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Could Deep-Sea Fisheries Contribute to the Food Security of our Planet? Pros and Cons

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Abstract: Hundreds of millions of people on the planet are affected by malnourishment. This contributes to the vulnerability of large swaths of the population, especially children under five years old extremely vulnerable to diseases and even death in the least developed countries. Today, by providing a substantial share of global protein intake, as well as fatty acids and micronutrients, fisheries contribute to global food security. As fish stocks in the upper sea levels have already been over-exploited, there might not be enough in supplying food security, deep-sea fisheries have been increasingly discussed to address this problem. Some mesopelagic fishes show the potential to provide important nutrients. Another way of supplying food security might be through using mesopelagic fish as fish feed. However, fishing in the mesopelagic zone could lead to severe ecological problems and the impact on the biological carbon pump is uncertain. This paper highlights and juxtaposes different perspectives regarding exploitation pathways of the fish riches of deep seas and reviews best practice model projects that deal with uncertainties related to fishery management in the mesopelagic zone.

Keywords: undernourishment; food security; deep-sea fisheries; uncertainties

1. Introduction

Millions of people living on earth benefit from low-cost protein, recreation and commerce provided by fisheries, particularly in areas where alternatives of nutrition and employment are scarce (McIntyre et al., 2016, p.12880f.). Fisheries have experienced technological innovation, exponential development of capacities, geographical expansion, as well as international trade and legal frameworks. All this leads to a surge of the sustainable yield of the fisheries and an increased level of food security. This however, led to fishery resources suffering, economic viability, as well as impacting the ecosystem at hand (Garcia & Grainger, 2005, p.21f.). The supply, being especially important for food security, is involved with underlying threats regarding sustainability and aquatic ecosystems (Hall et al., 2013, p.8393f.). Anthropogenic pressure on the natural environment inevitably rises, leading to global concerns regarding food security and biodiversity loss, showing the conflict between environmental costs and human benefits (Tehet al., 2017, p.57f.). Climate change will also have an effect on the ocean environment and capacities of fisheries, with its degree of influence on productivity and species composition unclear (Garcia & Grainger, 2005, p.21f.).

Food and nutrition security is one of the key global policy goals today (Hall et al., 2013, p.8393f.). More than 800 million people suffer from chronic hunger and as the population on earth rises, food production needs to increase as well (Alvheim et al., 2020, p.344f.). Fisheries analyses, even within a socioeconomic framework, often lack concerns of food supply, food security, nutrition security and human welfare, as they are primarily concerned with economic efficiencies. Even, if the link between food production, entitlement and access is complex, food security benefits, as well as a fair distribution from fisheries, must be discussed. When drawing policy implications toward greater economic efficiency and fish harvesting patterns, improved food security and reducing poverty should be addressed (Hall et al., 2013, p.8393f.).

In recent years, there has been increased interest in the opportunities of the mesopelagic zone, as a new way to sustainably meet the needs of the increasing human population. Mesopelagic fish live in the world´s oceans 200 to 1000 meters below sea level. Large-scale biomass estimates are however rare and the importance of mesopelagic fish on the ecosystem and carbon sequestration unknown (Dornan et al., 2022, p.1f.). The knowledge gaps involved, as well as international policies and governments that may not be sufficient enough in managing a new kind of commercial fishery with these unique characteristics, might lead to severe problems (Wright et al., 2020, p.5f.). Equity questions are also involved, as the economic benefits of potentially fishing in the mesopelagic zone accrue to just few countries, as well as large-scale fisheries rather than supporting local livelihoods and global food security (Roberts et al., 2020, p.3f.).

The paper addresses the pros and cons that are related to deep-sea fisheries as a source to grant food security for the planet as follows. In the first step, the meaning of food security and the link to fisheries will be presented. In the second step, the opportunities and risks related to mesopelagic fisheries will be discussed. Then, present scientific deep-sea fisheries projects will be demonstrated. The resulting policy implications will be drawn afterward and in the last step, the findings will be concluded.

2. Deep Sea Fisheries and Food Security

Within the frame of the 2030 agenda for sustainable development, several nations agreed that there is a common goal to fight poverty and hunger. The Food and Agriculture Organization of the United Nations (FAO) claims, that fisheries play a crucial role within this agenda. However, the state of fisheries resources is not well, since many fish stocks are over-exploited. This clashes with the vision of contributing to food security and the fight against malnutrition (Fernandez de la Reguera, 2019, p.1f.). There have been propositions to consider deep-sea fisheries to contribute to this goal, but there are gaps in our knowledge regarding the mesopelagic zone and the ecosystem involved, as well as other factors that need to be considered (Wright et al., 2020, p.5f.). In the following, the importance of fisheries regarding their impact on food security will be shown and the benefits and costs of mesopelagic fisheries discussed.

1.1. The Link between Fisheries and Food Security

There are 800 million people on the planet that are malnourished due to hunger, which is the physical discomfort due to the absence of being provided with enough nutritious food (Braathen et al., n.d., p.1f.). One of the main goals in our modern society is to secure plenty and nutritious food for the world, with close to two billion people suffering also from deficiencies such as vitamin A, iron and zinc. Oceanic food is one of the options to meet this need, especially as fish is highly nutritious and from a climate perspective preferable to pork or beef (Alvheim et al., 2020, p.344f.). Since the major part of earth is water, the ocean, represents a big potential for biomass (Braathen et al., n.d., p.1f.). The importance of fisheries and also on food supply and security can be shown by the fact that close to seventy percent of marine production is directly used as human food (Garcia & Grainger, 2005, p.21f.).

The link between fisheries and food security may be complex though, as availability of fish may not intuitively lead to increased food security. Availability of food supplies is not the only factor influencing food security. Social science research states, that food security is composed of three pillars. These pillars include availability, access and use. Sometimes stability, in terms of vulnerability to food security over time, is also included. Trade may also be a key determinant in food security. People may fish to contribute to their own and others food security directly, but also draw income from trading fish to other food commodities, increasing food security indirectly (Fabinyi et al., 2017, p.177f.). Community food security research focuses on the interdependent socio-ecological relationships that are involved with food systems, in terms of options to build more local and resilient food systems for the provision of long-term food security. The focus lies on Western countries, but increasingly aims towards developing countries within which farmers and fishers are trying to reclaim local control over food systems and livelihoods (Lowitt, 2014, p.47f.). Fishes for consumption are an important source of micronutrients and animal protein (Sumaila et al., 2013, p.428f.).

Also, it is a major contributor to proteins in general, as it is almost seven percent of the entire amount of proteins consumed by humans. Fish also contains minerals like iron and zinc, as well as long-chain omega-3 fatty acids, which are important in human dietary needs (Alvheim et al., 2020, p.344f.). Animal protein consumption is correlated to a country's wealth. Among wealthy countries, few rely on fish as the main supply of animal protein, however, this is the case for poorer countries. Countries with a per capita GDP of two thousand dollars or less, rely to more than twenty percent on fish as the main animal protein supplier (Hall et al., 2013, p.8393f.). A decrease in fisheries and catches may be linked not only to missed sources of healthy, varied nutrient-rich food but also to losses in maternal and child welfare, as well as reductions in disability-adjusted life expectancy through the likelihood of risks of coronary heart diseases (Sumaila et al., 2013, p.428f.). To name a geographical example, Teh et al. published a study about the status and threats to South China Sea marine fisheries in 2017.

The authors stated, that fishing in the South China Sea, including the Gulfs of Thailand and Tonkin in the western Pacific Ocean is still one of the main economic activities for the coastal communities living there. It provides not only livelihood but also employment and products for trade. Marine fish contributes to 15 to 65 percent of animal protein in the stated geographical area. One of the main downsides of fishing in the South China Sea remains the over-capitalization, especially in China, Taiwan, the Philippines and Thailand, as attempts to limit fishing have failed and fisheries remain mostly unrestricted. The global demand in line with poor governance may lead to a decline in marine resources and costs for society. In Southeast Asia some governments encourage fishing exports with the downside of risking domestic food security (Teh et al., 2017, p.57f.). That fish is not only linked to food security in Asian or developing countries, was described by Moore and Nesbitt in another paper. The authors showed, that the issue is of relevance for indigenous food security as well. Indigenous people are also considered to be very vulnerable to biodiversity loss, as it is a major component of indigenous food security (Nesbitt & Moore, 2016, p.1489).

Kristen N. Lowitt examined the relationship between changing fisheries and community food security on the west coast of Newfoundland in Bonne Bay. The study responds to the recognized need for more interdisciplinary approaches to the complex interrelations and involved problems around food security and fisheries. Many fishing policies treat seafood as a commodity vs human food, with the shortcoming of the importance of seafood within the food system and the communities' well-being (Lowitt, 2014, p.47f.). McIntyre et al. concentrated on fishery management to global food security and biodiversity conservation. The authors constructed a joint analysis of fish consumption and economic status, indicating that poor people and malnourished populations rely to a great deal on freshwater fisheries. To analyze this, the authors created an index of nutritional dependence on fisheries based on the according role in total animal protein consumption, in terms of the population of the according country. 81 percent of nutritional dependence on fisheries occurs in countries below the global GDP of 4800 USD or less per year. Highlighting the importance of conservation efforts for both humans and aquatic biodiversity (McIntyre et al., 2016, p.12880f.) As food security is a central concern for many countries living close to the ocean, one might not only consider changing the productivity of individual stocks of fish but total biomass in the ocean and the total catch derived from that biomass. By using 224 stocks of fish, Cody S. Szuwalski proposed in 2016, that the average decadal change in productivity overall stocks by biomass remained close to unchanged, rather than showing a negative trend in productivity, if the stocks were not weighted means but equally weighted to all stocks, regardless of size. Unweighted means are however not useful when concerned with the conservation of particular fish stocks (Szuwalski, 2016, p.1773). Instead of only fishing in the upper zone of the oceans, with increasingly diminishing fish supply, deep-sea fisheries are increasingly targeted and discussed (Glover & Smith, 2003, p.219f.). However, targeting new deep-water opportunities go along with raising environmental and management concerns (Caddell, 2020, p.255).

1.2. Mesopelagic Fisheries as a Source of Healthy Food

If fishes are seen as one of the main options to contribute to food security, the aquaculture industry needs to grow and mesopelagic fishes have the potential to become a major contributor in global nutrition, if exploited responsibly (Alvheim et al., 2020, p.344f.). That deep-sea fisheries could become part of commercial fisheries has already been proposed in the 1960s. However, worldwide mesopelagic fish catch per year only averaged 10640 tones between 1970 to 2015 and is concentrated on the North and South Atlantic and the Indian Ocean (Wright et al., 2020, p.9). The mesopelagic zone includes 60 percent of the earth´s surface as well as twenty percent of the volume of the ocean (Wright et al., 2020, p.9). Mesopelagic fish live in the twilight zone of the oceans and are rather small, with a typical size below 20 centimeters. The fishes are very likely to be the most abundant vertebrates, with the biggest stock of deep-sea fish being lantern-fish (Dornan et al., 2022, p.1f.). It has also been claimed that mesopelagic fishes as a whole may be the most abundant fishes in the whole biosphere, making them especially interesting in terms of fisheries (Irigoien et al., 2014, p.1f.). So-called biomass hotspots, such as the Kaikoura Canyon might be one potential future commercial fisheries yielded target, as it has substantial amounts of biomass and there is estimated to be a hundred of such hotspots in the ocean (De Leo et al., 2010, p.2783). Species within the mesopelagic zone that undertake daily migrations upwards, usually live in waters around 500 to 800 meters depth, species that do not migrate mostly remain at depths of 700 meters or deeper (Roberts et al., 2020, p.3f.). Most deep-water fishes are identified to have slow growth rate, high longevity and late maturity, however, most traits are not known yet (Hussey et al., 2017, p.688). Laternfish (myctophids) constist of a family of approximately 250 different species of fish, being fairly abundant and are eaten by many commercially exploited fish, such as tuna (Wright et al., 2020, p.6). There is rather little information about nutritional contents and values of different deep sea fishes, compared to commercial fishes, making it hard to evaluate the potential as a new form of food source (Alvheim et al., 2020, p.344f.). As mesopelagic fishes are small and could be consumed whole, they might be more efficient for food consumption as they have a higher productivity per unit biomass than large fishes then (Braathen et al., n.d., p.1f.). Further investigations of some mesopelagic species suggest a potential for fishery exploitation, especially glacier lanternfish (Myctophid Benthosema) and Muellers pearlside (Maurolicus muelleri), as they contain high levels of lipid and fatty acids, making them interesting for diverse purposes. However, the large-scale exploitation of such fishes definitely needs to be assessed with regard to their economic and ecological impacts first (Paoletti et al., 2021, p.1145f.). The fishes living in that zone of the ocean play a substantial role in biogeochemical cycling through extensive daily vertical migration, with a big amount of fish feeding on nutrient-rich surface waters under the cover of darkness and sequestering carbon when respiring at depth (Dornan et al., 2022, p.1f.). There are possibly several mechanisms linked between mesopelagic fishes and carbon cycling. Without deep sea fishes, there are estimations that the atmospheric Carbon Dioxide levels might be up to 50 percent greater (Roberts et al., 2020, p.3f.). However, quantifying carbon fluxes from primary production to deep sea fishes is one of the main challenges in assessing the role of mesopelagic organisms in the biological carbon pump and their influence in affecting climate in the following decades (Hidalgo & Browman, 2019, p.609f.). Additionally to the ecosystem services, potential by-catch stocks, food web interactions as well as biodiversity need to be considered when talking about mesopelagic exploitation (Paoletti et al., 2021, p.1145f.). As deep sea fishes may be one of the least investigated fraction of the entire ocean ecosystem, with severe gaps in understanding of biology and adaptations, state of the art scientific research is not even certain about the global biomass (Irigoien et al., 2014, p.1f.). Early net-based mesopelagic fish biomass estimates are likely to be underestimates (Dornan et al., 2022, p.1f.). First estimates using acoustics and local estimates in the northeast pacific come to the result that estimates should be one order of magnitude higher that prior biomass estimates suggested (Irigoien et al., 2014, p.1f.). Estimations for mesopelagic fish are 1000 million tones with approximately 70 to 191 Megatonnes in the Southern Ocean (Dornan et al., 2022, p.1f.). Others suggest a total biomass of 9 to 19.5 Gigatonnes, being equal to approximately 100 times the per year catch of all currently existing fisheries (Hidalgo & Browman, 2019, p.609f.). Estimates based on food-web models estimate a biomass of 2.4 Gigatonnes. These uncertainties regarding the biomass in the mesopelagic zone show the general uncertainties associated with the mesopelagic zone. It is known, however, that most deep-water fishes are identified to have slow growth rate, high longevity and late maturity (Hussey et al., 2017, p.688). Many traits are not known, such as fish swim-bladder volume, length distribution and different fish species morphology are also still unclear and needs further research (Hidalgo & Browman, 2019, p.609f.). Fishing mesopelagic species might also be involved with high costs, as the fishes are located in great depth and are recognized to show trawl avoidance behavior (Braathen et al., n.d., p.1f.). On the other hand, most mesopelagic fish species are low-value species and therefore only economical in the sense that one fishing trip has to be involved with large-scale catch rates, due to economies of scale. Increased harvesting leads to an increased Pony catch rates and high profits (Standal & Grimaldo, 2020, p.1f.). An evaluation of the economic performance of potential future mesopelagic fishery was conducted by Paoletti et al in 2021. Prices of Muellers pearlside fish would propably be around that of Herring prices, as the fat content is similar and linked to the price. Fishing costs would probably be similar to the current blue whiting fishery due to similar trawls needed. Additional costs may however arise, as vessel modifications or new vessels might be needed for efficient deep-sea fisheries. From a solely economic point of view, mesopelagic fisheries expected increased costs in comparison to revenues will not be too extensive to obtain profitability with the current fleet. However ecological sustainability needs to be considered first (Paoletti et al., 2021, p.1145f.). Also, catch quotas of commercial species will be limited soon, leaving excess capacities in commercial fisheries which may be taken for fishing for mesopelagic fishes (Hidalgo & Browman, 2019, p.609f.). From a nutritious and food security perspective, the findings suggest big potential as well. Alvheim et al. published a paper in 2020, analyzing six different species of mesopelagic fishes that are commonly found in deep Norwegian fjords, concerning their potential significance towards food security. Two fish species, three shellfish and one jellyfish were studied regarding their nutrient contents. Micronutrients found in the sample were high, but may be partly due to including all parts of the fish sample. All species, except the jellyfish contained large amounts of calcium and iodine. Fatty acids were also plenty, especially high in the lantern fish species. Iron and zinc levels were also pronounced in the samples. The authors claim that therefore mesopelagic fishes have the potential to fight iron deficiency, which is associated with lower scores in cognitive achievements in school children and lower work productivity in adults. Additionally to being nutrition-dense food sources, the mesopelagic fishes may also be taken for feed ingredients in aquaculture, as sustainable aquaculture is also a challenge today (Alvheim et al., 2020, p.344f.). Another study also provided nutrient composition data of fish species, including mesopelagic biomass from the EAF Nansen program. Nordhagen et al. published a paper in 2020, where they sampled different fish species on the coast of Bangladesh to determine their potential contribution towards nutrient intake. Comparing pelagic, mesopelagic and demersal zone fishes they found that demersal species had lower nutrient concentrations and mesopelagic fishes had greater concentrations of nutrients. Almost all species, except demersal ones, contribute to sufficiently high vitamin B, different acids, and selenium and all contribute to more than 25 percent of the recommended nutrient intakes. The two mesopelagic fishes that were sampled whole, were spinycheek lanternfish and unicorn cod. The species had higher values in iodine, calcium, iron, vitamin A, and selenium than all other species that were sampled. However, due to unknown concentrations of undesirable substances such as wax esters, mesopelagic fishes may be unsuitable for direct consumption, but rather used for fish feed (Nordhagen et al., 2020, p.1f.) It remains however clear, that small fish eaten whole have higher nutrients per weight than big fish, as they have higher micronutrients. Mesopelagic fishes are rather small fishes, hence there might be big potential for food security and nutritious security (Braathen et al., n.d., p.1f.). However, many things about mesopelagic fishes remain unclear and further research is needed (Hidalgo & Browman, 2019, p.609f.) The amount of potential fishes that may be exploited in the mesopelagic zone, led to Nations therefore spending substantial funding in research such as the EU and Norway. The United States in the past prohibited commercial fisheries in the deep sea due to potential adverse ecosystem consequences (Roberts et al., 2020, p.3f.). In the following section, some of these projects regarding mesopelagic fisheries will be demonstrated.

1.3. Projects on Mesopelagic fisheries

As the mesopelagic zone is to a great deal unexplored and the consequences of commercial fisheries unknown, there is a range of projects and initiatives set in motion to observe, monitor and identify different aspects of the mesopelagic zone (Wright et al., 2020, p.6). Especially as the potential impacts of harvesting mesopelagic fishes extend to a broader perspective of biogeochemical cycles. This calls for more precise estimates, as well as more narrow research (Irigoien et al., 2014, p.1f.). The MEESO project is an acronym for Ecologically and Economically Sustainable Mesopelagic Fisheries. It is a research project funded by the European Union´s Horizon 2020 research program with an amount of more than 6 million euros. It is coordinated by the Institute of marine research in Norway, running from 2019 to 2024, through ten work packages. The aim of the project is to get access to the knowledge gaps within the marine ecosystem of the mesopelagic and whether it can be exploited in an economically and ecologically sustainable manner. The implementation of new acoustic and trawling technologies will try to collect better estimates of fish species as well as interactions and functioning of the marine ecosystems, which are currently not sufficiently known. Also, the mapping of contaminant and nutrient content of mesopelagic species will be explored to analyze the potential for viable fisheries. From these insights, the project tries to gain information and knowledge to draw conclusions about the trade-offs between exploitation and negative impacts on the ecosystems. In the second step the gathered data and insights will be used to identify options of sustainable governance (MEESO, last visited 08/13/2022). Another project funded by the European Union is SUMMER, with the main goal of evaluating, if and to what extent, mesopelagic resources may be exploited without harming the essential ecosystem services that they provide. There are nine work packages, with most of them having started in 2019 with a duration until 2024. The project aims to estimate the biomass of mesopelagic fishes, quantify bycatch, measure the role of food webs, and estimate carbon sequestration. Furthermore, it is implemented to explore the potential of mesopelagic species towards human food and animal feed and to ensure that there will be strategies and responsible management of mesopelagic resources with strategies towards sustainability. Short-term impacts are proposed to be the increased knowledge of the mesopelagic ecosystem, the contribution of the United Nations agreement toward an effectively regulated marine harvesting, as well as the preservation of the ecological functioning of the deep sea. Furthermore, the project tries to foster innovative concepts toward food and nutrition security (H2020, last visited 08/13/2022). There are also other examples of recent initiatives to explore the potential for mesopelagic fisheries and the potential markets. Two other projects funded by the European Union with the EU Horizon 2020, are named MESOPP and PANDORA. Mesopelagic Southern Ocean Prey and Predators (MESOPP) consists of a collaboration between Australian and European researchers with the aim of investigating how climate change will affect exploitation in the Southern Ocean and Antarctica. The paradigm for new dynamic ocean resource assessments and exploitation (PANDORA) consists of 25 research teams, trying to analyze long-term benefits for European fisheries by developing different methods for mesopelagic fisheries. Other than European Union funding, there has been a Norwegian mesopelagic initiative in 2017, where researchers collaborated to develop sustainable mesopelagic fishing. The participants improved gear and developed new technologies to give those mesopelagic fishes that were caught accordingly with a sustainability label (Roberts et al., 2020, p.9). Also, to increase knowledge about deep sea fishes and get insights for a sustainable management practice, the Norwegian Institute of Maritime research (LMR) launched a project called Unleashing new marine resources for a growing human population. For this purpose trial fisheries, with licenses for experimental fisheries, were carried out in international waters, such as the Northeast Atlantic (Standal & Grimaldo, 2020, p.1f.).

1.4. Policy Implications

As all natural resources on the planet, fishes are finite, and therefore legal frameworks, international cooperation, and policy recommendations are needed (Canyon et al., 2021, p.1f.). A scientifically valid stock assessment is vital for the development of sustainable fisheries management. This is, however, not currently available yet, due to the limited scientific knowledge of the mesopelagic zone (Wright et al., 2020, p.9). Being aware of the uncertainties, biomass being exploited

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needs appropriate assessments of options to sustainably manage and govern this potential. The interactions between ecological, social, economic, and governance systems need to be understood and a robust governance system needs to be established. Biological trade-offs and risks involved with mesopelagic exploitation need to be weighted against the potential benefits. New technological developments in fishing methods, fitted for mesopelagic resource harvesting as well as investments are needed too (Paoletti et al., 2021, p.1145f.). Harvesting from this ecosystem can indeed supply more food, but the potential consequences associated with biomass extraction on the role of the deep sea in climate regulation, conservation, biodiversity, and ecosystem stability have to be very well considered and call for a precautionary approach to protect mesopelagic fish species (Hidalgo & Browman, 2019, p.609f.). There is also a need for high-quality representative data towards the different nutrient contents of mesopelagic fishes. Even if Nordic countries have food-based dietary guidelines, the guidelines should be more nutrition-sensitive. Mesopelagic fishes may very well contribute to nutrient dense food sources. However, the nutrient composition might vary, and as commercial deep-sea fisheries are at an early stage further nutrient investigation of mesopelagic fish species is needed to predict nutrient profiles and draw information from them (Alvheim et al., 2020, p.344f.). There are weak obligations on environmental assessment for exploratory fishes, as they often do not contain potential impacts on the whole ecosystem, but only on target stocks. This approach lacks the assessment to consider the effects of non-target species such as associated habitats, food web, and the whole ecosystem (Wright et al., 2020, p.9). In 1992, during a United Nation (UN) General Assembly, the problems related to harvesting fish from the ocean were addressed, with the result of the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNFSA). The agreement was enforced in 2001 with 83 participating parties and aims to ensure long-term sustainable conservation of fish stocks. The Conference furthermore agreed to participate in frequent performance reviews of Regional Fisheries Management Organizations (RFMOs) and develop best practice guidelines for doing performance reviews and to implement the result, as well as promote participation of the agreement (Wahlén et al., 2016, p.1) UNFSA lets the parties cooperate and govern through RFMOs. Those became the most preferred version in managing high sea fisheries, but may not be efficient in the regulation of new mesopelagic fisheries, especially with regards to climate change challenges. Also, often members do not follow the advice given by the RFMOs. There exists limited participation, consultation and transparency. Even though there have been improvements in recent years, there is limited integration of biodiversity expressed and followed by fisheries management (Wright et al., 2020, p.5f.). Beyond the regulations of national jurisdiction there is still a severe portion of open water where there are no regulations to protect deep-sea fishes. Human impact on marine life is recognized in treaties, but mostly neglects negotiations for the management and conservation on mesopelagic fishes (Roberts et al., 2020, p.3f.). There are, however, possible options for strengthening the governance. Those include proactive engagement by RFMO members, such as exploring the potential impacts of fishing on the carbon cycle, committing to transparency or participating in scientific bodies. Second, international guidelines could be developed, as soon as there is more scientific knowledge to base those guidelines on. Third, a United Nations general assembly resolution by giving the topic of mesopelagic fisheries more attention. Furthermore, there could be high seas treaty in place with an internationally binding instrument to enforce environmental obligations and closer cooperation and help. Another option would be on the other hand an agreement of states to refrain from deep-sea fisheries until scientific research is increased and therefore data and knowledge to provide appropriate management (Wright et al., 2020, p.9f.). Some claim that deep-sea fisheries require highly precautionary catch limits and credible and time constrained stock assessment advice. Sustainable management also needs to keep in mind that the ocean is a global ecosystem, fishing in one zone effects the other zones as well (Clark & Dunn, 2012, p.204f.). Large-scale exploitation of the deep sea should probably not begin, at least not until the severe gaps in information are accessed and incorporated into carefully considered management tools (Hidalgo & Browman, 2019, p.609f.). Others claim, that it should be the other way around. While in the long term mesopelagic fisheries may challenge biological, social and economic sustainability, in the short term policy instruments might be needed to stimulate the deep-sea fleet in order that it can successfully become a commercial fishery (Standal & Grimaldo, 2020, p.1f.).

2. Conclusion

he findings of this paper showed, that fisheries have an important impact on food security of the planet and the future exploitation of mesopelagic fishes may contribute to that goal as well. Many people are suffering from hunger and malnutrition (Alvheim et al., 2020, p.344f.). Fighting this, is one of the key global policy goals today (Hall et al., 2013, p.8393f.). For this purpose, and as upper level fishes are increasingly over-exploited, there has been increased interest in the opportunities of the mesopelagic zone as a new way to sustainably meet the needs of the increasing human population (Glover & Smith, 2003, p.219f.). Exploiting the fishes, living in the world´s oceans 200 to 1000 meters below sea level, may be linked to severe effects in the ecosystem and carbon sequestration (Dornan et al., 2022, p.1f.). There are major knowledge gaps involved, with the problem, that international policies and governments may not be sufficient enough in managing this potential new kind of commercial fisheries, until further research is done (Wright et al., 2020, p.5f.). However, there are close to two billion people suffering from deficiencies such as vitamin A, zinc and iron. Seafood is one of the options to meet this need and from a climate perspective preferable to pork or beef (Alvheim et al., 2020, p.344f.). The link between fisheries and food security may be complex though, as the availability of fish stocks may not intuitively lead to increased food security. People fish to contribute to their own and others' food security directly, but also draw income from trading fish to other food commodities, increasing food security indirectly (Fabinyi et al., 2017, p.177f.). Mesopelagic fishes may be the most abundant fishes in the whole biosphere (Irigoien et al., 2014, p.1f.). Mesopelagic fishes are small and could be consumed whole, making them particularly efficient for food consumption, due to higher productivity per unit biomass than large fishes (Braathen et al., n.d., p.1f.). Glacier lanternfish and Muellers pearl side, contain high levels of lipid and fatty acids, which are likely to be favored by consumers (Paoletti et al., 2021, p.1145f.). However, targeting new deep-water opportunities go along with raising environmental and management concerns (Caddell, 2020, p.255). There are possibly several mechanisms linked between mesopelagic fishes and carbon cycling though, which are not sufficiently studied yet (Roberts et al., 2020, p.3f.). Additionally to the ecosystem services, potential by-catch stocks, food web interactions as well as biodiversity need to be considered (Paoletti et al., 2021, p.1145f.).

From a nutritious and food security perspective, the findings suggest big potentials within different species of mesopelagic fishes. They contain large amounts of calcium and iodine. Fatty acids were also plenty and especially high in the lantern fish species. Iron and zinc levels were also found to be high (Alvheim et al., 2020, p.344f.). Due to the knowledge gaps of the mesopelagic zone and the implications of potential commercial fisheries, there are a range of projects and initiatives set in motion to observe, monitor and identify different aspects of the mesopelagic zone (Wright et al., 2020, p.6). There are a few projects of the European Union, that were funded within the European Unions Horizon 2020 programme. One of them being MEESO, coordinated by the Institute of marine research in Norway, running from 2019 to 2024. Another being SUMMER, with the main goal of evaluating, if and to what extend, mesopelagic resources may be exploited without harming the essential ecosystem services that they provide (H2020, last visited 08/13/2022). In the last section of this paper policy implications were shown. Harvesting from the mesopelagic ecosystem can indeed supply more food, but the potential consequences associated with the biomass extraction in climate regulation, conservation, biodiversity and ecosystem stability have to be very well considered and call for a precautionary approach to protect mesopelagic fish species (Hidalgo & Browman, 2019, p.609f.). There is also a need for high-quality representative data on the different nutrient contents of mesopelagic fishes to predict nutrient profiles and draw information regarding policy recommendations from them. The different mesopelagic fish stocks may very well contribute to nutrient-dense food sources, however, the nutrient composition might vary (Alvheim et al., 2020, p.344f.). It is clear, that deep-sea fisheries have the potential to contribute to the food security of our

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planet, but due to the indicated knowledge gaps and the stated ecological impacts, more knowledge and further research are necessary.

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