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Survey based estimation of consumption: spatial and seasonal aspects of cod predation on shrimp

by
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Abstract

Several assessment reports on the shrimp stock in the Barents Sea have concluded that any assessment model introduced should include the cod consumption on the shrimp stock. However, the shrimp stock does not show obvious response to the cod consumption. The method for estimating the cod consumption has been evaluated previously. These indicate that the cod consumption is overestimated both as a whole as well as in particular years. Still the shrimp stock does not respond directly on the cod consumption. We here study if the lack of overlap and different season of data collection has influenced the consumption estimate. This is now possible as the winter survey and the ecosystem survey sample cod, cod stomachs and shrimp. This should enable us to get consumption estimates and shrimp index estimates that are directly comparable and applicable in shrimp stock assessment. As the assessment relies on historical data the historical data should be properly described and evaluated. In this document we use and present historical data on shrimp abundance, cod stomach data, and estimated consumption to study spatial and seasonal variation in shrimp consumed by cod. The modified estimate had the same temporal signal as the unmodified estimate, and thus will not provide a better fit in the assessment model.

Cod consumption of shrimp might differ with season, but unfortunately, the survey coverage by season has varied from year to year. We tested for seasonal effects on consumption in years with good coverage in summer and winter. We did not find any consistent seasonal effect.

Introduction

Cod is considered an important predator on shrimp in most areas and imperative to any shrimp assessment model for the Barents Sea stock (Anon 2005). However, whereas there is little doubt that cod can consume considerable amounts of shrimp, the quantitative implementation of this observation in an assessment model might not be so straightforward. Currently, there are no agreed upon quantitative assessment of the Barents Sea shrimp stock. However, in recent years, IMR has performed an assessment based on logistic stock-recruitment function and Bayesian interference (Hvingel 2006). However, the shrimp assessment model performs less well when including the shrimp biomass consumed by cod (Hvingel 2006, Aschan et al. 2006), even though the estimated predation from cod on shrimp is of considerable magnitude and many times higher than the catches (Figure 1). This is also the case when using a modified approach to estimate consumption, based on survey design (Aschan et al. 2006 and below (Figure 1). In brief, cod abundance and cod consumption just includes more “noise” and makes the parameter estimates in the assessment model less precise (Aschan et al. 2006, Hvingel 2006).

Hvingel (2006) stated that “an underlying spatial structure of the estimates of shrimp stock size and consumption by cod need to be resolved”. This should be done in order to include cod predation into shrimp assessment. Unfortunately, until recently, monitoring of cod and shrimp in the Barents Sea, have been conducted on separate cruises (the Norwegian shrimp cruise 1981-2004, and the IMR winter survey for demersal fish 1981-), with different area coverage, making it difficult to compare spatial structure and distribution of cod and shrimp directly, and to study overlap (Figure 2). Furthermore, cod stomach data has only (with a few exceptions) been collected on cruises monitoring cod. Fortunately, from 2005 on; data on shrimp and cod abundance and cod diet are sampled on the Joint IMR-PINRO ecosystem survey, covering the whole of the Barents Sea and Spitsbergen area (Figure 2). Also, from 2006 on, the winter survey for demersal fish in the Barents Sea also records shrimp abundance. This should make it easier to get consumption estimates and shrimp index estimates that are directly comparable and applicable in shrimp stock assessment. However, assessment relies on historical data. Therefore,

the historical data should be properly described and evaluated. In this wd we use and present historical data on shrimp abundance, cod stomach data, and estimated consumption to study spatial and seasonal variation in shrimp consumed by cod.

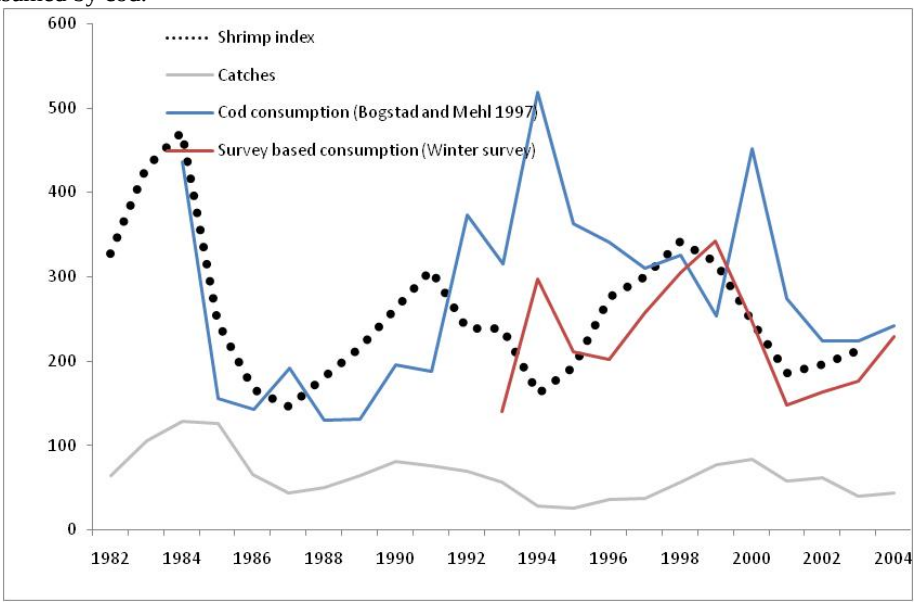

Figure 1. Time series of index of shrimp abundance (dotted line), shrimp catches (grey line) and cod consumption, in thousand tons. The red line is the shrimp consumption estimate based on the winter survey (1993-2004), whereas the blue line is consumption estimated by the method presented in Bogstad and Mehl (1997, see also Johannesen and Aschan 2005).

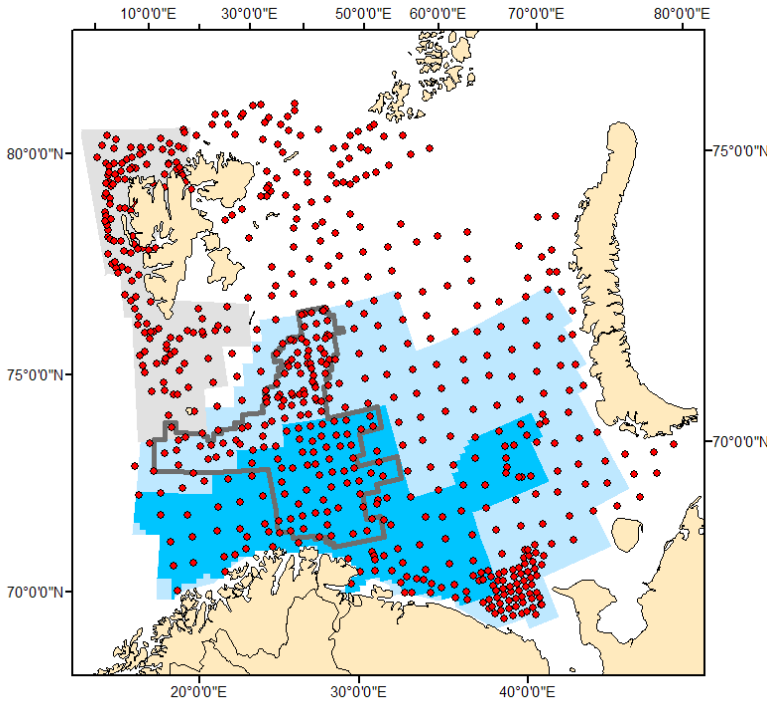

Figure 2. Survey coverage in the Barents Sea. The red bullets area the trawl stations at the Joint IMR-PINRO ecosystem survey in 2006. The grey shape along the coast of Spitsbergen and southwards is the shrimp survey area that was covered in August, whereas the grey outline in central Barents Sea is the shrimp survey area that was covered in April/May, both from 1981-2004. The blue shape is the area covered by the winter survey, the darker part is the area covered from the start of the survey in 1981, whereas the lighter part is the area included after 1992.

Data

Stomach data

Quantitative data on cod diet have been sampled and stored in a common Norwegian and Russian data base since 1987. The base currently holds data from more than 200000 cod stomachs. The cod stomachs have been sampled on Russian commercial vessels, Norwegian surveys and Russian surveys (Appendix 1).

The most consistent "time-series" in the stomach data base is the data sampled on the Norwegian winter survey (Jakobsen et al 1997, Figure 2, appendix 1: 1st Quarter). About one third of the stomach samples in the stomach data base are from the winter survey. The Norwegian winter survey started in 1981. The area surveyed expanded in 1993 towards the North and East (Figure 2). However, the coverage varies somewhat from year to year, depending on e.g. ice conditions. In 1997 and 1998, IMR vessels were not allowed entrances into the Russian Economic Zone. This was the case also in the current year. The survey has been run in cooperation with PINRO since 1999. Cod stomachs were sampled on this cruise from 1984 on. From 1996, cod stomach samples were taken from all trawl stations, with one sample per 5 cm length group of cod, before that, more stomachs were taken per station, but fewer stations were sampled (Appendix 1). From 2006, shrimp abundance data have been recorded on this cruise.

In 1996, IMR expanded the Spitsbergen cruise for demersal fish to cover also the Barents Sea (the "summer cruise"). The area coverage has, however, been quite variable (Appendix 1: 3rd Quarter). From 2003, PINRO and IMR run the summer cruise as a joint ecosystem cruise, covering most of the Barents Sea and Spitsbergen area (Anon 2006, Figure 2). From 2005, shrimp abundance data has also been recorded on this cruise, after the Norwegian shrimp survey was discontinued in 2004.

The Norwegian shrimp survey

This survey covered the parts of the Barents Sea with the densest concentrations of shrimp and important shrimp catching grounds (Aschan and Sunnanå 1997, Figure 2, Appendix 2). Areas in central Barents Sea have been covered in April/May, whereas the area west of Spitsbergen has been covered in August (Figure 2). Cod catches has also been recorded on this cruise (Appendix 2), but with a few exceptions, cod stomachs has not been sampled. The shrimp survey index has a CV of 0.35. The average catchability is 0.168 (Hvingel 2006).

Survey based cod consumption estimate

The method

The reasoning behind survey based estimation of consumption is that when a survey that collects cod stomachs covers most of the cod stock, the consumption estimate will not be biased by spatial differences in cod diet. Since cod is a generalist predator, the diet varies greatly from location to location due to differences in prey availability, so that sampling location greatly affects the diet observed. When a survey covers the cod stock adequately, as is the case for the winter survey most years (at least since 1993), and individual consumption estimates is weighted according to spatial distribution of the cod stock (stomach samples from stations in areas with high abundances of cod are given more weight than stomachs from stations with low abundance of cod), we should get representative estimates of cod consumption. By weighting each station by the number of cod per station and using station specific temperatures, we use a more correct estimate of the ambient temperature experienced by cod (Michalsen et al. 1998).

The method thus relies on good survey coverage, i.e. that most of the cod stock is representatively sampled. Consumption is estimated at the station level (see Appendix 3). Individual consumption is estimated for each 5 cm length group of cod. Temperature data from CTD stations taken adjacent to the trawl station are used as input temperature. We used the Temming and Hermannd (2003) stomach evacuation model. Stomach content that was not classified, but that potentially could include shrimp (mostly undetermined crustacean remnants), was added to the shrimp stomach content according to the area and length group specific proportion of shrimp out of classified crustaceans from stomachs samples. Average length specific consumption was estimated weighing each station with the number of cod in the length group caught in the station. We also weighed each station by the inverse of the distance to the nearest station, to account for uneven spacing of trawl stations. Age length keys were used to get the consumption per age group, and age specific consumption was multiplied with age specific abundance of cod derived from VPA and summed over age groups to get total consumption.

Spatial effects

Last year we calculated survey based consumption for the winter survey from 1993-2004, the period from the expansion of the winter survey area and until the discontinuation of the shrimp survey (Aschan et al. 2006). This new consumption time series had a better correlation with the shrimp index from the central Barents than the shrimp consumption times series calculated by the methods presented in Bogstad and Mehl (1997, see Aschan et al 2006), and presented in ICES working group of Arctic Fisheries each year (e.g. ICES 2007). However, this consumption estimate also added just noise when used in the shrimp assessment (see Hvingel (2006 and above).

The shrimp survey areas in central Barents Sea covers only part of the area covered by the winter survey. If the consumption differs spatially so that the consumption outside the shrimp area differs strongly from the consumption within the survey area, this might explain the lack of consistency between the shrimp index and the consumption estimates, which in turn contribute to the problems including cod predation into assessment. We checked for this by calculating shrimp consumption inside the shrimp survey area covered in April, by calculating individual consumption per length group as described above, using the stations cod stomachs sampled within the shrimp survey area on the winter survey. We estimated the proportion of cod in each length group inside the shrimp survey area from the survey data on cod abundance from the winter survey.

Seasonal effects

By using the winter survey times series of stomach data and cod distribution, we make sure that we have about the same coverage each year, so yearly differences in consumption is not confounded by yearly differences in where the stomachs have been sampled. That is, when years are compared, we compare real temporal differences in consumption and not yearly differences in spatial coverage of sampling. However, the problem is that we do not cover the seasonal dynamics in cod consumption, and has to assume that the consumption in February is representative of the consumption the whole year. Given the pronounced seasonal migration of cod and that the spatial variability in prey availability, this assumption is wrong. Unfortunately, in the cod stomach sampling program, the sampling at other times of the year than in the first quarter has been inconsistent over the years (Appendix 1). Therefore, including diet data from other times of the year lead to a confounding between year and season variation in consumption. However, if there is a consistent effect of season on consumption, we can extrapolate from years with good coverage in other seasons than the first quarter to other years. We chose six years with good spatial coverage of demersal survey in both summer and winter. We calculated survey based consumption from the winter and summer survey in years with quite good survey coverage in summer (1996, 1999, 2003, 2004, 2005, 2006). We used these consumption estimates to test for consistent seasonal (summer 3rd quarter versus winter 1st quarter) effects on shrimp consumption.

Results

Spatial effects

The individual cod consumption during the winter survey was higher in the shrimp survey area, compared to outside, especially for larger cod (Figure 3). On average, total shrimp consumption was highest for age class 4-5 both inside and outside the shrimp area, but the distribution of total consumption per year class was skewed towards larger fish inside compared to outside the shrimp area (Figure 4). The proportion of cod was higher outside compared to inside the shrimp area in the winter survey (Figure 5), so that the total consumption estimated from the winter survey data was about the same inside and outside the shrimp area (Figure 4 and 6).

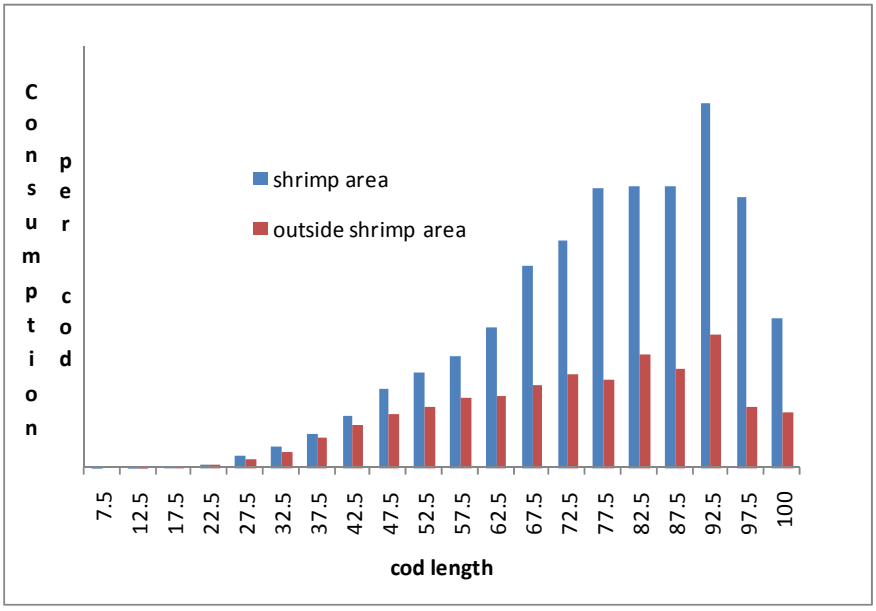

Figure 3. Individual consumption of shrimp per 5 cm length group of cod inside and outside the shrimp survey area. Mean values based on stomach samples from the winter survey 1993-2004.

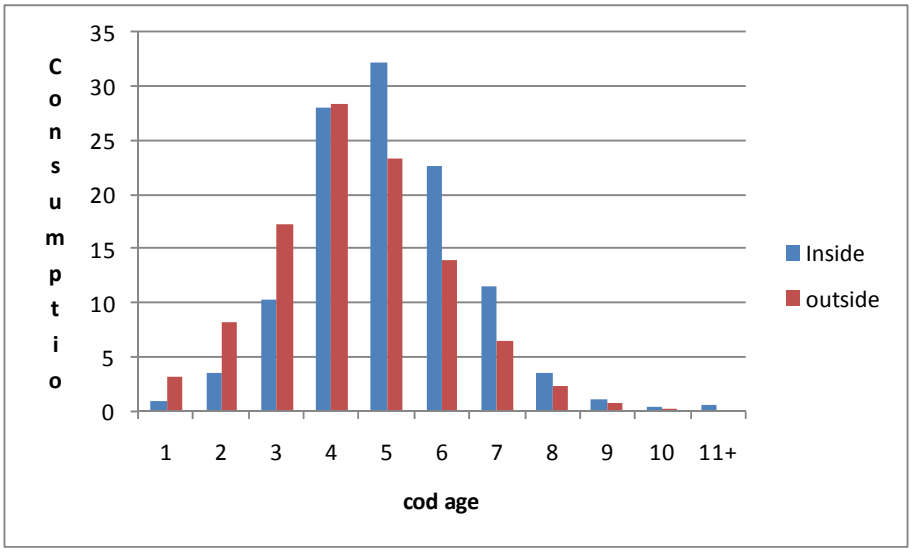

Figure 4. Average total yearly shrimp consumption (thousand tons) by cod age. Based on data from the winter survey 1993-2004.

The temporal trends inside and outside the shrimp survey area were highly correlated (Figure 6). Therefore, the cod consumption inside the shrimp area cannot explain the changes in the shrimp index any better than the consumption estimated for the whole of the area surveyed on the winter survey (Hvingel 2006).

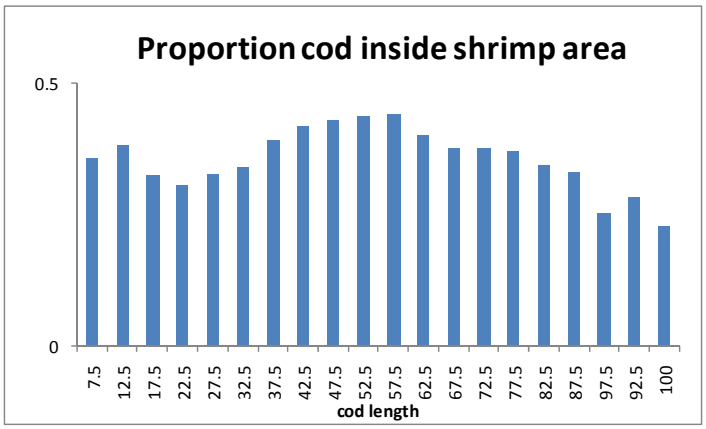

Figure 5. The proportion of cod in each 5 cm length group inside the shrimp. Average proportions for the winter survey 1993-2004.

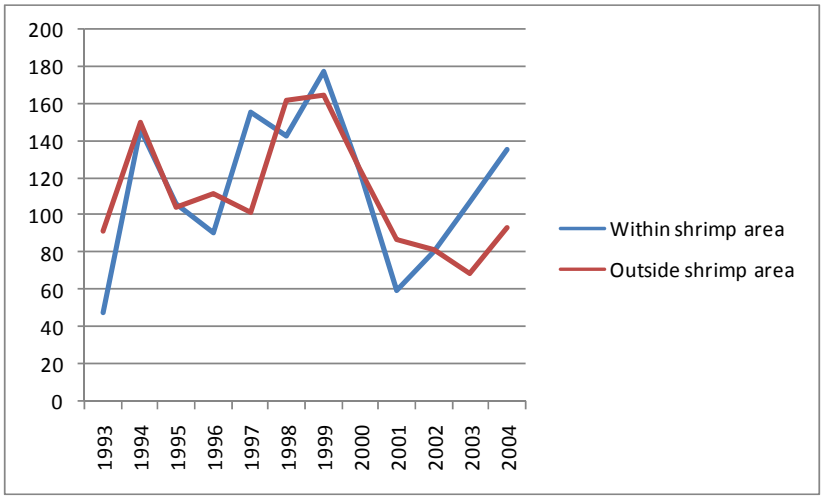

Figure 6. Estimated yearly consumption (thousand tons) of shrimp by cod from 1993 to 2004, inside and outside the shrimp survey area.

Seasonal effects by year and area

The areas where the total consumption of shrimp by cod was largest varied both by year and season but in not a very apparent, consistent way (Figure 7a and b). Some pattern can be seen in the recent years, with more shrimp consumed along the coast in winter, where cod aggregate to feed on shrimp, and more shrimp is consumed in areas with high densities of shrimp in summer (Figure 7b).

Testing for individual consumption by season, year and cod length revealed that season was significant in interaction with year and cod length, but not as a main effect (test statistics not shown). Individual consumption by cod length (15-75 cm) and by year and season is plotted in Figure 8. The most striking difference in individual consumption is between 1999 and the other years, with a higher consumption in 1999, especially in the winter survey (see also figure 1 and 7a). In 1999, the individual consumption increased with cod size, whereas the other years, the effect of cod size on consumption is less clear (Figure 8).

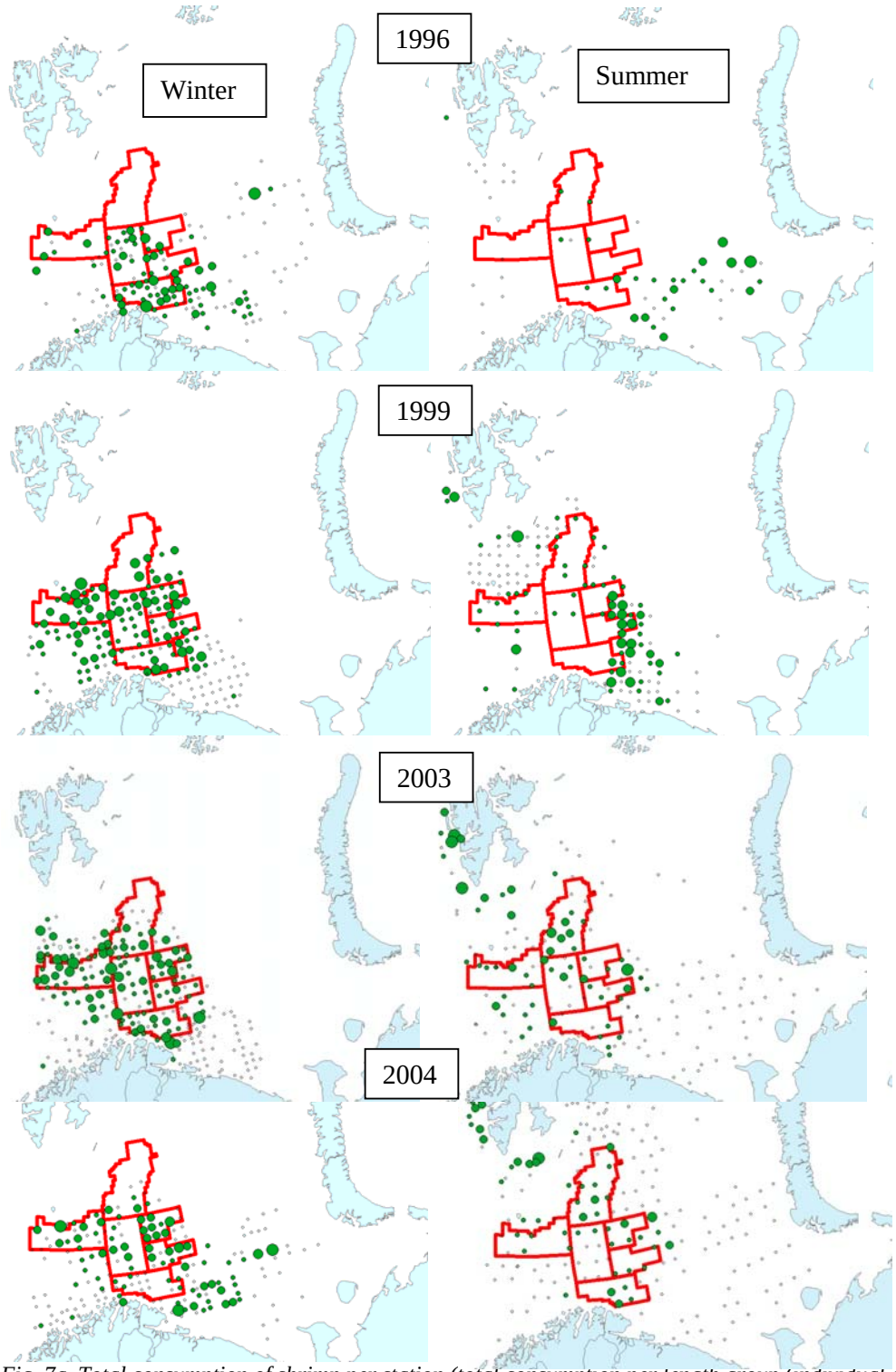

Fig. 7a. Total consumption of shrimp per station (total consumption per length group (individual consumption in the length group multiplied with number of cod in the length group) summed over length groups). The size of the green bullets is proportional to total consumption (NB! cannot be compared across years and season because they area scaled differently). Empty bullets indicates no shrimp consumed.

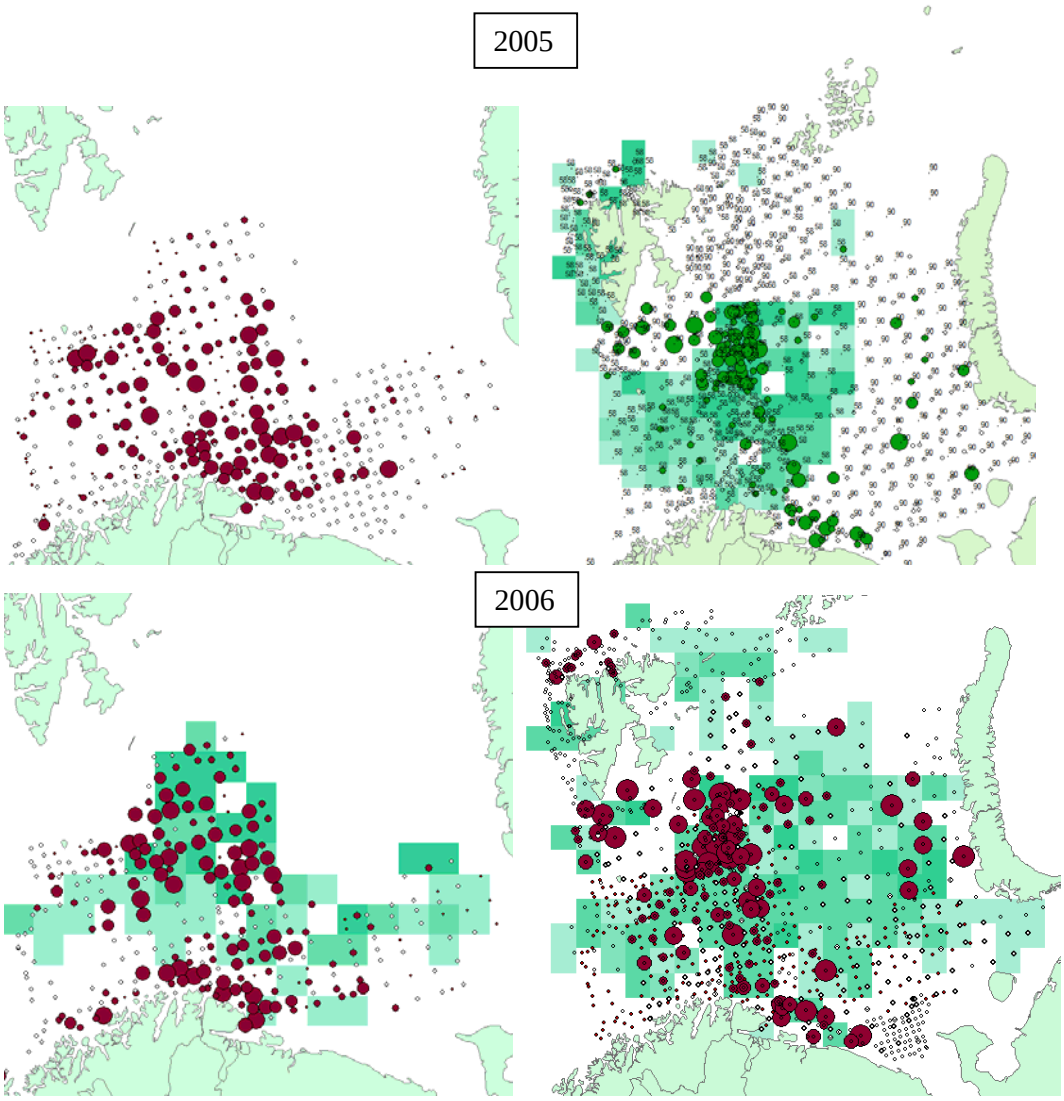

Figure 7b. Total consumption per station (see above), summer is to the right and winter is to the right. The size of the bullets is proportional to the total consumption, but not scale the same way in all figures. Average log shrimp catch by 40 by 40 nautical mile grid cells is shown in green. Note that in winter 2005, shrimp was not recorded on this cruise. For the ecosystem survey 2005, the Russian shrimp catch data was not available.

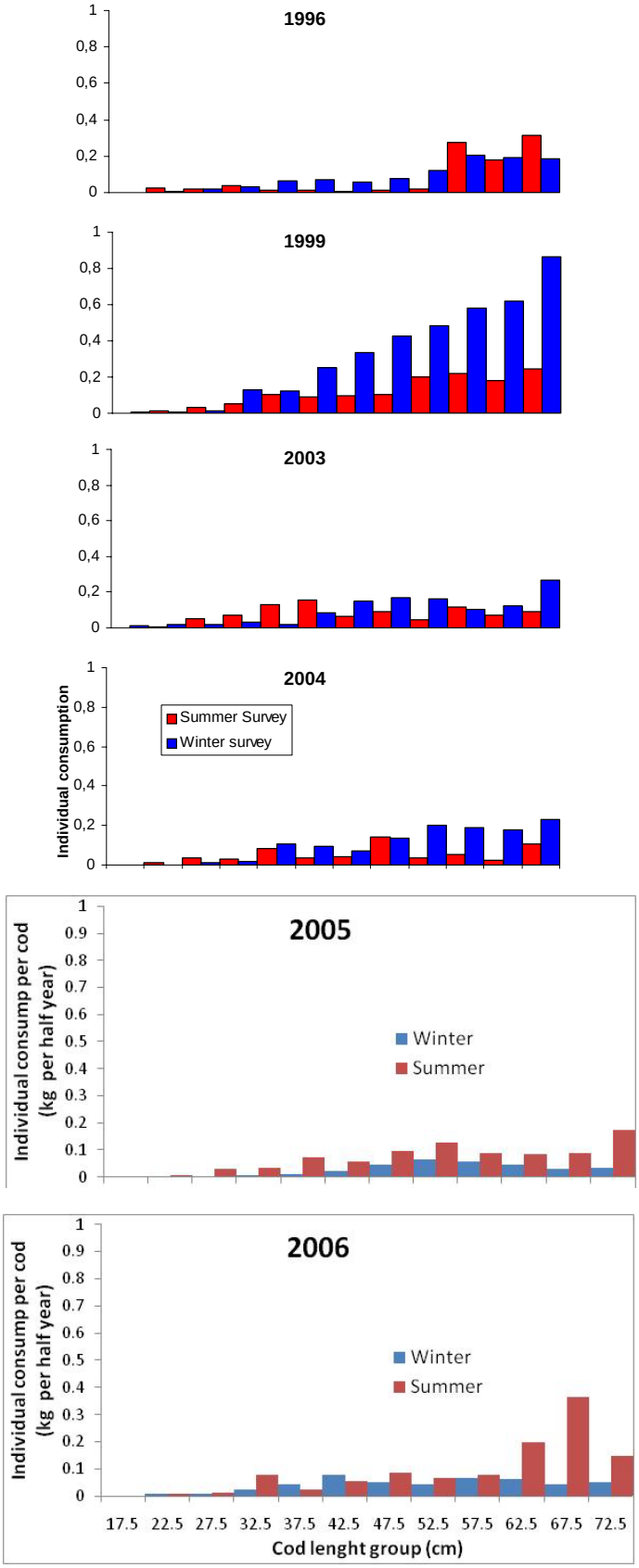

Figure 8. Individual consumption by year, cod length group and survey.

Conclusion

We tried to modify the estimated shrimp consumption by cod by calculating it for the area covered by the shrimp survey from 1993 to 2004, which is the survey that shrimp assessment is heavily dependent upon. However, the modified estimate had the same temporal signal as the unmodified estimate, and thus will not provide a better fit in the assessment model.

Cod consumption of shrimp might differ with season, but unfortunately, the survey coverage by season has varied from year to year. We tested for seasonal effects on consumption in years with good coverage in summer and winter. We did not find any consistent seasonal effect.

The total amount of shrimp consumed by cod at a particular location depends both on the shrimp availability and the abundance of cod. Plotting total consumption at the station level for 6 years (1996, 1999, 2003-2006) and summer and winter, revealed no apparent consistencies as to in which areas shrimp was consumed the most.

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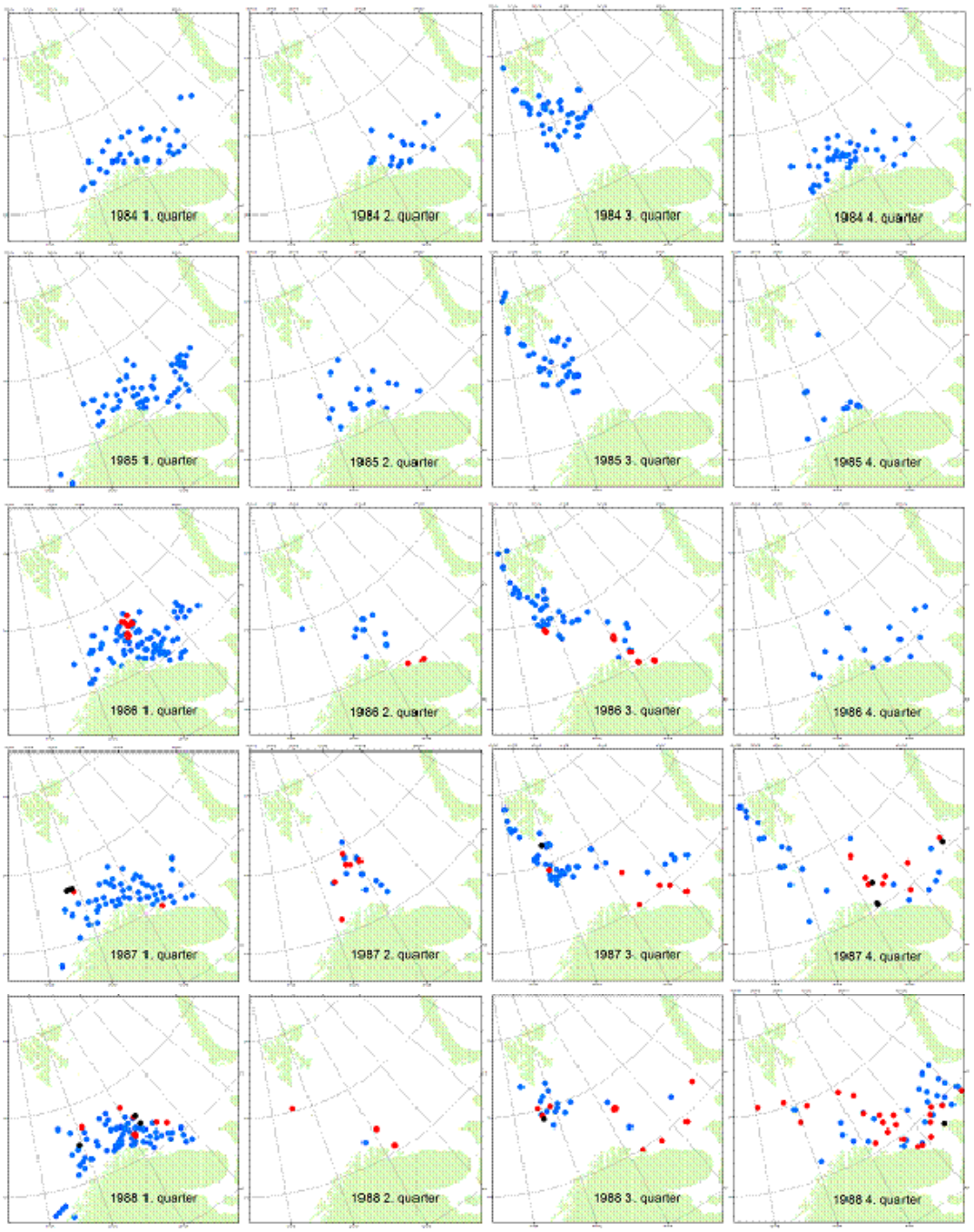
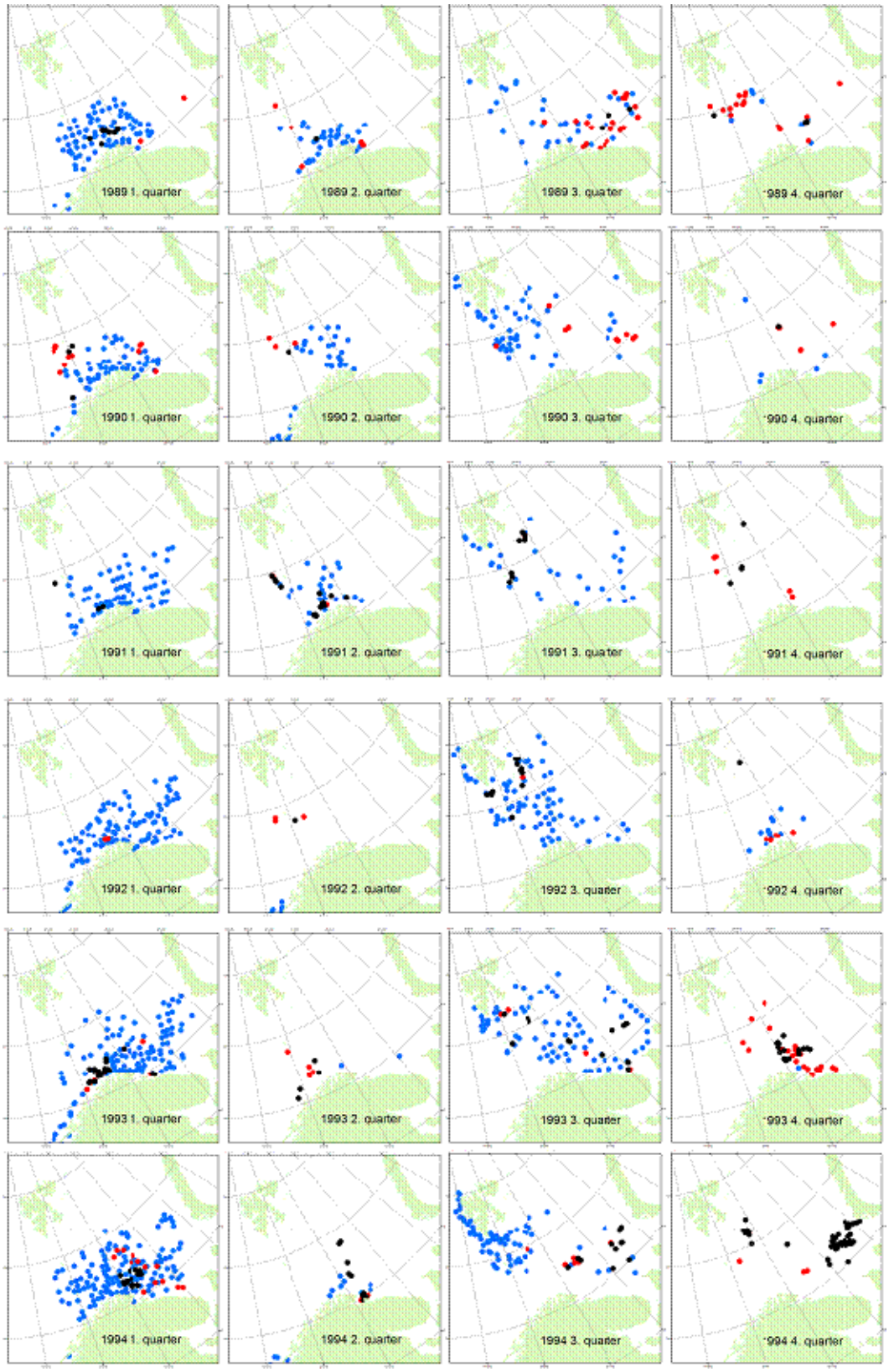
Appendix 1.

Stations with stomach samples by year and quarter 1984-2006. Blue represent Norwegian stations, red Russian stations with trawling time less than 1.5 h, and black Russian stations with trawling time more than 1.5 h. Note that not all Russian data for 2004 have yet been included.

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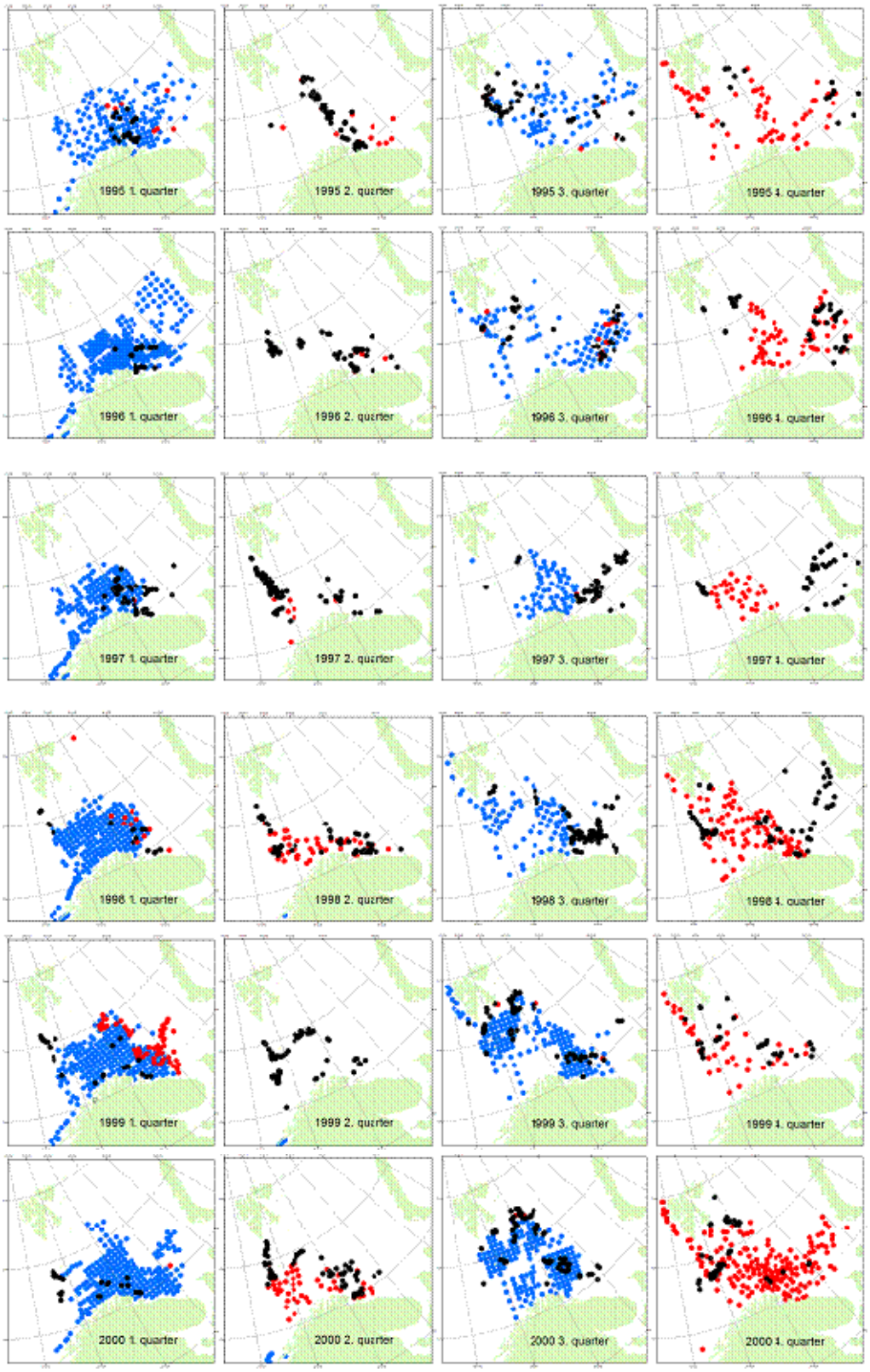
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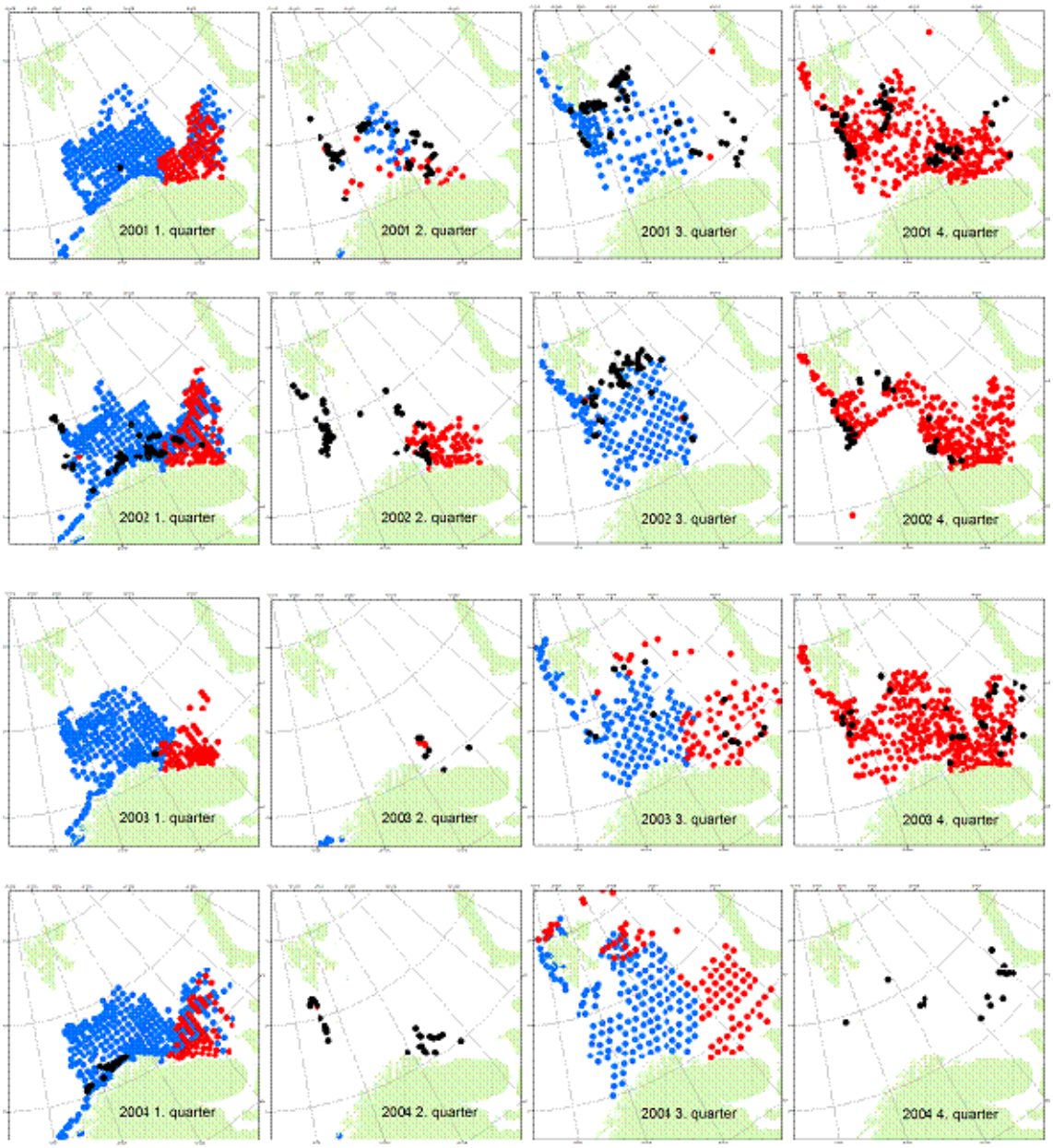
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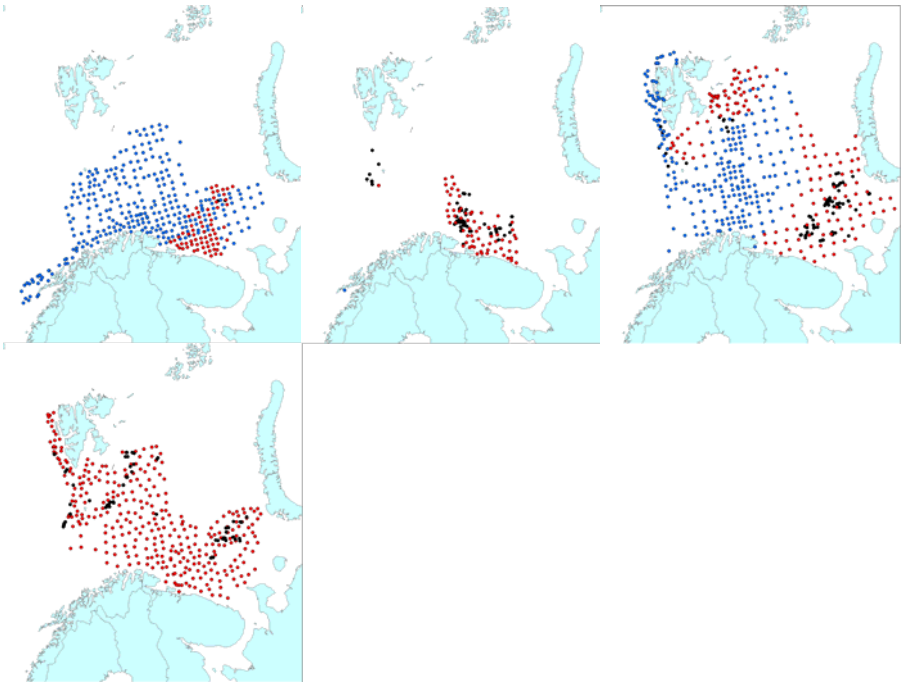

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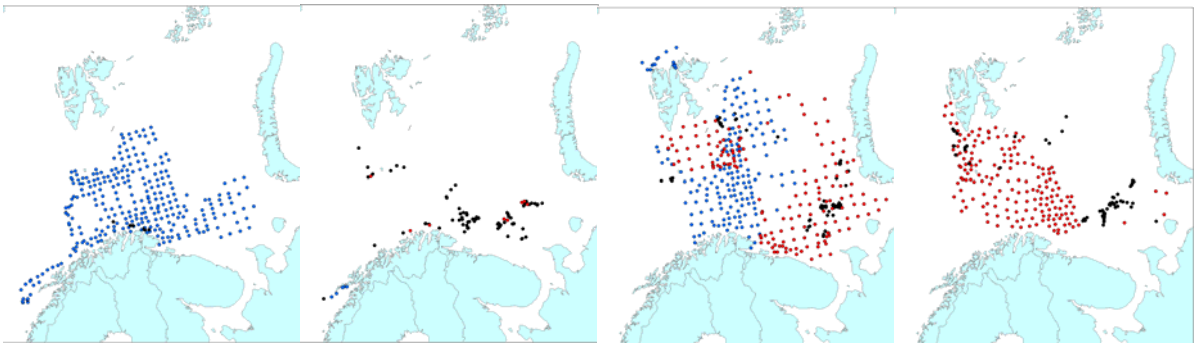
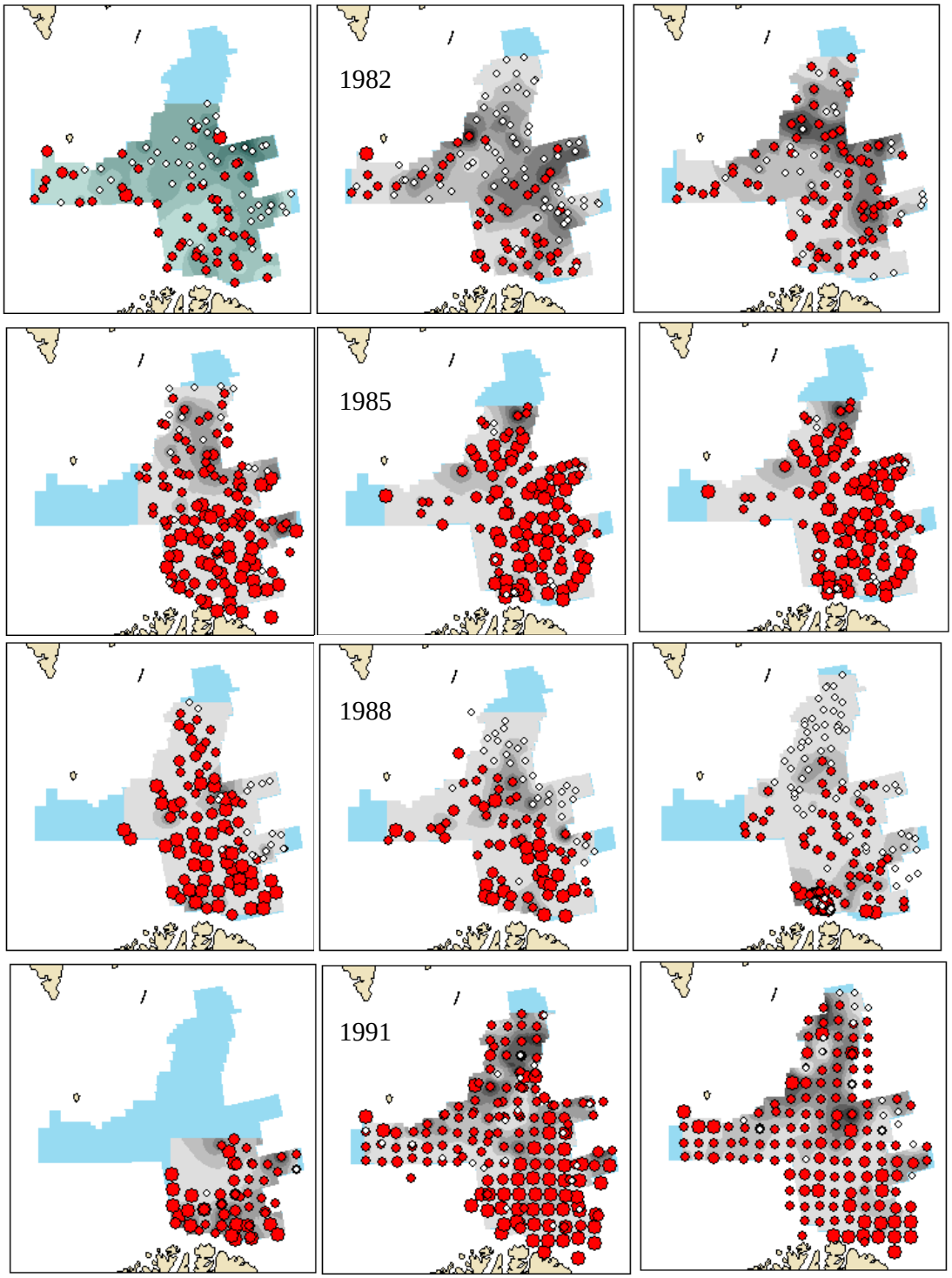
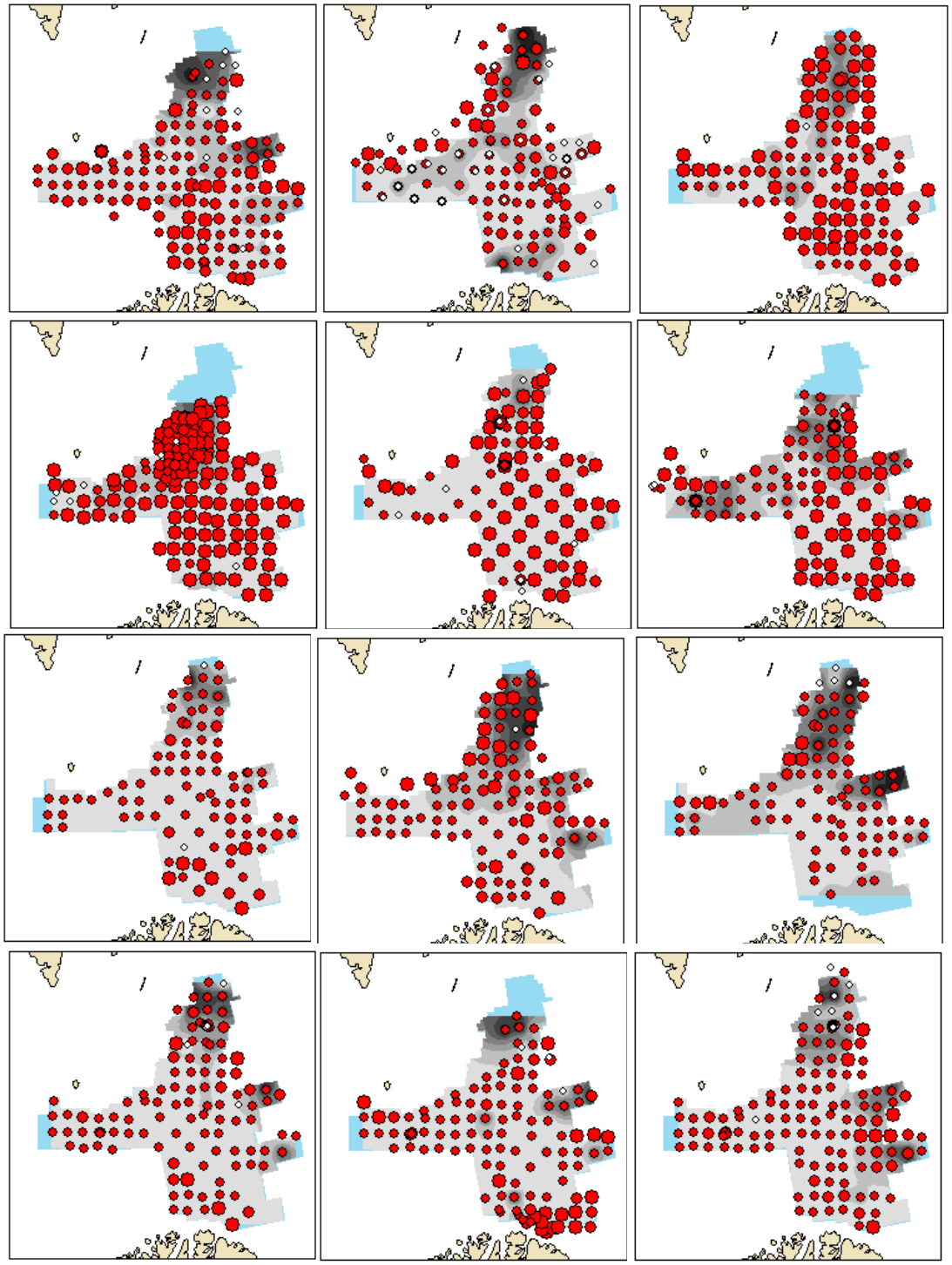




Catches of cod (red bullets) and shrimp (idw interpolated white: no shrimp to black: max cathces in kg), from 1981 to 1992 . The blue shape outlines the standard shrimp survey area.



Catches of cod (red bullets) and shrimp (idw interpolated white: no shrimp to black: max cathces), from 1993 to 2004 . The blue shape outlines the standard shrimp survey area.

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- 1 - 10
- 11 - 50
- 51 - 100
- 101 - 5000