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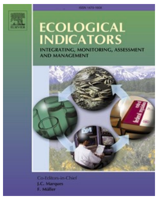

Short Note

Does the analysed size fraction of benthic foraminifera influence the ecological quality status and the interpretation of environmental conditions? Indications from two northern Norwegian fjords

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ABSTRACT

The introduction of the European Water Framework Directive has increased the interest in benthic foraminifera as a biomonitoring tool. This prompted the need to standardise the methods used to analyse benthic foraminifera, including which sediment fraction to analyse. In some regions benthic foraminifera produce small (< 125 μm) adult tests, and the current study assessed the effect of analysing the > 63 μm or > 125 μm fraction on determining the Ecological Quality Status (EcoQS) in two fjords in northern Norway. The diversity indices Shannon-Wiener index ($H'_{\log2}$) and Hurlbert's rarefaction index (ES_{100}), and the multi-metric Norwegian Quality Index (NQI), from both the > 63 μm and > 125 μm fraction resulted in the same or similar EcoQS, reflecting good environmental conditions in both fjords. The same applied to the AZTI's Marine Biological Index (AMBI), except at one location which had moderate EcoQS. At this location especially, more foraminifera with a tolerant or opportunistic response to organic matter enrichment occurred in the > 63 μm fraction than in the > 125 μm fraction. Hence, the higher $H'_{\log2}$ and ES_{100} of the > 63 μm fraction can be somewhat misleading as it indicates better environmental conditions, whereas the AMBI indicates more organic matter input. The *Stainforthia* group and *Epistominella vitrea*, indicating organic matter enrichment and increased primary productivity were, however, mostly absent in the > 125 μm fraction. Their absence in this fraction could have consequences for monitoring potential anthropogenic pressure factors and identifying long-term changes in environmental conditions when using this fraction. This study suggests the > 125 μm would be mostly sufficient for determining the EcoQS in northern Norway.

1. Introduction

The European Water Framework Directive (Water Framework Directive, 2000/60/EC) is a tool to protect coastal water bodies that uses predominantly benthic invertebrates to determine the Ecological Quality Status (EcoQS) of a waterbody defined as High, Good, Moderate, Poor, or Bad. Benthic foraminifera are known to rapidly respond to changes in environmental conditions (e.g. Sen Gupta, 1999), and after the WFD was introduced the interest in benthic foraminifera as a biomonitoring tool increased (Alve, 2003; Mojtahid et al., 2006). This prompted the need for a standardisation of the methods used to analyse benthic foraminiferal assemblages (see Schönfeld et al., 2012), which suggests samples should be washed over a 63 and 125 μm mesh but that only the foraminifera of the > 125 μm fraction are to be analysed unless research questions justify otherwise. The Norwegian guidelines (Veileder, 02:2018; based on the WFD) advises to follow the Dolven et al. (2013) method, which analysed the foraminiferal assemblages from the > 63 μm fraction.

Until this day a variety of different sediment fractions (e.g. > 63, > 100, > 125 or > 500 μm) have been and still are being used for benthic foraminiferal analyses (e.g. Dijkstra et al., 2017; Husum and Hald, 2004; Klootwijk et al., 2020; Schröder et al., 1987). It is not fully understood how environmental factors influence foraminiferal test sizes, however, small tests could indicate early reproduction stages (Diz et al., 2006), or reflect environmental conditions like heavy metal pollution and oxygen depleted environments (e.g. Alve, 2003, 1995; Bergamin and Romano, 2016; Mojtahid et al., 2006; Schönfeld et al., 2012). In the last scenario, it may be necessary to analyse the > 63 μm fraction. Benthic foraminiferal assemblage compositions can substantially vary depending on the analysed size fraction (e.g. Lo Giudice Cappelli and Austin, 2019), where even the difference between the > 125 μm and > 150 μm fraction can be significant (Weinkauf and Milker, 2018).

Analysing the > 63 μm fraction is regarded as substantially more labour intensive with an increased uncertainty in taxonomic identification (Schröder et al., 1987), but many scientific studies use this fraction as it is considered to contain the majority of environmental quality indicator species (e.g. Dolven et al., 2013; Duffield et al., 2017; Mojtahid et al., 2006). A study from the Norwegian Skagerrak found that the

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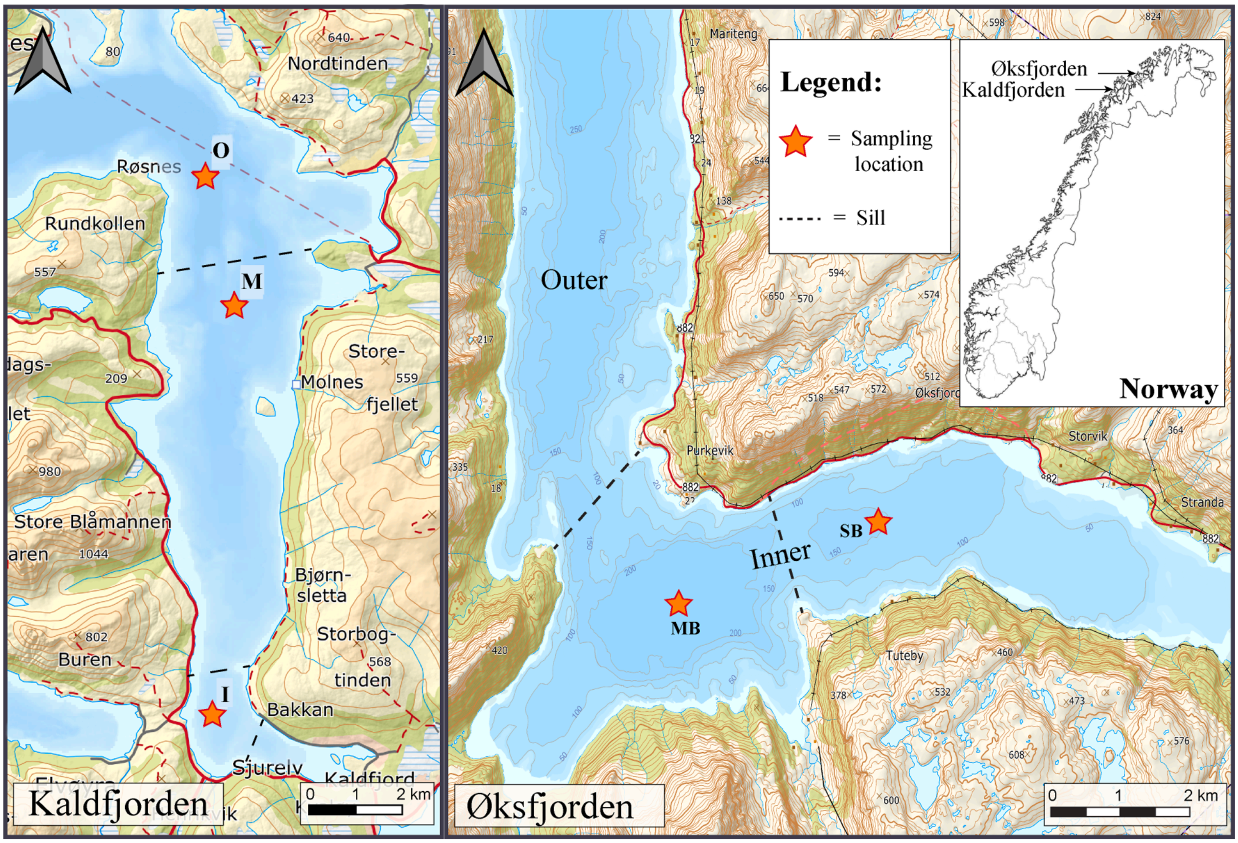

Fig. 1. left; Map of Kaldfjorden showing the Inner (I), Middle (M), and Outer (O) location (based on Norwegian Mapping Authority data; http://www.kartverket.no, 2020), right; Map of the inner and outer region of Øksfjorden showing the sampling locations in the main basin (MB) and sub-basin (SB), map from Statens kartverk (2007).

foraminiferal assemblages of the > 63 μm and > 125 μm fraction correlated suggesting a highly similar EcoQS, which indicates that the > 125 μm fraction may be good enough to establish the EcoQS (Bouchet et al., 2012). Another study from Nova Scotia, Canada showed that benthic foraminifera can produce small (< 125 μm), yet relatively easy to identify adult tests and that analysing only the > 125 μm fraction could create artificially barren zones (Schröder et al., 1987). Intensive fish farming is a major industry in Norway, which is most rapidly expanding in northern Norway (Fiskeridirektoratet, 2021). It is therefore important that the influence of the analysed size fraction on benthic foraminiferal biomonitoring in northern Norway is investigated.

This study is the first to investigate the effect of analysing the > 63 μm or > 125 μm fraction to establish the EcoQS using the Shannon Wiener ($H'_{\log 2}$), Hurlbert's rarefaction (ES_{100}), and the multi-metric Norwegian Quality Index (NQI; Alve et al., 2019), in addition to the AZTI's Marine Biological Index (AMBI; Alve et al., 2016) in northern Norway. To assess the potential loss of ecological information, foraminiferal distributions amongst Ecological Groups (EGs) representing the sensitivity of species to organic matter enrichment (*sensu* Alve et al., 2016) were investigated for both size fractions. The loss of species with ecological information was also assessed. This study provides new insights into benthic foraminiferal index functioning in an important fish farming region of Norway.

2. Anthropogenic influences in Kaldfjorden and Øksfjorden

In Kaldfjorden, northern Norway, a sewage wastewater outlet discharges mechanically treated wastewater of ~ 500 households at ~ 3.5 km distance from the nearest sampling location. The inner part of Øksfjorden (from here on referred to as Øksfjorden), is one of the most intensely fish farmed fjords in northern Norway. There are no large settlements, heavy industry or agricultural activities along both fjords. During sampling in 2017, the bottom waters of both fjords were well oxygenated, with a salinity of ~ 34–35 and temperatures between 5 and 6 °C (Klootwijk et al., 2020, 2021).

3. Methodology

In September 2017, both fjords were sampled for living rose Bengal stained foraminiferal analyses. In Kaldfjorden samples were collected using a box-corer (KC Denmark, 34.5 × 29 cm) collecting four different box-cores at three locations (Inner, Middle, Outer; Fig. 1) and from each box-core one sub-core (inner diameter 4.7 cm) was collected. In Øksfjorden samples were obtained using a modified Niemistö (1974) twin-barrelled Gemini gravity corer (inner diameter 8 cm), collecting three different cores from two basins (sub- and main basin; Fig. 1). From the collected cores, the upper 0–1 cm was sectioned off on deck and stored in a 70 % ethanol 2 g L^{-1} rose Bengal mixture (Schönfeld et al., 2012). The 0–1 cm sediment slices were washed over a 63 μm and 500 μm mesh after which the 63–500 μm fraction was split using a modified Elmgren wet splitter (Elmgren, 1973). These splits were further washed over a 63 μm and 125 μm mesh after which both fractions were completely picked until > 200 individuals could be identified and mounted. The > 500 μm sample could not be accurately wet-split due to large particles of organic material. Additionally, specimens in the > 500 μm fraction from the total sample comprised < 6 % of the picked assemblage. This fraction was, therefore, not included in the analyses. Some samples contained up to 1450 specimens of small (< 125 μm), difficult to tell apart *Stainforthia fusiformis* and *S. feylingi*. Hence, these two species were grouped into a *Stainforthia* group. Soft-

Table 1
Ecological Quality Status (EcoQS) class limits for the H'$_{log2}$, ES$_{100}$ and NQI after (Alve et al., 2019). The AMBI EcoQS is after Borja et al. (2003).

	H'$_{log2}$		ES$_{100}$		AMBI		NQI	
EcoQS	limits	width	limits	width	limits	width	limits	width
High	5 - 3.4	1.6	35 - 18	17	0 - 1.2	1.2	1 - 0.54	0.46
Good	3.4 - 2.4	1.0	18 - 13	5	3.3 - 1.2	2.1	0.54 - 0.45	0.09
Moderate	2.4 - 1.8	0.6	13 - 11	2	4.3 - 3.3	1	0.45-0.31	0.14
Poor	1.8 - 1.2	0.6	11 - 9	2	5.5 - 4.3	1.2	0.31-0.13	0.18
Bad	0 - 1.2	1.2	9 - 0	0	5.5 - 7.0	1.5	0.13-0	0.13

Table 2
The H'$_{log2}$, ES$_{100}$, AMBI and NQI for both the > 63 μm and > 125 μm fraction in both Kaldfjorden and Øksfjorden. Ecological Quality Status (EcoQS) for the H'$_{log2}$, ES$_{100}$ and NQI is after Alve et al. (2019). The AMBI EcoQS is after Borja et al. (2003).

		H'$_{log2}$			ES$_{100}$			AMBI			NQI		
Fjord	**Basin/ Location**	*> 63 μm*	*> 125 μm*	*Diff.*	*> 63 μm*	*> 125 μm*	*Diff.*	*> 63 μm*	*> 125 μm*	*Diff.*	*> 63 μm*	*> 125 μm*	*Diff.*
Kaldfjorden	Inner	4.5	3.9	0.6	26	21	5	2.4	1.2	1.2	0.71	0.72	-0.01
Kaldfjorden	Middle	4.2	4.2	0.0	25	28	-3	2.1	0.9	0.9	0.70	0.83	-0.13
Kaldfjorden	Outer	4.0	3.4	0.6	24	24	0	1.5	0.9	0.9	0.73	0.77	-0.04
Øksfjorden	sub-	3.4	3.4	0.0	21	19	2	3.5	1.2	1.2	0.55	0.69	-0.14
Øksfjorden	main-	4.2	3.5	0.7	23	18	5	3.0	2.4	2.4	0.61	0.59	0.02

shelled non-fossilisable foraminifera were excluded from the assemblages (*sensu* Bouchet et al., 2012).

Due to finding < 100 individuals in the > 125 μm fraction in Kaldfjorden, the replicates from each location for both size fractions were pooled in both fjords before calculating the indices. The H'$_{log2}$ (Shannon and Weaver, 1963) and ES$_{100}$ (Hurlbert, 1971) were calculated using the Vegan package in the R-data software program (Oksanen et al., 2010). The AMBI was calculated according to Alve et al. (2016), where only species or groups of species assigned to Ecological Groups (EG) were used. Foraminiferal distributions amongst EGs were calculated by adding the relative abundances of species or groups of species for each EG. The NQI was calculated using the AMBI and ES$_{100}$ following Alve et al. (2019). In this study, EcoQS class limits for the H'$_{log2}$, ES$_{100}$ and NQI according to Alve et al. (2019) were used (Table 1). For the AMBI no EcoQS class limits for foraminifera have been defined, therefore the class limits for macrofauna according to Borja et al. (2003; Table 1) were used. Species that appeared in the pooled > 63 μm fraction with a relative abundance ≥ 10 % at least one location were considered abundant, and species with relative abundances between 5 and 10 % were considered common (Lo Giudice Cappelli and Austin, 2019; Schröder et al., 1987). Species that appeared with abundances < 5 % were considered uncommon and will not be discussed. When calculating species relative abundances only the assemblage assigned to EGs was used. The foraminiferal densities (individuals per cm^2) were calculated as the number of foraminifera picked divided by the area that was picked for each replicate sample.

4. Results

In Kaldfjorden, the > 63 μm and > 125 μm fraction contained on

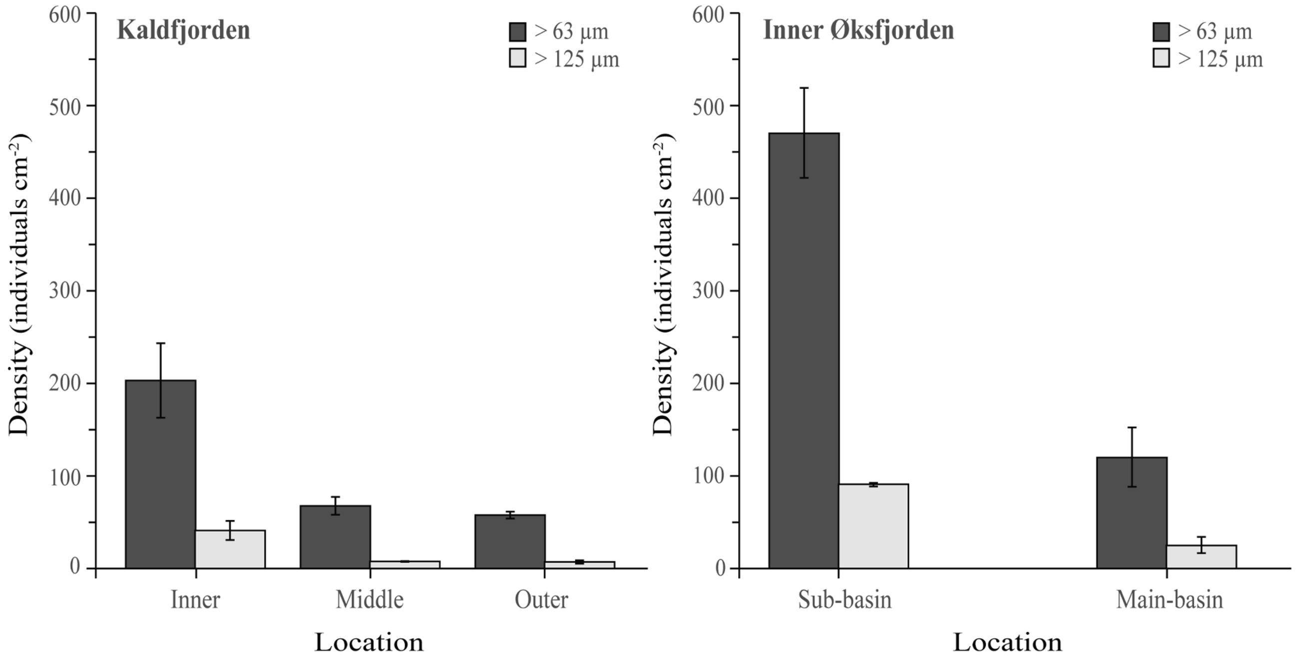

Fig. 2. Benthic foraminiferal densities (individuals per cm^2) from Kaldfjorden and Inner Øksfjorden where the dark bars represents the > 63 μm size faction and the light bars represent the > 125 μm fraction. Error bars denote the standard error (*n* = 4 for Kaldfjorden, and *n* = 3 for Øksfjorden).

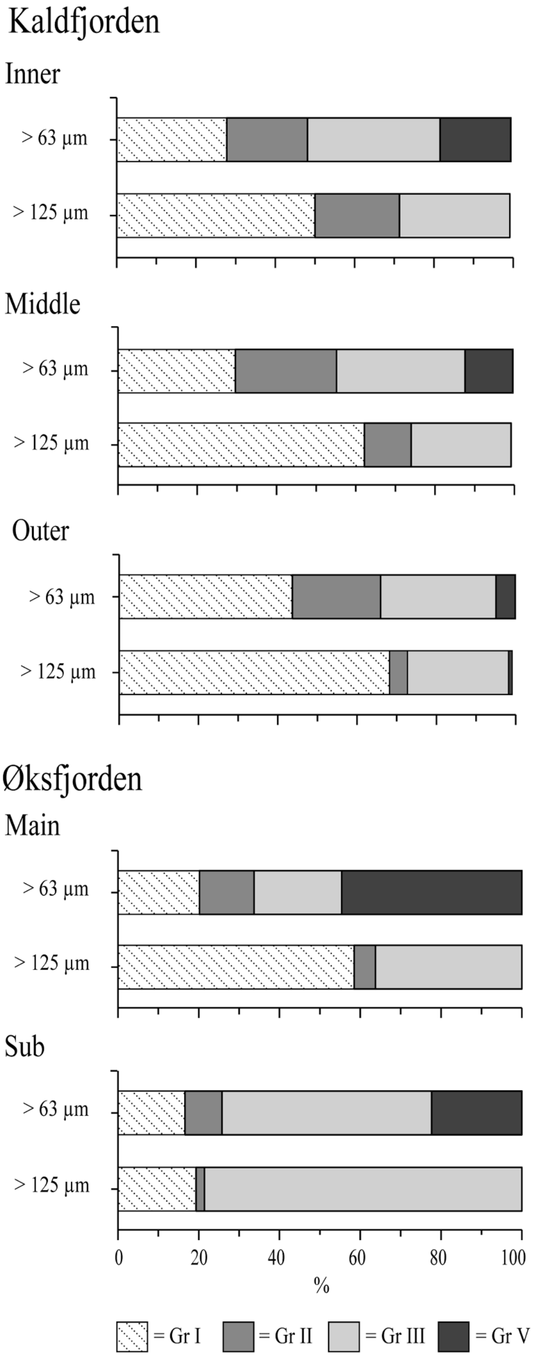

Fig. 3. Species distributions amongst the Ecological Groups (EGs) plotted for the > 63 µm and > 125 µm fraction for each sampling location.

average 65 and 32 species, respectively, and in Øksfjorden 67 and 36 species, respectively. The size fractions had a similar H'_{log2} and ES_{100} EcoQS reflecting a Good (green) and High (blue) EcoQS (Table 2). For the samples from both fjords, 86–95 % of the foraminiferal assemblage could be assigned to one of the five EGs defined in the AMBI, and in both fjords the AMBI of the > 63 µm fraction was approximately twice as high as the AMBI of the > 125 µm fraction (Table 2). The AMBI-based EcoQS only differed between the size fractions at the two outermost locations in Kaldfjorden and the sub-basin of Øksfjorden, where it changed from Good (green) to High (blue) and from Good (green) to Moderate (yellow) when only the > 125 µm fraction was analysed, respectively (Table 2). The foraminiferal densities were 5- to 9-fold higher in the > 63 µm fraction compared to the > 125 µm fraction (Fig. 2).

In Kaldfjorden and the sub-basin of Øksfjorden, relative abundances of species in EG I were 22 – 38 % higher in the > 125 µm fraction compared to the > 63 µm fraction (Fig. 3). In EG II species relative abundances were on average 9 % lower when only the > 125 µm was analysed (Fig. 3). In Kaldfjorden relative abundances of species in EG III were on average 5 % lower and in Øksfjorden on average 21 % higher when only the > 125 µm fraction was analysed (Fig. 3). The *Stainforthia* group, the only member of EG V, was mostly absent in the > 125 µm fraction (Tables 3 and 4). *Epistominella vitrea* (EG II), *Pullenia osloensis* (EG III), and *Textularia earlandi* (EG III), were fully to mostly absent in the > 125 µm (Tables 3 and 4). In Kaldfjorden, the relative abundances of *Nonionella iridea* (EG III) were lower in the > 125 µm fraction (Table 3), and the species was absent in the > 125 µm fraction in Øksfjorden (Table 4). Relative abundances of *Cassidulina leavigata*, *Cribostomoides* cf. *kosterensis,* and *Tritaxis conica,* all members of EG I, were up to 5-fold higher when only the > 125 µm fraction was analysed (Tables 3 and 4). Relative abundances of *Brizalina skagerrakensis* (EG III), *Eggerelloides medius* (EG III)*,* and *Nonionella turgida* (EG II)*,* were 2 to 3-fold higher when using only the > 125 µm fraction (Tables 3 and 4).

5. Discussion

The > 125 µm fraction generally contains fewer species than the > 63 µm fraction (e.g. Lo Giudice Cappelli and Austin, 2019; Schröder et al., 1987), which is in line with the results from the current study. Former studies investigating different size fractions showed that the Shannon-Wiener index from both fractions reflected the environmental conditions (e.g. Lo Giudice Cappelli and Austin, 2019; Weinkauf and Milker, 2018). Studies did, however, find stronger correlations between environmental conditions and the Shannon-Wiener index from smaller fractions compared to larger fractions (Bergamin and Romano, 2016; Bouchet et al., 2012). Both Kaldfjorden and the basins in Øksfjorden are considered relatively unpolluted (Klootwijk et al., 2020; Vågen, 2018), and the current study suggests that in relatively unpolluted fjords in northern Norway the H'_{log2} and ES_{100} from both size fractions should accurately reflect the EcoQS. Analysing the > 125 µm fraction is considered substantially less time consuming, but the results from this study may not be representative of other fjords. Some of the observed differences in H'_{log2} and ES_{100} between the size fractions were, however, equal to the range that sets the limits of the classes good and moderate (Tables 1 and 2). This suggests that differences between size fractions could potentially lead to misclassifications in fjords under more anthropogenic pressure depending on the analysed size fraction, but this should be further explored.

In both coastal and shelf settings, 2 to 21-fold higher foraminiferal densities were found in the > 63 µm fraction compared to the > 125 µm fraction in both polluted and unpolluted environments (Bergamin and Romano, 2016; Jennings and Helgadottir, 1994).The differences in both studied fjords are within the previously observed range (Fig. 1). The Bergamin and Romano (2016) study found that of the investigated indices (Fisher α, $H'_{(ln)}$, Simpson index), the $H'_{(ln)}$ index was the least affected by differences in foraminiferal densities. Another study established that both the $H'_{(ln)}$ and ES_{50}, comparable to the ES_{100}, were relatively unaffected by differences in foraminiferal densities (Barras et al., 2014). The current study also found no indication that foraminiferal densities greatly affected the H'_{log2}, ES_{100} as the differences between size fractions were small (Table 2), which indicates that differences in densities had little influence on the H'_{log2} and ES_{100} based EcoQS in this study. This is despite the relatively low foraminiferal densities in the > 125 µm fraction at the two outer locations of Kaldfjorden (Fig. 2). As Kaldfjorden appeared practically unpolluted (Vågen, 2018) the low densities are most likely natural indicating that low densities are not necessarily a sign of anthropogenic pressure factors. Previously, foraminiferal densities have been successfully used studying a clear pollution gradient for biomonitoring purposes (e.g. Mojtahid et al., 2006). The current study, however, indicates that the use of

Table 3

Species' relative abundances (%) calculated using only species or groups assigned to Ecological Groups (EG) of species considered abundant or common in the > 63 μm fraction from Kaldfjorden for each fraction (> 63 μm and > 125 μm). For the taxonomic list see Supplementary Appendix A.

		Kaldfjorden					
		Inner		Middle		Outer	
Species	EG	> 63 *μm*	> 125 *μm*	> 63 *μm*	> 125 *μm*	> 63 *μm*	> 125 *μm*
Bulimina marginata	3	11	15	1	2	1	1
Cassidulina laevigata	1	7	15	8	19	27	51
Cassidulina reniforme	1	2	3	4	5	5	3
Cribrostomoides cf. *kosterensis*	1	6	12	1	3	1	5
Eggerelloides medius	3	5	4	5	5	2	6
Epistominella vitrea	2	8	0	20	0	20	0
Nonionella iridea	3	9	1	9	5	12	6
Nonionella turgida	2	8	19	3	9	1	3
Pullenia osloensis	3	2	0	14	0	10	2
Reophax cf. *micaceus*	1	6	7	11	12	8	5
Stainforthia group	5	18	0	12	0	5	1

Table 4

Species' relative abundances (%) calculated using only species or groups assigned to Ecological Groups (EG) of species considered abundant or common in the > 63 μm fraction from Øksfjorden for each fraction (> 63 μm and > 125 μm). For the taxonomic list see Supplementary Appendix A.

		Øksfjorden			
		sub-basin		main basin	
Species	EG	> 63 *μm*	> 125 *μm*	> 63 *μm*	> 125 *μm*
Adercotryma glomeratum	1	2	3	7	7
Brizalina skagerrakensis	3	0	0	13	32
Bulimina marginata	3	5	5	12	16
Eggerelloides medius	3	5	11	6	13
Epistominella vitrea	2	11	0	3	0
Nonionella iridea	3	2	0	6	0
Stainforthia group	5	45	0	22	0
Textularia earlandi	3	2	0	9	0
Tritaxis conica	1	12	41	0	0

foraminiferal densities for biomonitoring in naturally transitional zones like fjords should probably be limited to long-term sediment core records (see Klootwijk et al., 2020).

Compared to larger size fractions, smaller size fractions more often contain opportunistic species with a strong response to eutrophication and these species also occur in greater abundances in these fractions (Alve, 2003; Lo Giudice Cappelli and Austin, 2019). In the current study fewer foraminifera considered sensitive to organic matter enrichment (EG I; Alve et al., 2016), and more foraminifera with a tolerant or opportunistic response to excess organic matter enrichment (EG III and V; Alve et al., 2016) were found in the > 63 μm fraction compared to the > 125 μm fraction (Fig. 3). Differences in AMBI scores and EcoQS between the fractions were relatively large compared to the other indices (Table 2), indicating that the analysed size fraction had the strongest effect on the AMBI. This could be partially related to the mostly absent *P. osloensis*, *N. iridea*, and *T. earlandi*, members of EG III, in the > 125 μm fraction (Tables 3 and 4). These three species were also mostly absent in living foraminiferal assemblages in the 100 – 1000 μm fraction in the Hammerfest harbour, northern Norway (Dijkstra et al., 2017.; supplementary data), and *N. iridea* was absent in the 100–1000 μm fraction in Malangen, northern Norway (Husum and Hald, 2004; Katerine Husum pers. com.). It should be noted, however, that these studies did not investigate the 63 – 100 μm fraction and that these species could be absent due to other reasons. Though the > 63 μm fraction in this study contained more foraminifera indicating an increase in organic matter input (EG III and V), the $H'_{\log2}$ and ES_{100} of this fraction was in most cases higher compared to the > 125 μm fraction. A higher $H'_{\log2}$ and ES_{100} would suggest better environmental conditions but could also be related to a greater chance of finding more species due to higher numbers of foraminifera in the > 63 μm fraction.

The NQI for macrofauna combines the AMBI with a modified species richness index (SN), which are both normalized to their highest obtainable value and equally weighted (Rygg, 2006). The NQI for foraminifera is based on the same principles using the foraminiferal AMBI and ES_{100} (Alve et al., 2019). Previous studies found that the NQI reflected anthropogenic pressure gradients in coastal waters and did not respond to differences in macrofaunal densities (Borja et al., 2011, 2012; Josefson et al., 2009). In the present study, the NQI scores showed no major differences and the NQI based EcoQS did not differ between the size fractions (Table 2). At the Inner and Outer location in Kaldfjorden and the main-basin in Øksfjorden, however, the ES_{100} and AMBI seem to mitigate each other's environmental signal. More species with a tolerant or opportunistic response to organic matter enrichment (EG III and V; Alve et al., 2016) in the > 63 μm fraction of the sub-basin in Øksfjorden seems to be reflected in the lower NQI of this fraction compared to the > 125 μm fraction. If results from this study are applicable to other fjords in northern Norway, the latter suggest that the NQI of the > 63 μm fraction should reflect potential anthropogenic pressure factors better than the > 125 μm fraction in this region.

Previous studies found that a number of species present in smaller size fractions were absent in larger size fractions (e.g. Lo Giudice Cappelli and Austin, 2019; Weinkauf and Milker, 2018). In the current study both *E. vitrea* and the *Stainforthia* group were mostly absent in the > 125 μm fraction (Tables 3 and 4). *Epistominella* species were also mostly absent in the 100 – 1000 μm fraction of the Hammerfest harbour (Dijkstra et al., 2017; supplementary data), and *E. vitrea* was absent in the living assemblages of the 100–1000 μm fraction in Malangen (Husum and Hald, 2004; Katrine Husum pers. com.). *E. vitrea* has been positively associated with phytodetritus (Duffield et al., 2015; Klootwijk et al., 2021), and has been shown useful for interpreting changes in primary productivity in sediment cores (Klootwijk et al., 2020). *S. fusiformis*, a prominent member of the *Stainforthia* group, occurred in the living assemblages of the 100 – 1000 μm fraction of Malangen with relative abundances predominantly < 2 % but with 9 % at one location (Husum and Hald, 2004; Katrine Husum pers. com.). This is lower than in the current study (Tables 3 and 4). *S. fusiformis* has a strong seasonal acme (Gustafsson and Nordberg, 2001) and a previous study indicated that high relative abundances of the *Stainforthia* group in the living assemblages of the sub-basin in Øksfjorden could be a bloom event (Klootwijk et al., 2020). Sampling during blooming events should be avoided according to the Schönfeld et al. (2012) protocol. The current study suggests that analysing the > 125 μm may avoid potential problems with the strong seasonal acme of the *Stainforthia* group. Analysing the larger fraction would, however, mostly exclude *E. vitrea* from the assemblages which would affect interpreting paleo-environmental conditions in sediment cores.

6. Conclusions

The $H'_{\log2}$, ES_{100} and NQI from the > 63 μm and > 125 μm fraction in this study resulted in the same or highly similar Ecological Quality Status (EcoQS), reflecting good environmental conditions in both fjords. The same applied to the AMBI at all locations except one, which had moderate EcoQS. Analysing the > 125 μm fraction is considered substantially less time consuming, but the results from this study may not be representative of other fjords. At this location, substantially more foraminifera with a tolerant or opportunistic response to organic matter enrichment occurred in the > 63 μm fraction compared to the > 125 μm fraction, which was also reflected in the lower NQI of the smaller fraction. The observed differences in $H'_{\log2}$ and ES_{100} between the size fractions were, however, equal to the range that sets the limits of the classes Good and Moderate, which could potentially lead to misclassifications in fjords under more anthropogenic pressure depending on the analysed size fraction. The large differences in foraminiferal densities between the size fractions did not seem to affect the EcoQS derived from the investigated indices. The mostly absent *E. vitrea* in the > 125 μm fraction could affect the interpretation of environmental changes in sediment core records. The absence of the *Stainforthia* group in the > 125 μm fraction would circumvent potential problems with its seasonal acme when using this size fraction. Overall, analysing the > 125 μm appeared mostly sufficient for determining the EcoQS in relatively unpolluted fjords in northern Norway, but potential anthropogenic pressure or long-term environmental changes would be better reflected by the assemblages from the > 63 μm fraction.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2021.108423.

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