Ms. Ref. No. Essd-2020-96 “Diets of the Barents Sea cod from the 1930s to the present day“ by Bryony L. Townhill, Rebecca E. Holt, Bjarte Bogstad, Joël M. Durant, John K. Pinnegar, Andrey V. Dolgov, Natalia A. Yaragina, Edda Johannesen, Geir Ottersen. https://doi.org/10.5194/essd-2020- 96

General comments

The manuscript by Townhill et al. describes a unique time series of Barents Sea cod diet data stretching from 1930 to 2018. This is a great source of information and in this manuscript, the data is presented to the scientific community and the public in general. The data sources are described, the applicability and usefullness and some results are presented and discussed. The data set and this manuscript are of great interest to the public and should be considered for publication. However, the authors should spend a little more time on presenting the data overviews, so that the reader gets more information about the data set without going into the analysis of the data.

Thank you for your comments. We have amended the manuscript as suggested and hope that the data description is now more detailed, particularly with the addition of the table.

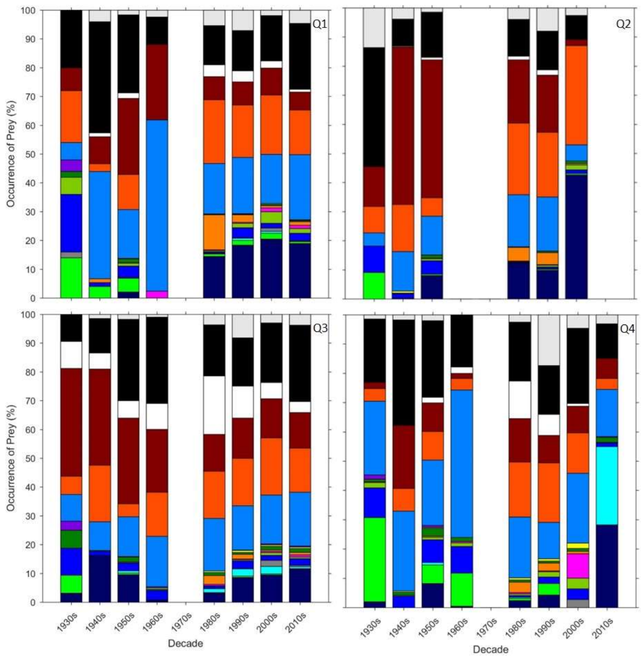
• In general, an overview table presenting the data sources, years, number of stomachs etc. would be very helpful. For example:

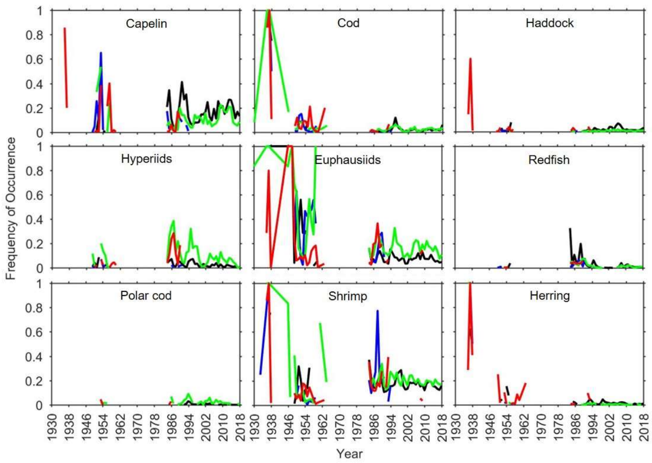
Source	Years	Total no. of stomachs	No. by quarter	% empty stomachs (or absolute)	Area (either ICES or „natural“ e.g. Svalbard, Bear Island etc.	Comments – pooled data, single stomachs	Etc.
UK	1930-1964	XY					
…							
..							

A table has been included as suggested. Table inserted at end of manuscript and reference to it in Data summary section.

• The sampling coverage is presented by quarter. It would be very nice to have at least figure 5 (eventually also for selected prey species/categories in figure 6) for each decade split up by quarter.

We produced these plots for figures 5 and 6 (below), but they are complicated and do not feel they add anything to the description of the data. Making separate plots for each quarter also does not reveal anything more of the data. Therefore we propose not to include these plots in the revised manuscript. Looking at how the prey change over the years and within each year, and the drivers of this, is the subject of further analysis on the data, and will be published separately.





The authors should avoid stating “The location of each stomach sample is shown in Figure 1“, but state what can be seen or deduced from the data and then refer to the figure in parentheses. This applies to the entire document.

This has been amended throughout the document.

Specific comments

L1: Title – Reading this title, one question comes to my mind immediately. Will you update this data set regularly? If not, then phrasing "…to the present day" could be a bit misleading, let us say in 10 years of time. So maybe, just indicating the latest year of data (2018) is more appropriate. However, this is just a recommendation. And maybe I am old fashioned, but in my opinion you should have the Latin name of cod in the title.

The title has now been amended to address both of these.

L39: "conducted" sounds better than "done"

This has been amended.

L70: "As part of the merging process, the data underwent a thorough quality control." Either you should refer to a publication specifying this quality control or you have to describe this in the data and methodology section.

This sentence has now been moved to section 2.4 and a reference included.

L75/76: Please add a few sentences elaborating why understanding trophic interactions in marine ecosystems is important -> e.g. multi-species assessments.

This has now been included in the introduction.

L142: "For items that can be identified, lenghts are recorded, …" – I assume that you refer to "For items that can be identified and were assessed as being intact (digestion grade 1, eventually 2), lengths are recorded,…", because it is possible to identify stomach items, based on fragments, where no length measurement is possible.

This has been amended in text.

L152/153: Does this sentence mean that the missing Russian data for years 1947-1983 will be digitized and added to the data set. Based on the Russian data policy most probably not, but I am just curious if they will become available in the future.

There are further paper records which are not yet digitized, but will be with over the coming years. They won't be added to the dataset that we present, but can be made available on future collaborations. We think it is important to mention that the data exist, as they are an important part of the picture, and are important to include in future analyses. In the Data and methodology section of the text we have made clearer what is and isn't included.

L223: "were" instead of „are"

This has been amended in the text.

Figure 2: In the two lower graphs, the factors "x 105" and "x 104" should be placed somewhere else, e.g. "No. of stomachs with food (x 105)"

After removing the Russian data, the scales are different and so these are no longer needed.

Supplementary material 2: In the first paragraph, the authors describe the presented table and refer to the column numbers, e.g. "predator information (columns 1-12)". For convenience it would be nice if you could add one column on the left hand side of the “Column name“, so that the reader can find the different columns more easily.

This has now been included.

Column No.	Column Name	Information	Units
1	Data_ID	Details whether the data is from either the IMR-PINRO joint database or CEFAS	-
2	Ser_No_Fish	Serial number for each individual fish	-
3	Country	Country code denoting either: 58: Norway (IMR-PINRO Database) U.K: CEFAS Data	-
4	Ship_code	Ship identification code	-
…	Year		

Editor comments

Dear authors, according to the now long lasting difficulties to find reviewers, I add this review on your manuscript.

Within your manuscript you describe and present a very impressive dataset spanning the period of 90 years of fishery ecology and feeding behaviour. The data from stomach analysis are tremendously valuable to the ecological community and modeling community. While the diet of cod as a very important species within the Barents Sea system is a quantified connection between the components of this ecosystem and the possible effects any change in stock size might have on the directly connected components or the system as a whole. This dataset it valuable and should be published after some revision. However the value of the data set should be emphasized with some more detailed informations on the dataset and its usability. Bringing the data to the for ground and having it ready for reuse is right at the hart of ESSD. The availability of the data is great a CC4 license and a flexible landing page at the repository directly pointing to the download of the dataset, well chosen.

Thank you for your comments. We have included your suggestions in the manuscript, with a few exceptions where we think these are best presented in future papers which analyse the data. We have described these below.

General comments: A table breaking the most important key data about the data set into digestible format would be great. Consider time slices as rows per dataset combined with the country of origin. Columns could be years or period, total number of samples, % empty stomachs, area of sampling (ICES rectangles or natural areas), Pooled data or individual samples, and other fields such as most important prey species or average number of prey species, fishing gear, ...

This table has been included as per the previous reviewer’s comment.

Within the section 2 of the text you present very well the methodology for the UK dataset. You do mention the fishing gear for that particular dataset (actually the oldest set, but you do not present this important information for the other datasets. I also have to say, that the structure of the section 2 is for me while reading a kind of puzzling. May be the already mentioned table and/or the leaving the Russian data out of the description at all could bring some clarity or structure to the text as well.

Please find a structure what you think is required to describe the datasets by and then keep to the structure in all subsections describing all the individual datasets.

Further description of the Norwegian methodology has been included in the Data and methodology section. It wasn't originally included because it is published in other easily accessible papers, whereas the UK description isn't. However, more information has now been added.

We have now included the table as suggested, and also rearranged the text in this section to make it clearer what is included and what is not.

The Russian data are not part of the published dataset and they are not available at all by the here publishing authors. Why are these data then mentioned to such great extent within the manuscript? Mentioning the data is important and a valuable information to the reader where to find more data if accessible. Just keep the focus more to the published dataset and not dilute the message of the published data by mentioning the unavailable data.

The text describing the Russian surveys has been moved to below the paragraph describing the Barents Sea dataset, to make it clear that these are not included. We do however think that it is important to highlight that these additional data exist, because they add information on a larger geographical area, and also the earlier time period. When further analyses are conducted on these data, it is important that scientists appreciate that there is other information available, that it can be available to collaborators, and that a lot of information is included in existing publications.

The figures presented to describe the datasets could have more resolution to increase information content. The Russian data could be removed or colored differently in the figures.

The data from the Russian surveys has been removed from the figures in the main paper, and have been included in a new supplement. Removing this data has made the figures clearer, as there is less data, and the resolution has been increased, particularly for the maps.

It would be nice to have representation of the most important prey species distribution maps

Maps have now been included for the four main prey species: cod, capelin, euphausids, shrimp.

Figure 2 the scales at the y axis are all in the same order of magnitude, but drawn differently, this should be avoided

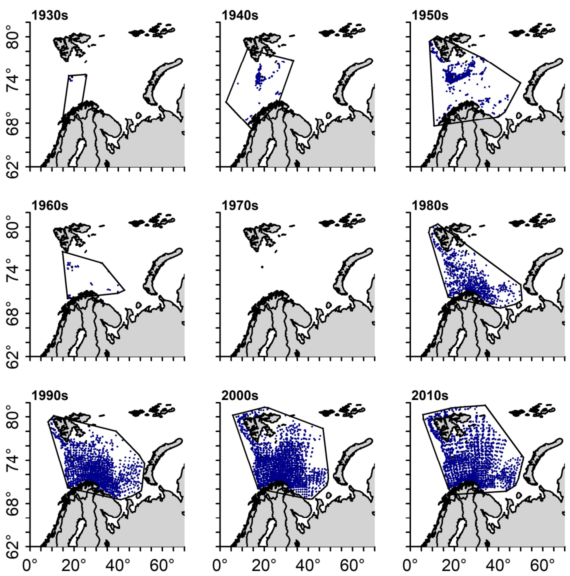
This is no longer a problem with the new figures.

Figure 3 could include information per time period on the ice extent, which would give some information on why there are only in the later years data from the east of Svalbard.

We have searched for data on ice extent but feel it would take a significant amount of work to calculate the average or minimum ice extent for each decade, particularly for the earlier years for which there is less data available. As such as have not added it to the maps here, but we have included mention that the surveys were able to go further north during the summer, when the ice cover was reduced. Further analyses could look at the role that the changing ice might have on predator and prey interactions, in which case calculating the change in ice in relation to the dates that these samples would be carried out.

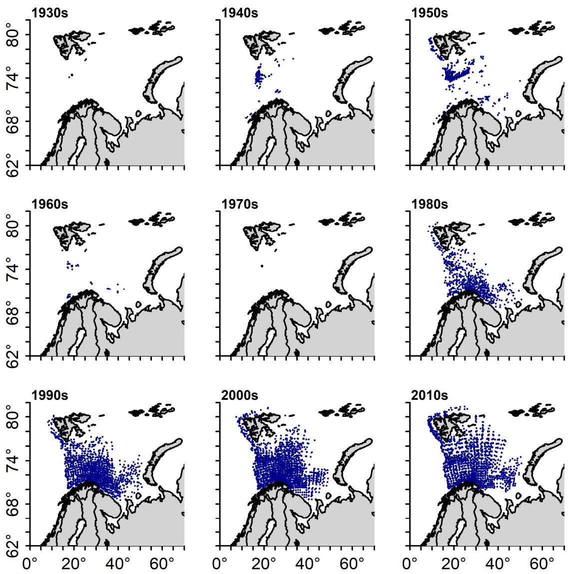
Is there a reason in figure 3 why the maps represent the decades and no other time periods? Anyway, it is good to stick to the chosen periods in all figures, which you did in the current status of the manuscript, but I would consider a different spacing in time or changing from points to like convex hulls to represent the sampling area to make the extent of the data more prominent Since all the points are not distinguishable from each other either figure size or type could help.

Having removed the Russian data from the maps, reduced the dot size and increased the resolution, these plots are now much clearer and it is easier to distinguish the different sampling locations. We produced maps with convex hulls, but don't think that these improve the maps. Rather, they are slightly misleading and they make the sampling area larger than it is because of a small number of sample sites which extend far beyond most of the other sites. As such, we propose to include the new maps with a higher resolution but without the convex hulls.



Maps on the stomach content could be summarized by pie charts representing the ICES rectangles this would also reveal if there were areas of increased number of empty stomachs.

We have produced the below map of the distribution of empty stomachs per decade. You can see that the location of the empty stomachs closely resembles the location of the sample stations, i.e. the empty stomachs are dispersed amongst the majority of the samples. As such, we do not think that this figure adds value to the paper. The maps that have been included on the extent of the four main prey species, also show that prey are widely dispersed across the area, rather than each being concentrated. However further work can look at the reasons for the empty stomachs or certain prey, such as time of year (there are seasonal cycles of feeding), whether they coincide with years of low biomass in prey species etc., productivity, links with NAO etc.



All these comments and suggestions do cause number of changes to the manuscript and I suggest that i will have a more detail oriented look at the manuscript after these revisions, which I consider only minor revisions.

Regards Dirk Fleischer

Diets of the Barents Sea cod *(Gadus morhua)* from the 1930s to 2018~~the present day~~

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Abstract

A new dataset on the diet of Atlantic cod in the Barents Sea from the 1930s to the present day has been compiled, to produce one of the largest fish diet datasets available globally. Atlantic cod is one of the most ecologically and commercially important fish species in the North Atlantic. The stock in the Barents Sea is by far the largest, as a result of both successful management and favourable environmental conditions since the early 2000s. As a top predator, cod plays a key role in the Barents Sea ecosystem. The species has a broad diet consisting mainly of crustaceans and teleost fish, and both the amount and type of prey vary in space and time. The data, from Russia, Norway and the United Kingdom, represents quantitative stomach contents records from more than 400,000 fish, and qualitative data from 2.5 million fish. Much of the data is from joint collaborative surveys between Norway and Russia. The sampling was conducted~~done~~ throughout each year allowing for seasonal, annual and decadal comparisons to be made. Visual analysis shows cod diets have changed considerably from the start of the dataset in the 1930s to the present day. There was a large proportion of herring in the diets in the 1930s, whereas in more recent decades, capelin, invertebrates and other fish dominate. There are also significant interannual asynchronous fluctuations in prey, particularly capelin and euphausiids. Combining these datasets can help us understand how the environment and ecosystems are responding to climatic changes, and what influences the diet and prey switching of cod. Trends in temperature and variability indices can be tested against the occurrence of different prey items, and the effects of fishing pressure on cod and prey stocks on diet composition could be investigated. The dataset will also enable us to improve parametrisation of food web models, and to forecast how Barents Sea fisheries may respond in the future, to management and to climate change. The Russian data is available through joint projects with Polar branch of VNIRO. The UK and Norwegian data (Townhill et al., 2020) is being released with this paper at doi: 10.21335/NMDC-2139169383.

1 Introduction

Here we document a new extensive dataset on the stomach content of Atlantic cod (*Gadus morhua*) in the Barents Sea. We have compiled the dataset by joining historical data from the UK (1930-1964) with historical data from the Soviet Union/Russia (1947-1983) and more recent (1984-2018) data from a large existing joint Norwegian-Russian cod stomach-content database. The resulting dataset spans the period from 1930 until present day.~~ As part of the merging process, the data underwent a thorough quality control.~~

Comprehensive information on the predation dynamics of ecologically important species, based upon the analysis of individual stomach-contents, is vital for an understanding of how the biological components in an ecosystem are connected (Hyslop, 1980; Holt et al., 2019). Such data can provide detailed knowledge on the diet of a species in an area at a particular time. When conducted over long temporal scales and across size classes, spatially high-resolution stomach-content data can provide data that is key to understanding trophic interactions in marine ecosystems.

Unfortunately, long-term high-quality fish population diet data with good spatio-temporal coverage are rare, as the effort and resources required to collect and analyse stomach-contents at this scale is considerable. However, due mainly to the stock's commercial importance, both Russia, Norway and the UK have invested considerable resources in sampling, working up and sustaining stomach-contents data for the Barents Sea (or Northeast Arctic) cod. Diet data is valuable in understanding trophic interactions; particularly important in areas where multiple species are caught. For example, diet data allows predation mortality to be included in stock assessments (ICES, 2019), and to understand inter-specific interactions between predators (Durant et al., 2014).

To support the cod fishery in the Barents Sea, the UK carried out surveys from the 1930s, mainly collecting catch and length data, but also recording stomach contents. They collected content data from between a few hundred to 3,500 stomachs each year, ending in the 1960s. The Norwegian-Russian data originate from a joint research project on the diet and food consumption of Barents Sea fish, with cod as the main study species, initiated in the mid-1980s. This was a joint endeavour between IMR (Institute of Marine Research, Norway) and PINRO (Knipovich Polar Research Institute of Marine Fisheries and Oceanography, since 2019 names ~~now named~~ the Polar Branch of the Russian Federal Research Institute of Fisheries and Oceanography (VNIRO); Mehl, 1986; Mehl and Yaragina, 1992; Dolgov et al., 2007, 2011; Yaragina et al., 2009). An average of 8,153 stomachs were analysed each year (Holt et al., 2019). In addition, there are also numerous Russian cod diet data that was collected from the 1930s-80s, (Dolgov et al., 2007; Yaragina and Dolgov, 2011) which are described here and summarized in the Supplementary Material.~~, however t~~ These could not be made available in the main dataset published with this manuscript, but are available under joint research projects.~~.~~

Atlantic cod is one of the most ecologically and commercially important fish species in the North Atlantic and the Barents Sea stock is by far the largest. As opposed to many other cod stocks and other fish world-wide, the Barents Sea cod are doing well, a result of both successful management and favourable environmental conditions since the early 2000s (Kjesbu et al., 2014, Ottersen et al., 2014, Fossheim et al., 2015). Cod plays a key role in the Barents Sea ecosystem and is the dominating top predator. While cod has a broad diet consisting mainly of crustaceans and teleost fish, the amount and kind of prey actually available varies in space and time as well as by cod size (Zatsepin and Petrova, 1939; Yaragina et al., 2009, Johannesen et al., 2012, 2015; Holt et al., 2019).

For Atlantic cod, being arguably one of the most important fish on the planet, such diet data exist in several seas: e.g. the Baltic (Neuenfeldt and Beyer, 2006); on Georges Bank (Tsou and Collie, 2001); the Gulf of Maine, US (Willis et al., 2013); Icelandic waters (Pálsson and Björnsson, 2011); and the northeast US shelf ecosystem (Link & Garrison 2002). A comparison of Atlantic cod diet and the role of cod in the various ecosystems was made by Link et al. (2009). Data on the diet of other northeast Atlantic species have been recently released, allowing analysis of herring, blue whiting, mackerel, albacore and bluefin tuna diets (Pinnegar et al., 2015). The time series of these pelagic species begin in the 1860s, and combine data from France, Norway, Iceland, Ireland and the UK. Here, we compile a similar dataset of Barents Sea cod diet data, from Norway, Russia and the UK.

2 Data and methodology

2.1 UK Barents Sea surveys

A UK fishery began in the Barents Sea in 1905, with increased exploitation from 1929. Catches of cod and therefore profits were high, particularly from the 1930s when sea temperatures in the area became warmer (Cushing, 1966) and cod stock sizes increased to historic high levels in the 1930s-1940s (Hylen, 2002). Aimed at investigating the cod fishery, and the influence of temperature, which already at the time was known to influence cod distributions, the UK carried out fisheries surveys in the Barents Sea from the 1930s to the 1960s, with a break for WWII. The surveys were conducted firstly on-board commercial fishing vessels, and later with a dedicated Arctic survey vessel, the *RV Ernest Holt* (Graham, 1953). The surveys collected data on cod abundance, length distributions, temperature, salinity and depth, and samples of cod stomachs were also taken. This was less systematic than for present-day cruises, and so the data is less statistically robust than for the data for the 1980s onwards. The frequency of prey items was recorded rather than the mass of each prey item, and no data on stomach fullness was collected. For the majority of surveys, prey occurrence is recorded for each stomach individually. For some however, pooled data is provided, for up to 198 stomachs in total. The survey methodology is described in Graham (1953) and summarised in Townhill et al. (2015). On the RV Ernest Holt, a standard otter trawl was used, with and without Vigneron-Dahl gear. Rather than using a statistically designed survey grid, the scientists wanted to find large cod groups and so vessels searched for high cod catches, operating more like a commercial fishing boat.

DAPSTOM database summary

Under the Centre for Environment, Fisheries and Aquaculture Science (Cefas) project Trawling Through Time (DP332) and the Norwegian-British-Russian research project CoDINA (Cod: Diet and food web dyNAmics), funded by the Research Council of Norway, the data for these surveys were digitiz~~s~~ed from paper logbooks held by Cefas and the stomach data is held in the DAPSTOM database (Cefas, 2014; Pinnegar, 2014). The DAPSTOM (Database And Portal for Fish STOM~~tom~~ach records diet database), described in Pinnegar (2019) contains 256,354 records from 360,561 stomachs, with the first records from the 1830s. These are from 204 species and 9,445 research cruises/sampling campaigns. 28% of the records are for Atlantic cod, mainly for the seas around the UK, but also including these for the Barents Sea.

2.2 The joint Norway-Russia research programme on trophic relationships in the Barents Sea

Russian and Norwegian surveys include cod stomach sampling in their regular procedures, as described in Dolgov et al. (2007 and 2011). The joint research programme began in 1987, initially collecting stomach samples of cod and haddock with the objectives of quantitative analysis of demersal fish stomachs, calculating consumption by cod of commercially important prey species, and creating the basis for developing ~~a~~ Barents Sea multispecies models (Dolgov et al., 2007). Since the surveys began, other species have been included to further understand trophic interactions. The stomach samples are taken on research surveys that use both pelagic and bottom trawls. Up to ten stomachs are collected for each 10 cm length group at stations which have biological sampling on Norwegian surveys ~~One cod stomach per 5 cm length group of cod is sampled per station~~ (Mehl and Yaragina, 1992)~~ on the Norwegian and joint Russian-Norwegian surveys~~. On Russian commercial vessels and Russian national surveys, 25 stomachs are sampled per trawl. Unlike the historical UK surveys in the Barents Sea, these stomachs are weighed and the total weight and degree of digestion for each prey item is recorded. For items that can be identified and intact, lengths are recorded, as well as the total number of identifiable prey in each stomach. Maturity and sex are also recorded, and otoliths read to measure age. Only the Norwegian data is included in the Barents Sea cod dataset, published alongside this paper.

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~~**2.3 Russian investigations on cod diet in the Barents Sea**~~

~~Since 1947, observations on cod diet in the Barents Sea have been performed throughout the year from commercial and research vessels as part of a Russian sampling programme. During sampling, the degree of stomach fullness was recorded using a five-division scale, ranging from 0: empty stomach, to 4: stomach expanded and unfolded by food, as well as the presence of different prey items (capelin, juvenile cod, redfish, herring, shrimp, euphausiids, and other) in the stomach. This qualitative method named "field feeding analysis" was widely used in Russian investigations of different fish species including cod (see references in Dolgov et al. 2007 and Yaragina and Dolgov, 2011). From 9 to 45 thousand cod stomachs were analyzed each year during 1947-1979. As yet, the qualitative Russian stomach samples for years 1947-1983 are not fully digitized.~~

2.34 Barents Sea cod dataset

The UK stomach contents dataset has been merged with the Norway ~~and Russian~~ data from 1984 as part of the project CoDINA, to form ~~. Only the UK and Norwegian data from~~ the Barents Sea cod dataset~~ is provided alongside this paper~~. ~~The Russian data is not available for publication for reasons stated above but is described and presented in a number of publications (e.g. Mehl and Yaragina, 1992; Dolgov et al., 2007; Yaragina and Dolgov, 2011; Holt et al., 2019; Yaragina et al., 2009).~~ As part of the merging process, data underwent a thorough quality control, as described in Holt et al., (201898). A description of each prey category is provided in Supplementary material 1, and the metadata for the dataset is provided in Supplementary material 2.

Data summary

~~The location of each stomach sample is shown in Figure 1.~~ The largest number and geographic spread of samples are from Norwegian ~~and Russian~~ surveys, with fewer samples from UK surveys (Figure 1). ~~The Russian data~~

~~extends further east and northeast than the Norwegian or UK data, while the~~ The~~UK and Norwegian~~ data includes the area to the west and north of Svalbard (Spitsbergen).

A total of 400,054 individual stomachs are contained in the Barents Sea cod diet dataset (Table 1). These include 102,197 empty stomachs. ~~In addition, there are 24,457 quantitative and 2,599,421 qualitative Russian stomach samples for earlier years (before 1984).~~ The numbers sampled in each year vary according to the number of surveys in each year, with no stomach data in some years (Figure 2). ~~The number of stomach records in each year are shown in Figure 2 along with the~~ The number of empty stomachs varies each year~~total number of empty stomachs in each year~~(Figure 2). The UK qualitative data in Figure 2 are the 103 pooled records in the UK dataset, where the contents of more than one stomach are recorded together. Up to 198 stomachs are combined in each of these records.

The Barents Sea cod diet dataset contains data from across the Barents Sea, from the north of Norway, to Spitsbergen and eastwards to Russia (Figure 1), however the overall coverage and sampling locations varied each year. The UK surveys in the 1930s and 1940s tended to be in the region south and east of Spitsbergen, and around Bear Island. From the 1980s onwards, the Norwegian ~~and Russian~~ survey area was further to the eastern Barents Sea (Figure 3). ~~There are also earlier Russian stomach records from the 1940s to 1960s with qualitative (frequency of occurrence, degree of stomach fullness) and quantitative data, mainly from the eastern part of the Barents Sea (Zatsepin and Petrova, 1939; Dolgov et al., 2007 and references therein; Yaragina and Dolgov, 2011 and references therein). For the 1970s there is only qualitative data,~~ There is no data in the dataset for the 1970s, as the UK surveys stopped in the 1960s, and the IMR and PINRO joint collection of quantitative data did not begin until the 1980s (Dolgov~~Johannesen~~ et al., 2007).

Stomachs have been sampled throughout the year (Figure 4) allowing for seasonal changes in the diet to be analysed. Sampling is widespread in quarters 1, 3 and 4, but does not go as far north in quarters 1 and 2.~~, and~~ This is because there is ice cover preventing the survey vessels from travelling north and east of Spitsbergen during the winter. It is generally more limited in geographical area during quarter 2 as few regular surveys have been carried out in that quarter. ~~During winter, coverage is limited by ice.~~

Diet composition

The dataset shows that cod diets do not remain constant, and occurrence of different prey items changes each decade (Figure 5) and year (Figure 6). ~~Overall composition in each decade is shown in Figure 5, and time series for the most important prey species in Figure 6, excluding empty stomachs.~~ In the 1930s, when there are fewer records, most of the food items are not identified to species, and there is a large proportion of other food and other fish in the diets (Figure 5). From the 1940s onwards, most of the fish items found in the stomach are identified to species. The data shows a large amount of herring in the diet in the 1930s, which is not found again in later decades. In the 1940s and 1950s, there is a high occurrence of euphausiids in the diet, and this decreases to the 2010s. There is a lower occurrence of capelin in the earlier decades, particularly in the 1930s and 1960s, and this increases again to a high proportion of the diet from 1990s onwards. Cod cannibalism is apparent in every decade, with the highest proportion of cod in the diet at >30% in 1930s, reduced to 20% or less thereafter in later years. These figures show how variable the diet compositions are between years and decades.

Cod diets have changed considerably from the start of the dataset in the 1930s to the present day, and Figure 5 shows the diet composition for the UK and joint Norwegian-Russia stomach dataset. The Russian qualitative data is not included as the prey categories recorded were different. Figure 5 shows There is a large proportion of herring in the diets in the 1930s, which does not occur again, and in more recent decades, capelin, invertebrates and unidentified fish (other fish) dominate.

Looking at the prey occurrence of the main prey items in each year (Figure 6), there are quite large annual fluctuations, particularly for capelin, cod, euphausiids and shrimp. Haddock, hyperiids, redfish, polar cod and herring have fewer annual spikes. Capelin, cod, euphausiids and shrimp have the highest frequency of occurrence in the earlier part of the time series, to the 1960s. The occurrence is still variable from the 1980s onwards, but to a lesser degree. Figure 6 shows the annual variations in the main prey types and includes the Russian qualitative data. Analysis of the early Russian data also shows that the diets of cod have changed considerably from the 1930s to the 2000s (Yaragina et al., 2009; Yaragina and Dolgov, 2011), reflecting the trends seen in Figure 5 and Figure 6 for herring, cod, capelin and polar cod, although not for haddock. The earliest Russian investigations into cod diets from the 1930s (Zatsepin and Petrova, 1939) show similar fluctuations in prey, with interannual asynchronous fluctuations in capelin and euphausiids (Yaragina and Dolgov, 2011), which is also shown in the data in Figure 6.

The four main prey species of cod (cannibalism), capelin, euphausiids and shrimp were caught across the whole geographical area of the surveys (Figure 7). All of these species are caught up to the northern limits of the surveys, around Spitsbergen and across the Barents Sea.

2.4 Russian data on cod diet in the Barents Sea

In addition to the joint Norway-Russia research programme, sSince 1947, a Russian sampling programme has collected observations on cod diet in the Barents Sea have been performed throughout the year from commercial and research vessels as part of a Russian sampling programme. During sampling, the degree of stomach fullness was recorded using a five-division scale, ranging from 0: empty stomach, to 4: stomach expanded and unfolded by food, as well as the presence of different prey items (capelin, juvenile cod, redfish, herring, shrimp, euphausiids, and other) in the stomach. This qualitative method named “field feeding analysis” was widely used in Russian investigations of different fish species including cod (see references in Dolgov et al. 2007 and Yaragina and Dolgov, 2011). From 9 to 45 thousand cod stomachs were analyzed each year during 1947-1979. As yet, the qualitative Russian stomach samples for years 1947-1983 are not fully digitized, and so only the digitized data are presented in the supplementary material.

There are 24,457 quantitative and 2,599,421 qualitative Russian stomach samples, and the Russian data extends further east and northeast than the Norwegian or UK data. The Russian data are not available for publication but are described and presented in a number of papers and reports (e.g. Zatsepin and Petrova, 1939; Mehl and Yaragina, 1992; Dolgov et al., 2007 and references therein; Yaragina et al., 2009; Yaragina and Dolgov, 2011 and references therein; Holt et al., 2019). They are available under joint research projects. Further information about the Russian data is provided in Supplementary material 3. The locations of the samples are shown in Figure S3.1, the location in each decade in Figure S3.2, the total number of stomachs in each year, and empty,

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are in Figure S3.3, the percentage occurrence of prey in each decade in Figure S3.4, and the time series of occurrence of the main prey is provided in Figure S3.5.

Analysis of the early Russian data also shows that the diets of cod have changed considerably from the 1930s to the 2000s (Yaragina et al., 2009; Yaragina and Dolgov, 2011), reflecting the trends seen in the Barents sea diet database for herring, cod, capelin and polar cod in Figures 5 and 6, although not for haddock. The earliest Russian investigations into cod diets from the 1930s (Zatsepin and Petrova, 1939) show similar fluctuations in prey, with interannual asynchronous fluctuations in capelin and euphausiids (Yaragina and Dolgov, 2011), which is also shown in the data in Figure 6.

3 Discussion

IMR/PINRO data have been used in numerous publications and assessments, such as Holt et al. (2019) who investigated how cod diet changes over time, across seasons and with ontogeny. The role of macroplankton in the diet has been studied by Orlova et al. (2005). The data were used to extrapolate cod cannibalism information back to the 1940s (Yaragina et al., 2018). Furthermore, these data were used to explore intra-and inter-specific interactions between top predators in the Barents Sea (Durant et al. 2014). The Arctic Fisheries Working Group has used the cod diet data to estimate cod predation on North East Arctic cod and haddock and Barents Sea capelin in their stock assessments (ICES, 2019). Spatial dynamics of cod and their main prey were determined by Johannesen et al. (2012), and seasonal variations in feeding and growth by Johannesen et al. (2015). The role of herring and capelin as prey sources have been studied in detail, particularly in relation to size-dependent predation (Johansen, 2002; 2003; 2004). The stomach data have also been used to assess Ctenophora abundance in the Barents Sea, by using cod as a Ctenophora sampling tool (Eriksen et al., 2018). They found that Ctenophora are increasing abundance in cod stomachs in recent years, coinciding with warm seas. The UK dataset covers the period of the 1940s when temperatures in the Barents Sea were similar to those found today (Boitsov et al., 2012). Analysis of this earlier dataset has shown how prey choice is influenced by temperature, with implications for the present day cod population (Townhill et al., 2016). By combining the early and recent years, this new long-term dataset will allow further comparison of temperature regimes throughout the past century. Also, by using cod as a sampling tool, the data can be used to investigate occurrence and trends in any of the species on which they prey. This has been done e.g. by Holt et al. (2021) for cod predation on snow crab (*Chionoecetes opilio*) which is a newly established species in the Barents Sea. UK data has been used to investigate diets in the last century and the role of sea temperature (Townhill et al., 2015). This analysis of the UK data alone found that temperature has a large role to play in explaining the presence of capelin and herring in cod diets. The Russian data were very useful for the understanding of the fluctuations in the ecosystem (e.g. Yaragina and Dolgov, 2011) and for the development of multispecies models. By combining these datasets, we can further understand how the environment and ecosystems are responding to climatic changes, and what influences the diet and prey switching of cod which is evident in the data. Such a long time series will enable trends in temperature and variability indices to be tested against the occurrence of different prey items, and investigate whether fishing pressure on cod and the stocks of their prey affect the diet composition. The dataset will also enable us to improve parametrisation of food web models, and to forecast how Barents Sea fisheries may respond in the future, to management and to climate change.

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3.1 Limitations

The UK data contains pooled data of up to 198 stomachs in one record, where -the stomach data for all of the cod at one sample station was recorded as one record. This data can be used for qualitative analysis, and exploratory analysis of the first half of the 20th century. The stomach contents from the pooled data have been previously presented by Brown and Cheng (1946). The UK data are not as robust as more recent data in that a statistically designed survey was not carried out, and instead the vessels sought the highest catches of cod that they could. This must be taken into account in any analysis of the dataset, but nonetheless the data is still valuable and is a record of cod diets in a certain place and time. There is more detail included in the Norwegian-Russian dataset, such as fullness of stomachs and length and weight of prey. Where such information is required in analysis, the UK data may be less useful. However, there is a lot of value in the combined dataset, even with fewer parameters recorded for the earlier years. The UK data shows similar trends in cod diet to quantitative Russian data for the same time period (Yaragina and Dolgov, 2011), showing that this qualitative data is still useful in investigating trends in cod diets.

The quantitative Norwegian and Russian data is more robust than the UK data, and full details of the sampling methods are available (Dolgov et al., 2007, 2011). The main limitation is that bottom trawls are generally used and so the cod are not well sampled if they are high in the water column. However, cod are generally a demersal species and as such bottom trawling is the most effective sampling method. Also, the sampling is limited in the Lofoten/Vesterålen area, an important spawning location for Barents Sea cod. Analysis of the stomachs of spawning cod has only been possible for certain years, owing to the low number of survey stations in the area (Michalsen et al., 2008). As such, cod stomachs sampled south of 70°N and west of 18°E (Lofoten and nearby areas), were excluded from the dataset and our analyses, as spawning cod is mainly found in this coastal area (Michalsen et al., 2008). This analysis showed that herring dominated the diet and stomach fullness was found to be lower in this area during the spawning period (March and April). As such, the location of the cod should be considered when using this Barents Sea cod diet dataset.

4 Summary

The release of the Barents Sea cod diet dataset is a significant contribution to the study of Atlantic cod ecology, feeding and the Barents Sea ecosystem as a whole. The data have been used in numerous analyses, which has helped scientists gain a detailed understanding of the stock, mainly analysis of separate datasets. Now, with the population at a high level, this combined dataset, covering almost 90 years and stretching back to 1930, can be used to investigate how climate may be affecting the dynamics of the stock, how this may have knock-on effects within the food_web, and what implications this may have for the future of this ecologically and economically important cod stock.

Data Availability

The Barents Sea cod diet database (Townhill et al., 2020) can be accessed and data downloaded from https://doi.org/10.21335/NMDC-2139169383. The prey categories and metadata for the database are found in Supplementary material 1 and 2 respectively. The Russian quantitative data from the joint database (1984-2018) and the qualitative Russian diet data (1947-1983), which are have not yet fullybeen entirely digitized, are not publicly available due to the Institution policy, but access to these data is granted through contracted collaboration in joint projects with the Polar branch of VNIRO. Summaries, descriptions and analyses of the Russian data can be found in the following publications: Zenkevich and Brotskaya, 1931; Zatseespin and Petrova, 1939; Mehl and Yaragina, 1992; Dolgov et al., 2007; Yaragina and Dolgov, 2011; Holt et al., 2019; Yaragina et al., 2009; and Yaragina and Dolgov, 2011.

Author Contribution

BLT conceived the idea for the paper. BB, EJ, NY, AD were all involved in data collection and survey organisation. REH and BLT formed, cleaned and prepared the new Barents Sea Cod Diet Database. REH and BLT prepared the figures for the manuscript. BLT wrote the manuscript with contributions from all co-authors.

Competing Interests

The authors declare that they have no conflict of interest.

5 Acknowledgements

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We further thank everyone involved in initiating, establishing, and updating the joint Norwegian-Russian and the UK stomach content databases, not least the colleagues undertaking the enormous practical task of identifying the stomach-contents.

6 References

Boitsov, V.D., Karsakov, A.L., and Trofimov, A.G. Atlantic water temperature and climate in the Barents Sea 2000–2009. ICES J. Mar. Sci., 69, 933–840, https://doi.org/10.1093/icesjms/fss075, 2012.Brown, W.W., and Cheng, C. Investigations into the food of the cod (*Gadus callarias* L.) off Bear Island and of the cod and haddock (*G. aeglefinus* L.) off Iceland and the Murman Coast, Hull Bull. Mar. Ecol, 3, 35-71, 1946.

Cefas. (2014) Cefas Fish Stomach Records, Available: http://www.cefas.defra.gov.uk/our-science/ fisheries-information/fish-stomach-records.aspx. Accessed 25 March 2014. 2014.

Cushing, D.H., The Arctic cod. A study of research into British trawl fisheries. The Commonwealth and International Library. Pergamon Press Ltd. London. 1966

Dolgov, A.V., Yaragina, N.A., Orlova, E.L., Bogstad, B., Johannesen, E., and Mehl, S., 20th anniversary of the PINRO-IMR cooperation in the investigations of fish feeding in the Barents Sea – results and perspectives. In Long ternm bilateral Russian-Norwegian scientific co-operation as a basis for sustainable management of living marine resources in the Barents Sea. Proceedings of the12th Norwegian-Russian Symposium, Tromsø, 21-22 August 2007. IMR/PINRO report series 5/2007, 212 pp, 2007

Dolgov, A. V., Orlova, E. L., Johannesen, E., and Bogstad, B. Piscivorous fish. In The Barents Sea. Ecosystem, Resources, Management. Half a Century of Russian-Norwegian Cooperation, pp. 466–484. Ed. T. Jakobsen and V. K. Ozhigin. Tapir Academic Press, Trondheim, Norway, pp. 44-78. Ed. By Haug, T., Misund, O.A., Gjøsæter, H., Røttingen, I. Institute of Marine Research, Bergen, Norway. Polar Research Institute of Marine Fisheries and Oceanography – PINRO. Tapir Academic Press, Trondheim, Norway. 2011.

Durant, J.M., Skern-Mauritzen, M., Krasnov, Y.V., Nikolaeva N,G, Lindstrom, U., Dolgov, A. Temporal dynamics of top predators interactions in the Barents Sea. PLoS One 9:e110933, https://doi.org/10.1371/journal.pone.0110933, 2014.

Eriksen, E., Bogstad, B., Dolgov, A., and Beck, I.M. Cod diet as an indicator of Ctenophora abundance dynamics in the Barents Sea, Mar. Ecol. Prog. Ser., 591, 87-100, https://doi.org/10.3354/meps12199, 2018.

Fossheim, M., Primicerio, R., Johannesen, E., Ingvaldsen, R.B., Aschan, M.M., and Dolgov, A.V. Recent warming leads to a rapid borealization of fish communities in the Arctic, Nat. Cli. Ch., 5, 673-677, https://doi.org/10.1038/nclimate2647, 2015.

Graham, M. English Fishery Research in Northern Waters, Arctic Institute of North America 6, 252-259, 1953.

Holt, R.E., Bogstad, B., Durant, J.M., Dolgov, A.V., and Ottersen, G. Barents Sea cod (*Gadus morhua*) diet composition: long-term interannual, seasonal, and ontogenetic patterns, ICES J. Mar. Sci. 76(6): 1641-1652, https://doi.org/10.1093/icesjms/fsz082, 2019.

Holt, R. E., Hvingel, C., Agnalt, A-L., Dolgov, A. V., Hjelset, A. M., and Bogstad, B. Snow crab (*Chionoecetes opilio*), a new food item for North-east Arctic cod (*Gadus morhua*) in the Barents Sea. ICES Journal of Marine Science xx:xxx-xxx. Doi: 10.1093/icesjms/fsaa168, 2021.

Hylen, A. Fluctuations in abundance of Northeast Arctic cod during the 20th century. ICES Mar. Sci. Symp., 215, 543-550, 2002.

Hyslop, E. J. Stomach content analysis – a review of methods and their application, J. Fish Biol., 17: 411–429, https://doi.org/10.1111/j.1095-8649.1980.tb02775.x, 1980.

ICES, 2019. Report of the Arctic Fisheries Working Group (AFWG). ICES Scientific Reports. 1:30. 934 pp. http://doi.org/10.17895/ices.pub.5292

Johannesen, E., Lindstrøm, U., Michalsen, K., Skern-Mauritzen, M., Fauchald, P., Bogstad, Bjarte, and Dolgov, A. Feeding in a heterogenous environment: spatial dynamics in summer foraging Barents Sea cod, Mar. Ecol. Prog. Ser., 458, 181-197. https://doi.org/10.3354/meps09818, 2012.

Johannesen, E., Johansen, G.O., and Korsbrekke, K. Seasonal variation in cod feeding and growth in a changing sea, NRC Research Press, 73, 235-245, https://doi.org/10.1139/cjfas-2015-0052, 2015.

Johansen, G.O. Temporal and spatial variation in predation on juvenile herring (C*lupea harengus* L.) by Northeast Arctic cod (*Gadus morhua* L.) in the Barents Sea in 1984-1997, ICES Journal of Marine Science, 59, 270-292. 2002.

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Johansen, G.O. Size-dependent predation on juvenile herring (*Clupea harengus* L.) by North-east Arctic cod (*Gadus morhua* L.) in the Barents Sea, SARSIA, 88, 136-153. 2003. DOI 10.1080/0036482031000148.

Johansen, G.O., Bogstad, B., Mehl, S., and Ulltang, Ø. Consumption of juvenile herring (*Clupea harengus*) by cod (*Gadus morhua*) in the Barents Sea: a new approach to estimating consumption in piscivorous fish, Canadian Journal of Fisheries and Aquatic Science, 61, 343-359. 2004. doi: 10.1139/F03-168.

Kjesbu, O. S., Bogstad, B., Devine, J. A., Gjøsæter, H., Howell, D., Ingvaldsen, R. B., Nash, R. D. M., and J.E. Skjæraasen. Synergies between climate and management for Atlantic cod fisheries at high latitudes, Proc. Nat. Acad. Sci. USA, 111, 3478–3483, https://doi.org/10.1073/pnas.1316342111, 2014.

Link J.S., and Garrison, L.P. Trophic ecology of Atlantic cod *Gadus morhua* on the northeast US continental shelf, Mar. Ecol. Prog. Ser., 227, 109-123, https://doi.org/10.3354/meps227109, 2002.

Link, J. S., Bogstad, B., Sparholt, H., and Lilly, G. R. Role of Atlantic cod in the Ecosystem, Fish and Fish, 10, 58-87, https://doi.org/10.1111/j.1467-2979.2008.00295.x, 2009.

Mehl, S. Stomach contents of North-East Arctic cod and possible changes in the diet the last years, ICES CM 1986/G: 29: 26 pp., 1986.

Mehl, S., and Yaragina, N. A. Methods and results in the joint PINRO-IMR stomach sampling program. In Interrelations between Fish Populations in the Barents Sea. Proceedings of the 5th Soviet-Norwegian Symposium. Murmansk, 12–16 August 1991, pp. 5–16. Ed. by B. Bogstad and S. Tjelmeland. Institute of Marine Research, Bergen, Norway. Polar Research Institute of Marine Fisheries and Oceanography – PINRO, 1992.

Michalsen, K., Johannesen, E., and Bogstad, B. Feeding of mature cod (*Gadus morhua* L.) at the spawning grounds in Lofoten, ICES J. Mar. Sci., 65, 571-580, https://doi.org/10.1093/icesjms/fsn019, 2008.

Neuenfeldt, S., and Beyer, J. E. Environmentally driven predator–prey overlaps determine the aggregate diet of the cod *Gadus morhua* in the Baltic Sea, Mar. Ecol. Prog. Ser., 310, 151–163, https://doi.org/10.3354/meps310151, 2006.

Orlova, E. L., Dolgov, A. V., Rudneva, G. B., and Nesterova, V. N. The effect of abiotic and biotic factors on the importance of macroplankton in the diet of Northeast Arctic cod in recent years, ICES J. Mar. Sci., 62, 1463e1474, https://doi.org/10.1016/j.icesjms.2005.08.003, 2005.

Ottersen, G., Bogstad, B., Yaragina, N.A., Stige, L.C., Vikebø, F.B., and Dalpadado, P. A review of early life history dynamics of Barents Sea cod (*Gadus morhua*)." ICES Journal of Marine Science 71(8): 2064–2087, 2014.

Pálsson, Ó. K., and Björnsson, H. Long-term changes in trophic patterns of Iceland cod and linkages to main prey stock sizes, ICES J. Mar. Sci., 68: 1488–1499, https://doi.org/10.1093/icesjms/fsr057, 2011.

Pinnegar JK. DAPSTOM—An Integrated Database & Portal for Fish Stomach Records. Version 4.7. Centre for Environment, Fisheries & Aquaculture Science, Lowestoft, UK. February 2014, 39pp., 2014.

Pinnegar, J.K. DAPSTOM—An Integrated Database & Portal for Fish Stomach Records. Version .5.5 Centre for Environment, Fisheries & Aquaculture Science, Lowestoft, UK. July 2019, 34pp., 2019.

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Pinnegar, J.K., Goni, N., Trenkel, V.M., Arrizabalaga, H., Melle, W., Keating, J., and Oskarsson, G. A new compilation of stomach content data for commercially important pelagic fish species in the northeast Atlantic. Earth Syst. Sci. Data, 7, 19-28, https://doi.org/10.5194/essd-7-19-2015, 2015.

Townhill, B.L., Maxwell, D., Engelhard, G.H., Simpson, S.D., and Pinnegar, J.K Historical Arctic Logbooks Provide Insights into Past Diets and Climatic Responses of Cod, PLoS ONE, 10, e0135418, https://doi.org/10.1371/journal.pone.0135418, 2015.

Townhill, B.L., Holt, R.E., Bogstad, B., Durant, J.M., Pinnegar, J.K., Johannesen, E., and Ottersen G. ~~(~~2020~~)~~ Barents Sea Cod Diet Data https://doi.org/10.21335/NMDC-2139169383, 2020

Tsou, T. S., and Collie, J. S. Estimating predation mortality in the Georges Bank fish community, Can. J. Fish. Aq. Sci., 58, 908–922, https://doi.org/10.1139/f01-044, 2001.

Willis, T. V., Wilson, K. A., Alexander, K. E., and Leavenworth, W. B. Tracking cod diet preference over a century in the northern Gulf of Maine: historic data and modern analysis, Mar. Ecol. Prog. Ser., 474, 263–276, https://doi.org/10.3354/meps10068, 2013.

Yaragina, N. A., Bogstad, B., and Kovalev, Y. A. Variability in cannibalism in northeast Arctic cod (*Gadus morhua*) during the period 1947–2006, Mar. Biol. Res., 5, 75–85, https://doi.org/10.1080/17451000802512739, 2009.

Yaragina, N.A., and Dolgov, A.V. Long-term variations in the importance of prey species for demersal fish in the Barents Sea under conditions of climate change. Pp. 160-180. In Climate change and effects on the Barents Sea marine living resources. Proceedings of the 15th Russian-Norwegian Symposium, Longyearbyen, 7-8 September 2011. Ed. Haug, T., Dolgov, A., Drevetnyak, K., Røttingen, I., Sunnanå., K. and Titov, O. Institute of Marine Research, Bergen, Norway. Polar Research Institute of Marine Fisheries and Oceanography – PINRO, IMR/PINRO report series 2/2011, 290 pp, 2011.

Yaragina, N.A., Kovalev, Y., and Chetyrkin, A. Extrapolating predation mortalities back in time: an example from North-east Arctic cod cannibalism, Mar. Biol. Res., 14, 203-216, https://doi.org/10.1080/17451000.2017.1396342, 2018.

Zenkevich~~atsepin~~, L.A. and Brotskaya, V.A. Materials on the feeding of the Barents Sea fishes, Proceedings of the 1st session GOIN, No 4: 1-35, 1931. In Russian.

Zatsepin, V.I. and Petrova, N.S. The food of the commercial stocks of cod in the southern part of the Barents Sea (from observations made in 1934-1938). Fisheries Research Board of Canada Translation Series 1064 No. 498. Original title: Pitanie promyslovykh kosiakov treski v yuzhno~~p~~i che~~a~~sti Barentsova Mo~~p~~ria (po nabliudeniiam v 1934-1938 g.g.) From: Trudy Poliarnogo N.-I. Instituta Morskogo Rybnogo Khoziaistva i Okeanografii imeni N.M~~N~~. Knipovicha (PINRO). No. 5, 170 pp., 1939.

7. Figures

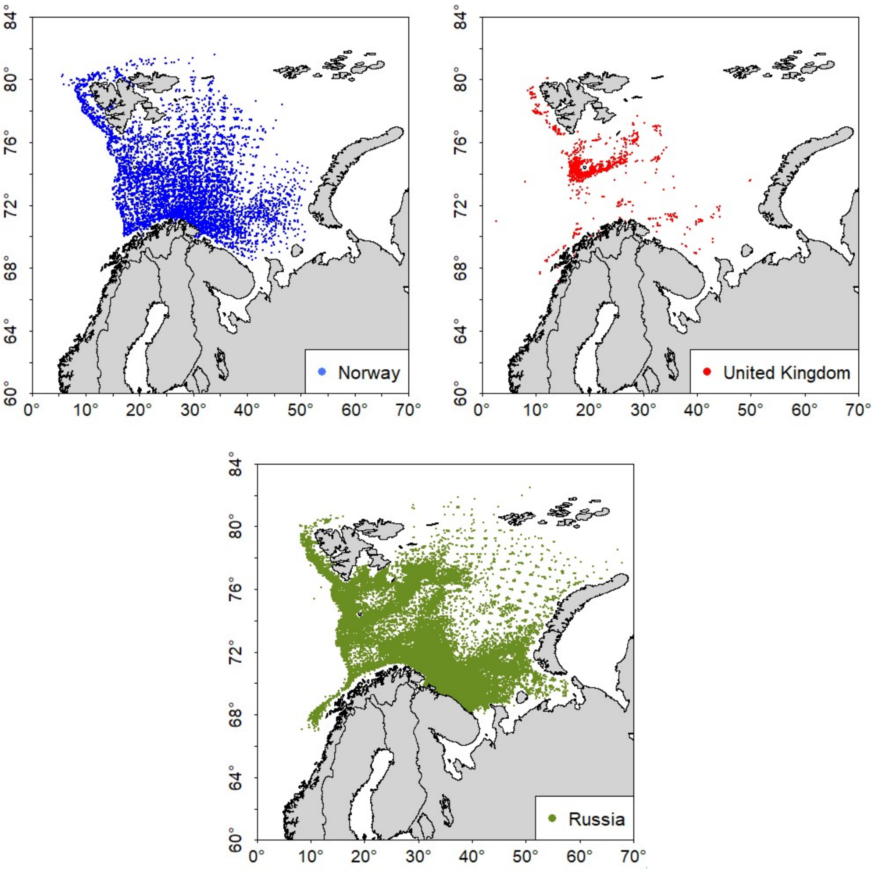


Figure 1. The location of the cod stomach samples taken in the Barents Sea by each institution.

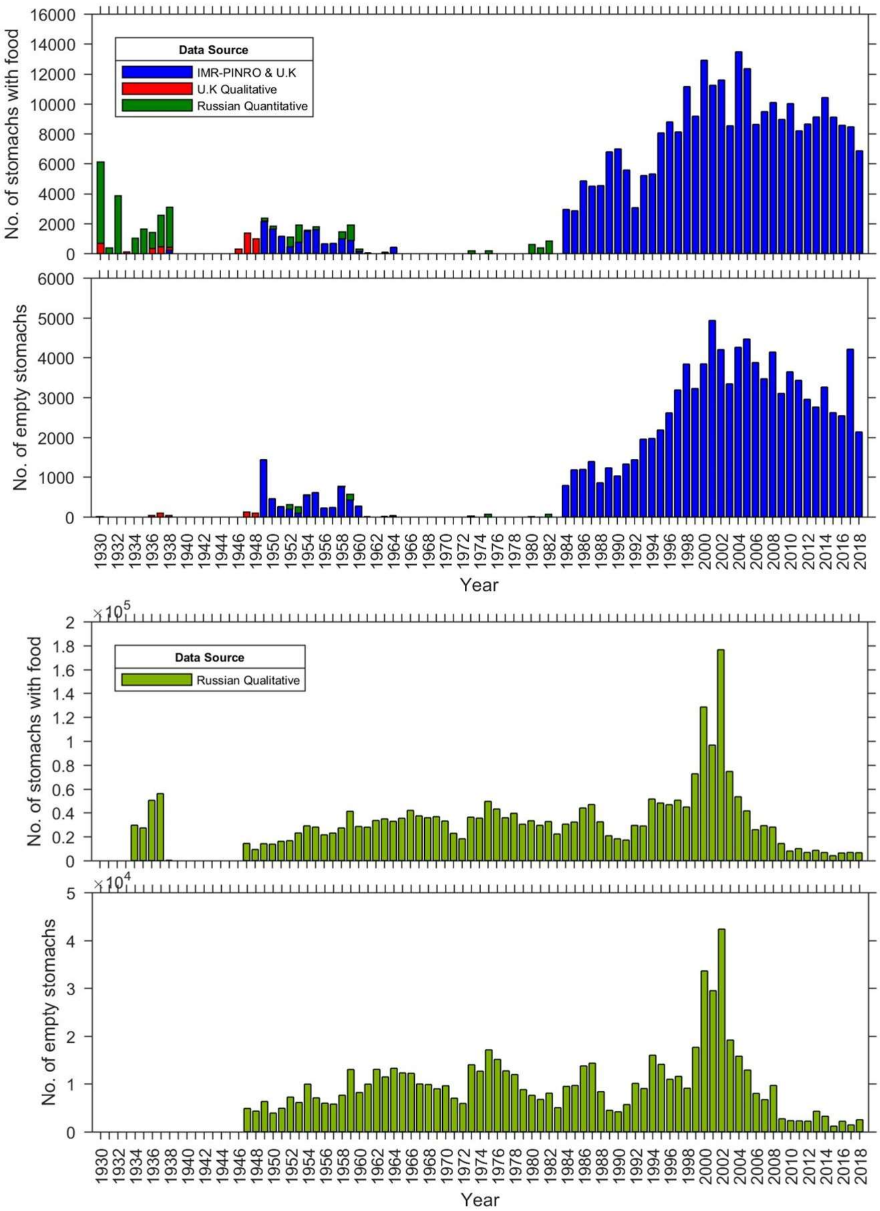


Figure 2. Number of stomachs sampled in each year, showing those with food contents and those that were empty. Upper two panels: All data except the Russian qualitative data. Lower two panels: Russian qualitative data only.

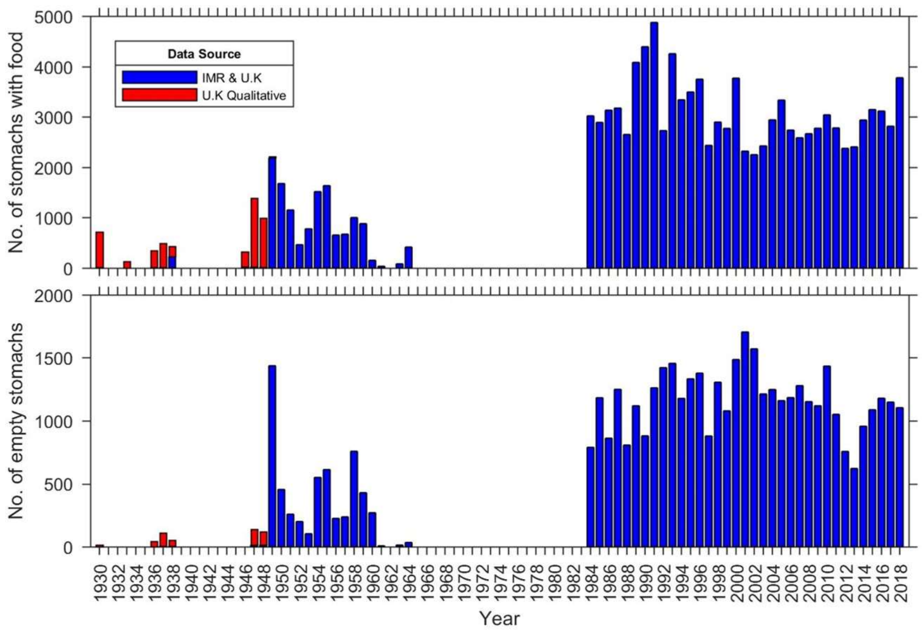
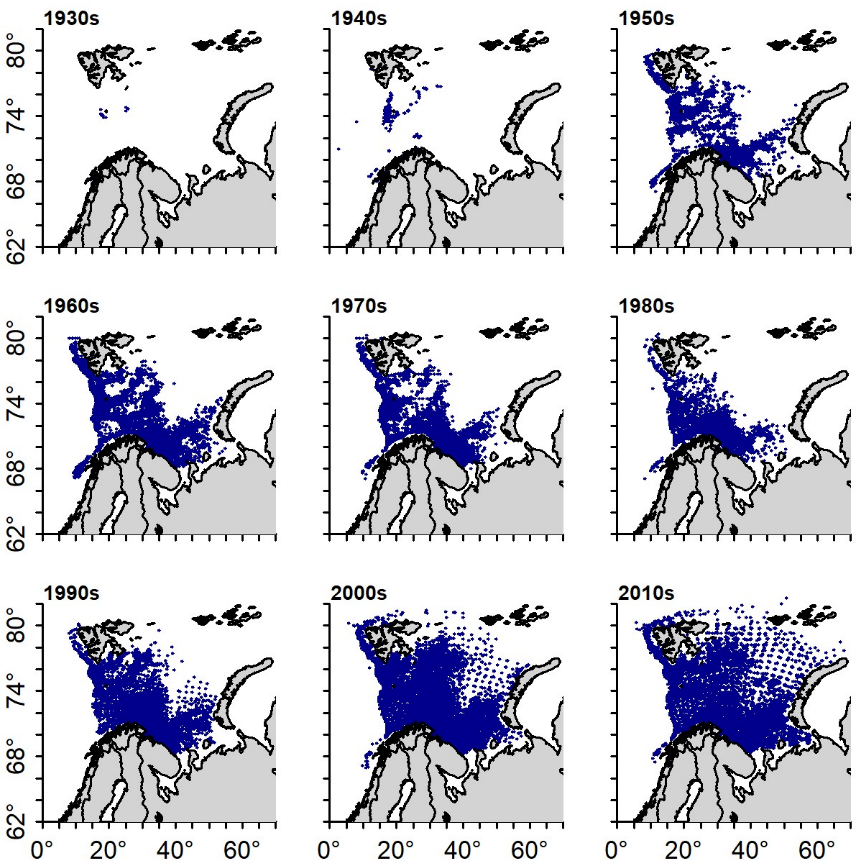


Figure 2. Number of stomachs sampled in each year, showing those with food contents (uUpper panel) -and those that were empty (lLower panel).


1930s
1940s
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1980s
1990s
2000s
2010s
80°
74°
68°
62°
0°
20°
40°
60°

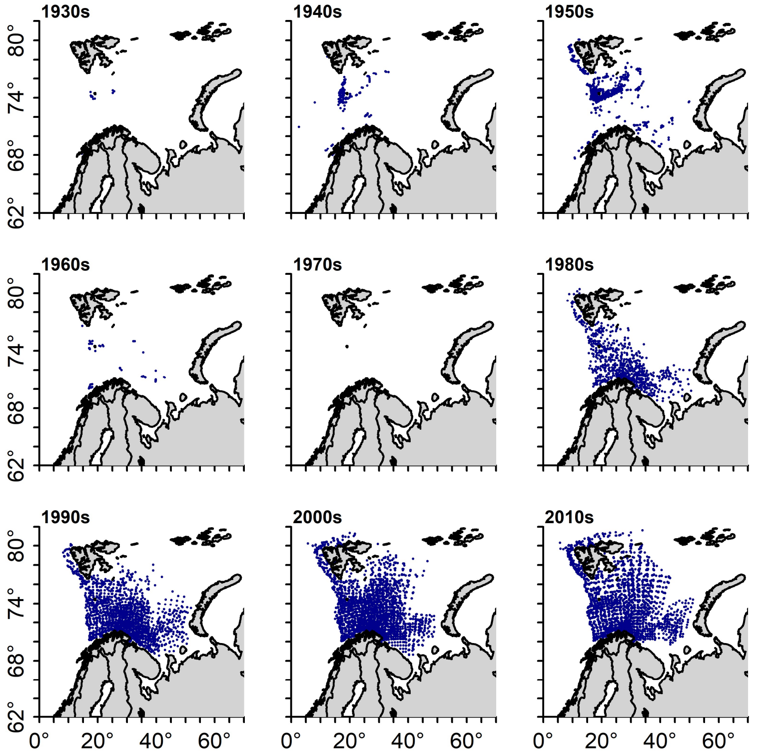
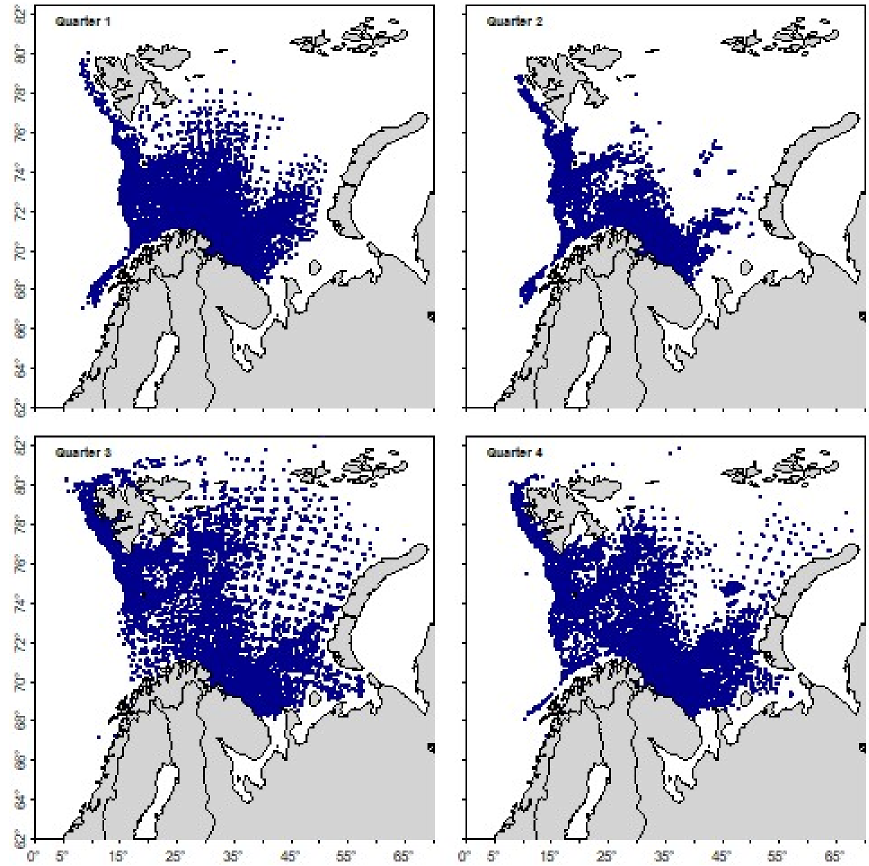


Figure 3. Sampling coverage in each decade ~~for all Russian, Norwegian and UK data combined~~. Each dot denotes a stomach sample.



Quarter 1
Quarter 2
Quarter 3
Quarter 4
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64°
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68°
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35°
45°
55°
65°

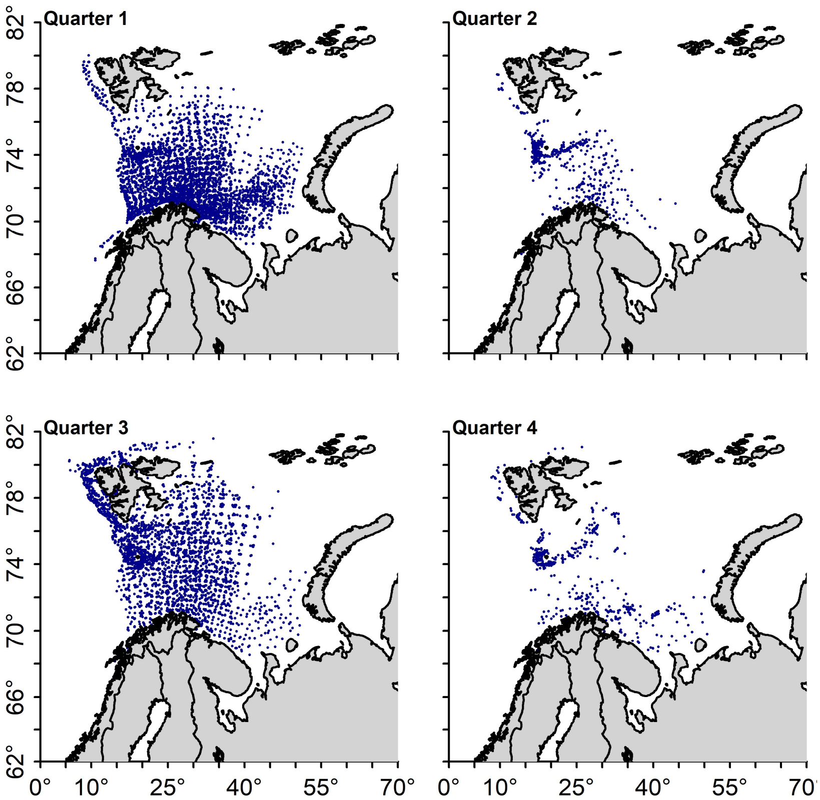
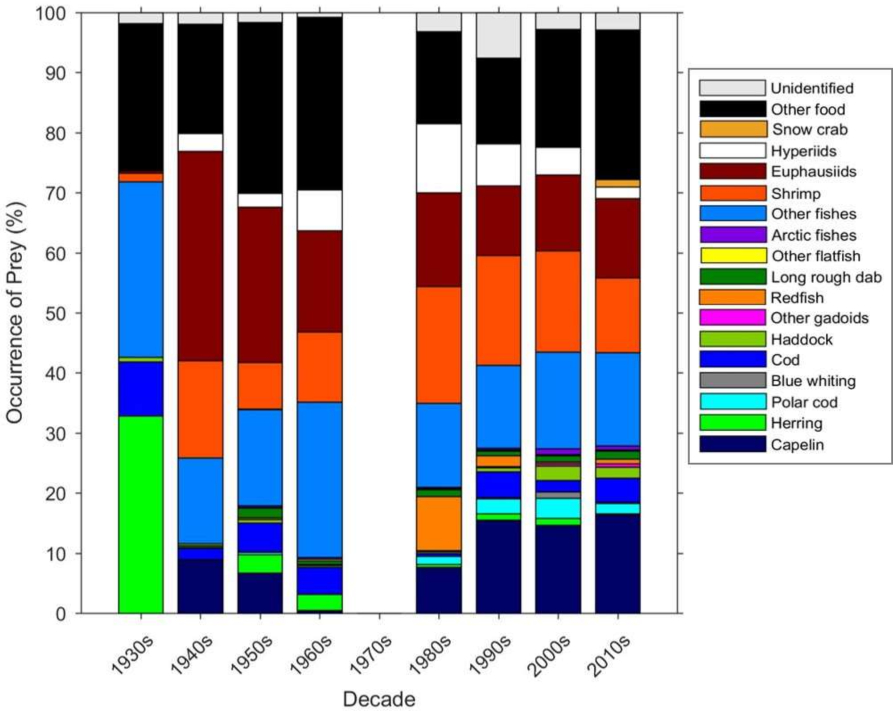


Figure 4. Sampling coverage in each quarter ~~for all Russian, Norwegian and UK data~~ over all years combined. Each dot denotes a stomach sample.


Occurrence of Prey (%)
0
10
20
30
40
50
60
70
80
90
100
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s
2010s
Decade
Unidentified
Other food
Snow crab
Hyperiids
Euphausiids
Shrimp
Other fishes
Arctic fishes
Other flatfish
Long rough dab
Redfish
Other gadoids
Haddock
Cod
Blue whiting
Polar cod
Herring
Capelin

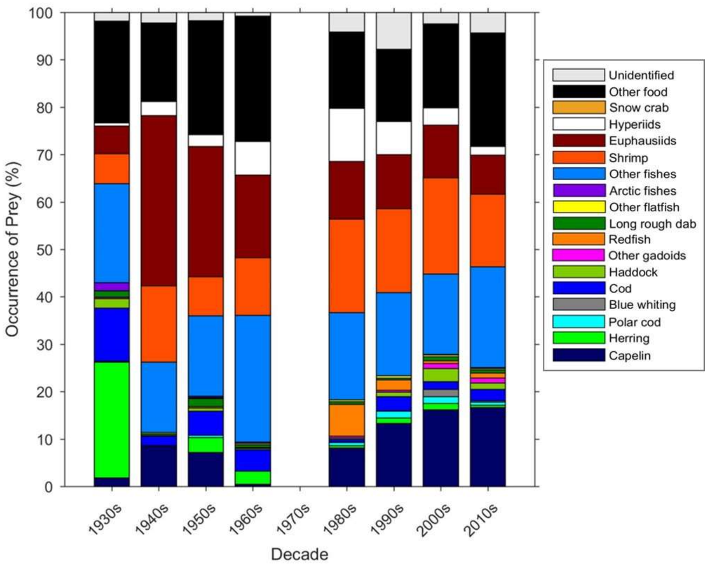


Figure 5. The percentage occurrence of prey in each decade. The percentage occurrence of each prey item is calculated based on the total prey items in each decade and excludes empty stomachs.

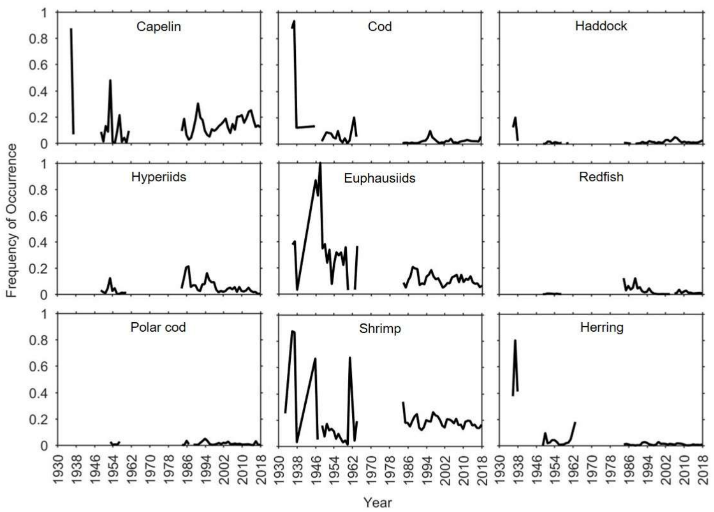


Figure 6. Time series of occurrence of the main prey items in the dataset, excluding empty stomachs. The frequency of occurrence of each prey item is calculated based on the total number of stomachs in each year.

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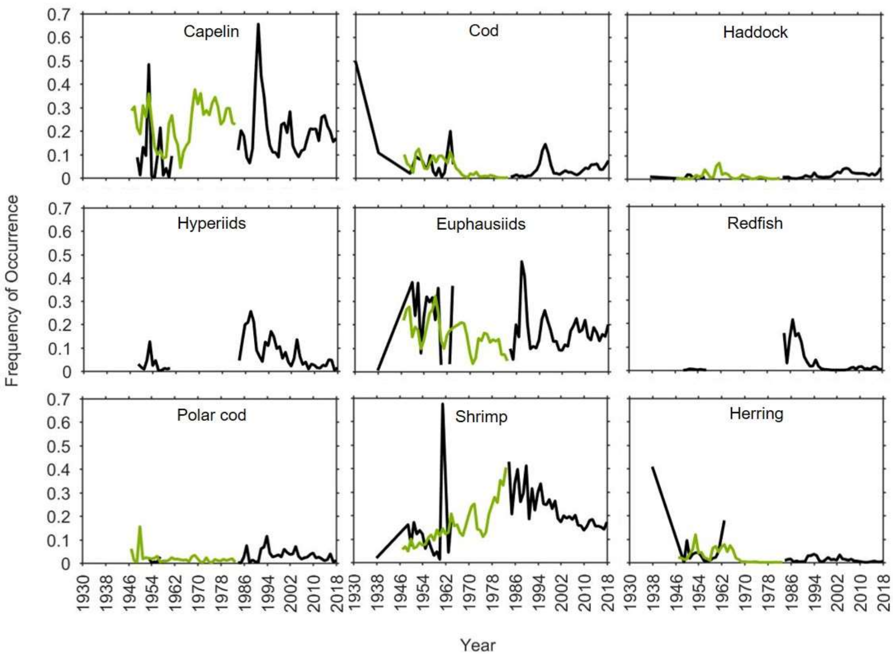

Figure 6. Time series of occurrence of the main prey items in the dataset, excluding empty stomachs. The frequency of occurrence of each prey item is calculated based on the total number of stomachs in each decade. (Black line: combined IMR-PINRO & U.K Barents Sea cod diet dataset data; green line: earlier Russian data).

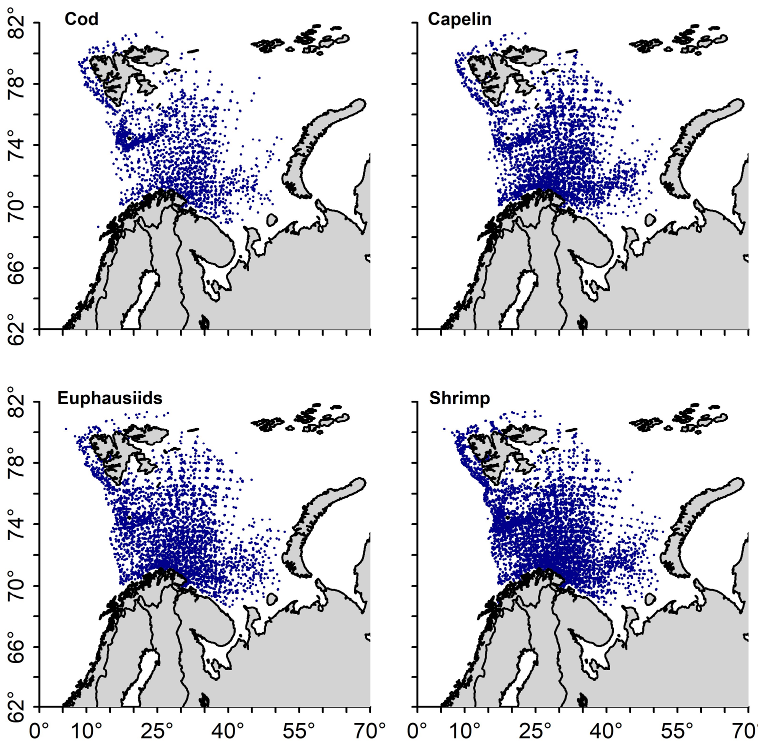

Figure 7. The presence of the main prey species in stomachs over all years combined. Each dot denotes a stomach sample.

8 Table

Table 1. The data available on Barents Sea cod stomachs

Source	Years	Total number of stomachs (Incl. Empty)	No. by quarter	Empty stomachs (~~(% or~~ number, n)	Area	Pooled or single stomachs	Fishing gear	Main prey species	Published in Barents Sea cod diet dataset
UK	1930-1949	103 records totalling 4532 stomachs	Q1: 263 Q2: 685 Q3: 2235 Q4: 1349	Unknown	Western Barents Sea, focused on Bear Island and Spitsbergen	Pooled	Commercial trawls	Euphausiids, shrimp, fish	Y
UK	1930-1964	19003	Q1: 2935 Q2: 6314 Q3: 4159 Q4: 5595	Q1: 850 Q2: 2498 Q3: 656 Q4: 1586	Bear Island, Spitsbergen	Single	Otter trawl	Euphausiids, shrimp, cod, capelin, herring	Y
Norway	1984-2018	146 360	Q1: 85 644 Q2: 6343 Q3: 49 032	Q1 26 723 Q2: 2079 Q3: 10 599	Western and central Barents Sea	Single	Pelagic, bottom and commercial trawl	Cod, capelin, shrimp, euphausiids	Y

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			Q4: 5341	Q4: 1238					
Russia	1986-2018	234 587	Q1: 26 274 Q2: 42 933 Q3: 60 638 Q4 104 742	Q1: 5970 Q2: 14 162 Q3: 8339 Q4: 27 453	Western, eastern and central Barents Sea	Quantitative	Pelagic, bottom and commercial trawl	Shrimp, euphausiids, capelin, other fish, hyperiids	N
Russia	1934 - 2018	3 304 134	Not available	n= 709 112	Western, eastern and central Barents Sea	Qualitative	Pelagic and bottom trawl	Capelin, euphausiids, shrimp, cod	N