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Inter-regional coherence: Can Northeast Atlantic pelagic habitat indicators be applied to the Arctic?

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ABSTRACT

As part of its commitment to the EU Marine Strategy Framework Directive (MSFD) OSPAR has developed three plankton indicators of Good Environmental Status (GES) for pelagic habitats in the Northeast Atlantic. In coming years, implementation of the MSFD will extend into the Arctic, requiring the application of pelagic habitat indicators in the region. Because plankton communities and monitoring effort are spatially variable, applicability to the Arctic of existing indicators must be assessed. A meta-analysis is applied to the Northeast Atlantic pelagic habitat indicators to establish their ecological applicability and relevance to Arctic marine ecosystems and their implementability using existing national monitoring effort. To identify gaps and potential improvements in the OSPAR indicators, two gap analyses were conducted. The first considered the Northeast Atlantic OSPAR-adopted indicators and existing plankton indicators currently employed by Arctic nations. The second assessed the minimum data attributes required to implement existing OSPAR indicators compared to existing national plankton monitoring effort by OSPAR Arctic contracting parties. Existing Northeast Atlantic pelagic habitat indicators were found to be ecologically applicable to the Arctic, primarily due to flexibility of the plankton lifeforms and biodiversity indices indicators, that allow selection of regionally relevant lifeform pairs or species for assessment. However, current national monitoring programmes were found insufficient to support their implementation. Additional regionally-specific indicators, such as for sympagic phytoplankton and sea-ice biota, are worthy of consideration. Budgetary constraints and a lack of year-round sampling and long-term datasets were found to be key limitations in the implementation of plankton indicators for establishing GES.

1. Introduction

Marine ecosystem health and resilience can be monitored by investigating identifiable and measurable ecological properties which, in turn, can be used in the development of marine policy indicators and management frameworks [85]. The Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC) was adopted by the European Union (EU) in 2008, requiring EU Member States to maintain or achieve Good Environmental Status (GES) in their seas by 2020 [30]. The MSFD stipulates that management measures and actions should be based on an ecosystem-based management (EBM) approach [30]. The suite of 11 MSFD descriptors aims to deliver a holistic management approach, representative of the state and functioning of the whole marine ecosystem [8,9], through the establishment of environmental thresholds and monitoring of associated indicators to determine GES [58].

Plankton can be effectively employed in EBM monitoring programmes to assess environmental status of regional waters and changes resulting from anthropogenic and climate pressures [60] and are mandated by the MSFD in the indicative list of characteristics to be considered (2008/56/EC, Annex III, Table 1). Plankton are particularly well suited as indicators of environmental change due to their rapid response to changes in climate, hydrology and water quality [26,40,82], with phytoplankton biomass commonly adopted as an indicator of primary production as part of EBM monitoring [10]. As the ocean's major primary producers, phytoplankton are fundamental to the marine food web [56] and perform a number of ecological functions, such as the cycling of key nutrients [28,59]. Phytoplankton also provide anthropogenically important ecosystem services, generating 50% of the world's oxygen, playing a fundamental role in carbon cycling and affecting the success of fish populations via the food web [33,81]. Zooplankton grazing on nutrient-rich phytoplankton facilitates energy flow to higher trophic levels via zooplanktivorous fish [82].

The OSPAR Convention is a cooperative mechanism adopted by fifteen EU and European Economic Area Member States which is collaboratively implementing EBM in the Northeast Atlantic to meet MSFD requirements [69]. OSPAR acts as the Regional Seas Commission for five marine regions within the Northeast Atlantic, including Region 1 - the Arctic, Region 2 – the Greater North Sea, Region 3 – the Celtic Seas, Region 4 – the Bay of Biscay, and Region 5 – the wider Atlantic ([69]; Fig. 1). Pelagic habitat indicators, based on plankton data, have been developed for the Northeast Atlantic Regions (Regions 2, 3, and 4). The three indicators, PH1/FW5 Changes in functional types (plankton lifeforms), PH2 Plankton biomass and/or abundance, and PH3 Plankton biodiversity indices, relate to multiple MSFD descriptors, including Descriptor 1 - Biodiversity, Descriptor 4 - Food webs, and Descriptor 6 - Seabed integrity [60,61]. A key consideration in the development and

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Table 1
MFSD descriptors and indicators and their corresponding OSPAR indicators. ● indicates links specified by OSPAR's Intersessional Correspondence Group on Coordinated Biodiversity Assessment and Monitoring (ICG-COBAM), adapted from the 2015 report of the ICES Working Group on Biodiversity Science (WGBIODIV) [47].

		OSPAR indicators Pelagic habitats		
		PH1: Changes in phytoplankton and zooplankton communities	**PH2: Changes in phytoplankton biomass and zooplankton abundance**	**PH3: Plankton biodiversity indices**
MSFD Indicators	**Biodiversity**			
	1.4.1 Distributional range	●		
	1.4.2 Distributional patterns	●		
	1.6.1 Condition of the typical species and communities	●		
	1.6.2 Relative abundance and/or biomass		●	●
	1.7.1 Composition and relative proportions of ecosystem components (habitats and species)	●		●
	Foodwebs			
	4.3.1 Abundance trends of functionally important selected groups/species	●	●	
	Seabed Integrity			
	6.2.2 Multi-metric index assessing benthic community condition and functionality	●		

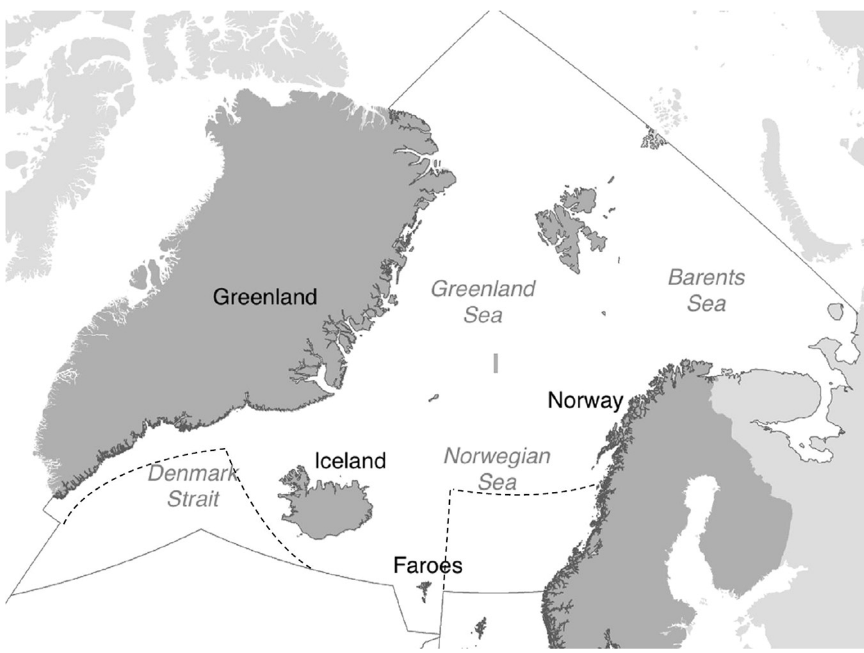

Fig. 1. Map showing the boundaries of OSPAR Region 1 (grey line) and an estimation of the boundary of the Arctic region as classified by Arctic Council working group Protection of the Arctic Marine Environment (PAME) (dotted line). Adapted from [69] ©OSPAR Commission.

implementation of marine policy indicators is regional ecosystem specificity [59]. The MSFD stipulates that *'the applicability of specific indicators related to the criteria may require consideration as to whether they are ecologically relevant to each situation being assessed'* ([31], Annex Part A, paragraph 7). Implementation of the MSFD will expand into the Arctic in the future, but it is unknown if the three plankton indicators, which have been developed and tested in the Northeast Atlantic Regions, will be ecologically applicable to the Arctic, which is characterised by complex temporal and spatial variability in ecohydrographic conditions [32,79,85].

The Arctic plankton community has some key differences from the Northeast Atlantic community. Sympagic (ice-associated) algae constitute up to 26% of total primary productivity in areas of seasonal ice cover [42], such as those found in the most northerly parts of the OSPAR Arctic region [53]. As in the Northeast Atlantic, *Calanus* copepod species are key components of the mesozooplankton biomass [7,15], with *Calanus finmarchicus* generally the most abundant across the region [48,68]. Lipid-rich Arctic species such as *Calanus hyperboreus* and *Calanus glacialis* also play an important role in the Arctic food web and become more abundant and account for increasing biomass in the more northern areas of the region [5,38,89].

Climate change is recognised as the greatest overall threat to Arctic ecosystems by both the IPCC et al. [49] and the Arctic Council [1] and is likely to affect Arctic plankton communities [80]. Changes in sea-ice retreat and seasonal ice melt will affect shade-adapted sympagic algal biomass which supports phytoplankton seeding and zooplankton grazing during the annual spring bloom in the marginal ice zone [42,53] and could result in decreased zooplankton abundance [4]. Further cascadal impact could affect commercial fisheries of major zooplankton grazers such as capelin (*Mallotus villosus*) and polar cod (*Boreogadus saida*), the latter having been reported at its lowest abundance level in the Barents Sea since 1990 [48]. Changes in circulation