Economic sustainable harvesting, challenges and prerequisites in fishing and conservation methods for potential mesopelagic exploitation?

Due to the global food demand and questions on how much food we can expect the ocean to sustainable produce (Branch et al., 2010; Garcia and Rosenberg, 2010; Costello et al., 2020; Van der Meer, 2020) there is an increasing interest in the potential for exploitation and harvesting of marine mesopelagic resources for use in production of fishmeal, oil, nutraceuticals as sources for dietary supplements, and in relation to bio-prospecting and production of pharmaceuticals (Grimaldo et al., 2018; 2020; Hidalgo and Browman, 2019; Wright et al. 2020; Standal and Grimaldo 2021; Paoletti et al. 2021). Proposals are emerging for fishery (e.g. Grimaldo et al., 2020), however, thorough scientific investigation on ecological sustainability and socioeconomic viability as well as need for strengthening of governance systems are fundamental prerequisites for potential exploitation (e.g. Holling, 2001; Hicks et al., 2016; Hidalgo and Browman, 2019; Wright et al., 2020; Paoletti et al. 2021).

Several studies have explored the *economic sustainability* and the challenges in fishing and conservation methods for harvesting potential mesopelagic resources and applicable harvest strategies compared to existing large scale pelagic fisheries (Paoletti et al. 2021; Prellezo, 2019; Grimaldo et al., 2020; Standal and Grimaldo, 2021).

A few pilot studies and trial fisheries have been conducted to investigate the economic viability of a potential mesopelagic fishery (reviewed in Wright et al. (2020) and Standal and Grimaldo (2021)) focusing on the fishing costs and needs of such potential fishery compared to current fisheries (Gjoesaeter and Tilseth, 1983; Gjosaeter, 1984; Hulley, 1996; Shotton, 1997; FAO, 1997; 2001; Valinassab et al., 2007; Thorvik 2017; Remesan et al., 2016; 2019; Daly, 2019; Prellezo, 2019; Wright et al., 2020; Grimaldo et al., 2020; Standal and Grimaldo, 2020; Bjordal and Thorvaldsen, 2020; Paoletti et al., 2021). Those have so far not obtained high yields and proven economically viable (FAO, 1997; Standal and Grimaldo, 2021). Until recently detailed analyses of the economic performance of current large-vessel pelagic fisheries and the economic preconditions necessary for the implementation of a potential mesopelagic fishery have been lacking (Grimaldo et al., 2020; Paoletti et. al., 2021). Paoletti et al. (2021) investigated the economic performance and dynamics of the current large scale Danish pelagic fishery, and compared it to evaluations of the economics of the potential exploitation of *M. muelleri* and *B. glaciale* according to different scenarios of cost and price dynamics and fishing trip length.

The economic sustainability does not only rely on the scale of resource supply, i.e. continuous availability of resources with respect to biological sustainable biomasses and aggregation in minimum needed densities, but also on quality and prices of the resources, their durability in processing, as well as on the fishing costs compared to other alternative fisheries and fishery switching possibilities (Paoletti et al. 2021; Grimaldo et al., 2020; Prellezo, 2019). Mesopelagic resources may be unlikely to be harvested for direct human consumption because they contain harmful concentrations of hazardous substances such as cadmium and arsenic (e.g. Olsen et al., 2020; Wiech et al., 2020; Alvheim et al., 2020), however, the high levels of lipid and fatty acid contents (e.g. 15-25% omega-3 fatty acids) found in among other *B. glaciale* and *M. muelleri* (Phleger et al., 1991; Lea et al., 2002; El-Mowafi et al., 2010; Koizumi et al., 2014; Alvheim et al., 2020; Grimaldo et al., 2020) make the species commercially and economically interesting for industrial, neutraceutical, and pharmaceutical purposes besides the use for fish meal and oil in animal feed for aquaculture production (Gjosaeter and Kawaguchi, 1980; Gjosaeter and Tilseth, 1983; Gjosaeter, 1984; Johannesson, 1991; Lamhauge et al., 2008; Tacon and Metian, 2009; Koizumi et al., 2014; Irigoien et al., 2014; Olsen and Torrisen, 2015; Grimaldo et al., 2018, 2020; Davidson et al., 2019; Paoletti et al., 2021).

Selective fishing gears need to be developed to secure high-quality oils and protein, and other challenges that may limit the efficiency of commercial mesopelagic fishing operations will need to be addressed to improve acoustic species identification and ensure cost-effective fishery (Grimaldo et al., 2020; Standal and Grimaldo, 2021; Paoletti et al., 2021). Adaptations or new developments in catch and processing methods also taking into account behavioral avoidance patterns of mesopelagic fish species to fishing gears will be necessary to efficiently exploit the potential resource, including vessel investments, and gear modifications (e.g., Kaardtved et al., 2008; 2012; Grimaldo et al., 2018; 2020; Standal and Grimaldo, 2021; Paoletti et al., 2021). The design and development of new fishing methods fit for mesopelagic resource harvesting may lead to efficient fishery, but thorough investigations in fishing patterns and the needed and investments are crucial as it will influence the fishing costs (Grimaldo et al., 2018, 2020; Standal and Grimaldo, 2021; Paoletti et al., 2021). Investments into the fishery will among others be more profitable on-board processing methods to deal with the high fat content of the species and their fast deterioration after harvest (Olsen and Torrisen, 2015). This makes the catching methods, catch handling, on-board processing, and conservation methods essential to assure a cost-efficient yield of high-value components (El-Mowafi et al., 2010; Vang et al., 2017; Paoletti et al., 2021). Also, it will be necessary to develop methods for on board analyses of chemical composition of catches including analysis of contents of omega-3 fatty acids and lipid classes but also the presence of hazardous substances (e.g. Grimaldo et al., 2020).

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