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The variability of fisheries and fish populations prior to industrialized fishing: An appraisal of the historical evidence

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ABSTRACT

This paper assesses the potentials of the available time series (50 years+) from historical records of the pre-industrial period until c. 1850–1950. A number of historical records from commercially important fish species are available for examining natural variability of fish stocks. Especially for North Atlantic and Japanese fisheries historical data have been retrieved from archives and museums, which cover time spans of 50–350 years. This makes it possible to examine natural variability of fish stocks over a much longer time span than what is normally possible with modern survey data and commercial catch data. Furthermore, historical evidence from the pre-industrialized period have the benefit of stemming from a period in time, when fishing had an insignificant impact on the abundance of open sea fish stocks. The best material comes from cod and herring fisheries, where it is possible to reconstruct CPUE as accurate as catch per boat per day absent, as well as changing spatial distribution over longer time periods.

1. Introduction

Much climate variability takes place within a multi-decadal and -centennial context. Therefore, the connections between climate variability and the natural variability of fish populations must be evaluated at similarly long time scales. Most scientifically collected data on fish populations though, can be found for the last 50 or 100 years only. This poses two problems. First of all, the limits of the time frame may have the effect that the climatically induced changes are not evident. Secondly, the last 50 or 100 years is also the one period in history, where the effect of fishing, eutrophication and pollution has had the greatest impact on marine ecosystems (Holm et al., 2001; Jackson et al., 2001; Pitcher, 2001; Pauly and Palomares, 2005). Ideally therefore, we must look for historical material from the period before industrialization, which can reveal natural variability of fish populations. However, since pre-20th century fisheries data were not collected in a scientific context, it is of vital importance to assess the qualities of historical material in light of the context in which they were produced. The intent of this paper is to present a quality assessment of historical data, which can be used as historical evidence of natural variability of fish populations.

2. Materials and method

2.1. The pre-industrialized period

When it comes to written testimonies of pre-industrial fishing activity, the time frame is in most cases limited to a few hundred years. The starting point of the industrial period is usually considered to be the second half of the 19th century in the major European and North American fisheries. The industrialization of fisheries is characterized by a number of technological changes in fishing techniques, which all contributed to more efficient fishing operations. In the 1860s machine made cotton nets gradually replaced the old heavier hemp nets, and in the following decades steam propulsion and, from the turn of the 20th century, motor propulsion gave extra trawling power and the ability to move independently of prevailing winds.

In principal then, historical evidence can be found as far back in time as fishing has taken place. However, the demands for available, consistent and reliable historical data limit the time frame considerably. Another limitation is that the historical datasets need to cover a number of years in order to be suitable for testing for climate signals. Therefore, the following discussion of historical data only includes datasets, which span more than c. 50 years.

2.2. Written documents

With regard to written documents the oldest known data for fishing are from Europe. During the course of the 14th–16th centuries writing on paper became increasingly common in Europe. This is also the time when the bureaucracy of the emerging modern state bureaucracy as well as larger private enterprises gradually became established. These developments ensured two aspects of fisheries record keeping. First of all, the fiscal interest of the modern state ensured an interest in accurate numbers. Secondly, state interest often lead to an institutionalization of fisheries regulations, whereby a steady, recurring and often quite uniform annual collection of data

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took place. In line with this, ancient record keeping deals exclusively with commercially important species. Cod, herring, anchovy, sardine, salmon, various flatfish and tuna therefore are the most prominent in this type of historical material. Thus, along with a bias towards European and Atlantic fisheries, there is an inherent bias in terms of which species feature in historical material.

During the last decade several large scale projects have been under way trying to recover archival material for reconstructing historical fish stocks, and this review stands on the shoulders of these efforts, which are producing online free access databases. The History of Marine Animal Populations project of the Census of Marine Life programme (2000–2010) is an umbrella for the research of c. 100 historians, archaeologists and marine scientists trying to assess what lived in the oceans before modern times (http://www.hmapcoml.org/). Within the INCOFISH Specific Targeted Research Project of the European Community (2005–2008) the recovery of time series for historical fisheries is a means to shift the baseline of understandings of ecosystem functioning (http://www.hull.ac.uk/incofish/index.htm). The Sea Around Us Project of the University of British Columbia is mainly concerned with fisheries developments since 1950, but also has strong components stretching back hundreds of years (http://www.seaaroundus.org/).

2.3. Long-term environmental time series

Comparing long-term changes in fish populations with environmental variability is strongly aided by the existence of equally long time series of environmental variability. Records of temperature, wind, air pressure and similar parameters for environmental variability and changes rarely exist for longer than c. 100–200 years back in time. Assessing historical climate reconstructions would be a topic for a paper in its own right, but it should be mentioned that much effort is currently being put into such reconstructions, and the following portals hold valuable collections of such time series:

CLIVAR, Climate variability and Predictability (http://www.clivar.org/). KNMI, The Royal Dutch Meteorological Institute, among other resources, provides access to the global CLIWOC project trying to reconstruct the global weather from 1750–1850 (http://climexp.knmi.nl/). The NOAA Satellite and Information Service is hosting a large amount of temperature proxies (http://www.ncdc.noaa.gov/paleo/data.html), while datasets from Greenland ice cores are available from the University of Copenhagen, (http://www.glaciology.gfy.ku.dk). Finally, a large collection of dataset can be extracted from NASA at (http://gcmd.nasa.gov/index.html). A very large project currently in progress is *Millenium*, which has as its main goal to reconstruct the climate variability in Europe during the last 1000 years to see whether changes in the last one hundred years are unique in scale (http://geography.swan.ac.uk/millennium/index.htm).

3. Results and discussion

3.1. Cod

Within cod fisheries, some of the longest time series for fishing activity deal with the cod fisheries near Iceland. The historical evidences for the cod populations around Iceland have been subject of a thorough investigation by Jónsson extracting sources from English, Dutch, French as well as native Icelandic fishers since the Middle Ages. This has led to estimates of total landings for the fishers around Iceland, which especially for the 18th and 19th centuries cover long uninterrupted phases (Jónsson, 1994).

Ogilvie and Jónsdóttir examined the historical relationships between the success of the Icelandic cod fisheries in the 18th and 19th centuries and the occurrence of sea ice in Icelandic waters in the period 1680–1780 (Ogilvie and Jónsdóttir, 2000). They constructed a time series for this period based on ordinal scales of catches being 'good', 'poor', 'reasonable' and other similar categories. They conclude from these observations that the period 1680–1760 with much sea ice coincided with years of generally very poor catches, but that socio–economic factors influencing the fishing activity were also to blame for the poor fishing. The authors thus refrained from any conclusive arguments with regards to climatically induced changes.

The cod fisheries around Iceland were also the topic for an analysis of the possible temperature effects on catch records from French cod fishermen. CPUE as catch per landed tonnes of Icelandic cod per vessel for the French fleet for the period 1823–1900 was tested against Iceland air temperature records for the same periods. The author has reservations on the quality of the sources available and explanatory power of the test, but concludes that the analysis is consistent with modern analysis showing a positive relationship between temperature and recruitment of cod stocks in the Northern Atlantic (Solow, 2001).

With the case of the Norwegian cod fisheries records have been reconstructed from tithes dating back to the late 16th century and through the aid of Norwegian export figures well into the modern day statistical period. Particularly good cod fisheries seem to have coincided with periods of relatively mild weather in the north east Atlantic (Øiestad, 1994). For more recent data stemming from 1872–1951 the Norwegian cod landings have been compared with lunar cycles as well as sun spot frequency revealing clear signals (Wyatt et al., 1994).

Further to the east into the Barents Sea and the White Sea, Russian catch data for cod and halibut for 33 years (out of the period 1710–1793) support the findings of Øiestad that those milder periods were beneficial for the cod populations in the north east Arctic area (Lajus et al., 2005). Also in the Northeast Arctic, the application of CPUE data (catch per man) on Norwegian based cod fisheries dating from 1865–1951 has been fruitful (Godø, 2003). Because of the long time span in both catch records and environmental time series it is possible to see that long-term environmental changes often provide a backbone to more short term developments in the fluctuations of the resident cod stock.

Further to the south a recent study of tithes being paid in the Faroe Islands in the period 1585–1652 has brought forward a time series of the catch of unspecified 'fish' (Guttesen, 2004). Potentially the Faroe Islands pose a rich source of information similar to Iceland and northern Norway.

In the Baltic Sea catch series for the resident cod stock has been the topic of an investigation of the custom rolls from c. 1600–1920. From this study the most prolific records have emerged from the Danish island of Bornholm (Bager et al., 2002). Ongoing research is looking into possible links between current theories of the natural variability of the Baltic cod and these records as well as records from the industrial period (MacKenzie et al., 2002a,b).

The largest cod fishery of all times however, is probably the Newfoundland fishery. At least from 1710–1833 CPUE can be reconstructed as catch per boat per season (Myers, 2001). Going further back in time catch records exist for a substantial number of years (Pope, 1997; Pope and Howse, 1675–1698).

Estimated total catch data have been used recently in an attempt to compare temperature with production, where the result indicates an environmental signal in the early 19th century, when colder climate coincided with lower catch rates and led to a decrease in population size, while fishing pressure was seen to have a decisive impact in 20th century fluctuations (Rose, 2004).

However, local cases of depletion should not be overlooked even in an essentially pre-industrial fishing operation. This has been demonstrated with regard to the 19th century spatial expansion of the Newfoundland cod fishery. The effects of local and serial depletion, a spatially changing labour market, as well the spatially dictated natural variability of the cod populations were likely forces at play at the same time (Cadigan and Hutchings, 2001).

A recent study of the 19th century Swedish cod and ling fisheries in Skagerrak and the North Sea have shown similar signs of serial depletion of ling stocks due to the impact of low-tech fishing operations (Poulsen, 2007).

3.2. Pelagic species

Herring, anchovy and sardine are all commercially important pelagic species. However, in written documents references to herring have provided the bulk of historical evidence for natural variability of populations.

Within European fisheries the timing and causes for the Bohuslen herring periods is probably the most ancient topic for a scientific discussion of this kind. Approximately once every century since the 10th century, a period of 30–60 years of extremely prolific herring fisheries has been recorded at Bohuslen. The causes of these Bohuslen periods have been subject to various speculations at least since the late 16th century (Poulsen, 2002). The first investigation of climatic reasons for the phenomenon came as early as 1879. A Scandinavian audience of fisheries scientists was treated to the hypothesis by A. V. Ljungman that changes in the frequency of sunspots lay behind the periodicity of the occurrence of herring (Ljungman, 1879).

The origin of the herring as well as the causes for its sudden emergence and later disappearance have been the focus of much debate. In the 1950s and 1960s Norwegian scientist Devold put forward the hypothesis that the herring at Bohuslen belonged to the Atlanto–Scandian herring race, and that it appeared in the Skagerrak in some periods, switching to the Norwegian west coast in others (Devold, 1963). In the 1960s though, the Swedish scientist Höglund analyzed fish bones excavated from 18th century production sites for train oil. He argued that the Bohuslen herring came from the North Sea, and was really spent (i.e. post-spawning) herring from the sub-population of the Buchan herring (Höglund, 1972). Today Höglund's theory still holds sway (Corten, 2001). Nonetheless, the causes for the periodic changes in the annual migration patterns for the North Sea herring are still much debated, and the topic for a discussion in its own right (Alheit and Hagen, 1997).

The periodical appearance of Atlanto–Scandian herring off the west coast of Norway has lead to large scale fisheries documented through historical documents over the last 500 years. One such distinct period was from 1518–1572 (Nedkvitne, 1988). The catches of herring in Norway are not known this far back in time, but through long time series of export statistics it is possible to reconstruct the production of salted herring in Norway from 1650 onwards. The Norwegian historian Fossem has published time series of the size of the export of herring from Bergen for about half of the years during the period 1650–1795 (Fossem, 1979). For the decade 1749–60 the total export from the ports of the west coast is known. In these years the average export from Bergen is 57% of the total Norwegian export. The historical records document a phase of particularly large scale fishing in c. 1730–1784 and another one from 1808–1872 (Solhaug, 1976).

There is one exception to the pattern of periods with large spring fisheries for herring in Norway, which is the first half of the 17th century from ca. 1620–1650. At this period the Sound toll registers reveal that Norway exported a large amount of herring through the Baltic — of a magnitude similar to the herring shipments from Norway through the Sound in the 1680s and 1690s (Michell, 1977). Contemporary qualitative evidence suggests that the herring period in the 1620s–1650 did not coincide with the emergence of spring spawning Atlanto–Scandian herring near the Norwegian shoreline. Rather, a few surviving custom rolls suggest by the timing of the exports, that this was an instance of a large herring fishery for autumn spawning herring. This fishery took place near the town of Stavanger and northwards around Bergen and Trondheim, which both became central areas for the later emerging spring fishery (Nedkvitne, 1988).

For the Scottish herring solid quantitative evidence is only available from 1809 onwards. From the mid-19th century the Scottish herring industry developed into a highly modern fishery (Coull, 1996). However in spite of fishing mortality having a potential impact on stock abundance from this time on, analyses of impacts from lunar cycles and sun spots have shown clear signals (Wyatt et al., 1995).

The English Channel has also been the focus of investigations into climate related issues in the last 20 years. Southward et al. (1988) presented an analysis of the fisheries for sardine and herring in the English Channel as they took place from the South English counties Devon and Cornwall from the late 16th century until the present. They compared climate factors such as sunspots and temperature changes with various evidences for fishing activity and they concluded that periods of warmer weather favoured the sardine fisheries, while colder climate was more beneficial to the herring fisheries. However, the historical fisheries data from before c. 1900 were mainly of qualitative nature. Thus for most of the time span the analysis rests on scarce reports from visiting travel writers and notes in old local newspapers on the relative success of the different fisheries (Southward et al., 1988). This makes the historical source material dependent on highly heterogeneous and subjective origins.

From the French side of the Channel, Binet (1988) had reached a similar conclusion, also based on mainly qualitative evidences. Going back to c. 1700, Binet constructed an ordinal scale for the French herring and sardine fisheries, grouping each year into one of the categories "poor", "medium" or "good".

In an overview of historical European herring fisheries it was proposed that long term developments in temperature affect the abundance as well as the spatial distribution of herring, sardine and anchovy in Northern Europe (Alheit and Hagen, 1997). Different reports on a number of historical fisheries were compared, showing that there are similar periodical patterns in the abundance of herring and sardine in different areas of Europe. Alheit and Hagen proposed that the herring fisheries of the Bay of Biscay, the English Channel, Devon and Cornwall as well as of Bohuslen in western Sweden showed signs of similarities because the good periods of fishing often co-occurred with low sea and air temperatures. Contrary to this pattern, the spring herring fisheries of western Norway and the sardine fisheries of Devon and Cornwall, and off North Brittany tended to be most productive during opposite climatic situations (Alheit and Hagen, 1997; Overland et al., 2010-this issue).

This last conclusion gains support from a study of the abundance of the Norwegian spring spawning herring in the 20th century. Here it was concluded that the recruitment of this stock of herring is positively correlated with average temperatures in the north east Atlantic region in the winter season. They attribute this relationship to environmental factors governing large scale fluctuations (Toresen and Østvedt, 2000).

When it comes to the long term historical abundance and distribution of the North Sea herring though, historical datasets

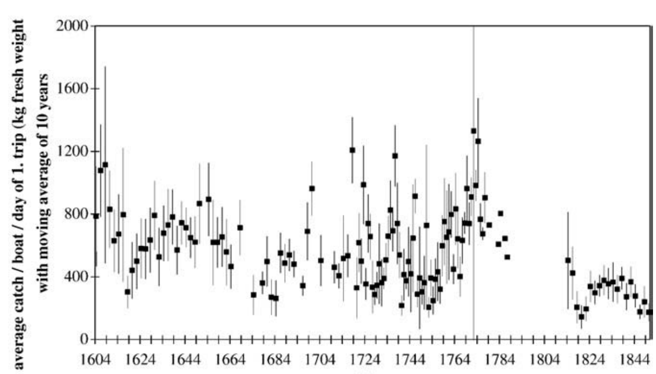

Fig. 1. Long-term series of catch rates in Dutch herring fisheries.

have only recently been created for the pre-industrial period. Based on landing records of individual Dutch fishermen, (n: >8000) CPUE has been measured as catch per boat per day at sea converted into kilograms herring (fresh weight). Results show that the catch rates fluctuated seemingly within phases of 20–40 years; but the catch rates from the first part of the season (June–August) did not always correspond with the catch rates later in the season (September–December). One reason for the varying catch rates from early until later in the season could then be that different sub-populations were targeted at different stages during the summer and autumn. During the first decades of the 1600s the Dutch herring fisheries had a succession of very good years reaping between 700–1000 kg/day they spent at sea (Fig. 1). In the following period from c. 1620–1670 around 600–800 kg was the daily average, but then a 30-year long set back with only 300–600 kg followed. The period from 1700–1760 was marked by the largest inter annual fluctuations in the entire 250 years period with catch rates ranging from 200–1200 kg/day, with a moving ten-year average of 500–700 kg. Results also showed that the first half of the 19th century was marked by very low catch rates when compared with the previous two centuries (Poulsen, 2006a).

Analyses of the spatial pattern of fishing from c. 1600–1893 illustrates, how the fishermen moved from north to south starting the season off the Shetlands, then moving gradually to the south and finally ending up in the waters off East Anglia or, at times perhaps, even in the English Channel. Differences in the spatial distribution, potentially caused by climate variability can thus be looked at, using snapshots of fishing patterns, as a supplement to long time series. Historical data for these snapshots can be fishers' logbooks as well as maps of fishing grounds from past centuries (Poulsen, 2006b) (Fig. 2).

In the Danish Limfjord the total catch of herring has been reconstructed using customs records and, later, official statistics for the period 1667–2000. The results thereof show two periods, c. 1680–1740 and again 1801–1829, where the total catch of herring reached c. 8–10,000 MT, which is more than at any time during the

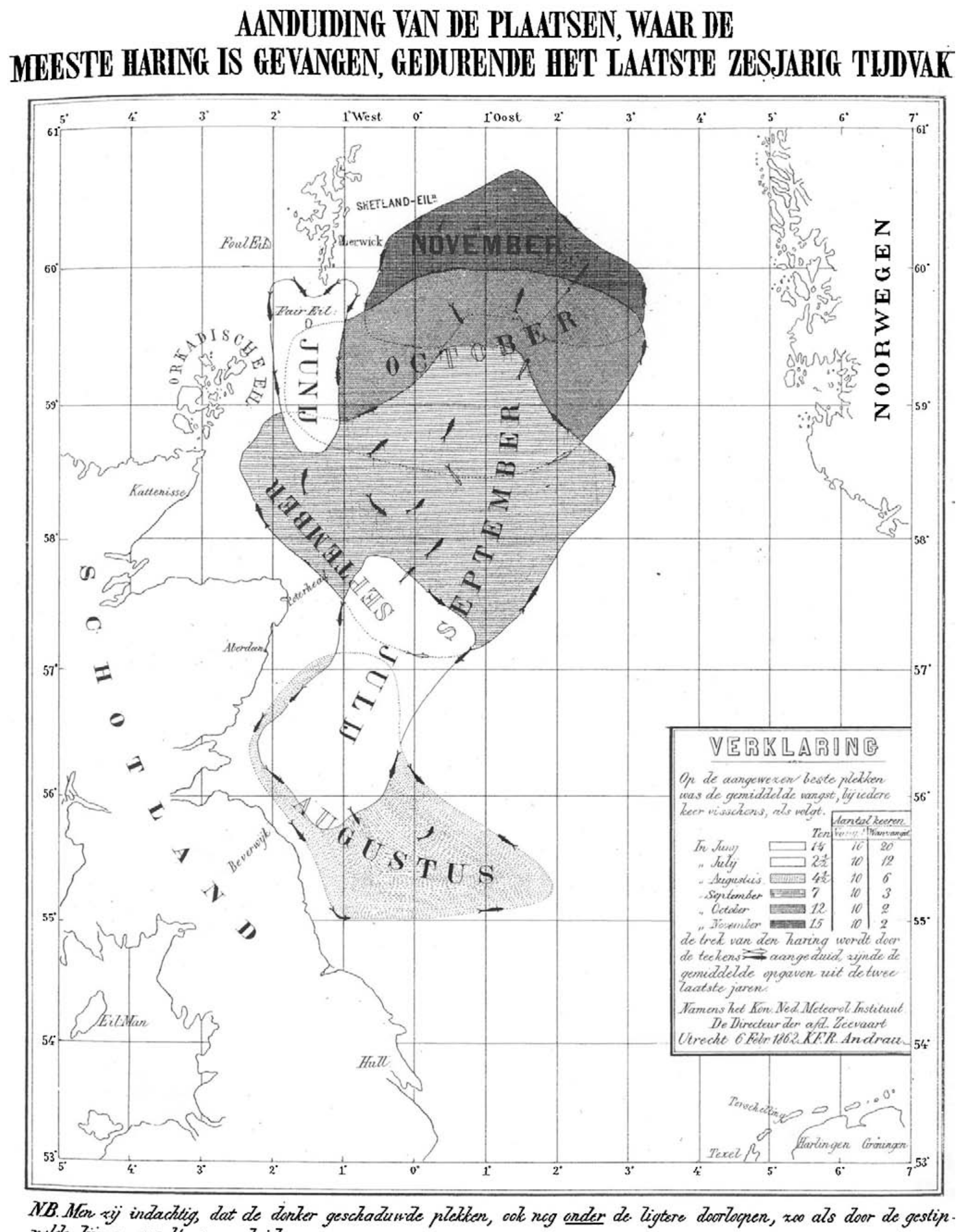

Fig. 2. Contemporary map produced by Royal Meteorological Institute showing the preferred fishing pattern in 1862 (Based on logbook information from Dutch herring fishers).

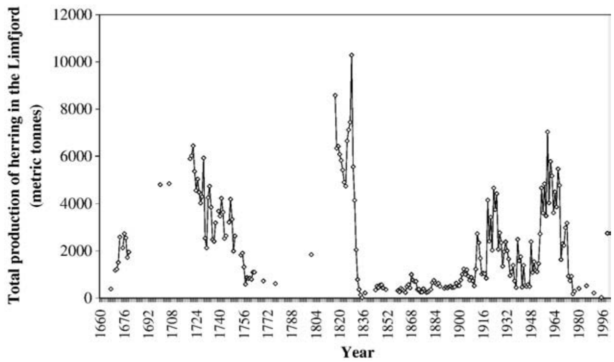

Fig. 3. Time series showing the estimated total catch of herring in the Limfjord from 1667–2004. Catches are reconstructed using custom records and account books as proxy-data, supplemented by recent statistics. Blank spaces: no data was available.

20th century. These two phases, however, do not directly match the high points of the Dutch North Sea herring fisheries, the Bohuslen periods or the great Norwegian herring fisheries (Poulsen et al., 2007) (Fig. 3).

3.3. Salmon

Stretching back to the 17th century a study of salmon fisheries in the northern parts of Russia has produced a time series with 51 years of catch data for the period 1615–1772 (Lajus et al., 2005). These data are based on records from Russian monasteries, which had the right to fish with large weirs in rivers running into the White Sea and the Barents Sea. Some records even reveal the average size of the fish caught. The data therefore stem from a reliable source with stable, uniform and geographically fixed data collection. The data are not directly linked with the fishing effort so that a CPUE analysis can be undertaken; but the evidence at hand demonstrates a stable fishing effort.

For other areas of the world, longer series of catch data do not exist this far back in time. However, since salmon has been a highly appreciated commercial species, the fishing rights in many European river systems have been regulated since the Middle Ages. Consequently, there is still the potential of finding additional historical evidence.

3.4. Tuna

Some of the world's longest time series on commercial fish catches stem from the bluefin tuna fisheries in the Mediterranean and along the Atlantic coast of Spain and Portugal, in some cases reaching back in time as far as 1599. Respective studies suggest that environmental factors such as variability of climate change as well as food availability might be responsible for the large fluctuations observed on multi-decadal and centennial scales (Ravier and Fromentin, 2001).

4. Conclusions

This paper has reviewed available historical datasets of potential relevance to asserting historical variability of fish stocks prior to industrialized fishing. Historical datasets from the pre-industrial period exist and in some areas are available from c. 1500 until some time in the mid-19th century or into the 20th century, depending on local processes of industrialization. Since this was a time in history, when scientific investigations were rare, historical evidence of fishery fluctuations can potentially be derived from commercial data. This means that fish, which for centuries have been of commercial interest, feature prominently in many archives. Especially for cod, salmon, sardine, anchovy and herring then, historical evidence of historical variability in fisheries and fish populations do exist for Northern European and Japanese waters. Some of this variability has been linked to climatic variability. Further recovery of historical data from archives and museums can potentially provide rich sources of information for documenting fish and fisheries and for identifying the reasons for these variations.

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