



Full length article

## Climate-smart fisheries: CO<sub>2</sub> emissions reduction and food security are complementary

Nwamaka Okeke-Ogbuafor<sup>a,\*</sup>, Tim Gray<sup>b</sup>, Sheku Kamara<sup>c</sup>, Edward Sesay<sup>c</sup>, Abdulai Dauda<sup>c</sup>, Selina M Stead<sup>a</sup>, Danielle Robinson<sup>a</sup>, Kelechi Johnmary Ani<sup>d</sup>

<sup>a</sup> School of Social & Environmental Sustainability, University of Glasgow, United Kingdom

<sup>b</sup> School of Geography, Politics and Sociology, Newcastle University, United Kingdom

<sup>c</sup> Conservation Society of Sierra Leone, Sierra Leone

<sup>d</sup> Alex Ekwueme Federal University Ndufu-Alike, Nigeria



## ARTICLE INFO

## Keywords:

CO<sub>2</sub> emissions  
Climate-smart fisheries  
West Africa  
Sierra Leone  
Small-scale coastal fisheries  
Climate change  
Food security

## ABSTRACT

In the global north, climate-smart fisheries (CSF) policies prioritise steps to combat CO<sub>2</sub> emissions from SSF, in a response to the fact that globally, CO<sub>2</sub> emissions from small-scale fisheries (SSFs) increased by over 5.8 times between 1950 and 2016. However, in the global south, CSF policies on SSF prioritise food and income security over CO<sub>2</sub> emission reduction. In this paper, we examine this apparently contrasting interpretation of CSF as a conceptual framework to interpret the case study of Sierra Leone, one of Africa's poorest countries where we found that small-scale coastal fishers are preoccupied with mitigating the impact of climate change on their food and income security rather than with lowering their CO<sub>2</sub> emissions. The self-image of SSF in Sierra Leone is that of being victims of climate change rather than perpetrators of it, and they justify this stance by claiming their livelihoods are being threatened by climate change. However, it could be argued that the best way to keep Sierra Leonean SSF CO<sub>2</sub> emissions low is to prioritise their food and income security: in other words, that food security and CO<sub>2</sub> reductions are complementary not contradictory. This, at any rate, is the argument of the current paper. The fieldwork for this study entailed co-created research in Sierra Leone and it involved 103 stakeholders who met face-to-face and online between January and March 2022 and through village meetings. The results of this fieldwork showed that food and income security and not CO<sub>2</sub> emissions are the priorities in the stakeholders' interpretation of CSF. However, if food and income security are not prioritised, communities are likely to adopt maladaptive strategies which undermine marine protected areas (MPAs) and exacerbate overfishing, thereby increasing CO<sub>2</sub> emissions. Moreover, investment in aquaculture as a supplementary or alternative livelihood can directly increase food security and incomes and at the same time indirectly serve as a CO<sub>2</sub> mitigation measure. In addition, weather information communication is an important CSF measure which both protects fishers from the impact of climate change and reduces their CO<sub>2</sub> emissions. Accordingly, we argue that the contrast between reducing CO<sub>2</sub> emissions and protecting food security from climate change may be more apparent than real in Sierra Leone coastal fisheries, since both policies may work in tandem together. This study therefore contributes a new interpretation of CSF in the global south: instead of seeing it as posing a conflict between CO<sub>2</sub> emissions reductions and food security, we have shown the two objectives can be complementary. The wider implication of this paper is that CSF strategies for SSFs do not have to be polarised between the global north's focus on the reduction of CO<sub>2</sub> emissions from fishing vessels and the global south's focus on the mitigation of the impact of global warming on SSFs. There are circumstances when the two objectives may be in harmony.

\* Corresponding author.

E-mail addresses: [nwamaka.okeke-ogbuafor@glasgow.ac.uk](mailto:nwamaka.okeke-ogbuafor@glasgow.ac.uk) (N. Okeke-Ogbuafor), [tim.gray@ncl.ac.uk](mailto:tim.gray@ncl.ac.uk) (T. Gray), [shekukamara2014@gmail.com](mailto:shekukamara2014@gmail.com) (S. Kamara), [edward.sesay@cs-sl.org](mailto:edward.sesay@cs-sl.org) (E. Sesay), [abduhai.dauda@cs-sl.org](mailto:abduhai.dauda@cs-sl.org) (A. Dauda), [S.stead@leeds.ac.uk](mailto:S.stead@leeds.ac.uk) (S.M. Stead), [d.robinson3@leeds.ac.uk](mailto:d.robinson3@leeds.ac.uk) (D. Robinson), [kelechi.ani@funai.edu.ng](mailto:kelechi.ani@funai.edu.ng) (K.J. Ani).

<https://doi.org/10.1016/j.marpol.2023.105926>

Received 4 February 2023; Received in revised form 9 October 2023; Accepted 13 November 2023

Available online 20 November 2023

0308-597X/© 2023 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

In 2020, more than 2.3 billion out of the global population of 7.78 billion lacked all year-round access to food, and about 811 million of these were undernourished [57]. In 2021, data from 93 countries revealed that 957 million people were hungry [34]. While Asia houses a considerable percentage of undernourished people, this number is highest in Africa, where about 21% of the continent's 1.3 billion people are undernourished [57]. Fishing communities are some of the world's poorest and most food insecure [12,38,44,54], and their condition could worsen globally by 2050 as climate change is projected to reduce marine capture fish catch by 7.7%. West Africa is predicted to be the worst hit region [16], yet few African countries have policies designed to mitigate the impacts of climate change on food security and household incomes of vulnerable coastal communities [47].

Climate change increases the threats to food security and livelihoods through the loss of rural income because of damage to marine coastal ecosystems and terrestrial water ecosystems [19,30,48]. For example, with regard to marine ecosystems, rising sea temperature plays a significant role in fish distribution and accessibility [61,40,58]. Tropical fish are migrating to colder waters, and West African fishers are increasingly faced with the choice of either following the fish northward or pursuing different species [8,10]. However, by pursuing migrating fish or targeting different species, fishers incur increased operational costs, and more hazardous weather conditions can damage fishing equipment or cause the loss of gear [11,40]. Overfishing, including the catching of juvenile fish, is one of the maladaptive coping strategies used by marine coastal fishers to deal with climate change, but this exacerbates food insecurity by reducing both local and commercial fish stocks [45]. A large share of global fish stocks is already at risk: currently about 90% of the world's marine fish stocks are reported as fully exploited, overexploited, or depleted [33]. Also, climate change warms up terrestrial waters, thereby impacting water quality, quantity, and inland fish habitats [59,32]. Climate change also damages fish processing systems and supply chains [44,40].

Fishers' attempts to cope with climate change impacts can lead to (mal)adaptive strategies that further increase CO<sub>2</sub> emissions, contributing to global warming. For example, SSF need more fuel to travel further away from shore to find fish, while industrial fishers use more damaging trawling or dredging gear which releases more CO<sub>2</sub> from the benthic substrate [41,46]. Also, illegal practices such as fishing in no-fish zones of marine protected areas (MPAs) increases the overall fishing effort [39]. Up-rooting mangrove trees to increase shrimp production releases large amounts of CO<sub>2</sub> into the atmosphere [53,4]. Thus, a central problem is how fishers can mitigate the negative livelihood impacts of climate change without exacerbating global warming. CSF policies are sets of strategies designed to do just that - not only to mitigate vulnerabilities associated with climate change, but also to reduce the causes of climate change. The United Nations Sustainable Development Goals (SDGs) covers both sides of this climate change coin in its aim to achieve the following goals by 2030: resilient household income (SDG 1); food and nutrition security (SDG 2); healthy lives and well-being (SDG 3); combatting climate change and its impacts (SDG 13); and conserving oceans, seas, and marine resources for sustainable development (SDG 14). However, in practice, resolving the tension between the two objectives may be difficult, especially in the global south, where the problem of food security is acute.

The present co-creation research documents the perceptions of stakeholders in the fishing sectors of post-war Sierra Leone about the impact of climate change on their fisheries and their perceptions of climate-smart fisheries. To tap into these perceptions, we posed three core questions: (1) how do stakeholders perceive the impact of climate change on fishers? (2) in what ways do fishers' responses to climate change exacerbate their vulnerabilities? and (3) how do stakeholders perceive CSF policies? The intended outcome of this research is to explore ways in which CSF policies for West Africa may be designed to

achieve both CO<sub>2</sub> reductions and increases in food security. In the next section, the concept of CSF which informs this research is analysed. In Section 3, the co-creation method which was used to generate primary data for this research is explained. In Section 4, the results of the fieldwork are set out. In Section 5, the implications of the results are discussed. In Section 6, the findings of the paper are summarised and their contribution to the literature identified.

## 2. Conceptual analysis of climate-smart fisheries (CSF)

### 2.1. Global north's interpretation of CSF as lowering CO<sub>2</sub> emissions from fishing

In 1950, SSFs emitted about 8,000,000 tonnes of CO<sub>2</sub> and this increased six-fold by 2016 (to forty eight million tonnes) [26]. CSF policies arose to "futureproof fisheries and allow them to play their role in combatting climate change, including achieving net Zero" [36]. The UK fishing industry interprets CSF as reducing carbon emissions that come directly from large-scale vessels and protecting blue carbon habitats from heavy dredging [36]. For many observers, CSF policies focus mainly on reducing or removing fossil fuels from fishing vessels [9,62]. These proposals are essentially science-driven and top-down initiatives. For example, several countries have introduced CSF policies to reduce fishers' impact on the climate [51,21,20]. The European Union (EU) has urged Member States to favour fishing vessels with more environmentally friendly sources of energy than fossil fuels [51]. The European Maritime and Fisheries and Aquaculture Fund provides financial support for engine replacements with 20% or lower CO<sub>2</sub> than fishers' current engines produce. As part of its CO<sub>2</sub> mitigation measures, the EU has proposed the designation of 30% of its waters as protected areas [51]. Similar measures have been proposed in the UK, where 38% of its waters are designated as MPAs and the UK government plans to further develop Highly Protected Marine Areas which will ban all mobile fishing, thereby reducing CO<sub>2</sub> emissions caused by dredging releasing carbon from benthic strata [42].

This is not to say that the global north has entirely ignored the other side of the climate smart coin - mitigating vulnerabilities to global warming. At least one study has addressed this issue - Alleway et al. (2020). To combine CO<sub>2</sub> reduction with increased food security, Alleway et al., [6] advised global north countries with high levels of fish consumption and fish imports to boost their fish supply and reduce CO<sub>2</sub> emission by investing in mariculture. The EU's proposed 'Farm to Fork' programme will support investment in aquaculture, thus reducing dependence on marine fisheries and thereby lowering CO<sub>2</sub> emissions [51].

### 2.2. Global south's interpretation of CSF as safeguarding food security and income for fishers

The global south's focus is much more on mitigating the impact of climate change on SSFs than on reducing SSFs' contribution to climate change. For example, FAO [19] describe the risks to fishers of tropical storms, sea surges, and sea level rises, which affect food security, social stability, and population migration. Both Haque et al. [27] and Ahmed & Solomon [3] note the irony that SSFs contribute the least to global warming yet suffer the most from climate change. Several writers suggest ways of protecting SSFs from climate change. The most comprehensive advice comes from FAO and includes shifting target species; disaster planning; improved vessel safety; weather warning systems; and diversification of livelihoods [21,22]. Examples of CSF being applied in the global south include collaborative arrangements put into place in the Western Pacific to access fish for livelihoods and maintain net incomes [15]. In South Africa, livelihoods are maintained by investing time and funds into targeting new fish species [56]. China has introduced insurance schemes that protect their fishers against loss and damage after climate events [20]. Pabi et al. [47], referring to Ghana, explained that

cooperative organisations provide easy access to loans, training in alternative livelihoods and the provision of fish smoking facilities, all of which help to alleviate the vulnerability to climate change of small-scale fishers and the fishmongers who depend on them. Aquaculture, especially the farming of indigenous fish species, is one potential for Indian fishers to manage climate risks [17]. SSFs in Bangladesh depend on high interest loans to manage the damaging impact of climate change on their fishing equipment [5]. However, in Africa, current CSF policies are inadequate for two reasons. First, their focus on mitigation measures is too broad-based, invariably excluding local adaptation strategies [7]. Adopting either a regional or a global agenda for CSF as a ‘one size fit all’ approach is inappropriate because community vulnerability to climate change and climate-smart adaptation measures are highly context-dependent [21,43,3]. CSF measures need to be developed and applied with consideration for local circumstances, including harnessing opportunities created by climate change [21,37].

Second, the few measures that have been taken to reduce SSFs’ contribution to climate change require sound science and technology skills which are lacking in most African’s fishing communities. For example, FAO and WorldFish [23] proposed an approach for CSFs based on information communication technology. The co-creation method adopted in the present study aims to overcome both the above deficiencies through a CSF framework developed by stakeholders in post-civil war Sierra Leone. By this research we hope to improve our understanding of CSF in West Africa’s coastal fishing communities by highlighting the key priority adaptive and mitigation strategies that are of importance to stakeholders. It is widely accepted that SSFs should have a stake in choosing which CSF measures are most appropriate for their situations. For example, according to FAO [21], CSF entails listening to small-scale fishers and their communities. Likewise, FAO [22] underline the need for CSF to be co-created by local stakeholders. Similarly, Ahmed & Solomon [3] say all stakeholders need to be involved in developing context-specific options to ensure that the fisheries and aquaculture sectors are climate-smart. In the next section, we describe the co-creation methodology in detail.

### 3. Methodology

The method used to obtain primary data for this study was co-creation. Co-creation is a means of generating data that involves engaging wholeheartedly with stakeholders in an endeavour to produce an outcome that everyone can identify as their own. Bertini [13] describes the process of co-creation as collective creativity, exploring the parameters of a problem from every direction. Co-creation promotes stakeholders’ sharing of ideas and brainstorming exercises with the goal of reaching well-thought-out solutions for complex and ‘wicked’ problems [18]. It is a form of interaction which goes beyond collaborative or participatory research in that stakeholders co-write or co-compose the text of the agreed policy. Co-creation enables the researcher to get closer to the respondent’s inner thoughts than normal interview techniques or focus group discussions do [18], empowering and inspiring respondents by drawing on their imaginations. Co-creation has also been described as a creative enterprise derived from lived experience – a research activity that is far removed from the ivory tower of academia and instead centres in the real world [25], bringing to bear local voices and ideas [35]. Saha et al. [50] notes that because co-creation creates mutual value, it is defined as value co-creation (VCC). The difference between co-creation and co-production is that co-creation delivers ideas and values whereas co-production delivers products.

A total of 103 stakeholders participated in this study and they were recruited through networking. Network sampling involves asking recruited stakeholders to recommend other stakeholders who have direct or indirect experience and knowledge of our research topic [28]. Network sampling can also be used to reach ‘hidden’ populations [28], and this study used this sampling technique to recruit elderly and retired fishers. Between January and March 2022, 16 stakeholders of Sierra

Leone fisheries were invited to meet face-to-face and online via Microsoft Teams in executive meetings to co-create a CSF framework. The 16 stakeholders who gave their consent to participate in this project comprised three representatives from Tombo fishing community including artisanal fishers; two staff from the Ministry of Fisheries and Marine Resources (MFMRs); four researchers from Fourah Bay College and Leeds University; one staff from Sierra Leone’s Meteorological Services (SLMet); three staff from Fisheries Community-Based Organizations (FCBOs) including women groups; two staff from non-governmental organizations (NGOs); and one policy maker (see Table 1).

Power imbalance between stakeholders is a major problem for co-creation research because vulnerable stakeholders may be discriminated against by their more powerful counterparts [24]. Since co-creation is a research method that shifts away from the traditional top-down approach [49], this study sought to build a tight horizontal relationship between the diverse stakeholders through the following processes which were organized by the research team and moderated by an experienced facilitator (Table 2).

- (1) Six village meetings. These meetings were set up to achieve two-way communication between the 16 stakeholders and a larger number of community members. The number of attendees to the village meetings ranged between 20 and 32. While some community members were regular attendees, others were not, because of their personal circumstances. In all, a total of 87 community members attended the six village meetings. Special efforts were made to recruit young fishers aged 18–40; women (involved in secondary fisheries activities); and elderly members aged 65–70 (retired fishers) to represent marginalised groups. A member of the research team and the facilitator coordinated the village meetings. These two team members shared research aims; discussed emerging themes from the 16 stakeholders; sorted out their opinions and raised them in the stakeholders’ meetings for consideration and feedback.
- (2) Four sessions of peer-to-peer communication workshops. The first session was an introductory workshop where all six stakeholders introduced themselves, agreed to work together, and the research team clarified their research objectives (understanding the impact of climate change on fishers; investigating whether fishers’ response to climate change exacerbated their vulnerabilities; and examining stakeholders’ perceptions of CSF policies). During the three remaining sessions, the research team taught stakeholders how to communicate their perceptions of the research topic to each other irrespective of economic and social differences between them. Sessions were moderated by a trained facilitator who also intermittently reminded stakeholders about respect for one another and how collaborative partnerships between them would help co-create CSF policies that could alleviate

**Table 1**  
Breakdown of category of stakeholders.

Description	Executive Meetings	Village Meetings
Category of participants	16 stakeholders	87 stakeholders
Young fishers	N/A	32
Retired fishers	N/A	19
Women fishmongers	N/A	36
Representatives from case communities	3	N/A
Meteorological agency	1	N/A
Fisheries community-based organization	3	N/A
NGO	2	N/A
Policy makers	1	N/A
MFMRs	2	N/A
Researchers from Sierra Leone and the UK	4	N/A

**Table 2**  
Stakeholders' responses on the impact of climate change on fishers and to CSF policies.

Category of stakeholders	Total # of participants	Perception of the impact of climate change on fishers	Responses
<b>Young fishers</b>	32	Many fishers unemployed	32
		Increased borrowing with high interest rates	32
		Impacts on household food and nutrition security	32
		Poses physical threat to fishers	32
		Destroys fishing equipment	32
		Fishing costs are increasing	32
		Causes increased drinking and smoking in coastal communities	14
		Increases unemployment and hunger in coastal communities	11
		Increases the rate of crime in coastal communities	1
		<b>Retired fishers' communities</b>	19
Losing customers	36		
Losing business capital	36		
Impacting on family relationships	17		
Increasing women unemployment	36		
Impacting on household food and nutrition security	36		
Increasing stress and risky behaviors	11		
Many fishers unemployed	3		
Increased borrowing with high interest rates	3		
Impacts on household food and nutrition security	3		
<b>Representatives from case communities</b>	3	Poses physical threat to fishers	3
		Poses physical threat to fishers	1
		Made many fishers unemployed	1
<b>Meteorological agency</b>	1	Increased borrowing with high interest rates	1
		Impacts on household food	1
		Made many fishers unemployed	3
		Increased borrowing with high interest rates	3
		Causes high levels of stress to fishers and fishmongers	1
<b>Fisheries community-based organization</b>	3	Impacts on household food and nutrition security	3
		Poses physical threat	3
		Destroys fishing equipment	3
		Cause of increasing crime in their communities	3
		Made many fishers unemployed	2
		Increased borrowing with high interest rates	2
		<b>NGO</b>	2
Increased borrowing with high interest rates	2		

**Table 2 (continued)**

Category of stakeholders	Total # of participants	Perception of the impact of climate change on fishers	Responses
<b>Policy makers</b>	1	Impacts on household food and nutrition security	2
		Destroys fishing equipment	3
		Increasing unemployment in fishing communities	1
		Impacting on household food and nutrition security	1
		Made many fishers unemployed	2
<b>MFMRs</b>	2	Increased borrowing with high interest rates	2
		Impacts on household food and nutrition security	2
		Poses physical threat	2
<b>Researchers from Sierra Leone and the UK</b>	4	Destroys fishing equipment	2
		Impacting on fishers' income	2
		Impacting household food and nutrition security	3
		Poses physical threat	2

Source: Authors fieldwork 2022.

the impacts of climate change on their fisheries and households. At the end of the four sessions, ideological differences between stakeholders were overcome; trust had deepened; and the participants had learned how to communicate with each other without rancour.

- (3) Seven co-investigation workshops. These sessions aimed to capture stakeholders' subjective interpretations of the research topic. During these sessions the facilitator asked questions around the above three research objectives, allowing sufficient time for stakeholders to draw upon their individual experiences, perceptions, and capabilities to respond to these questions. The research team picked up common themes from these stakeholder narratives.
- (4) Four co-interpretation workshops. These sessions allowed stakeholders to refine their views around common themes that emerged from the co-investigation workshops, reflecting on the opinions expressed by their peers. Here the facilitator probed for more details of stakeholder perceptions around the common themes and for new information. For example, because most stakeholders, including fishers themselves, believed they are victims of climate change and not contributors to it, the facilitator used different questioning techniques, including open-ended, probing, and clarifying questions to stir up contrary opinions.
- (5) Six-co-creation workshops. During the first session, the research team and facilitator surveyed stakeholders' subjective perceptions of the research aims against the common themes that had emerged from the co-investigation and co-interpretation workshops. This entailed asking questions in the open and in private to check that the facilitator and research team had captured the responses accurately. All workshops and village meetings were audio recorded, transcribed, and analysed using thematic and content analysis [55]. Themes and their frequencies of occurrence were counted and worked out in percentages. In the last co-creation session, the research team discussed the results with stakeholders in an attempt to co-create a new framework for CSF.

#### 4. Results

The results of this co-creation research are divided into three sub-sections: (1) stakeholders' perceptions of the impact of climate change on fishers; (2) stakeholders' account of how fishers' response to climate change exacerbates their vulnerability; and (3) stakeholders' perceptions of CSF policies.

##### 4.1. Stakeholders' perceptions of the impact of climate change on fishers

Nearly half (48%) of stakeholders were familiar with the term 'climate change', and many of them explicitly attributed their declining income to the effects of global warming. For example, an executive member of the Sierra Leone Amalgamated Fishers' Union (SLAFU) (S-4), described how climate change along with poor management has affected their fishing activities:

'It is very hard here and our fishermen are not getting help from anywhere. Our fishermen are all debtors, they spend double on fishing, our fish is moving away into the high sea and our fishermen are travelling far and spending days in the high sea to chase these fish and catch them. Sometimes they are caught up with very bad weather in the middle of the high sea, and they risk their lives, and if they make their way back with few catches, how do you think they can pay up the monies they borrowed to embark on the fishing trip? Our government is also not helping these fishermen: they allow industrial fishers to take away all our fish. We are battling climate change, bad management of our fisheries and there is no hope'.

Similarly, a woman fishmonger (S-14), highlighted the damaging impact of climate change on her source of income:

'Climate change is affecting our fish selling business...we can only smoke fish when fish is available, but no fish catch means no fish smoking and drying, so how do we survive? I am not a lazy woman, and this problem affects all of us [fishmongers], so I am speaking on behalf of all of us [fishmongers]. Fish is scarce and very expensive, and we pay to smoke them ...all these will raise the price of my processed fish... Our customers complain that the fish is expensive, most times I am forced to sell below the cost price, yet I have seven children to feed... this is how we survive'.

##### 4.2. Stakeholders' account of how fishers' response to climate change exacerbates their vulnerability

Almost everyone living in Tombo depends to a very large extent on wild capture fishing for food and income, and when facing declining stocks, they continue to overfish, thus exacerbating their vulnerability. A fisher (S-16) said: "we were born from fishing...we live on fish and no policy from anywhere can change this until this problem of climate change is looked into by the government.... Our people have no other source of income, and we are talking about survival here". The use of illegal fishing equipment and overfishing are maladaptive actions developed by SSFs to alleviate the impact of climate change on the livelihoods: "Our fish leave our waters because of warmth, and we all are left with nothing but struggle to survive on the few remaining fish...we overfish using any type of fishing net that will help us catch fish to feed our family. I have five children, if I do not go to the sea all the time, we would not have money to feed... I fish day-in-day-out" (S-65, a fisher). Catching juvenile fish and selling fish for fishmeal are additional maladaptive actions: "there are people that like the taste of small fish, so it is a good market too...people also use them for fish meal" (S-16, a fisher). An academic researcher (S-19), described these fishers' responses as problematic, both because they exacerbate their vulnerabilities, and they release more CO<sub>2</sub> into the atmosphere:

"our people have accepted their fate, and like auto-immune disease, they can no longer see and secure the remaining part of their

environment that would protect them and help them to manage the impact of climate change... they destroy all our mangroves, and fish all through the day, months and years, releasing more carbon dioxide, and thereby worsening the problem, increasing their own vulnerability by themselves".

##### 4.3. Stakeholders' perceptions of CSF policies

Whether or not they used the term 'climate change' or 'global warming', all the 103 stakeholders who participated in this study were in favour of a pro-poor CSF strategy designed to alleviate poverty and food insecurity of fishers and their households: "anything we want to talk about here is how our people can first survive here... the hunger and poverty is too much" (S-33, an executive of FCBO). However, most participants in the village meetings (65%) said there were no efforts made by government to ameliorate the negative effects of climate change on their fishing. For example, a retired fisher (S-93) said "in those days, fishing was not this bad, we did not need to travel far into the sea to look for fish, we had so much to take care of us and our family...the government needs to support fishermen at this time". Likewise, a young fisher (S-100) said there is "nothing I tell you; we brave it to the high sea all the time...most of us do not even have access to weather information at all, we trust God to take us safely to the high sea and bring us back safely".

On the other hand, 20% of fishers said at least there was weather information available from the Meteorological Agency in Sierra Leone (SLMet). An employee of SLMet (S-12) said his organisation sends weather information to fishers: "we send information to fishermen to notify them when it is safe to go to the sea and when it is not safe...but we are limited as an organisation, and this is why most fishermen have not started receiving this information". Such weather information was greatly welcomed by fishers. Twelve percent of the stakeholders said access to weather information helped fishers and communities plan their fishing activities. A member of a FCBO (S-27) highlighted the usefulness of weather information: "a few fishermen get weather information, and this is helping them to decide when to go fishing". A fisher (S-34) said access to weather information helps fishers decide where to sell their fish and how much to sell. More importantly, another fisher (S-24) said weather information tells him whether it is safe to go to sea: "I have been accessing weather information from SLMet through radio but mostly on my phones, and I consider the weather information that advise us not to go to the sea as the most important...the information is life-saving and helps me to plan how to look for money to feed my family".

All 103 stakeholders endorsed a proposal to add weather information to the co-created CSF strategy. An academic researcher said that sending bespoke long-term and short-term weather information rather than general weather information would be most beneficial to fishers: "you know some of our fishermen stay up to 2-3 days in the high sea, if they can access long-term weather information [2-3 day forecasts] it would help them plan whether to travel to sea and even if they receive it while in the sea, they can decide how and when to travel back" (S-19, an academic researcher).

Another pro-poor CSF strategy to emerge from the co-creation process involved aquaculture. A government official and an expert in aquaculture (S-29) suggested aquaculture as a means of maintaining food security and income earnings:

"aquaculture can help here, I mean mariculture, we can cultivate this fish... so we can depend less on the wild fishing especially when the weather is bad, this will reduce pressure on our marine fisheries. There are species of fish that can withstand high temperature, we can grow them, but the problem is how to start "

A fisher (S-35) said they can farm traditional fish: "using fish species that survive in both fresh and salt water, we can do our traditional fish". Many stakeholders agreed that supplementing marine fishing with aquaculture was an ideal way of dealing with decreasing sea fish stocks. For example, a fisher (S-1) said "you know fish scarcity is part of the



problem that we have, we can use aquaculture to help us [fishers] when there is closed season not just bad weather. If we can start this, our people will eventually get used to it, and at least our fishermen will have fish to sell through seasons". Another fisher (S-16) said "yes this is a good idea because as things are now fish is scarce and very expensive...with farming fish we can have more fish in our markets". Some stakeholders suggested a pilot of aquaculture on Lake Mapei: "Mapei is a good place to carry out this experiment...It will help us to learn more and when we harvest fish, we can share to our elderly people" (S-94, fisher).

However, only 5% explicitly suggested ways through which CO<sub>2</sub> emission can be reduced. One suggestion was solar power: "almost all our women use firewood to smoke their fish, we can reduce CO<sub>2</sub> if we promote the use of maybe solar energy" (S-99, staff of MFMRs).

## 5. Discussion

The first point to discuss about the above results is that only 5% of respondents, including an academic, explicitly drew attention to the contribution of fishers to global warming by emitting CO<sub>2</sub> into the atmosphere (see above). For every other respondent, CSF was interpreted as about protecting fishers from the adverse effects of climate change, not protecting the climate from the adverse impacts of fisheries. For example, in their endorsement of aquaculture as an element of CSF to protect food security and household incomes, respondents did not address the issue of how to minimise CO<sub>2</sub> emissions from aquaculture. Fish production through aquaculture, whether inland or mariculture, could potentially emit CO<sub>2</sub> through land use change (clearing land, use of plants for fish feed), feed processing, transportation, and use of fuel in farms [31,2]. Stakeholders were keen to set up a pilot aquaculture project on Lake Mapei so that fish produced from it could be harvested by more vulnerable groups (elderly and women). But issues about implementing climate-smart aquaculture in a way that generates low carbon emissions and maintains low greenhouse footprints were not analysed beyond the suggestion by about 5% of stakeholders to consider replacing firewood for fish smoking with low carbon sources like solar panels.

In one sense, this lack of acknowledgement of CSF as a way of reducing the carbon footprint of fishers is hardly surprising because of the magnitude of the socio-economic problems facing the country. Sierra Leone is one of the world's poorest countries and has always remained one of the Least Developed Countries: its Human Development Index remains near the bottom of the list [14]. The government's inability to effectively manage its declining fisheries following the impact of the country's 11 years of civil war compounded by the impact of climate change explains why nearly all the 103 stakeholders endorsed CSF it as pro-poor. Meeting the first two SDGs goals (food security and poverty alleviation) is an urgent need for Sierra Leone's coastal communities: about 4.7 million out of Sierra Leone's total population of over seven million people are food insecure, living below US\$1.25 per day [60], and over 31% of Sierra Leone's children are chronically malnourished [52,1]. So, the priority for respondents in Sierra Leone is understandably dealing with poverty not CO<sub>2</sub> emissions [3]. Similarly, [29] confirmed that the priority for African SSFs, especially including those from post-war countries like Sierra Leone, is food: "communities relying on fish as a source of protein have less to eat...times are rough for the nearly seven million people who depend on small-scale fisheries".

The second point to discuss about the results is that the fishers' priority for food and income may reflect the fact that small-scale fishers in Sierra Leone see a tension between CO<sub>2</sub> mitigation measures and their food security and household income, in that if they were required to reduce their CO<sub>2</sub> emissions, that would limit their fishing opportunities. Nearly 70% of stakeholders said fishers nowadays consume more engine fuel than in the past: "we now travel very far to look for fish, it takes more fuel...at present, my fuel use has doubled" (S-68, a fisher), which increases their CO<sub>2</sub> emissions. However, the vessels whose fishing opportunities would be most heavily curbed by CO<sub>2</sub> emissions targets are large-scale

not small-scale. So SSFs in Sierra Leone could embrace both objectives of CSF simultaneously – protecting their own food security and household income and reducing industrial vessels' CO<sub>2</sub> emissions by supporting measures to reduce vessels' fuel consumption. A similar conclusion may be drawn from the issue of weather information. The emphasis placed by respondents on weather information chimes with the literature in that the use of weather information endorsed by stakeholders was aimed at food security and income since early warning about unfavourable weather events would help fishers and those involved in secondary activities to reduce risks and plan for supplementary livelihoods (see [46]). However, weather data can also be interpreted as a means to reduce CO<sub>2</sub> emissions in that accurate information can enable fishers to avoid wasting fuel in going to sea in adverse conditions.

The same conclusion could be drawn from respondents' endorsement of aquaculture, namely that not only does aquaculture help to protect fishers' food security and household income, but it could also help to reduce CO<sub>2</sub> emissions. Investment in environmentally friendly aquaculture as either a supplementary or alternative livelihood can indirectly serve as a CO<sub>2</sub> mitigation measure as this could potentially reduce the number of days those fishers travel to sea for fishing, thereby reducing the number of fleets and boats that emit CO<sub>2</sub>. Sierra Leone's small-scale fishers have argued that the best way to keep their CO<sub>2</sub> emissions low is to prioritise their food security and household incomes. This can be achieved if the state Ministry of Fisheries and Marine Resources (MFMRs) co-develops with fishers a pilot sustainable aquaculture sector in the Lake Mapei area and other sites across the country.

## 6. Conclusion

To meet the climate change crisis, many countries in the global north are developing CSF policies to futureproof fisheries in ways that will reduce the carbon footprint of fishing vessels, whereas countries in the global south are focusing more on measures that will safeguard fishers' food security and household income. In this case study of Sierra Leone, we have found the priority to be so much on the latter objective of protecting fishers' food security and income that the objective of reducing CO<sub>2</sub> emissions appeared on the agenda of only a few respondents. However, we have shown that some respondents' prescriptions for protecting SSF from harm caused by climate change – such as aquaculture - will also reduce CO<sub>2</sub> emission. Moreover, we have shown how a government CSF policy to curb CO<sub>2</sub> emissions from fishing vessels would hit the industrial sector much harder than it would hit the SSF sector so would reduce overfishing and thereby alleviate SSF poverty. In other words, we have argued that it is possible to interpret the situation of SSF in Sierra Leone as one in which both sides of the CSF coin can be addressed simultaneously - i.e., where the carbon footprint of the fisheries can be reduced at the same time as the food security and household income of the SSF can be maintained.

The wider implication of this paper is that CSF strategies for SSFs do not have to be polarised between the global north's focus on the reduction of CO<sub>2</sub> emissions from fishing vessels and the global south's focus on the mitigation of the impact of global warming on SSFs. As we have demonstrated with Sierra Leone, it is possible to bridge the gap between these two alternative interpretations and show how both strategies can be pursued simultaneously – i.e., reduction in CO<sub>2</sub> emissions at the same time as protection from global warming. If other countries could be persuaded to adopt such a dual strategy, this would indeed be a 'smart' outcome.

## Funding

The Adaptation Research Alliance (ARA) provided funding for this project.

## CRedit authorship contribution statement

I, Nwamaka Okeke-Ogbuafor, the corresponding author of this manuscript, confirm that there is no conflict of interests. This confirmation has been approved by all co-authors.

## Data availability

We anonymised our empirical data used in the result section.

## Acknowledgements

The authors would like to acknowledge the support of their 103 participants for their contributions to co-creating CSF for Least Developed Countries in Africa. We are grateful to Mr. Victor Kargbo from the Ministry of Fisheries and Marine Resources, Sierra Leone (MFRMs); Mr. Gabriel Kpaka, from Sierra Leone Meteorological Agency (SLMet); Dr. Saliou Sankoh from the Institute of Marine Biology and Oceanography (IMBO), Fourah Bay College, University of Sierra Leone, and Mr Wudie Koroma, from Sierra Leone Artisanal Fishers' Union (SLAFU).

## References

- [1] Action Against Hunger, Liberia, Action Against Hunger, 2021. (<https://www.actionagainsthunger.org/countries/africa/liberia>).
- [2] N. Ahmed, M. Glaser, Coastal aquaculture, mangrove deforestation and blue carbon emissions: Is REDD+ a solution? *Mar. Policy* 66 (2016) 58–66.
- [3] O.O. Ahmed, O.O. Solomon, Climate smart aquaculture: a sustainable approach to increasing fish production in the face of climate change in Nigeria, *Intern. J. Weather, Clim. C. Conserv. Res.* 3 (1) (2017) 18–27, <https://doi.org/10.17352/2455-8400.000013>.
- [4] S. Ahmed, S. Thompson, M. Glaser, Integrating mangrove-shrimp cultivation: potential for blue carbon sequestration, *Ambio* 47 (4) (2018) 41–452.
- [5] E. Alam, B. Mallick, Climate change perceptions, impacts and adaptation practices of fishers in Southeast Bangladesh coast, *Intern. J. Clim. Change Strat. Man.* 14 (2022) 191–211.
- [6] H. Alleyway, A. Jones, S. Theuerkauf, R. Jones, A global and regional view of the opportunity for climate-smart fisheries, *T. R. Soc.* (2022), <https://doi.org/10.1098/rstb.2021.0128>.
- [7] F. Alves, W. Leal, P. Casaleiro, G. Nagy, H. Diaz, et al., Climate change policies and agendas: facing implementation challenges and guiding responses, *Environ. Sc. Policy* 104 (2020) 190–198, <https://doi.org/10.1016/j.envsci.2019.12.001>.
- [8] B. Goldfarb, 'Feeling the heat: how fish are migrating from warming waters', 2017. (<https://e360.yale.edu/features/feeling-the-heat-warming-oceans-drive-fish-in-to-cooler-waters>).
- [9] F. Bastardie, S. Hornborg, F. Ziegler, H. Gislason, O. Eigaard, Reducing the fuel use intensity of fisheries: through efficient fishing technique and recovered fish species, *Front. Mar. Sc.* (2022), <https://doi.org/10.3389/fmars.2022.817335>.
- [10] D. Belhabib, V. Lama, W. Cheung, Overview of West African fisheries under climate change: impacts, vulnerabilities and adaptive responses of the artisanal and industrial sectors, *Mar. Policy* 71 (2016) 15–28, <https://doi.org/10.1016/j.marpol.2016.05.009>.
- [11] D. Belhabib, R. Dridi, A. Padilla, M. Ang, P. Billion, Impacts of anthropogenic and natural "extreme events" on global fisheries, *Fish Fish* 19 (6) (2018) 1092–1109, <https://doi.org/10.1111/faf.12314>.
- [12] C. Béné, R.M. Friend, Poverty in small-scale fisheries: old issue, new analysis, *Prog. Dev. Stud.* 11 (2) (2011) 119–144, <https://doi.org/10.1177/146499341001100203>.
- [13] P. Bertini, Co-creation: designing with the user, for the user, 2014. ([https://www.academia.edu/9779361/Co-Creation\\_Designing\\_With\\_the\\_User\\_For\\_the\\_User](https://www.academia.edu/9779361/Co-Creation_Designing_With_the_User_For_the_User)).
- [14] O. Brown, A. Crawford, Conservation and Peacebuilding in Sierra Leone, The International Institute for Sustainable Development, Manitoba, Canada, 2012. ([https://www.iisd.org/system/files/publications/iisd\\_conservation\\_in\\_Sierra\\_Leone.pdf](https://www.iisd.org/system/files/publications/iisd_conservation_in_Sierra_Leone.pdf)).
- [15] S. Clark, J. Bell, T. Adams, V. Allain, et al., Chapter 12: The parties to the Nauru Agreement (PNA) "Vessel Day Scheme": a cooperative fishery management mechanism assisting member countries to adapt to climate variability and change', in *Adaptive management of fisheries in response to climate change*, FAO Technol. Pap. (2021) 3–15. ([https://www.pnatuna.com/sites/default/files/2022-01/Chapter%2012\\_0.pdf](https://www.pnatuna.com/sites/default/files/2022-01/Chapter%2012_0.pdf)).
- [16] Coalition for Fair Fisheries Arrangements, 'Living on the Frontline: climate change will first impact African coastal fishing communities', Coalition for Fair Fisheries Arrangements, 2021. (<https://www.cffacape.org/publications-blog/climate-change-also-impacts-small-scale-fisheries-in-africa#:~:text=According%20to%20a%20high%20CO2,Ivoire%20and%2060%25%20in%20Ghana>).
- [17] D. Debnath, B. Bhattacharjya, U. Yengkokpam, M. Sarkar, A. Hasssan, K. Das, B. Das, an overview of enclosure culture in inland open waters of India: Responding to Socio-economic, ecological, and climate change issues in inland fisheries, *Aqua. Eco. Health Man* 24 (4) (2022) 85–92.
- [18] H. Ellingsen, we had a co-creation workshop with thirty 14-year-olds, 2019. (<https://medium.com/finstart/we-had-a-co-creation-workshop-with-thirty-14-year-olds-d0e6b9b580c>).
- [19] FAO, 'Climate change and food security: risks and responses. food and agriculture organization of the United Nations, 2015. (<https://www.fao.org/3/i5188e/i5188e.pdf>).
- [20] FAO, 'Sierra Leone and FAO building resilience and sustainable food and nutrition security, 2017. (<http://www.fao.org/3/a-au073e.pdf>).
- [21] FAO, Adaptive Management of Fisheries in Response to Climate Change, FAO, Rome, Italy, 2021, pp. 1–301, <https://doi.org/10.4060/cb3095en>.
- [22] FAO, Climate smart fisheries and aquaculture, 2023. (<https://www.fao.org/cli-mate-smart-agriculture-sourcebook/production-resources/module-b4-fisheries/chapter-b4-4/ar/>).
- [23] FAO and WorldFish, Information and communication technologies for small-scale fisheries (ICT4SSF), 2020. (<https://www.fao.org/3/cb2030en/cb2030en.pdf>).
- [24] Geneva Global, Who's got the power? The awkward question at the heart of successful co-creation, 2020. (<https://www.genevaglobal.com/blog/co-creation-power>).
- [25] T. Greenhalgh, C. Jackson, S. Shaw, T. Janamian, Achieving research impact through co-creation in community-based health services: literature review and case study, *Milbank Quart.* 94 (2) (2016) 392–429, <https://doi.org/10.1111/1468-0009.12197>.
- [26] K. Greer, D. Zeller, J. Woroniak, A. Coulter, M. Winchester, et al., Global trends in carbon dioxide (CO<sub>2</sub>) emissions from fuel combustion in marine fisheries from 1950 to 2016, *Mar. Policy* 107 (2019), <https://doi.org/10.1016/j.marpol.2018.12.001>.
- [27] R. Haque, P. Sawant, N. Chadha, et al., 'Exploring climate-smart fisheries and aquaculture approaches and its implications', *Food Sc. Rep.* 1 (4) (2020) 1–6.
- [28] H. Heckathorn, C. Cameron, 'Network sampling: from snowball and multiplicity to respondent driven sampling, *Annu. Rev. Soc.* 43 (2017) 101–119.
- [29] K. Ighobor, Overfish-.-. destroying livelihoods (2017). (<https://www.un.org/afri-carenewal/magazine/may-july-2017/overfishing-destroying-livelihoods>).
- [30] IPCC AR5 Climate change 2014: impacts, adaptation, and vulnerability, IPCC, 2014. (<https://www.ipcc.ch/report/ar5/wg2/>).
- [31] A. Jones, H. Alleyway, D. McAfee, P. Reis-santos, et al., Climate-friendly seafood: the potential for emissions reduction and carbon capture in marine aquaculture, *BioScience* 72 (2) (2022) 123–143, <https://doi.org/10.1093/biosci/biab126>.
- [32] S. Karmaker, S. Purkait, A. Das, R. Samanta, L. Kumar, Climate change and inland fisheries: impact and mitigation strategies, *J. Exp. Zool. India* 21 (1) (2018) 329–335.
- [33] M. Kituyi & P. Thomson, '90% of fish stocks are used up – fisheries subsidies must stop emptying the ocean', 2018. (<https://www.weforum.org/agenda/2018/07/fish-h-stocks-are-used-up-fisheries-subsidies-must-stop>).
- [34] G. Laganda, 2021 is going to be a bad year for world hunger, United Nation, 2021. (<https://www.un.org/en/food-systems-summit/news/2021-going-be-bad-year-world-hunger>).
- [35] D. Lee, M. Jaatinen, A. Salami, T. Maltelmale, R. Smeds, M. Holopaine, Design choices framework for co-creation projects, *Intern. J. Des.* 12 (2) (2018). ([https://scholar.google.com/citations?view\\_op=view\\_citation&hl=en&user=yJmQYHwAAAAJ&citation\\_for\\_view=yJmQYHwAAAAJ:TFP\\_iSt0sucC](https://scholar.google.com/citations?view_op=view_citation&hl=en&user=yJmQYHwAAAAJ&citation_for_view=yJmQYHwAAAAJ:TFP_iSt0sucC)).
- [36] MarFishEco Fisheries, WWF, RSPB & Marine Conservation Society, Shifting gears: achieving climate-smart fisheries, 2021. ([https://media.mcsuk.org/documents/Climate\\_Smart\\_Fishing\\_Report\\_FINAL.pdf](https://media.mcsuk.org/documents/Climate_Smart_Fishing_Report_FINAL.pdf)).
- [37] S. Maulu, et al., Climate change effects on aquaculture production: sustainability implications, mitigation, and adaptations, *Front. Sust. Food Syst.* [Prepr. (2021), <https://doi.org/10.3389/fsufs.2021.609097>].
- [38] A.R. McWilliam, N.I. Wianti, Y. Taufik, Poverty and prosperity among Sama Bajo Fishing communities (Southeast Sulawesi, Indonesia), *Singap. J. Trop. Geo.* 42 (1) (2021) 132–148, <https://doi.org/10.1111/sjtg.12349>.
- [39] R. Mohammed, Modelling fishing location choice and spatial behaviour of fishers near a marine protected area, *Mar. Econ. Mangt.* 4 (1) (2019) 1–22.
- [40] I. Monnereau, H. Oxenford, 'Impacts of climate change on fisheries in the coastal and marine environments of Caribbean Small Island Developing States (SIDS)', *Sc. Rev.* (2017) 124–154.
- [41] M. Muñoz, A. Reul, B. Guijarro, M. Hidalgo, Carbon footprint, economic benefits and sustainable fishing: Lessons for the future from the Western Mediterranean, *Sci. Total Environ.* 865 (2023), <https://doi.org/10.1016/j.scitotenv.2022.160783>.
- [42] NFFO Climate-smart fisheries: protected areas or sustainable livelihoods, 2021. (<https://www.nffo.org.uk/climate-smart-fisheries-protected-areas-or-sustainable-livelihoods/>).
- [43] Nordic Development Fund, COP25: the impact of climate change on African blue economy and fisheries will be serious, Nordic Development Fund, 2019. (<https://www.ndf.int/newsroom/cop25-the-impact-of-climate-change-on-african-blue-economy-and-fisheries-will-be-serious.html>).
- [44] E. Ojea, S.E. Lester, D. Salgueiro-Otero, Adaptation of fishing communities to climate-driven shifts in target species, *One Earth* 2 (6) (2020) 544–556, <https://doi.org/10.1016/j.oneear.2020.05.012>.
- [45] N. Okeke-Ogbuafor, T. Gray, S. Stead, Is there a 'wicked problem' of small-scale coastal fisheries in Sierra Leone? *Mar. Policy* 118 (2019).
- [46] N. Okeke-Ogbuafor, T. Andrea, D. Andrew, et al., 'Alleviating impacts of climate change on fishing communities using weather information to improve fishers' resilience', *Front. Environ. Sc.* [Prepr. ] (2022) <https://doi.org/10.3389/fenvs.2022-951254>.
- [47] O. Pabi, S. Codjoe, & I. Addo, Climate change linked to failing fisheries in coastal Ghana, 2015. (<https://idl-bnc-idrc.dspacedirect.org/handle/10625/54163>).

- [48] R.B. Pickson, E. Boateng, Climate change: a friend or foe to food security in Africa? , *Environ., Dev. Sust.* 24 (3) (2022) 4387–4412, <https://doi.org/10.1007/s10668-021-01621-8>.
- [49] T. Redlich, M. Moritz, J. Wulfsberg, Introduction: co-creation in the era of bottom-up economics, *Management for Professionals*, in: T. Redlich, M. Moritz, J. Wulfsberg (Eds.), Co-creation, Springer, 2019, pp. 1–6.
- [50] V. Saha, P. Goyal, K. Jebarajakirthy, Value co-creation: a review of literature and future research agenda, *J. Bus. Ind. Mark.* 37 (3) (2021) 612–628.
- [51] F. Scholaert, EU climate action in ocean governance and fisheries policy. PE 690.572. European Parliamentary Research Service, 2021. ([https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690572/EPRS\\_BRI\(\(2021\)690572\\_EN.pdf\)](https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690572/EPRS_BRI((2021)690572_EN.pdf))).
- [52] G. Shibre, B. Zegeye, J. Haidar, Extent of and trends in inequalities in child stunting in Sierra-Leone from 2005 to 2013: evidence from demographic and health surveys and multiple indicator cluster surveys, *Intern. J. Equity Health* 19 (1) (2020), 88, <https://doi.org/10.1186/s12939-020-01212-5>.
- [53] F. Sidik, C. Lovelock, CO<sub>2</sub> efflux from shrimp Ponds in Indonesia, *PLoS ONE* 8 (6) (2013), <https://doi.org/10.1371/journal.pone.0066329>.
- [54] M.I. Somoebwana, O.I. Ayuya, J.M. Mironga, Marine fishery dependence, poverty and inequality nexus along the coastal lowlands of Kenya, *Natl. Acc. Rev.* 3 (2) (2021) 152–178, <https://doi.org/10.3934/NAR.2021008>.
- [55] M. Vaismoradi, H. Turunen, T. Bondas, Content analysis and thematic analysis: implications for conducting a qualitative descriptive study, *Nurs. Health Sc.* 15 (2013) 398–405.
- [56] Van der Lingen & Carl David, 'Chapter 10: adapting to climate change in the south african small pelagic fishery', *Adaptive management of fisheries in response to climate change*. Rome: FAO (FAO Fisheries and Aquaculture Technical Paper), 2021: 177–194, (<https://www.fao.org/fishery/en/openasfa/169f3602-25da-42f3-bc2c-d9d0351ced96>).
- [57] WHO Joint News Release, UN report: pandemic year marked by spike in world hunger, World Health Organization, 2021. (<https://www.who.int/news/item/12-07-2021-un-report-pandemic-year-marked-by-spike-in-world-hunger>).
- [58] J. Wilks, Fish are swimming to cooler waters as climate change heats our oceans, *Euronews Green*, 2021. (<https://www.euronews.com/green/2021/06/14/how-fish-are-swimming-to-cooler-waters-as-climate-change-heats-our-oceans#:~:text=The%20reason%20is%20that%20fish,ability%20to%20feed%20and%20breed>).
- [59] R. Woolway, S. Sharma, J. Smol, Lake in hot water: the impacts of a changing climate on aquatic ecosystems, *BioScience* 72 (11) (2022) 1050–1061.
- [60] World Food Programme, State of food security in Sierra Leone 2020 comprehensive food security and vulnerability analysis, (2021) ([https://docs.wfp.org/api/documents/WFP-0000129312/download/?\\_ga=2.143298549.1769798199.1696407790-166872627.1696407790](https://docs.wfp.org/api/documents/WFP-0000129312/download/?_ga=2.143298549.1769798199.1696407790-166872627.1696407790)).
- [61] F. Xu, Y. Du, H. Chen & J. Zhu. 'Prediction of fish migration caused by ocean warming based on SARIMA model', *Complexity*. S. Wang, (ed), 2021: 5553935. <https://doi.org/10.1155/2021/5553935>.
- [62] F. Ziegler & S. Hornborg, Decarbonising the fishing sector, 2023. ([https://www.europarl.europa.eu/RegData/etudes/STUD/2023/740225/EPRS\\_STU\(\(2023\)740225\\_EN.pdf\)](https://www.europarl.europa.eu/RegData/etudes/STUD/2023/740225/EPRS_STU((2023)740225_EN.pdf))).