consolidator Grant Agreement n° 101002784 funded by the European Research Council. The author also thanks the Consellería de Educación of Xunta de Galicia (Galicia, Spain) for additional funding support.

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