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Broad sustainability analysis of Northern shrimp fisheries in the Skagerrak

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Summary

Fisheries for Northern shrimp *Pandalus borealis* in the Skagerrak have been given much media attention in recent years, initiated by the World Wildlife Fund (WWF) in Sweden listing the product as "avoid" in their consumer guide in 2014. Even with the current eco-certification by Marine Stewardship Council (MSC), there is still questions concerning the development in the fishery since 2014. The WWF has therefore commissioned a report to follow up what has happened in the fishery.

The overall aim of the study is therefore to collate information on sustainability aspects of current shrimp fisheries in the Skagerrak (Norwegian, Danish and Swedish fisheries) to provide a transparent report on current fisheries. Since sustainability comprise of many dimensions, the shrimp fisheries are e.g. in Sweden seen as an iconic cultural activity for coastal communities, broader evaluations are needed than those that currently are done. The point of departure is therefore to utilize the approach of the Australian Fisheries Healthcheck – a project aiming to provide transparent reporting of a broad range of indicators (sorted into environmental, social & cultural, economic, governance and external influences categories). The intention of Healthcheck is to support existing seafood guides, fishery reports and managers, and provide information to interested citizens.

It was found that much data is already collected on an annual basis that may be used for the Healthcheck indicators, but the data was often not available and analysed on a fishery basis. The shrimp fishery, and many other European fisheries, is also different to most Australian fisheries since it is multijurisdictional, and thus associated to different management objectives between countries – this is markedly reflected by differences in the three countries' fleets and fishing patterns, data collection and officially available documentation concerning the shrimp fishery. Few across-countries, standardized indicators could therefore today be reported on for the whole fishery, thus requiring further effort. Several indicators may also require further investigation in terms what may be appropriate metrics for the indicator that is aligned with European circumstances. The study can therefore be seen as a pilot collating which data is currently available to report on broader sustainability aspects of relevance to European fisheries, whereas a future, more detailed analysis of the fishery is needed to investigate the data more in detail.

Concerning the sustainability of the Skagerrak shrimp fishery, the analysis indicates that the overall development shows some positive signals in recent years, such as improved selectivity and more area restrictions to protect sensitive habitats. However, the arguable most basic components of a sustainable fishery – exploitation level and stock status – exhibit some alarming signals. Furthermore, with landing per unit effort declining in recent years, pressure in the form of e.g. fuel use and habitat impact per kg landed shrimp may be negatively affected, requiring further attention.

Content

1 Introduction

Fisheries for northern shrimp *Pandalus borealis* in the Skagerrak and Norwegian Deep (ICES SD IIIa and IVa east) have been given much media attention in recent years. It started with the World Wildlife Fund (WWF) Sweden listing the product as 'avoid' (red light) in 2014, which disrupted the Swedish market. The reason was drop in biomass in combination with illegal discarding of small shrimp, lack of enforcement and, to a lesser degree, bycatch of non-target species. For consumers, this was the onset of a period of confusion. Some societal actors communicated that Swedish shrimp was a sustainable choice, others started to market Norwegian shrimp instead. The stock assessment by ICES communicated that the stock was being overall fished sustainably and in the following year (2015) the Swedish fishery became certified by the Marine Stewardship Council (MSC) – which transferred the product to 'recommended' (green light) in the WWF consumer guide. However, in the same year, the Swedish national IUCN Red List of Threatened Species was updated. This assessment categorised shrimp as 'Near Threatened', i.e. red-listed based on risk of extinction, based on the drop in biomass.

The different views provided by important societal actors originated in part from the different methods and purposes of the assessments. Therefore, RISE researchers and colleagues in Sweden, Denmark and Norway performed a product-based evaluation of the fishery to try and provide an objective evaluation of the sustainability of the fishery (Ziegler et al. 2016). The study provided a snapshot of the year 2012, and used quantitative indicators (ecological, economic and social) to illustrate a broad set of sustainability indicators per tonne of shrimp caught by Swedish, Norwegian and Danish fleets. It was found that the Danish fishery was the most efficient in terms of environmental and economic indicators while the Swedish fishery had the highest employment per tonne. Compared to other shrimp fisheries, fuel use was high. Per tonne shrimp landed, smaller vessels were the most efficient for Norwegian and Swedish vessels whereas the larger vessels were the most efficient in the Danish fishery.

With all these aspects in mind, the WWF has commissioned a report to follow up what has happened in the fishery since the MSC certification. Particular interest is given to the quantitative indicators provided in the study by Ziegler and colleagues from 2016 – how have these indicators developed over time? Furthermore, Swedish media has interviewed fishermen claiming that there were no real changes made in the fishery upon MSC certification, and most recently, it was revealed that the Swedish Marine and Water Management Agency (SwAM) had not properly followed up upon multiple indications that the fishery might have violated area restrictions enforced to protect sensitive coastal habitats, most alarmingly in Sweden's only marine national park with rare occurrences of sensitive deep-water corals. To grasp the complexity, a more standardized and holistic framework to assess the sustainability of the fishery may therefore be useful.

A recent initiative from Australia – "Healthcheck of Australian fisheries" (Hobday et al. 2019) – comprises of a framework of 48 indicators (covering environmental, social & cultural, economic, governance and external influences categories), developed by consolidating sustainability assessments for fisheries from around the world and more (those seen as e.g. emerging topics). It is intended to offer a transparent report of different Australian fisheries and has been well-received by stakeholders (Hobday et al.

2018), but is centred around Australian circumstances (data availability, management objectives, etc.); it would be interesting to apply the concept in other parts of the world.

1.1 Aim of the study

The overall aim of the study is to collate information on broad sustainability aspects of the current Northern shrimp *Pandalus borealis* fisheries in the in the Skagerrak and Norwegian Deep (ICES SD IIIa and IVa east) to provide a transparent report of the fishery. This will be done by using the Healthcheck framework developed in Australia.

1.2 Structure of the report

After this brief introduction to the topic, an introduction to the Healthcheck framework is given and details on methodological assumptions of this report is provided. The results section presents the outcome of each Healthcheck category (environmental, social & cultural, economic, governance and external influences), followed by a data quality summary across countries exploiting the stock. Finally, an overview of the development of the fishery since 2014 is provided and overall results are discussed.

1.3 Limitations and disclaimer

There will be limited time spent on collection of new data and analysis of existing data that are not officially available. Potential data gaps identified are important results in themselves and may be used to advocate for improved data collection. Furthermore, since it is a multijurisdictional fishery, special attention is given on what may be reported on for the whole fishery and what needs further standardizations.

The authors do not warrant that the information in this document is free from errors or omissions. The results in this report are not independently peer-reviewed, and rough assumptions may be made due to limited project time. Therefore, the authors welcome constructive feedback on the indicators and metrics for future refinement, as well as missing data for the shrimp fishery that was not found during the project period[1].

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2 Methods

2.1 The Australian Fisheries Healthcheck

The Australian Fisheries Healthcheck acknowledge that there is more to a fishery than status of target stocks if to be judged as sustainable or not. Australian fisheries are often seen as world-leading in terms of management – yet the general public may be alarmed at times. Increased level of transparency and data availability may offer a way forward. Therefore, the Australian Fisheries Healthcheck intends to transparently provide summary data to comprehensively report on a broad range of sustainability issues relevant to Australian fisheries (Figure 1; Hobday et al. 2018). The aim is to support existing seafood guides, fishery reports and managers, and provide information to interested citizens.

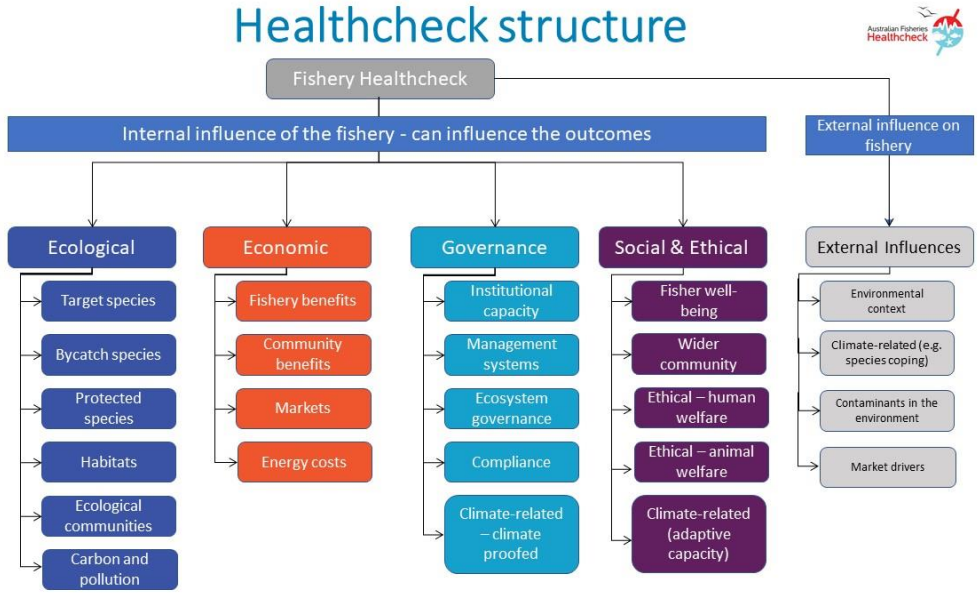


Figure 1 The Healthcheck framework (phase 2). After Hobday et al (2019).

In the first phase, a transdisciplinary team of researchers at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Institute for Marine and Antarctic Sciences (IMAS; part of the University of Tasmania) reviewed over 50 existing assessments and identified around 600 indicators in use. To be useful to the intended application, indicators chosen in a Healthcheck need to provide information sought by stakeholders and build on existing policy and legislation. Furthermore, they need to be cost-effective to deliver and up to date. The Healthcheck team therefore developed categories and sub-categories with expert groups and tested the coverage in interviews with stakeholders. It was found that no new issues were raised after around ten interviews; the Healthcheck coverage of categories and sub-categories could be seen as satisfying.

Phase 2 of the Australian Fisheries Healthcheck revised some sub-categories to include additional aspects of potential emerging concern, such as fish welfare (Figure 1) and

developed indicators and metrics for each sub-category (two per sub-category, in total 50). Of the indicators, 27 were quantitative, 9 were semi-quantitative and 14 were qualitative. The framework was also tested on a diverse set of fisheries around Australia (20 case studies), of which two were shrimp fisheries (Commonwealth Northern Prawn and Spencer Gulf Prawn), both certified by MSC. When testing the framework, it was found that underpinning data quality differed between fisheries and indicators, and some indicators could not be estimated at all. A data quality classification protocol was therefore developed (Table 1). The reason behind missing data to report on an indicator was also categorised into not applicable (e.g. by-catch when hand collecting), not found, not organised/analysed or not released (e.g. economic performance of vessels). Of the 50 indicators per fishery, the range of missing data was between 6 and 25 metrics.

Table 1 Definitions of data rating in the Australian Healthcheck (from Hobday et al. 2019).

	Bronze standard	**Silver standard**	**Gold standard**
Interpretation	Weakest or most general evidence available	Proxy or robust alternative	Direct information
Example of information quality for a quantitative metric	Information is available for like fisheries, species or habitats elsewhere in the world	Information is available for like fisheries, species or habitats in Australia (or as for Gold, but more than 5 years old)	Specific information is available for the fishery, species or habitat (and is obtained from the last 5 years)
Example of information quality for a qualitative metric	A national document exists	A specific policy covering the fishery exists	A specific policy covering the fishery exists and is backed up by evidence of action in the fishery.

2.1.1 Approach in this report

The consistent and comparative treatment of all Australia's diverse fisheries is interesting in the sense that it may allow for comparisons with international fisheries. The analysis of the shrimp fishery in this report therefore utilises the same indicators developed for the Australian Healthcheck. However, management objectives differ between Australia and other regions of the world such as the European Union (Marchal et al. 2016), which may affect data collection and choice of suitable metrics. A thorough investigation of these differences and their potential influence on choice of indicators is considered out of scope for this study.

The emphasis of this report differs slightly from the Australian Healthcheck assessments of fisheries. The purpose of the Australian initiative was to provide numbers or qualitative outcomes for all metrics for each fishery assessed, utilizing a data quality protocol to indicate how representative the results are (Table 1). In this report, a multi-jurisdictional fishery is assessed. This implies different management objectives for the fishery, as well as different fleets and data collection. To be able to report on an indicator

for the whole fishery, standardized data and metrics across countries are needed to provide a holistic view. Therefore, the outcome of each indicator is only presented quantitatively for the whole fishery if there is official data of sufficient quality for all countries exploiting the stock; reasons behind not being able to standardize across countries are summarized in Appendix 1. Available data is however presented in text and discussed for each indicator in terms of availability and what is needed to be able to report on standardized indicators across countries exploiting the same resource. This exercise may this be a useful starting point for future effort.

The Australian Healthcheck offers a recipe for how to estimate the metrics and where the data is found in Australia (Hobday et al. 2019). Other data sources and sometimes methodological approaches are needed to apply the framework in a European context. No European recipes are provided in this report since this demands further investigations and is considered to be out of scope of this project. Norway is e.g. not part of the European Union (EU), and thus not in e.g. the European Data Collection Framework (DCF). This implies that data sources concerning the fishery may differ – even if the countries exploit the same stock. The national data-collection programmes within the DCF may also differ. On the other hand, Norway has made further progress towards Ecosystem-Based Fisheries Management (EBFM) than EU fisheries and has qualitatively evaluated the most important stocks and fisheries from a broader ecological perspective (Gullestad et al. 2017). An important outcome of this report is thus collating where information is found for European fisheries and identifying the potential need for developing alternative indicators and/or metrics based on regional circumstances. This allows a point of departure for more detailed future investigations.

To this end, this study is a pilot study of how a Healthcheck approach to assess fisheries may be used in a European context, including ideas for potential other metrics needed and challenges with multijurisdictional fisheries in need for data quality standardisations across countries.

3 Results

3.1 The Northern shrimp fishery

3.1.1 Biological

3.1.1.1 Target species

Indicator	Metric	Sweden	Denmark	Norway
Stock status (2018)	Fishing pressure	Above F_{MSY}		
	Stock size	Close to B_{lim}		
Harvest level (2018)	Landing weight (tonnes)	1 374	1 863	5 493

Most of the fishing effort takes place ICES area IIIa; only up to 10% of landings are generally from the eastern Norwegian Deep. These indicators can be reported for the whole fishery.

Northern shrimp is included in ICES advisory framework and the latest advice is used. ICES states (in March 2019):

"*The spawning-stock biomass (SSB) declined after 2008 and has fluctuated at a lower level since then. SSB in 2019 is close to* B_{lim}. *Fishing mortality (F) has been above* F_{MSY} *in all years since 2011, except in 2015. Recruitment has been below average since 2008, except for the 2013 and 2018 year classes.*

ICES assesses that current fishing pressure on the stock is above F_{MSY} *but below* F_{pa} *and* F_{lim} *and spawning stock size is below MSY* $B_{trigger}$ *and between* B_{pa} *and* B_{lim}."

Based on this information, the shrimp may be seen as both overfished in terms of biomass and subjected to overfishing in terms of fishing mortality. It is also problematic to data quality for assessment that there is no discard sampling in Norway. Landing per unit effort is again declining since 2015 after having increased between 2012 and 2015 (NIPAG 2018).

3.1.1.2 Bycatch species

Indicator	Metric	Sweden	Denmark	Norway
Bycatch composition	Mean trophic level (MTL)	Not organised/analysed		Not collected
Bycatch amount	Total weight of bycatch (t)	Not organised/analysed		Not collected

Mean trophic level (MTL) illustrate the catch composition through utilizing the position in the food web; higher value implies higher occurrence of species higher up, i.e. top predators. These species are less abundant and may be more vulnerable to overexploitation through slower growth rates. This metric intends to reflect information on animals that are dead on return to the ocean, i.e. discard, which is more difficult compared to landed bycatch since there is different observer coverage in the different countries, thus requiring to be further analysed. STECF report on discards based on DCF data[2], but not specifically for the shrimp fishery. The discard values presented below for the different countries and fisheries are from different years and based on different sampling effort –thus not comparable since the rates vary between trips and years. Gear use, area and available quotas for fish also affect discard rates. Furthermore, the Healthcheck metrics would perhaps benefit from being separated into landed bycatch and discard.

The targeted species, shrimp, is sorted onboard into three size fractions: large shrimp boiled at sea (consumed directly); medium-sized shrimp that are either landed raw (processed on land before consumption) or discarded due to lower value; and small (less than 7 cm total length) which are discarded by all fleets. For 2017, shrimp discard estimates by ICES were 0.06 kg/kg shrimp for Sweden (or 6%) and 0.09 kg/kg shrimp for Denmark (9%) respectively. Before 2017, estimates for Norwegian discard rates has been based on applying Danish discard-to-landings ratio to Norwegian landings, since Norway has no on-board observer programme collecting of discards in the fishery (ICES, 2018a). In 2017, a new method for estimating Norwegian discards was used based on the reference fleet. This method compares length-frequency distribution of on-board samples of unsorted catches to samples from landings. As a result, the 2017 discard estimates for the Norwegian fishery was found to be considerably higher than previously assumed (19% instead of 2-7%; ICES 2018a). This is the equivalent of 0.23 kg shrimp discarded per kg shrimp landed. In the latest assessment, the method for estimating shrimp discard in the Norwegian fishery is revised again to show a much lower discard rate again, also for the 2017 estimate (ICES 2019).

The combined bycatch landings (mainly gadoids) of all gears and countries (excluding the category "other marketable fish")[3] in year 2017 had a landing volume of 2 366 tonnes and average MTL of 4.14. However, composition and volume vary considerably between areas and practices. Landings from grid fishing in IIIa comprise of 97% shrimp – however only 77% when grid fishing in IVa east respectively. When using a fish retention tunnel combined with the grid in IIIa, landings comprise of 80% shrimp. Fishing area IVa has the highest MTL of landed bycatch (4.21), even if only grid is used. The lowest MTL is found for grid fishing in area IIIa (3.48). Thus, the country-specific volume and MTL varies since the fleets vary in effort and gear use in the areas, decided by e.g. availability of fish quotas.

The Swedish fishery has the most updated and detailed information officially available on discards. In Bergenius and colleagues (2018) it is reported that between 2008-2015, between 25-65% of yearly catches (all catches) were discarded at sea in the fishery without grid – or varying between 250 and over 3 000 tonnes. The discarded fraction mainly comprised of shrimp and industrial species (blue whiting *Micromesistius*

[2] https://stecf.jrc.ec.europa.eu/web/stecf/dd/effort/graphs-annex
[3] "Landed bycatch in the *Pandalus* fishery in 2017. Combined data from Danish and Swedish logbooks and Norwegian sale slips (ICES, 2018a).

poutassou and Norway pout *Trisopterus esmarkii*), but also cod and saithe due to lack of quota for the fishers. In the grid fishery, the equivalent discard rate was between 17 and 39%, or between 110 and over 300 tonnes annually respectively (mainly shrimp and Norway pout). In total, around 60 species have been recorded in discards in the shrimp fishery. Use of sorting grid achieves very clean catches of shrimp (98% in volume; Bergenius et al. 2018).

The Danish fisheries released a report on discards in different fisheries in 2012 based on data from 2010 (Storr-Paulsen et al. 2012). In this report, total discard per species in the Skagerrak (IIIa) is reported for different métiers[4] with on-board observers (thus an underestimation). In terms of shrimp fisheries without a species-selective grid (OTB_CRU_32-69_0_0), total discards were in 2010 estimated to be 515 tonnes while landing 1 373 tonnes (of which 1 114 tonnes were shrimp), i.e. a discard rate of 27%. Norway pout *Trisopterus esmarkii* dominated discards (49% of volume).

For Norway, there is no on-board observers in the fishery. However, the Fisheries table for EBFM qualitatively reports on bycatch in the shrimp fishery (Fiskeridirektoratet 2018). This indicates high priority/pressure for bycatch of non-endangered species, discard problems and size-selectivity in the fishery. The shrimp fishery is categorized as red, i.e. the highest priority/pressure on a 3-grade scale (low-medium-high), with an additional category of lack of data. The fishery was scored as high based on 1) bycatch is a larger problem in the Skagerrak region compared to further north; and 2) sorting grid is only required outside of 4 nm; and 3) sorting out of small shrimp/alternatively potential closure of areas is not satisfactory.

3.1.1.3 Protected species

Indicator	Metric	Sweden	Denmark	Norway
Capture amount	Total captures	Not organised/analysed.		Not collected.
Reporting	Fraction of monitoring by independent observers	During 2010-2014, 0.7% of trips with grid and 1.2% of trips with grid and fish retention tunnel.	In 2010, 0.5 % of shrimp trips.	No existing observer program.

In Australia, protected species are defined based on State or Territory legislation, such as the Environmental Protection and Biodiversity Conservation Act 1999. In the Skagerrak area, other definitions must be made, based on legislation for the area. The metric Total captures thus needs an adapted definition for European circumstances.

When the Swedish fishery was initially assessed by MSC, species listed under CITES Appendix II and EU Regulation 43/2014 were defined as protected (ETP), whereas species on non-binding lists (e.g. ASCOBANS, IUCN Red List, OSPAR, HELCOM) were

[4] Term used in the EU Data Collection Framework (DCF) to define a relatively homogenous group of fishing based on e.g. target species and gear type

not considered. The EU regulation referred to is a TAC and Quota regulation for 2014, i.e. annually updated. The subsequent MSC assessments of Denmark and Norway thus referred to EU Regulation 104/2015, where one more skate species was added. The MSC performance indicator related to interaction with protected species got a score of 80 out of 100 for all countries and passed the threshold (MSC, 2015; 2016a; 2016b). There were no conditions given for this indicator, thus not followed up upon in the subsequent MSC surveillance reports.

According to the latest EU 124/2019 regulation however, i.e. the equivalent to the regulation used to define ETP in 2014, it is prohibited to fish for or retain on board the following species in the IIIa fishing area (i.e. protected as defined by MSC)[5]: Starry ray (*Amblyraja radiata*), white shark (*Carcharodon carcharías*), basking shark (*Cetorhinus maximus*), common skate (*Dipturus batis*) complex (*Dipturus* cf. *flossada* and *Dipturus* cf. *intermedia*), porbeagle (*Lamna nasus*), 11 species of *Mobula*- rays, 5 species of sawfish (*Pristis* and *Anoxypristis*), thornback ray (*Raja clavata*), whale shark (*Rhincodon typus*), guitarfishes (*Rhinobatidae*), picked dogfish (*Squalus acanthias*) and angel shark (*Squatina squatina)*. Many species are not found in the fishing area, but the list is longer than the list used for the initial assessment, e.g. also including picked dogfish as protected.

The officially available discard assessments of the shrimp fishery reports on some interaction with protected species (i.e. as defined by MSC but updated with the latest EU regulation). In Sweden, species in the *Dipturus* complex and dogfish (*Squalus acanthias*) are listed as occurring in discards (Bergenius et al. 2018). In the latest Danish discard report (Storr-Paulsen et al. 2012), the Danish shrimp fishery landed 80.1 tonne of spurdog (aka *Squalus acanthias*) and discarded 10.4 tonnes of thorny skate (aka *Amblyraja radiata*) in 2010[6].

Besides the species listed by MSC as protected, the Council Directive 92/43/EEC (the Habitats Directive) is also of importance in the area, with a strict protection regime mandated for species listed in Annex IV and V. Furthermore, some species are protected in e.g. Sweden in the form of fishing prohibition. Combined, this would add to the list of protected species.

Related to monitoring of catches, Denmark and Sweden are part of the EU and thus the Data Collection Framework (DCF). These requirements equal to sampling of ~1% of the effort of the fishery with independent observers. However, there is no specific reporting on protected species, thus requiring further organisation/analysis. In Sweden, the ambition of the onboard observer program for the shrimp fishery is to sample twelve trips per year and gear (separates trawl with sorting grid and sorting grid with collection bag); the outcome varies slightly per year and fishery[7]. The systematic onboard sampling commenced in in 2008. In Denmark 3 out of 643 shrimp trips (or 2 out of 15 vessels) were sampled in 2010 by on-board observers (Storr-Paulsen et al. 2012). For Norwegian fisheries, there is no existing observer programme; the discard ban is a package of other measures such as surveillance, reference fleet and more (Condie et al. 2014). As a result,

[5] Listed in Article 14

[6] Common names translated to scientific names based on www.fishbase.org

[7] ANNUAL REPORT FOR THE SWEDISH NATIONAL PROGRAMME FOR COLLECTION OF FISHERIES DATA https://www.havochvatten.se/en/swam/eu--international/international-cooperation/data-collection-framework-dcf/national-programs-and-annual-reports.html

there is only qualitative information available on Capture amount in the form of the Fisheries table for EBFM (Fiskeridirektoratet 2018). This indicates medium priority/pressure for bycatch of endangered species, motivated by no requirement to use grid inside of 4 nm and that outside of 4 nm a fish retention bag is allowed which may catch spiny dogfish and coastal cod (*Gadus morhua*).

3.1.1.4 Habitats

Indicator	Metric	Sweden	Denmark	Norway
Habitat impact	Impact score	Further investigations needed.		
Habitat status	Habitat status	Further investigations needed.		

Habitat impact indicates the impact of the fishing gear, in Australia preferably by using results from Ecological Risk Assessments of the fishery. If this is not available, generic gear impacts may be used (Chuenpagdee et al. 2003) and translated into the risk assessment scoring range of from negligible to catastrophic (1-6; Hobday et al. 2011). In a European context, where risk assessments of fisheries are more sparse, other metric may be more appropriate, such as those required by the Marine Strategy Framework Directive (MSFD; 2008/56/EG) and provided by ICES. Further investigations are needed to decide appropriate metrics and quantify shrimp-specific impact score to be comparable across countries.

The fishing area (predominantly ICES IIIa) belongs to the top intensively trawled areas in the world amongst assessed areas (Amoroso et al. 2018). The shrimp fishery has shown to cause resuspension of sediments in the water column after a trawl event for the smallest particles that last for several days (Linders et al. 2017). Historical damages to sensitive cold-water corals (e.g. habitat fragmentation and altered genetic structure) from the fishery are documented (Dahl et al. 2011). Today, area restrictions are enforced to protect known sensitive habitats. The shrimp fishery was in 2012 evaluated in terms of hectare affected per tonne shrimp (Ziegler et al. 2016): 1 500 ha/tonne for the Norwegian fleet; 1 200 ha/tonne for the Swedish fleet and 930 ha/tonne for the Danish fishery respectively. Since then, landing per unit effort increased considerably until 2015, but after that decreased again but not down to the level of 2012 (NIPAG 2018). These temporal variations in LPUE will be reflected in areal pressure per landing volume, but also gear use (increased use of twin trawl is seen for all three fleets).

The metrics may when applied in Europe benefit from recent initiatives. ICES was given a special request by the EU for advice on "indicators of the pressure and impact of bottom-contacting fishing gear on the seabed, and of trade-offs in the catch and the value of landings"[8]. For the indicator "Habitat impact", the fishing métier shrimp fishing belongs to (otter trawls for crustaceans) has a high average impact per landing ratio (0.38 compared to 0.02-0.25 for other demersal gears in the area) and high intensity in terms of number of times the area is swept (1.23 compared to 0.55-1.06). For the indicator "Habitat status", the ICES pressure indicator "Proportion of area fished" may be useful.

[8] http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.13.pdf

The shrimp fishing grounds in Skagerrak are approximately the equivalent to EUNIS habitat code A6.5 (Deep-sea mud) and Table A.3 of the ICES advice informs that 91% of this habitat type was trawled in 2015. However, the table A.3 estimates only cover the 0–200 m depth zone, and most Skagerrak shrimp fishing takes place at larger depths (there is very little Deep-sea mud habitat in shallower waters and practically all of it is fished). Hence, an appropriate shrimp-fishery based pressure indicator would include also the deeper fishing grounds and A6.5 habitat areas (e.g. 0-1000 m), in which case the indicator estimate would likely be lowered, but still high (Eigaard et al. 2017).

Furthermore, the Descriptor 6 'The sea floor integrity ensures functioning of the ecosystem' of the MSFD is useful as a metric for Habitat status in an EU perspective. In Sweden, GES is not achieved for the fishing area (D6C5; HaV 2018:27); no Danish assessment is found. Norway is not a part of the European Union, and thus not the directive. The Fisheries table for EBFM (Fiskeridirektoratet 2018) indicate high priority/pressure for habitats (highest impact on a 3-grade scale).

Impacts to habitats are assessed by MSC with several performance indicators, where all three of them (Outcome of habitats, Management of impact of the fishery on habitats and Information on habitats) scored below acceptable level (80 points) in the initial assessment, and conditions were given. The assessment was based on how the fishery potentially impacts on five vulnerable marine habitats: coral gardens, deep sea sponge aggregations, *Zostera* beds, *Lophelia pertusa* reefs and seapen and burrowing megafauna communities, all on OSPARs list of threatened or declining habitats[9]. The OSPAR list of sensitive habitats is longer, and it is unclear how these habitats where chosen. The MSC reports states that they were chosen based on distribution of fishing activity and known habitat occurrence – while also stating that there is no potential interaction with the fishery and *Zostera* beds. It is indeed impossible for shrimp trawling to interact with *Zostera* beds (it is a deep-water fishery and *Zostera* habitats are very shallow since they require sun light, thus occurs at depths and areas where shrimp trawling does not). It would be more relevant to include carbonate mounds (not mentioned in the MSC report) and *Modiolus modiolus* beds (mentioned) which were not considered. Furthermore, even if the habitat that the fishery exploit (Deep-sea mud) is not protected it doesn't imply that it is unproblematic given the scale of utilization (91% trawled in 2015). Principle 2 of MSC requires that the fishery does not cause serious or irreversible harm to habitat structure and function. Criteria includes maintenance of "natural functional relationships among species" and that the fishery "does not threaten biological diversity". In the latest surveillance audit, higher performance scores were given compared to the initial assessment after implementation of new fishing regulations in the Bratten area in 2017; the initial condition was considered to have been fulfilled (MSC, 2018a; 2018b; 2019).

[9] https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats

3.1.1.5 Ecological communities

Indicator	Metric	Sweden	Denmark	Norway
Ecosystem status	Ecosystem status	Further investigations needed.		
Ecosystem structure	Species diversity	Further investigations needed.		

The Australian Fisheries Healthcheck indicators reflect the general status of the ecosystem, including the cumulative effects of human pressure where the fishery operates (i.e. not fisheries-specific). In EU waters, metrics in this sub-category should ideally be based on the requirements of the MSFD (2008/56/EG) of achieving Good Environmental Status (GES) by year 2020. Descriptors such as number 1 'Biodiversity is maintained' and 4 'Elements of food webs ensure long-term abundance and reproduction' may comprise of useful indicators. These metrics thus require further investigations.

In Sweden, the MSFD directive is incorporated into Swedish law through 'Havsmiljöförordningen' (2010:1341[10]) and associated national criteria (HaV 2018:27). Ecosystem status is assessed by several indicators and per sea basin (e.g. inner and outer waters, fjords, estuaries– on the Swedish west coast nine areas in total). Overall ecosystem status is the combined outcome of several descriptors (Biodiversity, Invasive species, Commercial species, Eutrophication). Most components assessed do not reach threshold values for GES, even if some improvements are seen. In terms of Ecosystem structure, Descriptor 4 evaluations indicate strong effects from human pressure, but no formal assessment of criteria is enabled yet.

Norway is not a part of the European Union, and thus not the directive. In their EBFM tool, Norway has categorized some targeted species into having key roles in the ecosystem (2-grade scale, very important to important, some species have no indication at all[11]); shrimp is categorised as important (score 2).

ICES also provides ecosystem overviews that may be used. In the Greater North Sea (which includes the fishing area), the Large Fish Indicator (LFI) index is followed up upon. This has declined since the mid-1980s (start of time series) but has been relatively stable but fluctuating since 2004 (ICES 2018b).

[10] http://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/havsmiljoforordning-20101341_sfs-2010-1341

[11] https://www.fiskeridir.no/Yrkesfiske/Dokumenter/Reguleringsmoetet/Sakspapirer-innspill-og-referat-fra-reguleringsmoetene/Reguleringsmoetet-juni-2018

3.1.1.6 Carbon and pollution

Indicator	Metric	Sweden	Denmark	Norway
Macro plastics	Plastic code of conduct	Not found.		
Carbon footprint	CO_2-equiv.[12]	14.5	11.5	14.5

Fisheries are a major contributor to plastics in the ocean (Lebreton et al. 2018; ICES 2018b). No plastic code of conduct with commitment to a zero waste overboard was found for the fisheries, but Swedish fishers are engaged in collecting plastic debris[13]. In the Australian Healthcheck, MARPOL regulations are referred to (general prohibition for ships, including fishing vessels, to discharge garbage). It is unclear what are the regulations for fishing vessels in the shrimp fishery.

In the MSFD, Descriptor 10 'Marine litter does not cause harm' is divided into micro- (< 5 mm) and macro litter. Only trend-based indicators are used, effect-based thresholds are not possible. GES is not achieved in Sweden (HaV 2018:27).

The carbon footprint (only from combustion of diesel onboard fishing vessels) in 2012 could be calculated based on Ziegler and colleagues (2016). This is equivalent to silver standard data in terms of data quality. Fuel use data is collected for the fishery but not analysed and officially available for specific fisheries (STECF 2018). The Swedish fishery has a Code of Conduct which amongst others include efforts to minimize fuel consumption and use clean fuel[14].

[12] Assumptions: use of diesel MK1 with 2.54 kg CO_2e/litre (https://spbi.se/uppslagsverk/fakta/berakningsfaktorer/energiinnehall-densitet-och-koldioxidemission/)
[13] http://www.hallhavetrent.se/
[14] https://www.sfpo.se/UserFiles/MSC%20dok/Code_of_Conduct_f_r_Svenskt_r_.docx

3.1.2 Economic

Economic indicators (e.g. gross value added, profitability, net profit, fuel use) of EU fisheries are on an annual basis collated and analysed by STECF (2018); this is the STECF report referred to throughout this chapter. Economic data is thus regularly collected but may not be presented/analysed on a fisheries-basis, rather per fishing sector (such as demersal trawl fisheries with different vessel sizes). This implies that the data is collected but not released unless upon request, where Danish data related to the shrimp fishery has been difficult to obtain earlier from confidentiality concerns (Ziegler et al. 2016). There are no major data concerns raised in the STECF report for Denmark or Sweden. For Sweden it is reported that:

"*Most of the Swedish data comes from registers, only cost data is collected separately. Sweden uses mandatory questionnaires for data on costs (combined with tax declarations from registers). Previously, Sweden used probability sampling when sending out the questionnaires. Since 2012, questionnaires requesting 2011 data are sent to all vessels (census). Instead of getting 60% response from a 50% sample, Sweden now gets more than 85% response from a census sample, i.e., the number of data points has increased threefold.*"

In Denmark, national economic analysis of fisheries in general are available from the Department of Food and Resource Economics (IFRO)[15].

Norway collects economic data on their fisheries through the annual profitability survey sent out to a representative sample of vessels for each fleet segment since year 1966 by the Directorate of Fisheries, making this one of the longest time series regarding fisheries profitability in the world.

3.1.2.1 Fishery benefits

Indicator	Metric	Sweden	Denmark	Norway
Net economic returns	Economic rent	Not organized/analyzed		
Gross value of production	Gross value of production (GVP), million EUR	122.6 million SEK (shrimp only)	Not organized/analyzed	
Profitability	Financial performance	Not organized/analyzed.		
Latency	Inactive licences/ unused SFR/uncaught TAC	Further investigations needed.		

[15] https://ifro.ku.dk/publikationer/ifro_serier/fiskeriets_okonomi/

Landing value is reported on by EU member states by STECF, but this metric may require more detail for shrimp since there is an almost tenfold price difference per kilo if landed raw compared to boiled for Skagerrak shrimp (Ziegler et al. 2016). Norway and Denmark do not even separate shrimp from the Skagerrak region with other areas fished in the official statistics found. Sales slips are available for all countries including Norway[16], where this information would be found for the whole fishery but were not requested by responsible authorities for this report. Officially available records (STECF report) states that the average price per kg shrimp landed in Sweden was slightly less than €10 per kilo (2017) whereas in Denmark, the landing value was €5.1 per kilo (2016). Official Swedish records separate the shrimp fractions and reports that the total value of landed shrimp from the Skagerrak in Sweden was 110 million SEK (boiled, 723 tonnes in volume) plus 12.6 million SEK (raw, 586 tonnes in volume) in 2017[17]. There are also fish auction prices available for Denmark[18]. In Norway, the combined value for all deep-water shrimp (boiled and raw, including all fishing areas, in total 13 314 tonnes) was NOK 577 million[19] in 2017 (i.e. 43 NOK/kg). The Institute of Marine Research reports that fresh and boiled Skagerrak shrimp have a value of 80-100 NOK/kg and more, while the smaller sizes delivered raw tot industry on shore only yields 15-20 NOK/kg[20]. Note that all values of production only include shrimp whereas the total value of the fishery should also include fish landings.

There are indicative signals available for the three fleets related to profitability. For Sweden, STECF reports that the four active fleet segments which include shrimp fishing comprise of 142 vessels operating in the Baltic, the Kattegat, Skagerrak and the North Sea targeting a variety of species. The largest vessel segment is the most profitable but mainly fish for pelagic species. None of four segments using active gears made economic losses in 2016, and the economic development is improving, even if the smallest vessel segment (12-18 m) has the weakest economic performance. In Denmark, STECF reports that the large vessel segments using active gears had all high profitability in 2017, whereas smaller vessel segments (12-18 m) had reasonable performance respectively. The fleet segment Demersal trawl/seine (24-40 m), which shrimp fishing belongs to, comprise of 34 vessels and operates predominantly in the North Sea and Skagerrak targeting a variety of species but in particular, cod, plaice, monkfish, and Northern shrimp. Total landing value in 2017 was around €88 million, contributing to over 16% of the total landings value of the whole Danish fishing fleet. The gross profit was €32 million and net profit €22 million. In the earlier shrimp study (Ziegler et al. 2016; data from 2012), the Norwegian fishery was the only fishery with positive profit – 5 000 DKK per tonne (Denmark did not release data). The Norwegian profitability analyses are regularly performed but official records found are old (data from 2013) and not analysed/organised to specifically report on the shrimp fishery in Skagerrak. The data available to research has unfortunately low coverage of the fishery (only 10 out of 195 vessels in 2012; Ziegler et al. 2016). The coastal shrimp fisheries have been found to have the highest operating margin of the coastal fleets in Norway (8.7 % in 2013; Directorate

[16] https://www.rafisklaget.no/portal/page/portal/NR/Salgavfangst/Seddelinformasjon
[17] Statistiska Centralbyrån
https://www.scb.se/contentassets/6706ca62dd964ddda52a4851849b28cf/jo1101_2017a01_sm_jo55sm1801.pdf
[18] "Dybvandsrejer", "Alle konsum", all auctions, annual average
https://dwp.fiskeristyrelsen.dk/art_auktionsrapport/art_auktionsrapport__page
[19] Statistics Norway https://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/fiskeri/aar-forelopige
[20] https://www.hi.no/hi/temasider/arter/reke-nordsjoen-og-skagerrak

of Fisheries 2019). Average economic data for coastal shrimp trawlers in the Norwegian fleet in 2013 was (observe that this includes shrimp trawling in other areas than the study area as well): operating revenues 2 938 300 NOK; operating expenses 2 681 800 NOK; and operating profit 256 500 NOK.

The metric related to inactive licences/uncaught TAC may require further investigation on which one is the most appropriate and where to find the most accurate account. The different data sources available on quota uptake[21] are confusing, probably from that the fishery takes place in two areas with separate TACs (ICES IIIa and the Norwegian zone subarea 4). For 2016, it appears as if Sweden had 13 % of TAC uncaught, Denmark 53% uncaught whereas Norway exceeded their quota with 7% – all in all totalling in 17% of TAC uncaught in IIIa. Based on ICES (2019), the recommended catch limit for the whole fishery was 10 316 tonnes in 2017, which was exceeded but unclear with how much since the ICES 2018 and 2019 reports have different discard estimates for the Norwegian fishery: 12 438 tonnes were estimated to have been caught in the 2018 report, (exceeding TAC with 20%), whereas the updated figure in the 2019 report was 11 004 tonnes (exceeding with 6% respectively). Denmark reports on unutilized quotas: 31.6% in 2017 for Northern shrimp in the fishing area IIIa[22]. Related to inactive licences, the latest STECF report categorise 300 out of total 1 211 fishing vessels to be inactive in all fisheries in Sweden in 2017 (decreasing trend). In Denmark, the equivalent is 419 inactive vessels and 1 374 active vessels respectively (note that the total number of vessels as reported by STECF differs from the Danish reporting, where the latter is 2 700 vessels in total[23]). The data is thus collected but not analysed specifically for the shrimp fishery. Based on information from SwAM, 62 permits to fish shrimp existed in Sweden in 2018, of which only 33 vessels landed more than 10 tonnes of shrimp in 2017, or in total 1 326 tonnes of the shrimp landings (i.e. many licenses may be considered as relatively inactive). There are no inactive licences in the Danish shrimp fishery. For Norway, the annual permits to fish shrimp with trawl south of 62N by Norwegian coastal fishing vessels are decreasing[24]: from 123 vessels in 2016 to 114 vessels in 2018. No information was found on number of inactive licences in Norway.

3.1.2.2 Community benefits

Indicator	Metric	Sweden	Denmark	Norway
GDP value to communities	Contributions to national GDP/State's GSP/GRP	Not organized/analyzed.		
Wealth spread	Distribution of fishing firm size	Not organized/analyzed.		Not found.

[21] Quotas: https://eur-lex.europa.eu/legal-content/SV/TXT/PDF/?uri=CELEX:32016R1252&from=EN; Landings: https://eur-lex.europa.eu/legal-content/SV/TXT/PDF/?uri=CELEX:32016R1252&from=EN; Norwegian quotas: https://lovdata.no/dokument/SF/forskrift/2018-12-18-2127?q=skagerrak
[22] http://webfd.fd.dk/stat/kvoter_x/kvox17.pdf
[23] https://fiskeristyrelsen.dk/english/commercial-fisheries/
[24] https://www.fiskeridir.no/Yrkesfiske/Statistikk-yrkesfiske/Fiskere-fartoey-og-tillatelser/Om-statistikken-Konsesjons-og-deltakerregister

EUMOFA[25] reports on the fish market for EU member states and Statistics Norway[26] reports on first-hand value. In 2016, total landings of northern shrimp in Sweden accounted for €22 million (3 000 tonnes), i.e., higher than the national landings, and shrimp belong to the top commercial species in Swedish fisheries (22% of total value). For Denmark, shrimp is not found amongst top commercial species landed, thus not organised/analysed in the same sense as in Sweden. EUROSTAT[27] collate all the data also for Denmark, however, but this level of detail was not further investigated here. For Norway, all landings of Northern shrimp in all areas fished contributed to 3% of the total landing value of all fisheries in 2017.

EUMOFA reports on number of companies, value added and employees per country and total fishing industry for EU member states[28]. In the latest STECF report, new ratio system in Sweden is intending to facilitate a more efficient capital use in the shrimp fishery, thus higher profitability for individual fishing firms. In 2017, Danish fisheries received critique over the concentration of quotas in Danish fisheries in general[29]. The shrimp fisheries were observed to have the highest quota concentration of vessel quota shares (i.e. in fisheries for direct human consumption), where ten quota owners hold 95-99% of all Danish shrimp. No information on the topic was found for Norway.

3.1.2.3 Markets

Indicator	Metric	Sweden	Denmark	Norway
Fish distribution	Fish receivers	Three fish auctions were shrimps are sold. Other options, such as direct to restaurants, are utilized as well.	There are nine fish auctions in Denmark, unclear if all sell shrimp.	Not organized/analyzed.
Volatility in market price	Price volatility (EUR/kg)	1.3 EUR/kg	Not found.	Not organized/analyzed

EUMOFA reports on number of fish auctions per EU member state. There are three fish auctions in Sweden were shrimp are sold: Göteborg, Smögen and Stockholm. Based in interviews, other market opportunities are used too[30]. Based on Swedish logbooks (year 2017), 97 % of the shrimp volume was landed in in whereas 3% in Denmark respectively. There are nine fish auctions in Denmark, but it is unclear if all market shrimp. Danish vessels often boil the shrimp on board and land in Sweden for higher market price.

[25] https://www.eumofa.eu/
[26] https://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/fiskeri/aar-forelopige
[27] https://ec.europa.eu/eurostat
[28] https://www.eumofa.eu/the-eu-market
[29] http://www.rigsrevisionen.dk/media/2104613/kvotekoncentrationen-i-dansk-fiskeri.pdf
[30] https://www.fiskekommunerna.nu/images/Marina_verksamheter/Fiskerapport_low2.pdf

Smaller sizes of shrimp (that are not discarded) are landed raw to be further processed on land.

Norway holds the largest share of the quota, and land fresh shrimp in both Norway and Sweden[31]. Information on how much of the Norwegian catches that are landed in respective country are provided by the fishermens' sales organization Skagerak fisk[32]: 395 tonnes of shrimp was exported to Sweden in 2018 from their district and none to Denmark. The Norwegian Seafood Council also collates national export statistics, but not separated for the specific fishery of shrimp.

For EU members, volatility in market price can be calculated as standard deviation per year or quarter of year based on official EUMOFA data. For Sweden this was 1.3 EUR/kg (2012-2017). For Denmark there was no equivalent data found. Norway has reported data for shrimp, but with no specification on fishing area.

3.1.2.4 Energy costs

Indicator	Metric	Sweden	Denmark	Norway
Energy use	Fuel use per kg of fish harvested (l/kg)	5.72	4.47	5.73
Fossil fuel subsidies	Fuel subsidies/rebates directed to the fishery (€/l)	0.14	Not found.	0.28

Energy use during fishing may be reported with at silver standard data level through the study by Ziegler and colleagues from 2016. However, fuel use is reported on by STECF and collected as part of the DCF of EU fisheries which may allow for gold standard data for Sweden and Denmark (see Chapter 3.3 for more information). Fuel use is also collected in Norway in the profitability survey, but not organised/analysed for the fishery.

Fuel costs for fishing vessels are often subsidized; the extent may vary between countries[33]. In Sweden, the refund level was 0.14 €/l in 2019[34]. In Norway, the estimated total exempted fuel taxes were NOK 999 million (or 6.3 % of the landing value) in 2011 (Isaksen et al. 2015). Information on refund levels are found at "Garantikassen for fiskare"[35]; in 2019, the refund was 0.28 €/l in Norway. Danish fishing vessels are also entitled to rebates for fossil fuels[36], but the actual refund level was more difficult to find[37].

[31] https://www.hi.no/hi/temasider/arter/reke-nordsjoen-og-skagerrak
[32] https://www.skagerakfisk.no/
[33] http://www.europarl.europa.eu/RegData/etudes/note/join/2013/513963/IPOL-PECH_NT(2013)513963_EN.pdf
[34] Refund level of energy tax or carbon dioxide tax, https://www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/energiskatter/verksamhetermedlagreskatt/jordbrukskogsbrukvattenbruk/bransle.4.15532c7b1442f256baebbb2.html
[35] http://www.garantikassen.no/no/ordningene/refusjon_av_mineraloljeavgift/
[36] https://skat.dk/skat.aspx?oid=2061408
[37] https://skat.dk/skat.aspx?oid=2234584

3.1.3 Social and Ethical

The social and ethical category has so far been given limited attention in research and data collection in Europe. Therefore, limited information is available even at national level. Scattered information exists today. Interestingly, Sweden has during 2017 commenced the work with preparing the data collection for social data (STECF 2018), with surveys sent out during 2018 to collect data for 2017 (which will be a reference year).

3.1.3.1 Fisher wellbeing

Indicator	Metric	Sweden	Denmark	Norway
Fisher satisfaction	Satisfaction scores	Many challenges identified for small-scale fishermen	Not found.	
Age structure	Proportion of fishers in standard age cohorts	67% older than 50 years.	Not organized/analyzed.	

In Sweden, interviews with west coast fishermen was performed in 2014 to collect information on e.g. optimism of the future. The survey included more sectors then the shrimp fishery. Overall, 60% of the respondents were satisfied with the economic situation but there were concerns expressed related to the future development. Some tension between larger and smaller vessels were expressed in the shrimp fishery. The interviews were followed up in 2018 with results to be presented later in 2019[38]. Information on fisher satisfaction in Denmark and Norway was not found.

All countries collect data on age structure and report on general trends; no country officially reports on age structure in a specific fishery. In Sweden, age structure of all fishers is reported as part of Sweden's Environmental Quality Objectives[39]. On the west coast (Västra Götalands län and Hallands län), 55% of fishers were older than 50 years (based on fishing licenses in 2013). From a request to SwAM, information on age structure was provided for the shrimp fishery. In the shrimp fishery in 2019[40], 57% of all licenses were held by fishermen older than 50 years; however, 10 licences were held by companies (without age of fisherman reported) – excluding them results in 67% of the fishers being older than 50 years. In Denmark, no detail on the shrimp fishery is found but average age is increasing in fisheries in general and was in 2016 58 years for the all owners of vessels (6 812 registered)[41]. In Norway, age structure is also reported in general, and age cohorts are officially available but not at a fisheries level. The average age for fishermen (with fishing as main occupation) has between 1990-2014 gone up in

[38] https://www.fiskekommunerna.nu/images/Marina_verksamheter/Fiskerapport_low2.pdf
[39] https://www.miljomal.se/Miljomalen/Alla-indikatorer/Indikatorsida/?iid=142&pl=1
[40] Data provided upon request by SwAM
[41] https://fiskeristyrelsen.dk/english/fishery-statistics/age-statistics/

Norway in general; the average age was 46 years in 2014[42]. Norway also reports on number of women involved (which is increasing).

3.1.3.2 Wider community

Indicator	Metric	Sweden	Denmark	Norway
Community satisfaction with fishery	Community feedback	Not collected		
Levels of local employment	Percentage of local employment versus overseas	Not organised/analysed.		

Community feedback is not collected, but shrimp are popular seafood products for all three countries. There are different regional initiatives illustrating strong coastal community support for the fishery, such as the Swedish co-management initiative in the Koster-Väderö Fjord[43]. Shrimp fisheries are in coastal communities seen as iconic and boiled shrimps are a trade-mark of the Swedish west coast. Media content analysis (not performed here) would however comprise of both negative and positive feedback in recent years, as presented in the introduction of the report. The fleet structure is also very different between the countries. In Sweden, the shrimp fishing fleet comprise of a higher number of vessels that are predominantly smaller in size, whereas the Danish fleet is more industrialized, with few and large vessels. The Danish fishery has gone through dramatic changes in fleet structure, in particular from the introduction of an ITQ system in 2007, reducing the number of vessels down to ten vessels (mainly >25 m). This concentration of the quota to few vessels has received critique[44] which may be a measure of community feedback. Even if the number of vessels has decreased with over 50% since mid-1990s, the Norwegian shrimp fleet comprise of the most vessels by far (188 in year 2013; Ziegler et al. 2016). Small-scale coastal fisheries in Norway are in general seen as important to coastal areas and are favoured in the management system; the concept of "social contract" (samfunnskontrakt) concerns social responsibilities to keep communities running, overriding economic efficiency (Viðarsson et al. 2018).

In a European context, small-scale coastal fleets versus large-scale fleets are more discussed compared to overseas employment; the metric may need further investigation. Data on Full-Time Equivalents (FTE) in the seafood sector is collected and reported on by STECF. Processing of seafood takes often place where cheaper labour is found, within or outside of Europe. Local employment is however high in the Skagerrak region shrimp fishery, especially for boiled shrimp which are prepared on the vessel. Number of vessels in the Swedish shrimp fishery declined with approximately 20% between 2003 and 2015. Full-time employment in all Swedish fisheries in general has continuously declined in recent years, from 990 to 845 between 2010 and 2014 (HaV 2018:27). In Denmark, there are in total about 2 700 fishing vessels, crewed by approximately 1 900; there are around

[42] https://www.fiskeridir.no/English/Fisheries/Statistics/Booklets
[43] http://www.samforvaltningnorrabohuslan.se/
[44] http://www.rigsrevisionen.dk/media/2104613/kvotekoncentrationen-i-dansk-fiskeri.pdf

8 000 people employed in the whole fishing industry[45]. In Norway, no information is found on the shrimp fishery, but use of foreign labour has been increasing in general in Norwegian fisheries (Thorvaldsen & Sønvisen 2014).

3.1.3.3 Ethical – human welfare

Indicator	Metric	Sweden	Denmark	Norway
Protection in place	Legislation exists	Legislation exists for all countries.		
Level of compliance	Levels of compliance (or violation of) with Workplace Health and Safety	There are control agencies for all countries.		

It was considered out of scope of this assessment to compile and compare potential differences between countries. For EU member states there are directives concerning work on board fishing vessels[46], and the International Labour Organisation (ILO) Convention on "Work in the fishing sector" is signed. In Sweden, information on regulations are found at Transportstyrelsen[47], e.g. safety onboard for fishers are mandated through following STCW Manila, renewed every five years (TSFS 2011:116[48]). In Norway and Denmark, there are several regulations that defines rules for fishers and processing industry, collated by the Norwegian Maritime Authority[49] and the Danish Maritime Authority[50] respectively.

In general terms, there are different EU directives related to working conditions with different scope (i.e. rule that applies for vessels larger versus smaller than 15 m), making it difficult to generalise. One report[51], notes that fatal accidents in the whole fisheries and aquaculture sectors in the EU is almost ten times that of all workplaces (based on 11 out of 22 member states). Trawling is mentioned as one activity with frequent cases of accidents. In Denmark there is a dedicated organisation for fishermen safety and health, Fiskeriets Arbetsmiljøråd[52]; number of accidents for the whole Danish fishing fleet (all species and areas) is also reported on annually[53]. In Sweden, Arbetsmiljöverket reports on accidents[54], but not at a level of detail to be able to report specifically for even the whole fisheries sector. In Norway, Arbeidstilsynet[55] is responsible for working

[45] https://fiskeristyrelsen.dk/english/commercial-fisheries/
[46] https://osha.europa.eu/en/legislation/directives/13
[47] https://www.transportstyrelsen.se/sv/sok/?q=fiske
[48] https://www.transportstyrelsen.se/sv/sjofart/Fartyg/Arbetsmiljo/
[49] https://www.sdir.no/en/shipping/legislation/#regulations
[50] https://www.dma.dk/Sider/default.aspx
[51] DG Employment, social affairs and inclusion (2015) Evaluation of the Practical Implementation of the EU Occupational Safety and Health (OSH) Directives in EU Member States.
[52] https://www.f-a.dk/english
[53] http://fiskeriforening.dk/wp-content/uploads/2018/05/FISKERI_I_TAL_2018.pdf
[54] https://www.av.se/
[55] https://www.arbeidstilsynet.no

environment, defining rules for working conditions (e.g. working hours, minimum wage).

3.1.3.4 Ethical – animal welfare

Indicator	Metric	Sweden	Denmark	Norway
Animal welfare protections	Animal welfare protections in place for fish	Not found for the fishery.		
Level of compliance	Levels of compliance or violations of animal welfare	Not found for the fishery.		

3.1.3.5 Climate related (adaptive capacity of the fishery)

Indicator	Metric	Sweden	Denmark	Norway
Access to information	Availability of information	High level of information available.		
Access to networks	Level of membership of industry association	High access to networks.		

In Sweden, fishers may find information about the shrimp fishery at SwAM[56], where they can also choose to subscribe to emails with information on real time closures or other changes in the fishery. In Denmark, fishers may find information on e.g. rules and regulations at the webpage of Fiskeristyrelsen[57]. Furthermore, Danmarks Fiskeriforening[58] is a producer organisation compiling statistics and useful information (such as regulations) for and about the fishing industry. In Norway, the Fiskeridirektoratet[59] offers information on their website on e.g. real-time closures. There are also several fisheries associations providing information to fishers at their websites, such as Norges Kystfiskarlag[60] and Norges Fiskarlag[61].

In the EU, the seafood sector is organised in more than 200 producer organisations[62]. There are two Producer Organisations for commercial fishers in Sweden which includes shrimp fishing: one with 250 member vessels, with a dedicated committee for the shrimp

[56] https://www.havochvatten.se/hav/fiske--fritid/yrkesfiske.html
[57] https://fiskeristyrelsen.dk/erhvervsfiskeri/krav-og-reguleringer/
[58] http://fiskeriforening.dk/om-danmarks-fiskeriforening/
[59] https://fiskeridir.no/Yrkesfiske/Regelverk-og-reguleringer
[60] http://www.norgeskystfiskarlag.no/index.php
[61] https://www.fiskarlaget.no/index.php/organisasjonen/om-norges-fiskarlag
[62] https://ec.europa.eu/fisheries/cfp/market/producer_organisations_en

fishery[63] and another with membership number not found[64]. Denmark also has producer organisations such as Danmarks Fiskeriforening Producent Organisation, but there is no dedicated committee for the shrimp fishery. All members and vessels are listed at the website[65] but there is no information on which fishery they operate in (i.e. the level of membership of the shrimp fishery). In Norway, Norges Kystfiskarlag started a dedicated group in 2016 called Sørøst Norges Kystfiskarlag much based on industry fears related to the shrimp fishery[66].

3.1.4 Governance

The governance component (i.e the capacity of institutions to achieve objectives) is an important part of EBFM, repeatedly identified to deserve special attention in EBFM implementation (e.g. Garcia 2003). The shrimp fishery is challenging in the sense that it is a multijurisdictional fishery, involving two EU member states under EU regulation (Denmark and Sweden) and one external country (Norway) with national regulations in combination with bi-lateral agreements. This category is thus difficult to disentangle, and the authors don not guarantee it is free from potential errors.

3.1.4.1 Ecosystem governance

<table>
<tr><th>Indicator</th><th>Metric</th><th>Sweden</th><th>Denmark</th><th>Norway</th></tr>
<tr><td rowspan="2">Bycatch mitigation</td><td rowspan="2">Description of the bycatch mitigation measures that are used, required, or verified for the fishery</td><td colspan="3">Minimum mesh size 35 mm. Selective grid (Nordmore), 19 mm bar spacing is mandatory for all countries since 2013. If the vessel has a fish quota, a fish retention device may be used (a 120 mm square mesh tunnel at the grid’s fish outlet) in combination with the grid except for in restricted areas (e.g. inside of the national trawl border in Sweden).

Many vessels voluntarily use a bigger mesh size than 35 mm to avoid small shrimps.

Real Time Closures to protect juvenile gadoids may be enforced for all countries in the Norwegian economic zone, the latest took place on April 27th 2019; shrimp fishing with grid is however permitted.</td></tr>
<tr><td colspan="2">High-grading forbidden since 2009 (COM/EU Reg 850/1998).

All quota-restricted species should be landed since 1st of January 2019 except for skates and rays, which should be released directly under the surface (EU 2018/2035). When fishing with grid without retention</td><td>Discard ban since 1983 in the Norwegian Economic Zone (Gullestad et al. 2015).

Have a Minimum</td></tr>
</table>

[63] https://www.sfpo.se/om-sfpo/kommitteer
[64] http://www.hkpo.se/om-oss/
[65] http://fiskeriforening.dk/wp-content/uploads/2019/03/19.03.2019-Kutterliste.pdf
[66] http://www.norgeskystfiskarlag.no/index.php/lokalelag/sorost-norge

<table>
<tr><th>Indicator</th><th>Metric</th><th>Sweden</th><th>Denmark</th><th>Norway</th></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td colspan="2">tunnel, some species are excepted from the landing obligation (e.g. many gadoids).</td><td rowspan="3">Catch Size (MCS) of 6.5 cm total length, but landings below MCS of up to 15% of weight is allowed; there are also several juvenile fish bycatch restrictions (J-39-2019; Fiskeridirektoratet). The allowed amount of fish bycatch landed relative to shrimp landings are regulated[67].

Mandatory with selective grid also inside of 4 nm starting 1st of May 2019[68].</td></tr>
<tr><td>Around half of the effort is performed with grid without fish retention device.

Predominantly 45 mm mesh size used, some even 52 mm (MSC 2018a).

Allowed discard of species with landing obligation should be recorded in logbooks, and will be followed up upon by Swedish authorities.</td><td>Fish retention device used on almost all hauls when fishing for shrimp (MSC (2018b).</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Protected species mitigation</td><td>Description of the protected species mitigation measures that are used, required, or verified for the fishery</td><td colspan="3">AIS required for all vessels fishing in areas with restrictions: the Koster-Väderöarna Marine National Park (regulated by SWaM) and Bratten (regulated by EU[69]) and there are gear restrictions in place in some areas to minimize bycatch (see chapter 3.1.1.2 on Bycatch).

However, there is no verified effectiveness of the overall protected species mitigation for the fishery since 1) Norway have no onboard observer sampling programme; and 2) the habitats where the fishery operates is under high pressure (see chapter 3.1.1.4); and compliance has been questioned (see chapter 3.1.4.5).</td></tr>
</table>

[67] https://www.hi.no/hi/temasider/arter/reke-nordsjoen-og-skagerrak
[68] https://www.fiskeridir.no/Yrkesfiske/Regelverk-og-reguleringer/J-meldinger/Gjeldende-J-meldinger/J-251-2018
[69] EU 2017/118

There are Norwegian regulations in place since 2004 to close areas to protect small shrimp and gadoids fish in the Norwegian economic zone, i.e. Real Time Closure (RTC)[70]. The latest closure was in March 2019 affecting all fleets[71]; however, shrimp trawling with selective grid and without fish retention tunnel is allowed[72]. In recent years, there have been negotiations on further RTC regulations between the three countries that are not yet in place.

Another component of Ecosystem governance is protection of sensitive habitats. There are already areas protected from fishing in the Koster-Väderöarna Marine National Park and Bratten[73]. Fisheries fishing in these areas are required by Swedish law to have an AIS signal on. To fish in the Koster-Väderöarna area, education and a special permit (on a yearly basis) is also required; breaches may cause withdrawal of permit. Shrimp fishing in the Gullmar fjord also have specific restrictions. However, short-term closures and small-scale marine protected areas are of limited use if effects from resuspension of sediments are to be included in management (Linders et al. 2017). The County Administrative Board in Sweden have initiated strategies for improved conservation of sensitive species and habitats[74].

For Norway, a move-on rule is in place if gear collides with sponges or corals (defined by 60 kg corals or 800 kg of sponges; regulation J-128-2011). This must also be reported on.

3.1.4.2 Management systems

Indicator	Metric	Sweden	Denmark	Norway
Harvest strategy	Scope of harvest strategy	The fishery has been regulated by quotas since 1992, with the total quota split between the three countries based on history. Today it follows a Maximum Sustainable Yield (MSY) approach, includes reference points for F and B related to MSY and Precautionary approach (ICES 2018a).		
Management plans	Scope of management plan	The implementation of a long-term management plan for the shrimp stock started on 1st of January 2019, including harvest control rule. Yearly updated agreement between Norway and the EU with the objective to have the same rules for all to the extent possible. In the Norwegian zone, EU fisheries have to comply with Norwegian rules.		

[70]Norsk förordning 22 December 2004 sektion 47 3§; https://fiskeridir.no/Yrkesfiske/Regelverk-og-reguleringer/Stenging-og-aapning/Soer-for-62-N
[71]https://www.havochvatten.se/hav/fiske--fritid/yrkesfiske/kvoter-och-fiskestopp/realtidsstangningar/arkiv-rtc/2019-03-06-realtidsstangning-i-nordsjon.html
[72]https://fiskeridir.no/Yrkesfiske/Regelverk-og-reguleringer/Stenging-og-aapning/Soer-for-62-N
[73] https://www.havochvatten.se/hav/fiske--fritid/skyddade-omraden/skyddade-omraden/fiskereglering-i-skyddade-omraden/kosterfjorden---vaderofjorden.html
[74]https://www.lansstyrelsen.se/vastra-gotaland/privat/djur-och-natur/vatten/atgarder-i-vattenmiljoer.html

Indicator	Metric	Sweden	Denmark	Norway
		Regulated by the Common Fisheries Policy (1380/2013) and associated yearly directives such as quotas.		The fishery is included in the EBFM approach (Gullestad et al. 2017) and is catch regulated by individual vessel quotas (Søvik & Thangstad 2014). Measures are taken to ensure continuous market supply through allocating the quota evenly to three periods of 4 months each (40, 30, and 30% of the quota respectively (Ziegler et al. 2016).
		To keep permit to fish for shrimp a minimum landing volume of shrimp per year is required (1 tonne). There are specific national regulations of the shrimp fishery in Sweden with individually transferable quotas within two segments (small and large vessels). This is not a permanent ITQ as in Denmark; quotas are transferable within each year (and segment).	Introduced Individual Transferable Quotas (ITQ) in 2007 (Eigaard et al. 2011), given to fishers free of charge based on their landings in a reference period (2003 to 2005) intended to reduce overcapacity and improve the economic performance (Nielsen et al. 2013). Current system only give access through buying existing quotas.	

3.1.4.3 Institutional capacity

Indicator	Metric	Sweden	Denmark	Norway
Accountability of decision-making bodies	Level of accountability	Medium	Medium	High
Uncertainty management	Extent of incorporation of uncertainty in management of the targeted stock	High		

The Healthcheck indicator Accountability of decision-making bodies utilizes MSC scores on accountability and transparency through the decision-making process. Performance indicator 3.2.2d evaluates how easy stakeholders can get access to information about the fishery's performance and management actions. For 80 points, information on fishery performance and management action is available on request, and explanations are provided for any actions or lack of action associated with findings, and relevant recommendations emerging from research, monitoring, evaluation and review activity (which were achieved for Swedish and Danish shrimp fisheries). Maximum score is achieved if there is formal reporting to all stakeholders, which provides comprehensive information on fishery performance and management actions and describes how the management system responded to findings and relevant recommendations emerging from research, monitoring, evaluation and review activity (achieved by Norwegian shrimp fisheries). For Healthcheck, this equals to:

- Low – Some information on the fishery's performance and management action is generally available on request to stakeholders;
- Medium - Information on the fishery's performance and management action is available on request, and explanations are provided for any actions or lack of action associated with findings and relevant recommendations emerging from research, monitoring evaluation and review activity;
- High - Formal reporting to all interested stakeholders provides comprehensive information on the fishery's performance and management actions and describes how the management system responded to findings and relevant recommendations emerging from research, monitoring, evaluation and review activity.

Uncertainty management are in the Healthcheck framework addressed by using MSC Performance indicators 1.2.4c,d. In the initial assessment, 1.2.4c was met with the justification (MSC 2015):

"*The surplus production model takes uncertainty into account in a probabilistic way. The assessment model is a Bayesian model which provides posterior distributions of parameter estimates, and which provides projections of estimated risk of falling below biomass reference points and of exceeding fishing mortality reference points.*"

The performance indicator 1.2.4d, "the assessment has been tested and is robust, exploring alternative hypothesis and assessment approaches", was however not met. The reason for complying with this criterion was that the "*the lack of size structure information in the model results in the model being insensitive to large and rapid changes in recruitment*."

Weighed together, however, the performance indicator 1.2.4 Assessment of stock status was met in the initial assessment (score 90). Of note, both assessment methodology and management strategy have changed since the MSC-certification.

3.1.4.4 Compliance

<table>
<tr><th>Indicator</th><th>Metric</th><th>Sweden</th><th>Denmark</th><th>Norway</th></tr>
<tr><td>Compliance regime (catch)</td><td>Level of compliance</td><td colspan="3">Not analysed/organised at the fishery level for all countries exploiting the stock. Illegal high-grading of small shrimp is documented in e.g. stock assessments. The MSC reports state that for the shrimp fishery in 2017:

Sweden (MSC 2018a): recent infringements concern minor issues such as late logbook submissions and inaccurate reporting in logbooks but also one prosecution of high-grading offences.

Denmark (MSC 2018b): minor non-compliance such as inaccurate recording in logbooks.

Norway (MSC 2019): minor non-compliance such as document control or landing site.

Furthermore, after the high-grading issue was raised by WWF, Sweden has developed a control strategy for the shrimp fishery, commissioned by the Swedish Government[75].</td></tr>
<tr><td rowspan="2">Surveillance (compliance monitoring)</td><td rowspan="2">Surveillance effort</td><td colspan="2">All fishing vessels ≥12 m are required to be equipped with VMS.</td><td rowspan="2">Only vessels ≥15 m are required to record logbook data. Vessels <11 m length don’t require fishing license.

The Norwegian Coast Guard is responsible for exercising resource control, together with the Directorate of Fisheries and the sales associations.

Norway samples shrimp catches at sea to measure the percentage shrimp below</td></tr>
<tr><td>SwAM is responsible for overall control, the Coast Guard is responsible for at-sea surveillance. There are also inspections with airplanes. Based on information from SwAM, approximately 30 000 fishing</td><td>The whole fleet is equipped with VMS.

The Danish coast guard is responsible for control at sea. Regular control of potential high-grading of shrimp at sea is not performed; the shrimp vessels</td></tr>
</table>

[75] Havs- och vattenmyndighetens och Kustbevakningens rapport 2014-05-30. https://www.kustbevakningen.se/globalassets/documents/hallbar-havsmiljo/rapport-ru---kontrollstrategi-rakfisketpdf

Indicator	Metric	Sweden	Denmark	Norway
		trips are performed each year in all fisheries in Sweden (2 716 trips in the shrimp fishery in 2013[75]). Since 220 inspections at sea were carried out in 2017 (of which 68 targeted eel and salmon)[76], the percentage surveillance effort is very low for the fishery. In the shrimp fishery, 30 inspections at sea was performed under 2014[76].	are few and they mainly fish in Swedish waters[76].	Minimum Catch Size (MCS); if above a certain threshold, the fishery have to move to other area to fish (Real-Time Closure). If discard is seen, this is reported on.

In Sweden, there's around a hundred entrances recorded into restricted areas that have the potential to be illegal fishing activities but requires further investigation to be sure if fishing activities has occurred or only transit of vessel (HaV 2018).

3.1.4.5 Adaptive capacity – climate

Indicator	Metric	Sweden	Denmark	Norway
Governance arrangements	Climate change recognition	Not found.		
Coping strategies for climate change	Climate responses	Not found.		

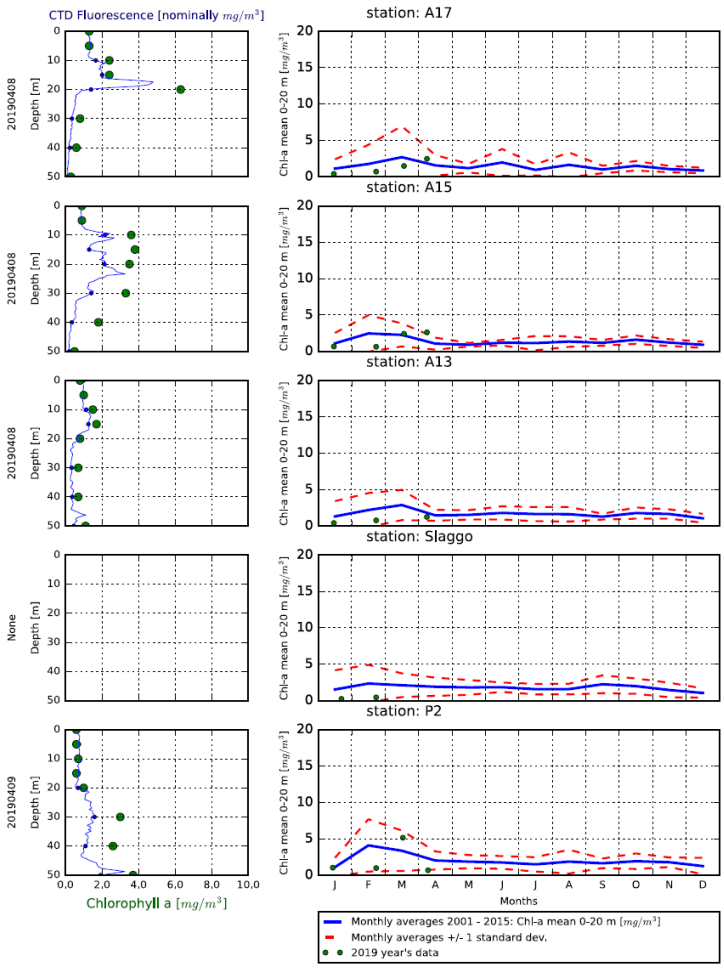
This indicator reports on if the management consider impact of climate change on the fishery and if the fishery has initiated coping strategies to mitigate potential impacts. No information is found for the fishery.

[76] https://www.kustbevakningen.se/globalassets/documents/om-oss/vart-uppdrag/budgetunderlag-sammanstallning/kustbevakningens-budgetunderlag-2019-2021pdf

3.1.5 External influences

External influence on the fishery may be of high importance, such as occurrence of toxins which may restrict markets.

3.1.5.1 Environmental context

Indicator	Metric	All countries
Environmental productivity	Mean chlorophyll (mgC*m3)	 From: AlgAware. Algal situation in marine waters surrounding Sweden. No. 4 April 2019. Dnr: S/Gbg-2019-48.
Ecosystem character	Description of the ecosystem	Deep soft sediments.

In the Australian Healthcheck, a time series with average monthly values (in mg/m^3) from the MODIS database (provided by NASA) is recommended to use[77]. For the Skagerrak, chlorophyll is measured in situ and reported on by several organisations. There is e.g. an oceanographic database provided by ICES[78]. Chlorophyll is e.g. included in OSPAR assessments and reported on as an indicator of pressures from human activities (for Skagerrak, a decreasing trend offshore and fluctuating but stable in coastal waters)[79]. Chlorophyll a is monitored by all three countries and potential differences between sampling strategies evaluated[80]. Here, the latest report by the Swedish Meteorological and Hydrological Institute (SMHI) is presented (published every month)[81].

The Greater North Sea Ecoregion overview provided by ICES[82] reports:

"• *The North Sea is characterized by episodic changes in the productivity of key components of the ecosystem. Phytoplankton, zooplankton, and demersal and pelagic fish have all exhibited such cycles in variability. Managers should expect change and ensure that management plans have the potential to respond to new circumstances.* [...].

• *The changes have been described as regime shifts; a notable example is the composition of the zooplankton community, which changed both in terms of species and size composition in the late 1980s and again around 2000.*"

3.1.5.2 Climate-related fishery impacts

Indicator	Metric	All countries
Susceptibility of target species captured by the fishery to climate change	Target species impacted by climate change	Documented susceptibility (Arnberg et al. 2013).
Susceptibility of key fishery habitats to climate change	Habitat impacts of climate change	Not found.

Effects from climate change (such as ocean acidification and rising water temperatures) may affect the fishery directly or indirectly, both positively and negatively. The indicator Susceptibility of target species captured by the fishery to climate change can be reported with Silver standard since limited information is found (one peer-reviewed study).

[77] https://modis.gsfc.nasa.gov/data/dataprod/chlor_a.php
[78] https://www.ices.dk/marine-data/data-portals/Pages/ocean.aspx
[79] https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/eutrophication/chlorophyll-concentrations/
[80] Carstensen, J. 2016. Intercalibration of chlorophyll a between Denmark, Norway and Sweden. Western Baltic (BC6), Kattegat (NEA8b) and Skagerrak (NEA8a, NEA9 and NEA10). Aarhus University, DCE – Danish Centre for Environment and Energy, 38 pp. Technical Report from DCE – Danish Centre for Environment and Energy No. 76 http://dce2.au.dk/pub/TR76.pdf
[81] https://www.smhi.se/polopoly_fs/1.146899!/algsit19_4.pdf
[82] http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/GreaterNorthSeaEcoregion_EcosystemOverview.pdf

The Greater North Sea Ecoregion overview provided by ICES[82] reports that temperature cycles, such as the Atlantic Multidecadal Oscillation, affects the North Sea.

3.1.5.3 Contaminants in the environment

Indicator	Metric	EU	Norway
Detection system for seafood contaminants	Risk for concentration of contaminants	Addressed by Descriptor 8 Concentrations of contaminants give no effects but only assessed, to our knowledge, by Sweden so far.	NIFES monitors the content of undesirable substances in wild seafood on a yearly basis. Contaminants in the marine environment is monitored by Havforsknings-instituttet[83]. Norway also reports on this aspect in their EBFM tool[84].
Management arrangements to ensure food safety related to contaminants	Evidence for arrangements	Food legislation is to a large extent harmonized within the EU, where the National Food Agencies assist to develop new legislation in co-operation with other EU member states. The company that produces or sells food is responsible for food safety. The National Food Agency carries out food control at the national level. In Sweden, the County Administrations carries out at the regional level and the municipal Environment and Health Protection Committees at the local level.	Based on NIFES monitoring[85], no diet restrictions or health risks found for shrimp[86].

For this indicator, the MSFD Descriptor 8 Concentrations of contaminants give no effects and Descriptor 9 Contaminants in seafood are below safe levels may be useful for EU

[83] https://www.hi.no/temasider/forurensing/nb-no
[84] https://www.fiskeridir.no/Yrkesfiske/Dokumenter/Reguleringsmoetet/Sakspapirer-innspill-og-referat-fra-reguleringsmoetene/Reguleringsmoetet-juni-2018
[85] https://nifes.hi.no/forskningstema/trygg-sjomat/
[86] https://sjomatdata.hi.no/#/seafood/1107

fisheries. Shrimps are not monitored for the descriptor D9C1[87], only blue mussels, perch and herring (but no risk was found for those species and substances investigated). For Descriptor 8, the water basin where the fishery takes place has been assessed by SwAM (three criteria). Presence of PTB, Cesium-137, TBT and oil spills risks not achieving GES.

In a recent investigation commissioned by the Swedish Agency for marine and Water Management (SwAM), residues from chemical weapons found in the area were detected in shrimp samples; no samples exceeded levels of safe human consumption (Ahlsén et al. 2018).

3.1.5.4 Market drivers

Indicator	Metric	Sweden	Denmark	Norway
Macroeconomic factors	Exchange rates (relative to €)	0.096	0.134	0.103
	Diesel price (€/l)	1.64	1.34	1.51
Consumer trends	Per capita annual consumption of seafood (kg)	26.9	22.9	Further investigations needed, indicative value: > 50

Exchange rates are based on conversion by www.xe.com (Accessed: 20th of March 2019).

Diesel price for the three countries are based on https://gasoline-germany.com (Accessed on 27th of March 2019). The latest STECF report states that the average fuel prices increased in Denmark with 14% from 2016 to 2017 and has continued to rise. In Norway, there is a discussion on increasing CO_2 taxes for fisheries[88], on the other hand, if the vessel reduces NO_x emissions through adopting a reduction measure, fuel costs can decrease (vessels are taxed on NO_x emissions; Jafarzadeh et al. 2017).

Data on Consumer trends for Sweden and Denmark are easily accessible through EUMOFA, updated every year. Apparent consumption for Norway is reported in the latest FAO report (FAO 2018); Norway belongs to the top countries in the world in terms of seafood consumption (>20% contribution of seafood to animal protein supply).

[87] Pollutants included are cadmium, lead, mercury, benso(a)pyren, dioxins and dioxin-like PCBs and non-dioxin-like PCBs.
[88] https://www.stortinget.no/no/Saker-og-publikasjoner/Vedtak/Vedtak/Sak/?did=40021826&p=66653

3.2 Summary Healthcheck outcome

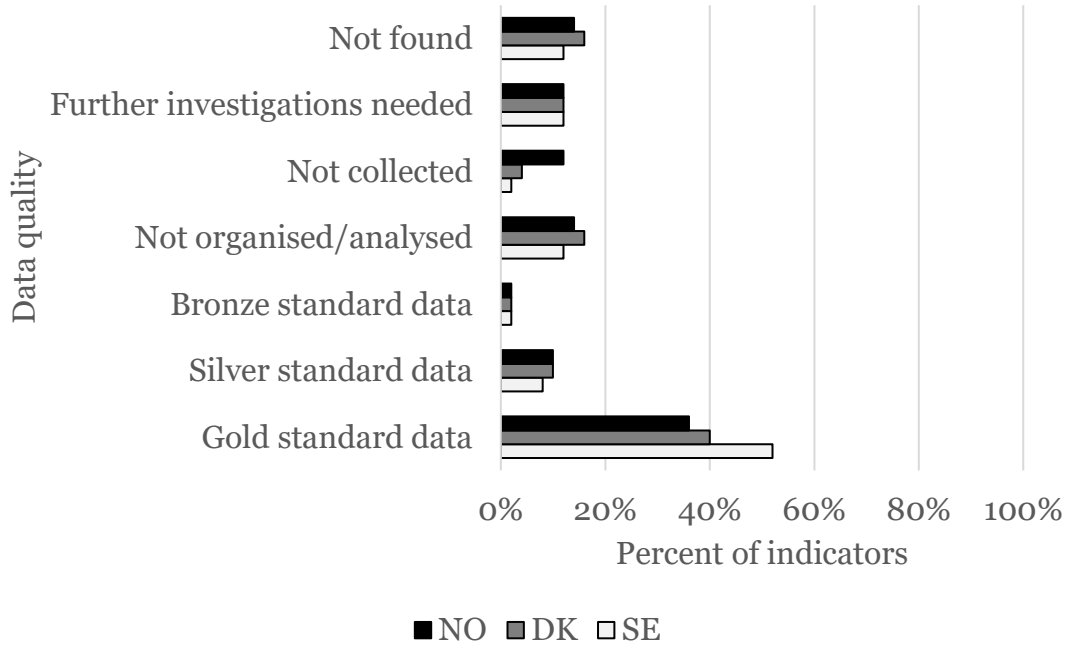


Figure 2 Data quality outcome for the Healthcheck indicators applied to the Skagerrak shrimp fishery. NO= Norway, DK= Denmark and SE= Sweden.

Across Healthcheck indicators investigated, the Skagerrak region shrimp fishery could be reported on with gold standard data for 36-52% of the indicators between countries while 14-26% of the indicators could not be found or were not collected (Figure 2). To be able to transparently report on the whole fishery, some challenges remain concerning standardizations of data across countries; 24-28% of the indicators were not organised/analysed or required further investigations (such as appropriate metrics or require effort to standardize between countries).

3.3 Recent development

Many changes have occurred in the fishery since 2012, some examples include:

2013 Use of selective grid became mandatory for all countries (inside of 4 nm in Norway since 1st of May 2019), with the possibility to include a fish retention tunnel when fishing outside of the national trawl border if the vessel holds quotas for fish.

2016 The landing obligation began to be gradually enforced, and as a result, official fish discards in the Swedish and Danish fisheries have decreased. Increased effort with only grid is seen in the Swedish fishery, and therefore, less discard since 2013 (Bergenius et al. 2018).

2017 Individual fishing rights in the Swedish shrimp fishery is distributed on an annual basis.

Official scientific estimates of discard rates of shrimp reveal that discard (in tonne per tonne shrimp landed) has dramatically decreased in the Swedish fishery since 2012 and is now at similar level as the Danish fishery. Discard data on shrimp is not collected in Norway, thus not possible to evaluate.

Standardized Landing Per Unit Effort (LPUE) of shrimp increased continuously between 2013 and 2015 but has in recent years started to decline again (NIPAG 2018). As a result, many of the indicators investigated in the paper by Ziegler and colleagues in 2016 (in particular seafloor area swept and fuel use per tonne) would have improved since then (the LPUE estimate was in 2012 around 0.6-0.7, in recent years it has been around 1.0) – even if they are likely increasing again. The Swedish fleet has continuously had the lowest standardized LPUE of the three countries until latest assessment when all countries exhibit the same LPUE. Perhaps this development is explained for Sweden as the result of an overall decrease in effort in the shrimp fishery between 2012 and 2017. With the same LPUE across fleets, potential differences between countries are perhaps smaller.

For the 2012 assessment (Ziegler et al. 2016), the DCF collected fuel use and employment data for the shrimp fishery was not available for research at a detailed enough level for Danish and Swedish fisheries. Based on a theoretical model using kW and effort, fuel use in this fishery was at the time estimated to be 5.7 L/kg shrimp in Sweden and Norway whereas 4.5 l/kg shrimp in Denmark (Ziegler et al. 2016). For this report, Swedish EU-MAP data on fuel use was provided by SwAM upon request[89] but not reported on under the indicator Energy use since it only covered Swedish fisheries and would not have provided a comparable figure with the other countries. Based on this data, fuel use was estimated to be 3.1 l/kg (0.6 standard error) in the Swedish fishery in 2017 (57% of landing volume comprised of shrimp, based on 38 vessels). These estimates are not comparable with the 2012 results by Ziegler and colleagues (2016) since they are based on different methods, e.g. includes all fishing activities by the vessel (not only shrimp trawling). In the EU MAP data set, the largest vessels (>24 m) are the most fuel intensive

[89] Vessels defined as prawn fishers if more than 50% of landed value comprise of prawn (the sample includes vessels contributing with on average 90% of the total shrimp landing value and volume).

per kilo landing (4.1 l/kg), followed by the smallest (<12 m; 3.5 l/kg); the categories in between, 12-18 m and 18- 24 m are equally fuel efficient (around 2.6 l/kg landing). Furthermore, employment data (FTE) for the Swedish fishery was also provided by SwAM based on EU-MAP data. FTE has decreased since 2012 and is now around 0.04 FTE/tonne compared to 0.06 FTE respectively.

4 Discussion

This exercise has provided insights on a broad range of sustainability aspects related to Northern shrimp fishing in the Skagerrak region – data availability, differences between national fleets and management agencies – offering a uniquely broad overview of the fishery. Therefore, the study is also a point of departure for future work studying the collected data more in detail and the possible implications of different management objectives and actions taken.

The indicators of the Australian Healthcheck could most often be reported on with gold standard data, but further investigations are also needed for many indicators. It is widely accepted that development of indicators for assessments of fisheries is a continuous work-in-progress (e.g. Rice and Rochet, 2005; Stephenson et al. 2017). Further development may thus be needed also for the Healthcheck. Some indicators are e.g. not very transparent, such as those related to Institutional capacity, and may be difficult to evaluate for many small-scale fisheries, without an MSC assessment. However, the general structure of the Australian Healthcheck, i.e. combining the most important aspects of seafood product-based assessment (Life Cycle Assessment-related in the form of carbon footprint and fuel use per tonne) and ecological risk assessment of fisheries (some indicators related to the ecological category such as habitats) with social, economic and institutional aspects of a fishery may be seen as a tiny proportion of the best of many worlds of assessing seafood sustainability – but also comes with compromises: keeping it simple, holistic and realistic (the latter based on data requirements).

A challenge ahead is also to identify how data could be standardized across countries to holistically report on a multijurisdictional fishery, and adaptations potentially needed for the Australian Healthcheck to be useful in a European context. This task should ideally include comparing management objectives in Europe and Australia, and how data collection may differ. One particularly important task for EU fisheries may be to integrate with the requirements of the Marine Strategy Framework Directive (2008/56/EG) of the European Union, aiming at achieving Good Environmental Status (GES) by year 2020. There may be more indicators that should be included to provide a holistic environmental assessment of fisheries in EU waters, such as Descriptor 11 Introduction of energy (including underwater noise) does not adversely affect the ecosystem; Descriptor 2 Non-indigenous species do not adversely alter the ecosystem; Descriptor 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem. Of note, Sweden recently evaluated GES for Descriptor 3: 'The population of commercial fish species is healthy'. Northern shrimp is not classified as GES for either D3C1 on fishing mortality nor D3C2 on spawning stock biomass (HaV 2018:27). The authors are not aware of any Danish MSFD assessments.

At last, to evaluate the sustainability of a fishery, it is very important to not only look at one indicator or metric in isolation. Habitat pressure is e.g. in general high from shrimp fishing (Chapter 3.1.1.4) but this may be mitigated in the form of suitable governance arrangements (Chapter 3.1.4). Evaluating whether this is enough to be categorized as sustainable is to a certain extent science-based, but also a matter of personal values and depends on management objectives since it represents a trade-off between different needs: conservation and fishing. In particular what is not currently protected may in this regard deserve attention; deep soft mud habitats where the fishery operates are intensively utilized today (91% of area in 2015[90]) and may need to decrease to safeguard ecosystem structure and function.

To this end, in a multijurisdictional fishery such as the fishery assessed here, the different management objectives between national agencies may be reflected in the outcome for the country. These potential differences may be used to 1) transparently report on potential trade-offs of different management systems, and 2) provide decision-support for management agencies to act upon to mitigate unintentional consequences.

5 Acknowledgements

The analysis was initiated and funded by World Wildlife Fund (WWF) Sweden. The authors also want to thank Daniel Valentinsson (SLU) and Ole Ritzau Eigaard (DTU) for valuable input to the study.

[90] http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.13.pdf

6 References

Ahlsén, J., Bergkvist, J., Magnusson, M. and Granmo, Å. (2018) Undersökning av biota i anslutning till dumpade fartyg med kemisk ammunition. Havs- och vattenmyndighetens rapport 2018:21. ISBN 978-91-88727-12-1 (In Swedish)

Amoroso, R. O., Pitcher. C. R., Rijnsdorp, A. D., McConnaughey, R. A., Parma, A. M., Suuronen, P., et al. (2018) Bottom trawl fishing footprints on the world's contintental shelves. *PNAS* 115(43): E10275-E10282

Arnberg, M., Calosi, P., Spicer, J. I., Taban, I. C., Bamber, S. D., Westerlund, S., et al. (2018) Effects of oil and global environmental drivers on two keystone marine invertebrates. Scientific reports, 8.

Bergenius, M., Ringdahl, K., Sundelöf, A., Carlshamre, S, Wennhage, H. Valentinsson, D. (2018) Atlas över svenskt kust- och havsfiske 2003-205. Aqua reports 2018:3. Sveriges lantbruksuniversitet, Institutionen för akvatiska resurser, Drottningholm Lysekil Öregrund. 245 s.

Chuenpagdee, R., L. E. Morgan, S. M. Maxwell, E. A. Norse and D. Pauly (2003) Shifting gears: assessing collateral impacts of fishing methods in US waters. Frontiers in Ecology and Environment 1(10): 517-524

Condie, H. M., Grant, A., & Catchpole, T. L. (2014) Incentivising selective fishing under a policy to ban discards; lessons from European and global fisheries. Marine Policy, 45, 287-292.

Dahl, M. P., Pereyra, R. T., Lundälv, T. and André, C. (2011) Fine-scale spatial genetic structure and clonal distribution of the cold-water coral *Lophelia pertusa*. Coral reefs 1:1135-1148

Directorate of Fisheries (2019) Booklets. Available at: https://www.fiskeridir.no/English/Fisheries/Statistics/Booklets

Eigaard, O. R., Bastardie, F., Hintzen, N. T., Buhl-Mortensen, L., Buhl-Mortensen, P., Catarino, R., et al. (2017) The footprint of bottom trawling in European waters: distribution, intensity, and seabed integrity. ICES Journal of Marine Science 74(3): 847-865

Eigaard, O. R., and Munch-Petersen, S. (2011) Influence of fleet renewal and trawl development on landings per unit effort of the Danish northern shrimp (*Pandalus borealis*) fishery. ICES Journal of Marine Science 68: 26–31

FAO (2018) The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Licence: CC BY-NC-SA 3.0 IGO.

Fiskeridirektoratet (2015) http://fiskeridir.no/Yrkesfiske/Regelverkog-reguleringer/J-meldinger/Gjeldende-J-meldinger/J-175-2015) (last accessed 18 August 2015).

Fiskeridirektoratet (2018) Vedlegg 1. Fisheries table 2018. Accessed February 2019. Available at: https://www.fiskeridir.no/Yrkesfiske/Dokumenter/Reguleringsmoetet/Sakspapirer-innspill-og-referat-fra-reguleringsmoetene/Reguleringsmoetet-juni-2018

Garcia, S. M. (2003) The ecosystem approach to fisheries: issues, terminology, principles, institutional foundations, implementation and outlook (No. 443). Food & Agriculture Org.

Gullestad, P., Blom, G., Bakke, G., and Bogstad, B. (2015) The "Discard Ban Package": experiences in efforts to improve the exploitation patterns in Norwegian fisheries. Marine Policy 54: 1–9

Gullestad, P., Abotnes, A. M., Bakke, G., Skern-Mauritzen, M., Nedreaas, K., & Søvik, G. (2017). Towards ecosystem-based fisheries management in Norway–practical tools for keeping track of relevant issues and prioritising management efforts. Marine Policy 77: 104-110

HaV (2018) https://www.havochvatten.se/hav/fiske--fritid/skyddade-omraden/skyddade-omraden/nyheter-om-skyddade-omraden/arkiv/2018-11-21-sa-kontrollerar-hav-fiske-i-skyddade-omraden.html

HaV (2018:27) Marin strategi för Nordsjön och Östersjön 2018-2023. Bedömning av miljötillstånd och socioekonomisk analys. Havs- och vattenmyndighetens rapport 2018:27. ISBN 978-91-88727-18-3

Hobday, A. J., Fleming, A., Ogier, E. M., Thomas, L., Hartog, J. R., Hornborg, S., & Stephenson, R. L. (2018). Perceptions regarding the need for broad sustainability assessments of Australian fisheries. Fisheries Research 208: 247-257

Hobday, A. J., Ogier, E. M., Fleming, A., Hartog, J. R., Thomas, L., Hornborg, S., & Stephenson, R. L. (2019) Australian Fisheries Healthcheck Phase 2. FRDC Project No 2016/060. ISBN 978-1-4863-1241-2 online

Hobday, A. J., Smith, A. D. M., Stobutzki, I. C., Bulman, C., Daley, R., Dambacher, J. M., et al. (2011) Ecological risk assessment for the effects of fishing. Fisheries Research, 108(2-3): 372-384

ICES (2018a) Northern shrimp (*Pandalus borealis*) in divisions 3.a and 4.a East (Skagerrak and Kattegat and northern North Sea in the Norwegian Deep) http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/pra.27.3a4a_oct.pdf

ICES (2018b) Greater North Sea Ecoregion – Ecosystem overview. https://doi.org/10.17895/ices.pub.4670

ICES (2019) Northern shrimp (*Pandalus borealis*) in divisions 3.a and 4.a East (Skagerrak and Kattegat and northern North Sea in the Norwegian Deep). http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2019/2019/pra.27.3a4a.pdf

Isaksen, J. R., Hermansen, Ø. and Flaaten, O. (2015) Stubborn fuel tax concessions: the case of fisheries in Norway. Marine Policy 52: 85-92

Jafarzadeh, S., Paltrinieri, N., Utne, I. B., & Ellingsen, H. (2017) LNG-fuelled fishing vessels: A systems engineering approach. Transportation Research Part D: Transport and Environment 50: 202-222

Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R. et al. (2018) Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. Scientific reports 8(1): 4666

Linders, T., Nilsson, P., Wikström, A. and Sköld (2017) Distribution and fate of trawling-induced suspension of sediments in a marine protected area. ICES Journal of Marine Science 75(2): 785-795

Marchal, P., Andersen, J. L., Aranda, M., Fitzpatrick, M., Goti, L., Guyader, O. et al. (2016) A comparative review of fisheries management experiences in the European Union and in other countries worldwide: Iceland, Australia, and New Zealand. Fish and fisheries 17(3): 803-824

MSC (2015) Sweden Skagerrak, Kattegat and the Norwegian Deep cold water prawn fishery. Public Certification Report. https://fisheries.msc.org/en/fisheries/sweden-skagerrak-kattegat-and-the-norwegian-deep-cold-water-prawn/@@assessments

MSC (2016a) Denmark Skagerrak and Norwegian Deep cold water prawn fishery. Public Certification Report. https://fisheries.msc.org/en/fisheries/denmark-skagerrak-and-the-norwegian-deep-cold-water-prawn/@@assessments

MSC (2016b) Norway Skagerrak and Norwegian Deep cold water prawn fishery. Public Certification Report. https://fisheries.msc.org/en/fisheries/norway-skagerrak-and-the-norwegian-deep-cold-water-prawn-fishery/@@assessments

MSC (2018a) Surveillance audit – Report for the Sweden Skagerrak, Kattegat and Norwegian Deep cold water prawn fishery. https://fisheries.msc.org/en/fisheries/sweden-skagerrak-kattegat-and-the-norwegian-deep-cold-water-prawn/@@assessments

MSC (2018b) Surveillance audit – Report for the Denmark Skagerrak and Norwegian Deep cold water prawn fishery. https://fisheries.msc.org/en/fisheries/denmark-skagerrak-and-the-norwegian-deep-cold-water-prawn/@@assessments

MSC (2019) Surveillance audit – Report for the Norway Skagerrak and Norwegian Deep cold water prawn fishery. https://fisheries.msc.org/en/fisheries/norway-skagerrak-and-the-norwegian-deep-cold-water-prawn-fishery/@@assessments

Nielsen, J. R., Ulrich, C., Hegland, T. J., Voss, B. D., Thøgersen, T. T., Bastardie, F., Goti, L., et al. (2013) Critical report of current fisheries management measures implemented for the North Sea mixed demersal fisheries. National Institute of Aquatic Resources, Technical University of Denmark (DTU Aqua Report; No. 263-2013).

NIPAG (2018) NAFO/ICES *Pandalus* Assessment Group Meeting, 17 to 22 October 2018. SCS Doc. 18/21 Serial No. N6898. NAFO Secretariat, Dartmouth, Canada. NAFO

Rice, J. C. and M.-J. Rochet (2005) A framework for selecting a suite of indicators for fisheries management. ICES Journal of Marine Science 62: 516-527

STECF (2018) Scientific, Technical and Economic Committee for Fisheries (STECF) – The 2018 Annual Economic Report on the EU Fishing Fleet (STECF-18-07). Publications Office of the European Union, Luxembourg, 2018, JRC112940, ISBN 978-92-79-79390-5, doi:10.2760/56158

Stephenson, R. L., A. J. Benson, K. Brooks, A. Charles, P. Degnbol, C. M. Dichmont, M. Kraan, S. Pascoe, S. D. Paul, A. Rindorf and M. Wiber (2017) Practical steps toward integrating economic, social and institutional elements in fisheries policy and management. ICES Journal of Marine Science 74(4): 1981–1989

Storr-Paulsen, M., Håkansson, K. B., Egekvist, J., Degel, H. and Dalskov, J. (2012) Danish sampling of commercial fishery: Overview with special attention to discards 2010 data. Charlottenlund: National Institute of Aquatic Resources, Technical University of Denmark. DTU Aqua Report, No. 250-2012. http://orbit.dtu.dk/files/12618227/250_2012_danish_sampling_of_commercial_fishery.pdf (Accessed on 22nd of March 2019)

Søvik, G. and Thangstad, T. H. (2014) The Norwegian Fishery for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east), 1970–2014. NAFO SCR Doc. 14/063. 33 pp.

Thorvaldsen, T. and Sønvisen, S. A. (2014) Multilingual crews on Norwegian fishing vessels: Implications for communication and safety on board. Marine Policy 43: 301-306

Viðarsson, J. R., Einarsson, M. I., Ragnarsson, S. Ö., Laksá, U., Danielsen, R., Iversen, A., et al. (2018) Nordic coastal fisheries and communities: Status and future prospects. Nordic Council of Ministers. TemaNord 2018:507. ISBN 978-92-893-5377-9 (PDF)

Ziegler, F., Hornborg, S., Valentinsson, D., Skontorp Hognes, E., Søvik, G., and Ritzau Eigaard, O. (2016) Same stock, different management: quantifying the sustainability of three shrimp fisheries in the Skagerrak from a product perspective. ICES Journal of Marine Science 73(7): 1806-1814

Appendix 1 Data availability and quality

Tabell 1 Summary table of data quality and further investigations needed. Gold standard equals to existing and standardized data across countries exploiting the stock; Silver standard is the equivalent of existing data but not recent. Further investigations needed implies that there is no standardized data collection across countries for the metric or the metric requires development for the fishing area.

Category	Indicator	Indicator	Sweden	Denmark	Norway
Biological	Target species	Stock status	Gold standard data		
		Harvest level	Gold standard data		
	Bycatch species	Bycatch composition	Not organised/analysed		Not collected
		Bycatch amount	Not organised/analysed		Not collected
	Protected species	Capture amount	Not organised/analysed		Not collected
		Reporting	Gold standard data	Silver standard data	Not collected
	Habitats	Habitat impact	Further investigations needed		
		Habitat status	Further investigations needed		
	Ecological communities	Ecosystem status	Further investigations needed		
		Ecosystem structure	Further investigations needed		
	Carbon and pollution	Macro plastics	Not found.		
		Carbon footprint	Silver standard data		
Economic	Fishery benefits	Net economic returns	Not organised/analysed		
		Gross Value of Production	Gold standard data	Not organised/analysed	
		Profitability	Not organised/analysed		
		Latency	Further investigations needed		
	Community benefits	GDP value to communities	Not organised/analysed		
		Wealth spread	Not organised/analysed		Not found

Category	Indicator	Indicator	Sweden	Denmark	Norway
	Markets	Fish distribution	Gold standard data		Not organised/analysed
		Volatility in market price	Gold standard data	Not found	Not organised/analysed
	Energy costs	Energy use	Silver standard data		
		Fossil fuel subsidies	Gold standard data	Not found	Gold standard data
Governance	Ecosystem governance	Bycatch mitigation	Gold standard data		
		Protected species mitigation	Gold standard data		
	Management systems	Harvest strategy	Gold standard data		
		Management plans	Gold standard data		
	Institutional capacity	Accountability of decision-making bodies	Gold standard data		
		Uncertainty management	Gold standard data		
	Compliance	Compliance regime (catch)	Gold standard data		
		Surveillance (compliance monitoring)	Silver standard data		
	Adaptive capacity - climate related	Governance arrangements	Not found		
		Coping strategies for climate change	Not found		
Social & Ethical	Fisher wellbeing	Fisher satisfaction	Not collected		
		Age structure	Gold standard data	Not organised/analysed	
	Wider community	Community satisfaction with fishery	Not collected		

Category	Indicator	Indicator	Sweden	Denmark	Norway
		Levels of local employment	Further investigations needed.		
	Ethical - human welfare	Protections in place	Gold standard data		
		Level of compliance	Gold standard data		
	Ethical - animal welfare	Animal welfare protections	Not found		
		Level of compliance	Not found		
	Adaptive capacity of the fishery	Access to information	Gold standard data		
		Access to networks	Gold standard data		
External influences	Environmental context	Environmental productivity	Gold standard data		
		Ecosystem character	Gold standard data		
	Climate-related fishery impacts	Susceptibility of target species captured by the fishery to climate change	Bronze standard data		
		Susceptibility of key fishery habitats to climate change	Not found		
	Contaminants in the environment	Detection system for seafood contaminants	Gold standard data		
		Management arrangements to ensure food safety related to contaminants	Gold standard data		
	Market drivers	Macroeconomic factors	Gold standard data		
		Diesel price	Gold standard data		
		Consumer trends	Gold standard data		Silver standard data

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