Historical diets, food web dynamics and climate change in the Arctic

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Summary
Atlantic cod *Gadus morhua* stocks in the Barents Sea are currently at levels not seen since the 1950s, however it is unclear how these very high population numbers can be supported in terms of prey availability and whether high cod numbers will have consequences for other important commercial fish. Cefas are carrying out analysis of datasets for the Bear Island (Spitsbergen) region between the 1930s and 1970s. Initial analysis of stomach data in the region has shown that cod diets have varied considerably over recent decades. Developing an understanding of historical food web dynamics, and in particular relationships between climatic conditions and diet, can enable predictions of how future changes might impact fisheries. This study is placing changes in cod diet in a long-term context of both warming and cooling periods, changes in fishing mortality as well as changes in the availability of particular prey organisms. As the Arctic is highly sensitive to climate change, but is also fished by many nations, the results of this project are directly relevant to future management of cod stocks.

Introduction
Atlantic cod are found in the Barents Sea at the northernmost habitat range and with some of their lowest temperatures. In warmer years, the stock produces stronger year classes than in colder years. There was a trend of warmer temperatures in the area from the 1930s to the 1950s, corresponding to high cod catches, followed by a cooler periods to the 1990s. Since the 1990s, the temperatures in the Barents Sea are again warmer, and cod catches are currently at levels not seen since the 1950s. In the 1930s, British researchers boarded commercial fishing vessels to measure length distribution of cod near Bear Island (Graham et al., 1954). In the 1940s a ship was custom-built for the area by the Ministry of Agriculture and Fisheries (MAFF) in the UK. The Ernest Holt's (Figure 1a) maiden voyage was in 1949. Logbooks are available up to 1976 and are held by Cefas. The coverage of sample stations so far digitised is presented in Figure 1b. The aim of this ongoing study is to compare hydrographic and cod catch data and changes in cod diet to try to determine reasons for the high stock size both in the 1950s and presently. Preliminary results are presented.

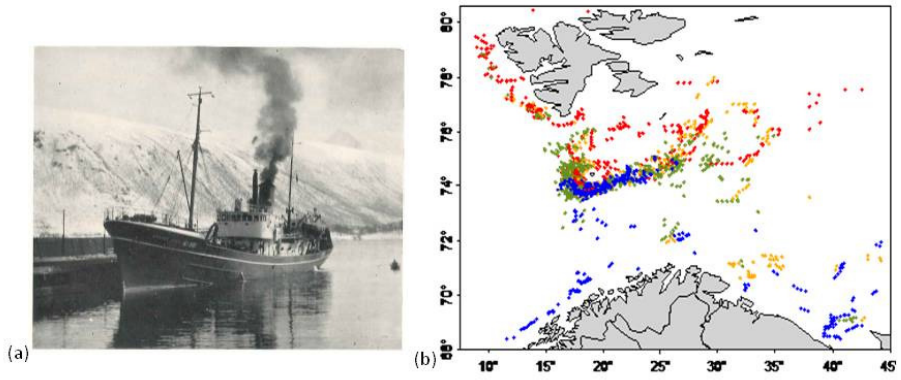

Figure 1 (a) The Ernest Holt in Trömso. Photograph by David Vaux, *In* Lee (1956). (b) The sample stations from MAFF cruises in the Barents Sea between 1930 and 1958. Blue: winter (Q1); green: spring (Q2); red: summer (Q3); orange: autumn (Q4).

Materials and Methods
Catch species, weight, surface and bottom temperature, salinity and stomach content data from the cruise log books between 1930 and 1958 were digitised. The data were visually explored by mapping the catch per unit effort (CPUE) per quarter, and by plotting stomach contents data per year.

Results and Discussion

Here we present preliminary results. The CPUE of two years with a large spread of sampling stations is shown in Figure 2. While sampling effort was generally concentrated between 74 and 76 °N, it can be seen that the larger catches tended to be further north and west during the years shown. Initial analysis at the time of the cruises recognised that before and after the feeding season, immature cod were concentrated in areas with bottom temperatures between 2 and 4 °C (Lee, 1956). It was also reported that the fish aggregated in areas of warmer water. Further work will use more sophisticated analytical tools to investigate these relationships between temperature and catch size at different times of year and in different locations. We will investigate trends in catches and temperatures throughout the spread of the data from the 1930s and to the 1970s.

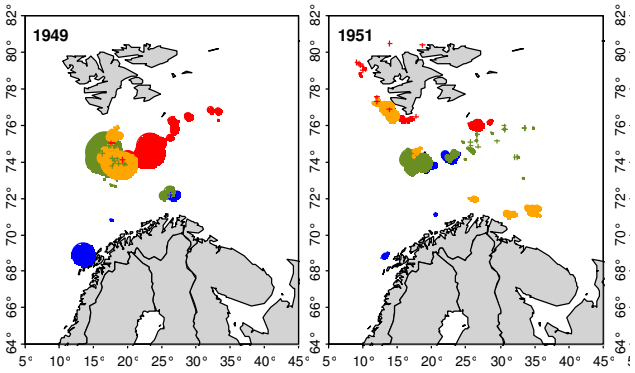

Figure 2 The CPUE of cod at each station during selected years. Each spot size is proportional to the CPUE, and the crosses represent nil catches. Colours as for Figure 1.

Initial analysis of stomach contents shows that cod diet may have changed significantly over the survey period. During the 1930s cod were eating more herring, while in the 1940s, the diet was dominated by krill (see Figure 3).

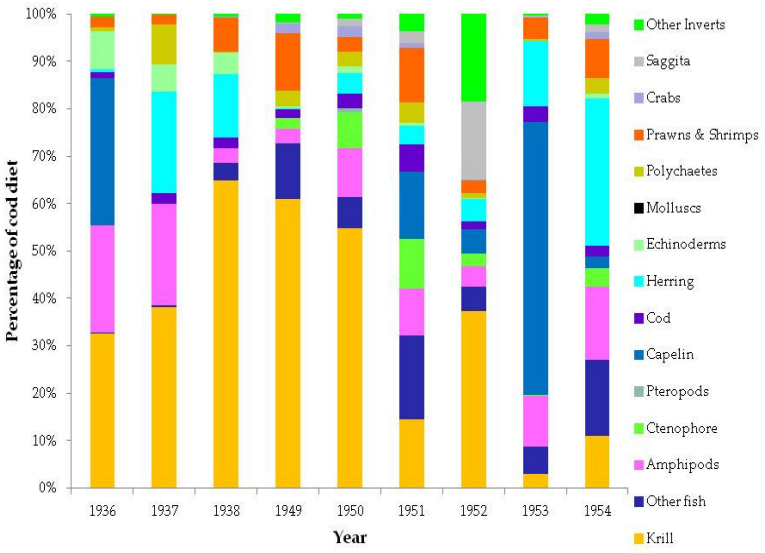

Figure 3 Proportion of diet represented by different prey types (number of prey items) for cod.

The projected temperature increase in the Barents Sea is approximately 1-2 °C by 2080 (Furevik et al., 2002). The combined effect of the warming and cooling cycles and climate change warming may force Barents Sea cod to remain in northern areas for longer periods when temperatures are warm. Further work will investigate the potential effects of this type of warming on Barents Sea cod stocks, prey and on the fishery. The historical data will be compared with more recent datasets collected by Norwegian and Russian scientists to look at more recent, and predict future, changes.

References

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