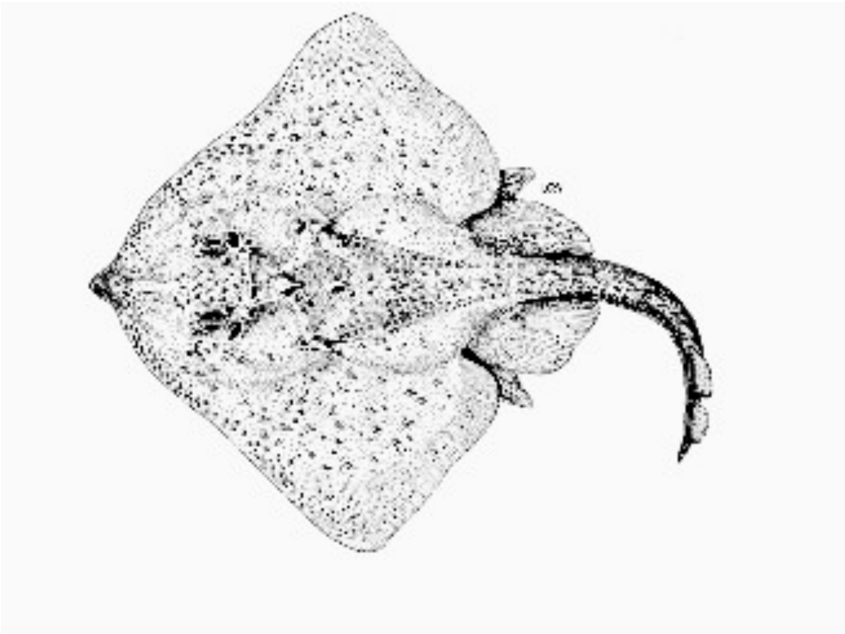
Cartilaginous fishes along the North-Norwegian coast

Distributions and densities with regard to fishing and sea temperature



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Master thesis in International Fisheries Management
(30 credits)

By

Tom Williams

Department of Aquatic Biosciences

Norwegian College of Fishery Science

University of Tromsø

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Abstract

Scientists are becoming increasing aware that many of the world's cartilaginous fish stocks are particularly vulnerable to overexploitation by modern fishing activities. Very little is known about the cartilaginous fish stocks found in the North Norwegian coastal area. In other areas some of these species have been severely depleted by fishing. The aim of this study was to broaden the knowledge these species within this area and determine what factors play an important role in controlling their abundances. Demersal trawl catch data, from 1992 to 2005, was applied for analyzing abundances and distributions of the species present along the North Norwegian coastline. Abundances were determined using the swept area method. Distributions were assessed with respect to position along the coastline and depth. Further investigation focused on whether temporal and spatial differences in abundance could be linked to changes in sea temperature or shrimp trawl fishing effort. For most species, clear distribution patterns could not be determined, either because sample variances were too high or observed abundances were too low. Rabbitfish, velvetbelly lantern shark, piked dogfish and blackmouth catshark were all found in higher abundances at lower latitudes. Thorny skate was distributed along the entire coastline, but found in higher densities at northern latitudes. Between 1992 and 2005, these species abundances appeared not to significantly change. Their distributions appear to be related to spatial variations in temperature, but no conclusion could be made as to whether shrimp trawl fishing or temporal differences in temperature did significantly affect distributions or abundances. Further work is necessary in order to improve abundance estimations, clarify species identification. Data relating to more appropriate fisheries is required for determining how fishing effort may influence species abundance.

Keywords:

Cartilaginous, elasmobranch, skate, Norway, coast, distribution, abundance, bottom trawl surveys, temperature, fishing effort.

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Contents

1 Introduction

This objective of this study was to investigate the abundances and distributions of the various species of cartilaginous fishes that are to be found along the North Norwegian coast. Changes in abundances or distributions were further analyzed to determine whether fishing effort and/or temperature had played a significant role.

Cartilaginous fish is the common term used to describe the taxonomical class of fishes known as Chondrichthyans (Froese and Pauly, 2007), and will be the standard term used in this study. This class can be divided into two sub-classes: the elasmobranchii, which includes sharks and skates; and the holocephali, of which the chimaeras belong to. All species within this class are characterized by having a cartilaginous skeleton and reproduce using internal fertilization (Froese and Pauly, 2007). Modes of reproduction vary from viviparity to oviparity, but all are characterized as having low fecundity (Stevens et al., 2000).

Within both fisheries science and the media, there has been an increasing awareness that cartilaginous fish stocks are particularly susceptible to exploitation by fishing activities (Stevens et al., 2000). This is largely because of their life-history strategies. All have few or no natural predators when fully matured, and as such have not evolved strategies that allow populations to withstand rapid changes in mortality (Stevens et al., 2000, Last, 2007). To varying degrees, all species are slow growing, have a low rate of fecundity and attain sexual-maturity at late age. These traits mean that species do not have a high capacity for density-dependant change in population size. This has often been exemplified by the poor record of sustainability by fisheries that have targeted cartilaginous species (Stevens et al., 2000). But these species are not just vulnerable in fisheries where they are targeted. Because of prey and habitat overlaps with other more commercially important fish, they are often caught as by-catch. In many fisheries, their relatively large size at birth means that size selective fishing gear is similarly effective at catching both adults and juveniles.

Although some pelagic Chondrichthyans do at least seasonally inhabit the North Norwegian coastal seas, this study focuses on the species that are primarily demersal.

The demersal species with known distributions along the North Norwegian coastline include sharks (superorder-Selachimorpha), one species of holocephali (the rabbitfish *(Chimaera monstrosa)*) and skates (Rajidae). The ranges of depths they inhabit vary between species. All can be found at depths between 200-300m. Some, such as the arctic skate *(Amblyraja hyperborean)*, are more deepwater fish and are known to live at depths greater than 2000m; whilst others are more often associated with shallower waters, such as the thornback ray *(Raja clavata)* (Pethon, 2005).

There are considerable size differences between the species. The largest of the skate species, the blue skate *(Dipturus batis),* can grow to nearly 100kg, and the greenland shark *(Somniosus microcephalus)* can reach 6m in length. The smaller species more commonly weigh no more than a few kilos. All are predators. The skates primarily feed on benthic invertebrates and small fish, while the sharks often include more pelagic prey in their diets. The Greenland shark is an opportunistic feeder and its diet ranges from demersal invertebrates to small marine mammals. Being much larger, it often preys on larger fish including skates (Pethon, 2005).

Cartilaginous fish are not targeted by the commercial fisheries operating along the North Norwegian coastline, but are taken as bycatch in many of these fisheries. The coastline is home to rich fishing grounds, which have a long history of exploitation. Because of the demersal nature of these cartilaginous species, the fisheries of interest to this study are the demersal fisheries (Froese and Pauly, 2007). The coastal demersal fleet consists of vessels that use a variety of gear including trawl, line and gill-netting. There are management strategies in place in order to minimize bycatch levels of undersized commercially important species, but none relating to cartilaginous species (Valdemarsen and Nakken, 2002).

In many other areas, lack of control and monitoring has resulted in severe declines of some species. The barndoor skate *(Raja laevis)* has been documented as being close to extinction as a result of fisheries targeting other species in the NW Atlantic (Casey and Myers, 1998b). In more nearby areas a number of skate species have suffered severe declines in abundance. Stocks of thornback ray *(Raja clavata)* and spotted ray *(Raja montagui)* are considered to have decreased to below safe biological limits in the North Sea (ICES, 2006), whilst the blue skate *(Dipturus batis)* may have disappeared from both the North Sea and the Celtic Sea (Ellis et al., 2005). But fisheries have not only been shown to negatively effect cartilaginous fish stocks. Thorny skate *(Amblyraja radiata)* and round skate *(Rajella fyllae)* stocks in the Barents Sea are said to be in stable condition, despite being taken as bycatch in the existing demersal fisheries (Drevetnyak et al., 2005). Fishing pressure can alter community structures of cartilaginous fishes. Smaller skate (Rajidae) species have been shown to increase in abundance in areas where larger skate stocks have been depleted. It has been suggested that this shift is due to the smaller skates being less vulnerable to size selective fishing gears and competition for prey is largely dependent on juveniles densities of the larger skate species (Ellis et al., 2005). In the NW Atlantic, declines in abundances of commercially important teleosts, such as the gadoids, have coincided with populations growing for certain cartilaginous species. It has been suggested that a dietary overlap between the species has lead to increased resource availability, but this has not been confirmed (Stevens et al., 2000).

The direct and indirect effects of fishing activities cannot fully explain all variations observed in the distribution patterns of cartilaginous species. Climatic factors also play a part in determining species distributions. Dolgov (2005) describes that the distributions of various skate species in the Barents Sea appears to be related to sea temperature, and it is realistic to suppose that temperature plays a large role in determining abundances in areas near the limit of species distributions. Sea temperatures along the coast are not stable, fluctuating on both yearly and annual timescales. Since the 1990's there has been a marked increase in sea temperatures, particularly in the southern regions of the North Norwegian coastline (Aure et al., 2002). Many of the cartilaginous species found along this coastline are living in areas close to the limits of their distribution, and so climatic events would be expected to effect local abundances.

The declines in stocks of cartilaginous species have often gone unnoticed or unchecked. The reasons for this has been well described by a number of authors (Bonfil and Musick, 1994, Dulvy et al., 2000, Stevens et al., 2000, Clarke et al., 2005). Fisheries research is generally directed toward commercially important species and as such very little research has been undertaken within this group of fishes. Relevant statistics from commercial fisheries are mostly very weak or nonexistent.

Bycatches of these species are mostly discarded overboard and are rarely recorded. When catches are recorded, more often than not species are grouped in categories such as ‘sharks’ or ‘skates’, which can mask declines or shifts in community structures. As a result, even the most basic data is unavailable for quantitative studies of stock status of most species. This is particularly so for the NE Atlantic area (Clarke et al., 2005). In response the International Council for Exploration of the Seas (ICES) set up an Elasmobranch Working Group to improve understanding and collect data in this area. Their work began in 1989, but the current working group was established in 2002. Although much research has been undertaken throughout most of the areas covered by ICES, the North Norwegian coastline has received little attention and is poorly understood (M. Clarke, 2006. ICES, Personal communication).

Because fishery statistics for cartilaginous species are either nonexistent or too unreliable, research in other areas of the NE Atlantic has mostly been carried out using fishery-independent surveys. The most common method has been the demersal trawl survey, with abundances estimated using catch per unit of effort (CPUE) data.

The aim of this study was to:

- Identify which species can be confirmed as being present along the North Norwegian coast between 1992 and 1995.
- Make a descriptive analysis of the distributions and abundances for each species present.
- Determine whether there are significant spatial or temporal differences in species abundances along the coastline.
- To analyze whether observed changes in distributions and abundances are significantly affected by sea temperature and/or fishing effort.

The hypothesis for this study is that abundances and distributions of cartilaginous species are not affected by fishing pressure and by changes in sea temperature.

2 Material and Methods

2.1 The Study Area

The study covered the North Norwegian coastline from Vågsøy south of Ålesund (62°00'N 4°50'E) to the Russian border near Kirkenes in the north (69°50'N 30°50'E) (see figure1). It incorporates (Norwegian Directorate of Fisheries) Statistical Areas 00, 03, 04, 05, 06, 07 and the eastern limit of 37.

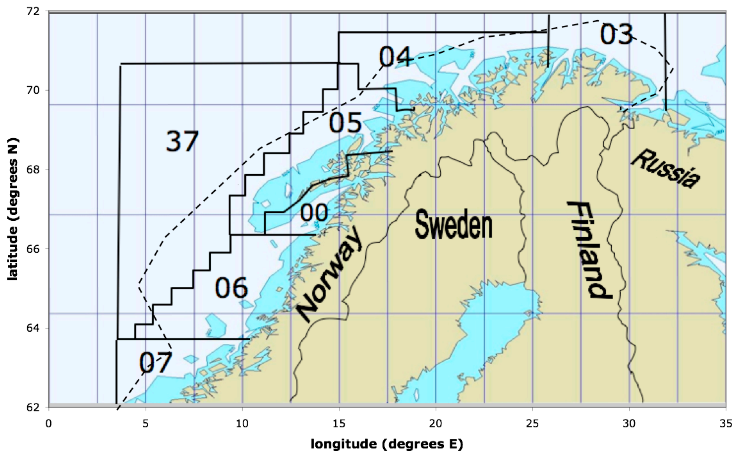


Figure 1. North Norwegian coastline showing coastal areas less than 200m deep in darker shading, the boundary of the study area as a dashed line and Norwegian Directorate of Fisheries Statistical Areas.

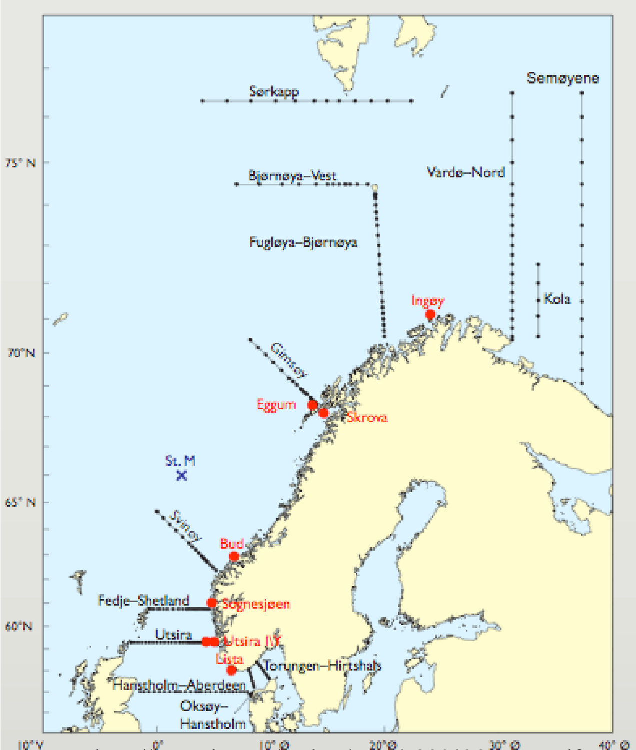
The bathymetry of the region includes the fjord systems of the coastal boundaries and areas of the Norwegian Shelf. As this is a coastal area, sea-bottom depth is very variable. This study predominantly covers areas between 100m and 300m deep, but the total range does include areas of less than 50m and exceeding 700m deep.

This coastline borders two seas: the Barents Sea in the north and the Norwegian Sea in the south. Despite its high latitude, sea temperatures are comparatively warmer than many other northern coastal regions due to the Norwegian current. This is a branch of the Gulf Stream that flows in a northeast direction along the coast. As the current passes through higher latitudes, there is an overall reduction in sea temperature (Gyory et al., 2005). The current temperatures are not constant and are known to fluctuate both in short and long-term intervals. In the past century, average temperatures have been shown to have increased (Berstad et al., 2003).

2.2 Temperature Data

Annual changes in sea temperature were represented by data given in the database from the permanent hydrographical stations positioned along the Norwegian coast. This data was produced by the Institute for Marine Research (IMR) (Hansen, 2007). In the period between 1935 and 1947, a number of permanent hydrographical sample stations were established along the length of the Norwegian coast. Of these, 5 are located within the study area (see figure 2). All of the sample stations measured water temperature and salinity at chosen depths using CTD sensors deployed from research vessels. Temperatures were given to an accuracy of 0.01°C. Because this study focused on demersal species, the data only included approximate bottom temperatures that were taken as close to the sea bottom as the equipment could allow (within 10m). Annual temperatures at each station were calculated as the mean of the quarter-year values given in the database.

Finding suitable temperature data for this analysis proved to be a difficult task. Most sources were insufficient in covering the necessary areas or time scale used in this analysis. This data set proved to be the best source. However, further steps were necessary to compensate for some periods missing data. Gaps in the data were filled in either by estimating values using linear regression correlations between the closest situated stations, or by taking halfway values between the previous and the proceeding values in the time series.



IMR - http://www.imr.no/__data/page/7390/6.3_Kart.pdf (accessed: 16/04/2007)

Figure 2. Positions of the permanent hydrographical stations along the Norwegian coast. The 5 considered for application in the data analysis are highlighted with black crosses.

2.3 Survey

2.3.1 Field Sampling

From 1992-2005, assemblage and distribution data for cartilaginous species was collected via demersal trawl sampling during the Annual Autumn Acoustic Survey for Coastal Cod *(Gadus morhua),* Saith *(Pollachius virens)* and juvenile Herring *(Clupea harengus harengus)*. The Norwegian Institute of Fisheries and Aquaculture Research (Fiskeriforskning) carried this out from 1992 to 2001, and from 2002 onwards it was by the Institute for Marine Research (IMR).

The primary purpose of the surveys was to study the commercially important species associated with the coastal region from Varanger in the north, to Stad in the south. However, all species caught during trawl sampling were identified, counted and weighed. In 14 of the trawl samples taken between 1997 and 2004, all skate (Rajidae) species were grouped and recorded as either 'Skate', 'Skates' or 'Skate family'. Due to difficulties in defining which species of skate was being represented, these categories have not been included in this study.

Various research vessels conducted the surveys and the duration for each survey was between 24 and 39 days. The timing of the surveys was not consistent throughout the total period. After 1998 all surveys were conducted during the months of October and November, whilst earlier surveys took place between August and October (see table 1, next page).

Table 1. Area, time, vessel and trawl gear categories for each annual survey.

Year	Survey period	Vessel name	Statistical Areas (Directorate of Fisheries)	20mm inner net mesh size?	Strapping?
1992	25th Aug—3rd Oct	R/V Johan Ruud	03, 04 and northern sector of 05	Yes	Yes
1993	1st Aug—8th Sep	R/V Mikael Sars	05 and eastern limit of 37	Yes	Yes
1994	22nd Sep—19th Oct	R/V Mikael Sars	06, 07 and eastern limit of 37	No (35mm)	No
1995	13th Sep—11th Oct	R/V Mikael Sars	00, 03, 04, 05, 06 and 07	No (35mm)	No
1996	11th Sep—6th Oct	R/V Mikael Sars	As above	No (35mm)	No
1997	20th Aug—23rd Sep	R/V Mikael Sars	As above	Yes	For most
1998	26th Oct—19th Nov	R/V Jan Mayen	As above	Yes	Yes
1999	22nd Oct—19th Nov	R/V Jan Mayen	As above	Yes	Yes
2000	23rd Oct—16th Nov	R/V Jan Mayen	As above	Yes	Yes
2001	23rd Oct—17th Nov	R/V Jan Mayen	As above	Yes	Yes
2002	29th Oct—26th Nov	R/V Jan Mayen	As above	Yes	Yes
2003	11th Oct—14th Nov	R/Vs Jan Mayen & Johan Hjort	As above	Yes	For most
2004	13th Oct—9th Nov	R/Vs Jan Mayen & Johan Hjort	As above	Yes	For most
2005	11th Oct—8th Nov	R/Vs Jan Mayen & Johan Hjort	As above	Yes	For most

Sample trawl and rigging specifications:

The design of the trawl had been developed for the purpose of research on cod and other demersal fish species (Aschan and Sunnanå, 1997). The trawl gear used as standard was the Campelen 1800 meshes shrimp trawl with a 30m headline, 19m ground rope and 80-42mm knot to knot stretched mesh size in the body with 20mm standard mesh size in the inner net (see table 1 for exceptions). 40m upper and lower bridles were used in the bridle arrangement, which remained unaltered. The ground gear consisted of a 'rockhopper' type. 8'' steel spacers were used between 14'' rubber discs so to hold the gear closer to the bottom in order to minimise loss of small cod under the gear. Sensors were mounted to the doors and the headline in order to monitor the geometry of the trawl while in use and allow irregularities in trawl width and height to be easily detected (M. Aschan, personal communication, 05 Mar. 2007). Strapping was also used for the majority of trawl samples (see table 1 above). This constrained the distance between the doors whilst trawling to approximately 47m (Aschan and Sunnanå, 1997). This exact width is significant because when the doors are 47m apart, the silt plume is directed toward the trawl wings and thus maximises the herding effect between the doors and the trawl net (M. Aschan, personal communication, 07 May. 2007).

Sampling design:

All the surveys began at the north-eastern limit of the survey area and systematically proceeded along the coastline to the south. From 1995-2005 each annual survey covered every Statistical Area included in this study (Statistical Areas – 00, 03, 04, 05 06, and 07 (see figure 1)). In the three previous years, the survey area was split into 3 parts (see table 1, previous page).

Sampling was evenly distributed along the coastline and included both within fjord areas and offshore areas near the coast. The same trawl sampling stations were used for each survey from 1995 to 2005, and were covered by the three earlier annual surveys collectively. The depths surveyed ranged from 30 to 700m. All the sample trawl stations were confined to soft bottom areas that were suitable for the trawl gear and where demersal trawl sampling was permitted.

2.3.2 Survey Data

The annual survey data from 1992 to 2005 was transferred to a single Microsoft Excel worksheet, covering all the cartilaginous species observed. All cartilaginous species logged as present in one or more sample trawls during the surveys (1992-2005) were selected and listed for inclusion in this study. The survey data named all species in Norwegian. The English and scientific names for each species were obtained using FishBase (Froese and Pauly, 2007), and crosschecked with Pethon (2005) for possible discrepancies.

The validity of the results from this study relied heavily upon species identifications being accurate and consistent. Investigations were made to clarify survey data uncertainty during the 2006 IMR coastal survey. Participating scientists were observed whilst sampling and interviewed in order to better understand the limitations of identifying cartilaginous species. Due to the uncertainties involved in making any modifications to the raw data, alterations were limited to only clear inconsistencies that could be shown to occur between the shifts during the survey period in question.

The criteria used was as follows:

a) For each species, details and pictures obtained via FishBase (Froese and Pauly, 2007) and Aschehougs Store Fiskebok (Pethon, 2005) were compared and species with similar morphologies were grouped in pairs accordingly for further evaluation.
b) The survey data was tested. To be considered inconsistent a definite correlation needed to be seen, where each shift displayed an opposite preference in identifying each of the paired species over the same time period.
c) Finally, misidentification could only be assumed for observations where one of the two species had been recorded in the survey data as present in an area outside its known distribution(Froese and Pauly, 2007).

When an inconsistency was shown to satisfy the 3 criteria, the data was amended. The amendment followed the assumption that it is more likely to observe a species within its known distribution than outside. Inconsistent observations were revised so only the species with a known distribution in the respective area were represented. The alterations that were made are described in the Appendix.

2.4 Fishing Effort Data

Effort data was obtained from the Norwegian Directorate of Fisheries vessel logbook database, and presented as annual values of the standardized effort for Statistical Areas: 03,04, 05 and 37 combined. These areas constitute the northern proportion of coastline to as far south as 67°N; but do not include Vestfjord and other fjords situated east of the Lofoten Islands (see figure 1).

Standardised effort was given as number of trawl hours and calculated by dividing the total annual catch by the combined standardized CPUE indexes derived from the included areas. The standardised CPUE indexes were calculated using multiplicative models based on those used by (Hvingel et al., 2000). The variables included for standardising indexes were: fishing vessel size group, gear (1-2-3), area, month and annual mean CPUE.

From 1990 the use of sorting grids became compulsory for the northern coastal shrimp fishery. In January 1992 this was extended to include the offshore shrimp fisheries (Isaksen et al., 1992). A sorting grid is assembled as part of the trawl gear and is designed to function as a bycatch reduction device (BRD). In the Norwegian shrimp fisheries, the selective ability of the device is based on both difference in size and behaviour between bycatch and shrimp. During the research process, the selectivity of the BRD focused on reducing unwanted bycatch of commercially important species and not cartilaginous species (Matt, 2000). However all commercial and non-commercial fish species that are larger than approximately 20cm are excluded by this device (M. Aschan, personal communication, 07 May. 2007).

2.5 Abundances and Distribution

All species recorded in the survey data were listed and classified into their respective taxonomic groups.

2.5.1 Distribution mapping

Distribution maps for each species were accompanied by a brief description of when and where the observations occurred. Observed distribution was presented for each species as a bubble-chart, created using Microsoft Excel, covering the total survey period (1992–2005). The positions of observations were presented by bubble markers plotted on a map of the Norwegian coastline. The size of each bubble in comparison to a given reference represented the estimated abundance of the species at the point of observation.

The "swept area" method was used to estimate species abundances from the survey data. Abundances were expressed in terms of the density of each species in the trawl sample area and given in numbers of individuals km^{-2}. Densities were calculated for the area trawled in each sample using the same method as described by Jakobsen et al. (1997):

(1) $$\rho_s = \frac{f_s}{a_s}$$

ρ_s is the density in numbers of fish/km^2 at sample station s

f_s is the number captured (frequency) at sample station s

a_s is the swept area at sample station s

(2) $$a_s = \text{distance trawled (nm)} \times 1.852 \times \text{EW}$$

EW is the effective catching width of the trawl gear.

The effective catching width of the trawl gear was standardized as being equal to the spread between doors, which was 0.047km (47m) (Aschan and Sunnanå, 1997). The spread between the doors represents the upper limit of possible values that could best represent the mean effective catching width of the gear. A more precise estimation of the effective catching width was beyond the scope of this study. The limitations to this assumption are described in detail by Dickson (1993) and will be included in the discussion together with the reasons for choosing this particular value.

Observed distributions were then compared with the known distributions for each species. Aschehougs Store Fiskebok (Pethon, 2005) and the FishBase database (Froese and Pauly, 2007) both comprehensively describe the known distribution for each species and were assessed for their suitability to the task. The known distributions for each species presented by Pethon (2005) was found to be more precise in describing distributions within the study area and hence chosen as the source for known distributions. For most species the distributions given were consistent between the two sources. The exceptions were blue skate, shagreen ray, sailray, spinetail ray and blackmouth catshark. All were described by Pethon (2005) as having a more northerly distribution than was given in FishBase (Froese and Pauly, 2007).

Inconsistencies between the survey data and the literature were identified and categorized in relation to the observed positions outside the corresponding known distributions.

2.5.2 Statistical analysis

Annual mean catch rates were used as a guide for a preliminary comparison of species abundances and presented in a table and graphically. Abundances for species with catch rates of less than 5 individuals yr^{-1} were not expected to be statistically significant, and were therefore omitted from the statistical analysis. This figure was based on the conclusions made by Bonfil and Musick (1994) on elasmobranch species data recorded during demersal trawl surveys of the North West Atlantic, conducted by Northeast Fisheries Science Center, NMFS, 1967-2003.

For the selected species, the relative densities (number km^{-2}) in each trawl sample were used to assess the statistical significance of temporal and spatial variations in abundances for each species. Year and area were used as the independent variables. From 62°N to 68°N the area variable was categorized into 1°-latitude ranges. The most northern region of coastline, from 69°N to 71°N, was divided at longitude 25°E into two areas and identified as east and west. The locations of each area are illustrated in figure 3. For each species, the probable differences in abundances were tested against the two variables separately using one-way single factor ANOVA. The year variable was used to assess temporal variations. Average abundances were given in terms of the annual mean densities of a species over the whole area included in the survey. The data from 1992-1994 was given as one mean value because these years only covered the total survey area collectively. The latitude variable was used to assess spatial variations. The average abundances represented the mean density of a species within each range of latitude over the total survey period. The significance level was set at p=0.05. Species were considered for further investigation if a variable was shown to have a significant effect on average abundance. Temporal variations were presented graphically by plotting mean density against year with 95% confidence intervals.

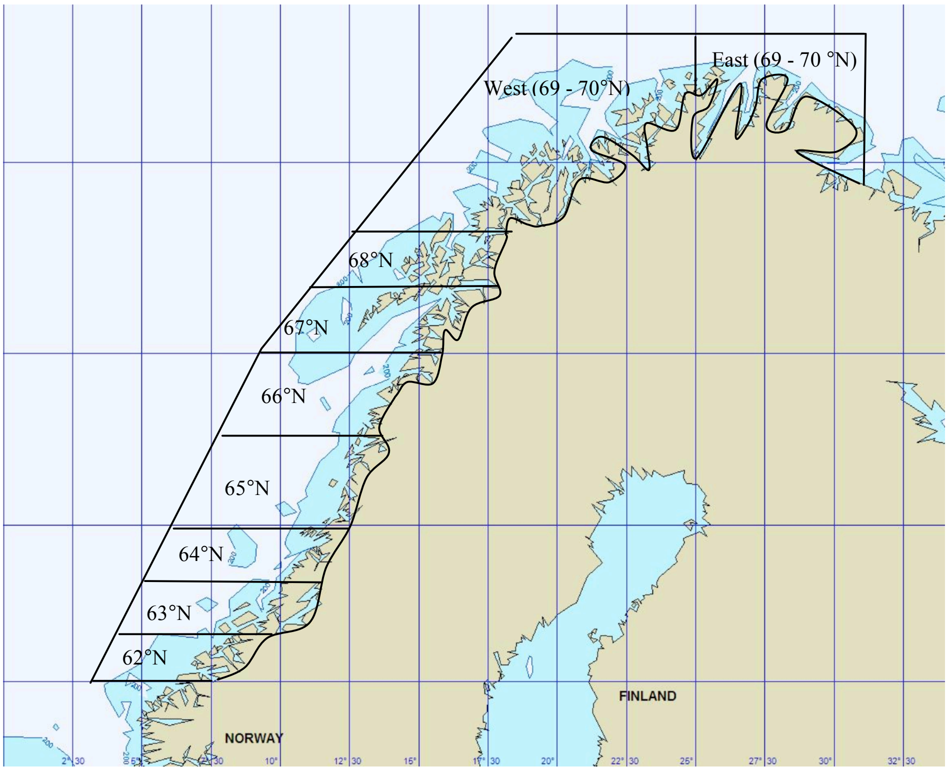


Figure 3. Geographical positions of each area variable along the North Norwegian coastline.

To analyse spatial variations, mean densities were plotted with 95% confidence intervals against each area. Patterns in variations were described in terms of the direction of distribution along the coastline. Peaks in distribution were identified and tested against the adjacent area with the highest average abundance to determine probable differences. The null hypothesis of no difference in average abundances between the two latitude ranges was assessed using a student t-test with significance set at p=0.05.

Temporal differences in abundance were then compared with the average trawl sampling depth for each respective area. Possible correlations were commented upon but not investigated further.

The statistical analysis was repeated using the variable of bottom depth instead of latitude. Depth was grouped in 50m intervals covering the entire depth range trawled by the survey. Depth dependant average abundances were shown graphically with 95% confidence intervals for each species. Significant differences in depth-dependant abundance was analysed using one-way single factor ANOVA.

2.6 Species Abundance and Shrimp Trawl Effort

Due to availability of shrimp trawl effort; analysis was restricted to covering only the Directory of Fisheries Statistical Areas 03, 04, 05 and the eastern limit of 37 (shown in figure 1, page 12). For the same reasons as described earlier, only species with mean annual catch rates higher than 5 individuals yr^{-1} in these areas were considered for this investigation.

The relative densities in each sample were used to calculate annual mean densities for the selected species in Statistical Areas 03, 04, 05 and the eastern limit of 37. Due to the small sample sizes (N=13), correlations between annual variations in effort and species densities were tested using the Spearman's rank-order correlation *(ρ)*. Predictive regressions were calculated using ordinary least-squares technique. The relationship between the two variables was assumed to be linear; no adjustments were made to compensate for possible non-linear interactions.

2.7 Species Abundance and Sea Temperature

Correlations were tested for all species shown by in the statistical analysis (section 2.5.2) to have distribution significantly affected by the area of latitude. The locations of the temperature survey stations determined which area (given in figure 3, page 21) was used for assessing correlations between abundance and temperature. These areas were 62°N, 64°N, 67°N, West(69-71°N) and East(69-71°N). Spearman's rank-order correlation *(ρ)* was used to test whether the average temperature in each area throughout the total survey period, significantly affected species distributions.

Further investigation was undertaken to determine whether annual temperature variations in each area affected species abundances. Species abundances were grouped for each area and variations in mean annual densities were tested for statistical significance. The Kruskal-Wallis non-parametric test was used in order to avoid the assumption that the data was normally distributed. Species and area combinations shown to have significant annual variation were selected for analysis of correlation with sea temperature. Again due to the small sample sizes (N=13), correlations between annual variations in sea temperature and species densities were tested using the Spearman's rank-order correlation *(ρ)*. Annual variations in species abundance (with 95% confidence intervals) and temperature were plotted to compare possible correlations.

3 RESULTS

3.1 Species overview

18 different species of Chondrichthyes were identified over the total survey period from 1992 to 2005, and are listed in table 2 below. Of these one belonged to the sub-class Holocephali and the rest to the sub-class Elasmobranchii. Four different families of Elasmobranchii were identified. The Rajidae family (skates) was the most diverse, which included 13 different species (Froese and Pauly, 2007).

Table 2. Elasmobranch species identified along the North Norwegian coastline during the Annual Autumn Acoustic Survey (1992 – 2005)

Scientific name	**Author**	**Family**	**Common name**
Chimaera monstrosa	Linnaeus, 1758	Chimaeridae	Rabbit fish
Etmopterus spinax	Linnaeus, 1758	Dalatiidae	Velvet belly lantern shark
Somniosus microcephalus	Bloch & Schneider, 1801	Dalatiidae	Greenland shark
Galeus melastomus	Rafinesque, 1810	Scyliorhinidae	Black-mouth catshark
Squalus acanthias	Linnaeus, 1758	Squalidae	Piked dogfish
Amblyraja hyperborea	Collett, 1879	Rajidae	Arctic skate
Amblyraja radiata	Donovan, 1808	Rajidae	Thorny skate
Bathyraja spinicauda	Jensen, 1914	Rajidae	Spinetail ray
Dipturus batis	Linnaeus, 1758	Rajidae	Blue skate
Dipturus linteus	Fries, 1838	Rajidae	Sailray
Dipturus nidarosiensis	Storm, 1881	Rajidae	Norwegian skate
Dipturus oxyrinchus	Linnaeus, 1758	Rajidae	Longnosed skate
Leucoraja circularis	Couch, 1838	Rajidae	Sandy ray
Leucoraja fullonica	Linnaeus, 1758	Rajidae	Shagreen ray
Raja brachyura	Holt, 1894	Rajidae	Blonde ray
Raja clavata	Linnaeus, 1758	Rajidae	Thornback ray
Raja montagui	Fowler, 1910	Rajidae	Spotted ray
Rajella fyllae	Lütken, 1887	Rajidae	Round skate

3.2 Abundance and Distribution

3.2.1 Distribution mapping

Throughout the whole survey period, only 4 blonde ray (*Raja brachyura*) were observed. All 4 individuals were caught in one trawl sample during the 1994 survey (see figure 4 below).

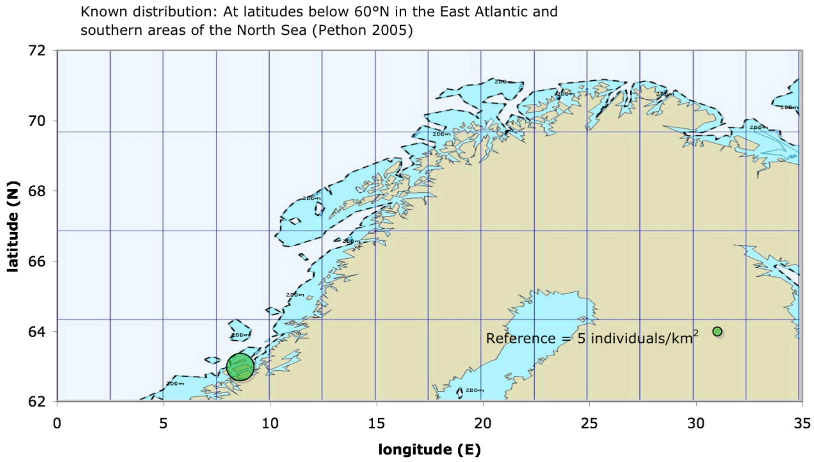


Figure 4. Observed densities (number km^{-2}) for Blonde Ray (*Raja brachyura*):-1992 - 2005

Arctic skate (*A. hyperborea*) observations occurred in just three of the survey years: 1994, 2002 and 2004. There were too few observations (between 1 and 7 individuals observed per year) to note any clear patterns between these years. All observations except for a single individual caught in 1994 were distributed close to the coast (see figure 5 below).

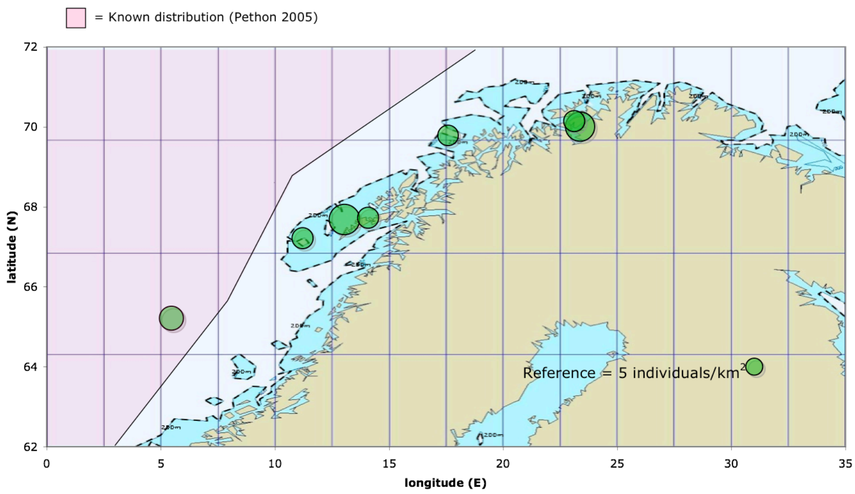


Figure 5. Observed densities (number km^{-2}) for Arctic Skate (*Amblyraja hyperborea*):-1992 - 2005

Blue skate (*D. batis)* was observed at low frequencies (maximum of 7 observations in 1997 and 1998) in specific areas along the whole coastline covered by the survey (see figure 6 below). No observations were made in 1994 and 2004. The frequencies of observations were too low to determine any clear pattern of distribution.

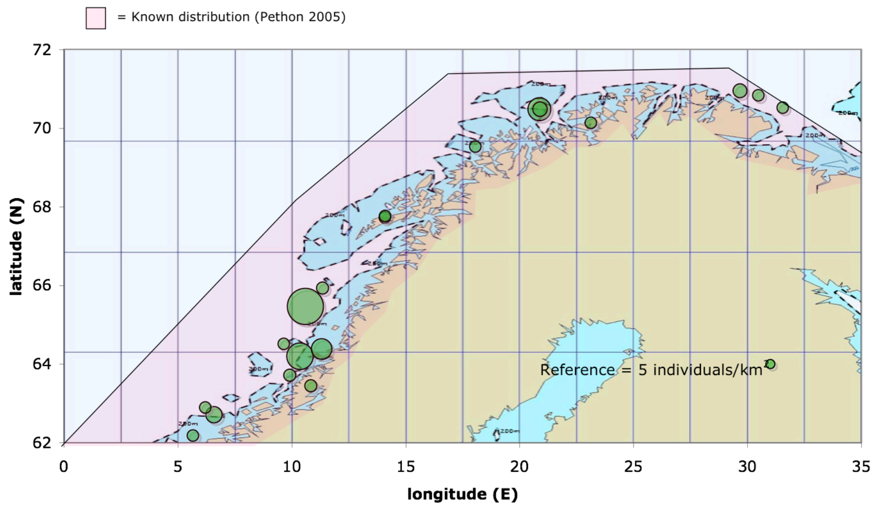


Figure 6. Observed densities (number km^{-2}) for Blue Skate (*Dipturus batis*):-1992 - 2005

Annual observations of longnosed skate (*Dipturus oxyrinchus*) were more concentrated towards southern latitudes (max. 68°N) (see figure 7 below). No individuals were recorded in the 1992 and 1993 surveys, which did not cover below 65°N. Observations were also absent from the surveys of 1999 and 2000. Frequencies were low with a mean average of 7.7 individuals per year. The high standard deviation (see table 3, page 35) reflects proportionally higher catches from the surveys of 1994 and 1997. In the latter survey one sample caught 19 individuals near 63°N.

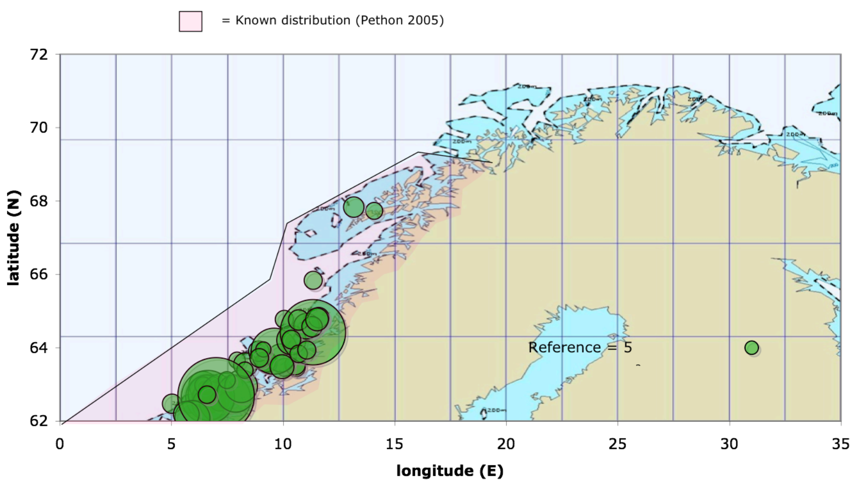


Figure 7. Observed densities (number km^{-2}) for longnosed skate (*Dipturus oxyrinchus*):- 1992 - 2005

Records of Norwegian skate (*D. nidarosiensis*) only occurred in five of the surveys from 1996 to 2004 and the highest number of individuals observed in one survey year was 3. All observations were made below 64°N with the exception of one individual caught in the Lofoten area (approx. 68°N) in the 1997 survey (see figure 8 below).

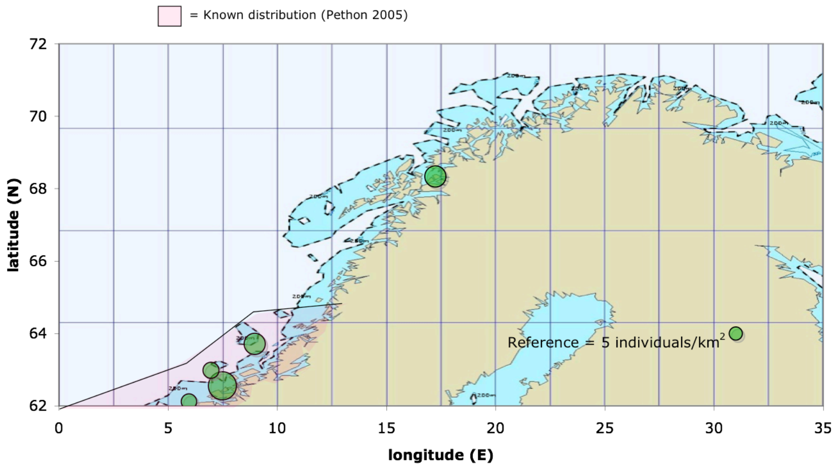


Figure 8. Observed densities (number km^{-2}) for Norwegian Skate (*Dipturus nidarosiensis*):- 1992 - 2005

The mean average annual frequency of observations for round skate (*Rajella fyllae*) was low (5.5 individuals per year)(see table 3, page 35). The high standard deviation (8.4) reflected an increasing frequency of observations over time. Up until 2000, annual frequencies were low with no round skate recorded in a number of the survey years and the maximum number recorded was 4 in 1993. From 2000 onwards the annual frequency of observations increased, and the 2004 survey recorded the highest with 30 individuals. The distribution of observations was mainly confined to along the whole coastline north of 67°N. 4 individuals were observed between 2002 and 2004 further south between 62° and 65°N (see figure 9 below).

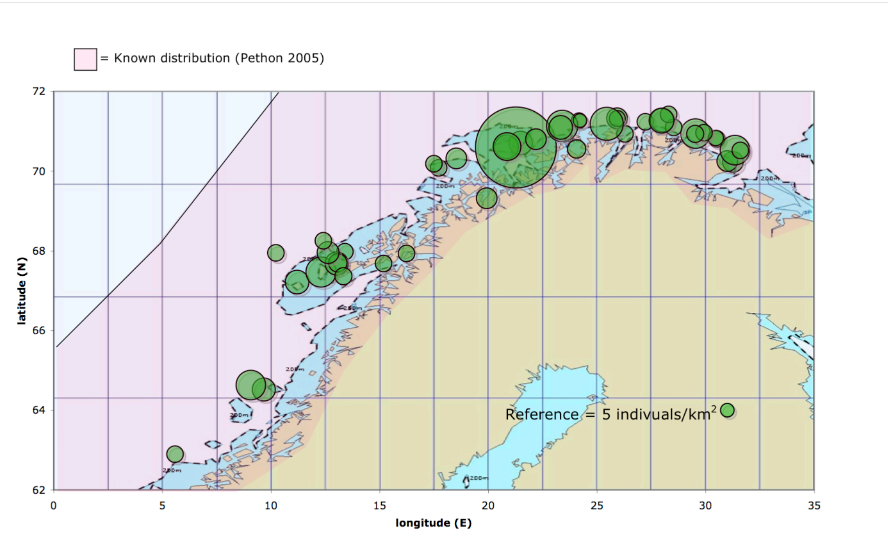


Figure 9. Observed densities (number km^{-2}) for Round Skate (*Rajella fyllae*):- 1992 - 2005

The only observation of the sailray (*D. linteus*) occurred in 1997. One individual was identified in the Lofoten region at 68°N (see figure 10 below).

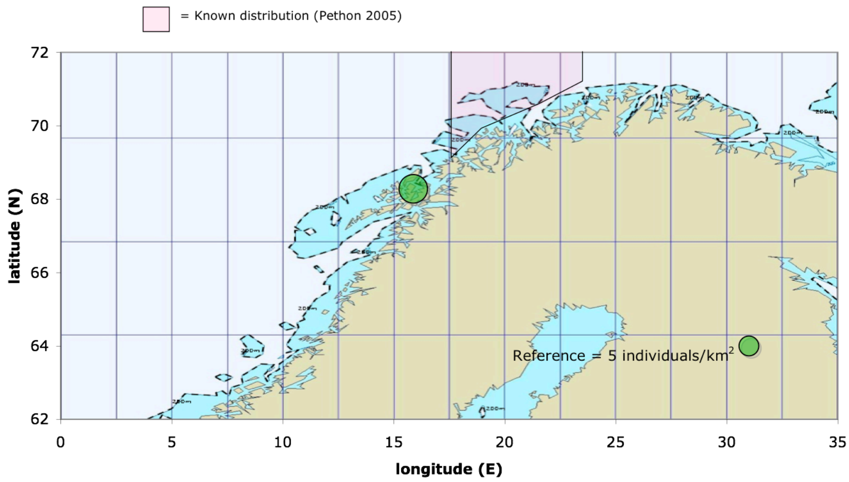


Figure 10. Observed densities (number km^{-2}) for <u>Sailray (*Dipturus linteus*</u>):- 1992 – 2005

The frequency of annual observations of sandy ray (*L. circularis*) was low (mean average of 1.7 individuals per year (see table 3, page 35)); with 9 being the highest number of individuals that were recorded in the 2003 survey. In addition none were identified before 2000. The observed distribution of this species was limited to one small area at about 62.9°N (see figure 11).

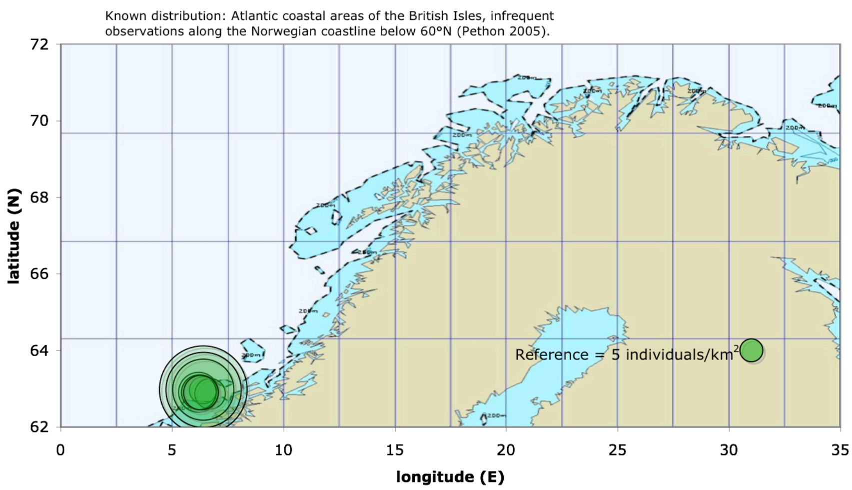


Figure 11. Observed densities (number km^{-2}) for Sandy ray (*Leucoraja circularis*):- 1992 - 2005

The shagreen ray (*L. fullonica*) was observed at low frequencies (see table 3, page 35) (mean average of 10 individuals per year) with no observations occurring before 1997. Observed distribution was scattered. In the1997 survey observations were confined to the Finnmark and northern Troms coastal areas above 69°N, whilst all later identifications occurred at all other latitudes below 69°N (see figure 12 below).

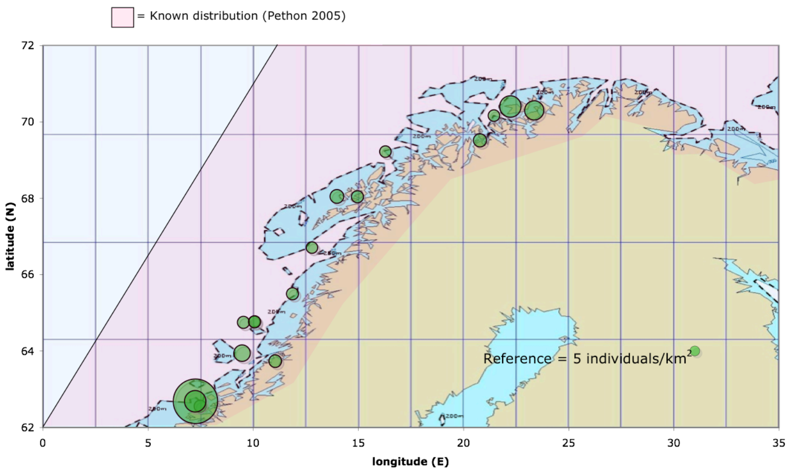


Figure 12. Observed densities (number km^{-2}) for Shagreen ray (*Leucoraja fullonica*):- 1992 - 2005

The spinetail ray (*B. spinicauda)* was identified in six of the survey years from 1993 to 2004. Frequencies of observations were low (mean average of 1.1 individuals per year), the highest being in 2004 with 4 observations. Observed distribution after 1994 was confined to above 69°N whilst earlier observations were below this latitude (see figure 13 below).

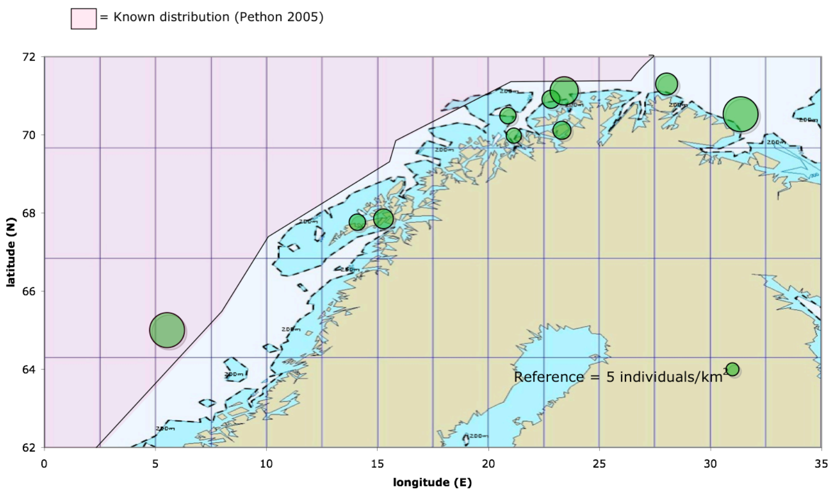


Figure 13. Observed densities (number km^{-2}) for Spinetail ray (*Bathyraja spinicauda*):- 1992 - 2005

Only 4 individuals of spotted ray (*R. montagui)* were identified over 4 of the survey years occurring between 1999 and 2004. The observed distribution was mostly below 63°N, the exception being an identification made at 69°N in 2002 (see figure 14 below).

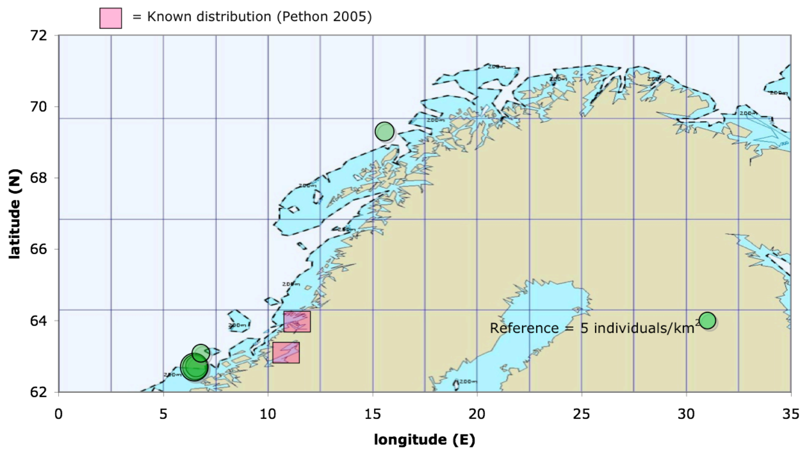


Figure 14. Observed densities (number km^{-2}) for Spotted ray (*Raja montagui*):- 1992 - 2005

Thornback ray (*R. clavata*) was observed in all years except for the surveys of 1996, 2001, 2002 and 2005. The highest annual frequency occurred in 1999 with 28 individuals. For all years, observations were spread among sample trawls with low frequencies of less than 8. Observed distribution was mostly concentrated to above 70°N (see figure 15 below).

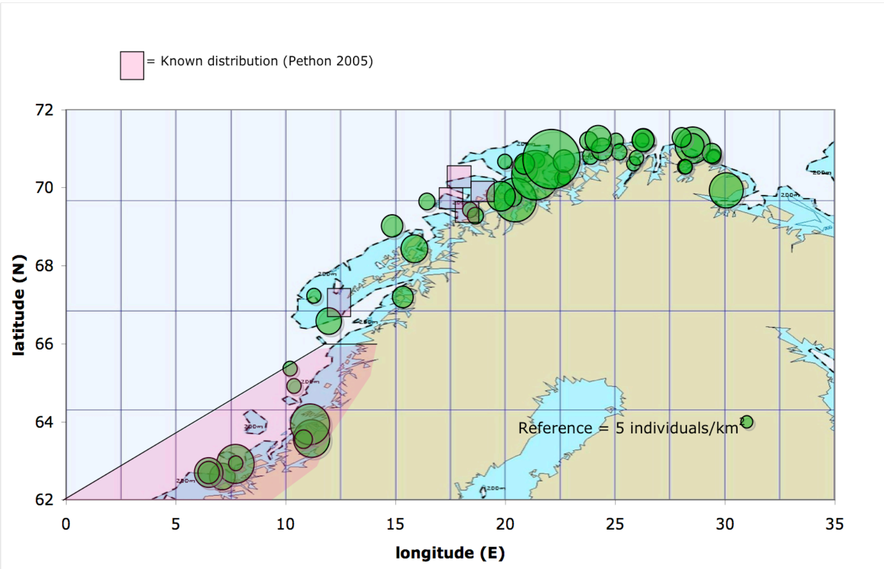


Figure 15. Observed densities (number km^{-2}) for Thornback ray (*Raja clavata*):- 1992 - 2005

Throughout the whole survey period the thorny skate (*A. radiata*) had the highest frequency of observations of all the skate species (mean average of 55.2 individuals per year). There was a low variation in annual frequencies (standard deviation was 20.7) relative to the other species included in this study (see table 3, page 35). For all years, the observed distribution was more concentrated toward the northerly latitudes, but this species was present along the whole coastline (see figure 16 below).

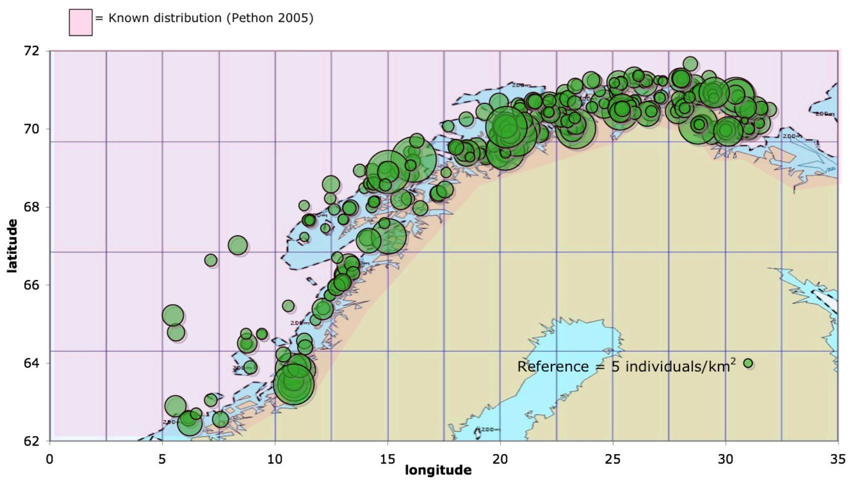


Figure 16. Observed densities (number km^{-2}) for Thorny Skate (*Amblyraja radiata*):- 1992 - 2005

Throughout all the surveys, only one greenland shark (*S. microcephalus*) was identified. This occurred in the 1993 survey at approximately 69°N at a depth of 480m (see figure 17 below).

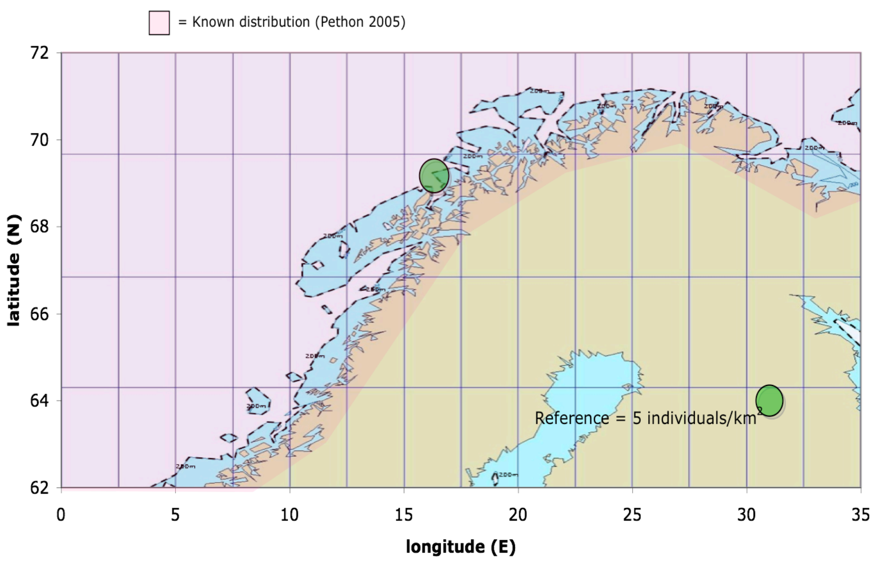


Figure 17. Observed densities (number km^{-2}) for Greenland Shark (*Somniosus microcephalus*):- 1992 - 2005

Rabbitfish (*C. monstrosa*) was observed in every survey year. Catches were more concentrated to lower latitudes, although observations were made as far north as 70°N (see figure 18 below). The mean annual frequency of observations was per year was 2856 individuals. The high standard deviation (3250.7) reflected high variation in annual frequencies (see table 3, page 35). The 1992 survey only covered the region (north of 69°N) that showed to be least productive for all years and also yielded the lowest annual frequency. Over the whole survey period, 76% of samples produced zero frequencies and only 2% of samples caught more than 100 individuals. The years with the highest frequencies (1994 and 1997) can be attributed to single samples with considerably larger catches than other years, rather than a general trend to higher catch rates for all sample trawls.

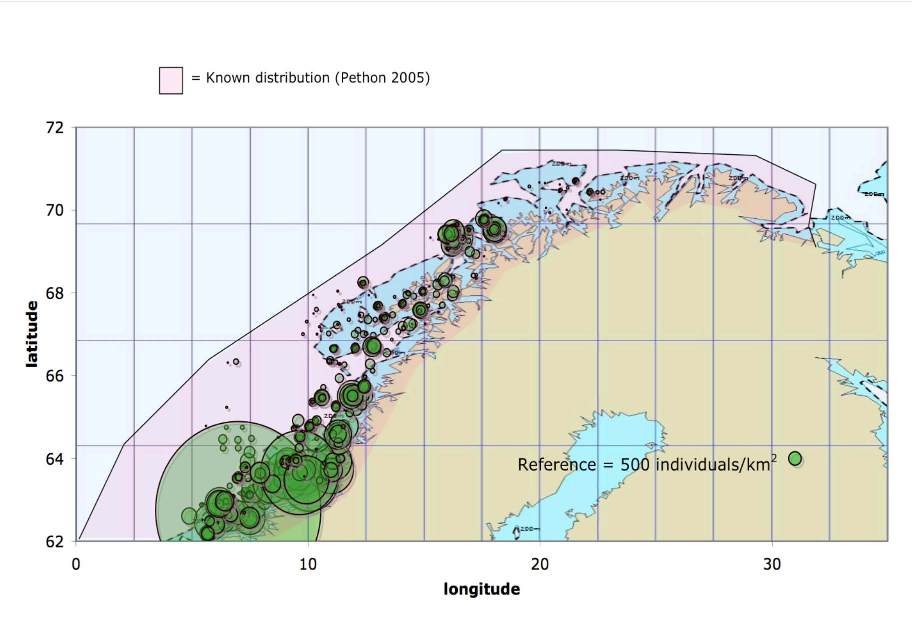


Figure 18. Observed densities (number km^{-2}) for Rabbitfish (*Chimaera monstrosa*):- 1992 - 2005

Observations of blackmouth catshark (*G. melastomus)* occurred in every year that covered the coastline below latitude 69°N. The frequencies of observations were concentrated toward the lower latitudes below 66°N (see figure 19 on the next page). The number of individuals caught in trawl samples varied from 0 to 1000. For the whole survey period 90% of samples produced zero frequencies. The remaining 10% of catches consisted of mostly low frequencies (less than 10) with each survey year yielding one or a few large catches (greater than 200). The number of individuals observed varied from year to year with 1994, 1995, 1997 and 2002 being the strongest years. Despite sample sizes deviating annually, there was no significant deviation between the variations in annual observed frequencies and the mean averages for yearly observations.

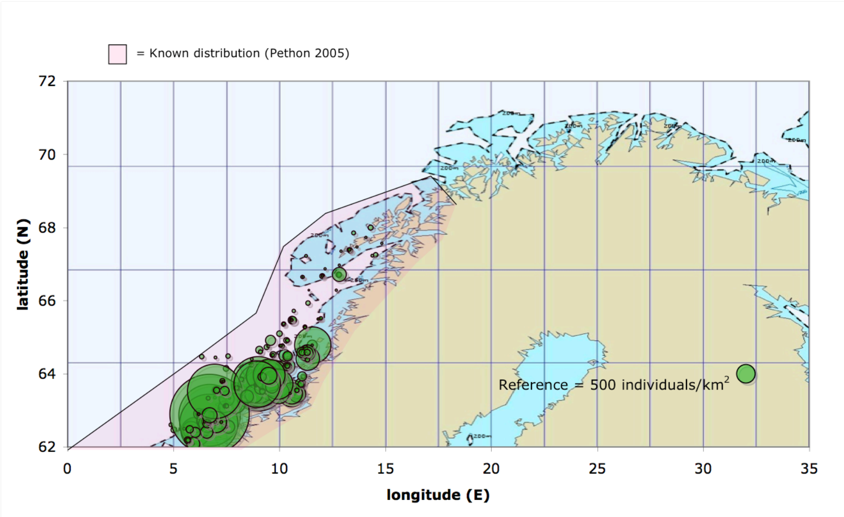


Figure 19. Observed densities (number km^{-2}) for Blackmouth Catshark (*Galeus melastomus*):- 1992 - 2005

Piked dogfish (*S. acanthias*) was observations along the whole coastline, but was seen in higher densities toward the southern latitudes (see figure 20 below). None were observed above 64°N after 1998. The mean average annual frequency for this species was 49.3 individuals; the standard deviation was also 49.3 (see table 3, page 35). 1998 and 1999 yielded the highest total annual frequencies (117 and 169 individuals), over 50% of which came from single trawl samples in each respective year.

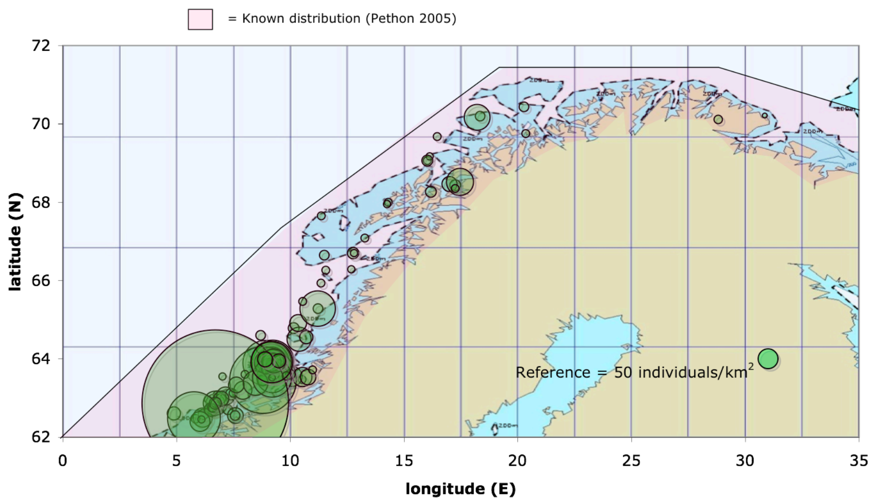


Figure 20. Observed densities (number km^{-2}) for Piked dogfish (*Squalus acanthias*):- 1992 - 2005

Throughout the whole survey period the velvet belly lantern shark (*E. spinax*) had the highest frequency of observations of all the Squaliforme species (mean average of 2078.4 individuals per year (see table 3, page 35)). The observed distribution was generally confined to small areas spread along the coastline as north as 70°N, with higher numbers occurring at the lower latitudes (see figure 21 below). The survey years with the highest total frequencies (1994, 1997 and 1999) all included sample trawls with catches of more than 1000 individuals. 84% of all trawls samples recorded zero frequencies, whilst 2.4% of catches contained more than 500 individuals.

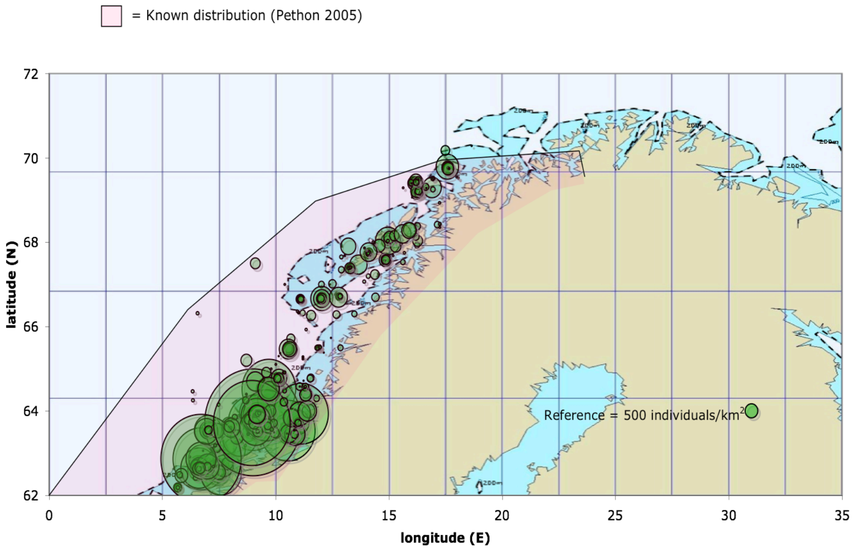


Figure 21. Observed densities (number km^{-2}) for Velvet Belly Lantern Shark (*Etmopterus spinax*):- 1992 - 2005

3.2.2 Statistical analysis

A preliminary comparison of each species' abundance is described using the average annual catch rate and given in Table 3 below. Rajidae (skates) and Non-Rajidae species have been grouped and presented graphically in Figure 22. The species with mean annual frequencies higher than 5 individuals yr^{-1} have been selected for further statistical analysis. These are rabbitfish, black-mouth catshark, velvet belly lantern shark, piked dogfish, round ray, longnosed skate, thornback ray and thorny skate.

Table 3. Average annual catch rates (1992 to 2005) listed in descending order:

Species	Annual mean catch rate	Std dev.	% of positive trawl samples
Rabbit fish	2586.2	3250.7	30.5
Velvet belly lantern shark	2078.4	2234.0	18.6
Black-mouth catshark	605.7	598.0	13.7
Thorny skate	55.2	20.7	19.0
Piked dogfish	49.3	49.3	4.8
Longnosed skate	7.7	15.6	2.6
Thornback ray	7.1	8.4	2.5
Round skate	5.5	8.3	2.1
Blue skate	2.2	2.2	1.0
Shagreen ray	1.8	2.7	0.9
Sandy ray	1.7	3.2	0.4
Spinetail ray	1.1	1.4	0.4
Arctic skate	0.6	1.9	0.4
Norwegian skate	0.5	0.9	0.3
Spotted ray	0.4	0.6	0.3
Blonde ray	0.3	1.1	0.1
Sailray	0.1	0.3	0.1
Greenland shark	0.1	0.3	0.1

Abundant species selected for statistical analysis

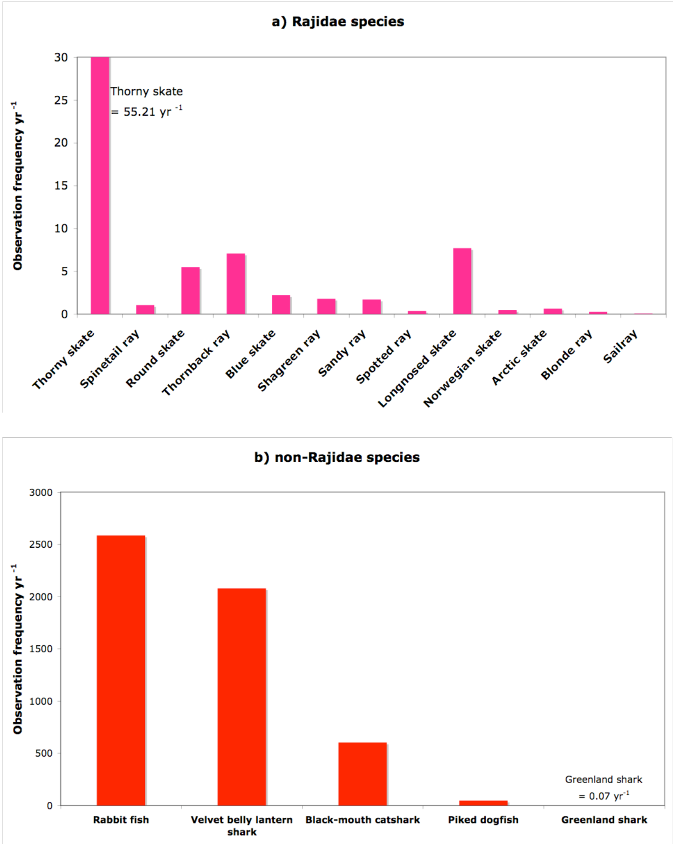


Figure 22. Average frequency of observations per year (1992-2005) for a) Rajidae and b) Non-Rajidae species.

For further statistical analysis, abundances are described by the estimated mean densities given in number of individuals per square kilometre. Assumptions of constant annual abundance along the total length of the coastline and equal distribution in each one-degree latitude range were investigated using one-way single factor ANOVA analysis. The analysis showed that observed differences in annual abundances along the total length of the coastline were only significant for thorny skate (significance of 4.4%) (see table 4, next page). For all years combined, the mean density for thorny skate was 2.7 individuals km^{-2}. The highest densities occurred in 1997 and 2004, whilst the lowest densities were observed in 2002 (see Figure 23, next page). The estimates given for 1992-1994 are a collective mean and as such hide any variations that may have occurred during these 3 years.

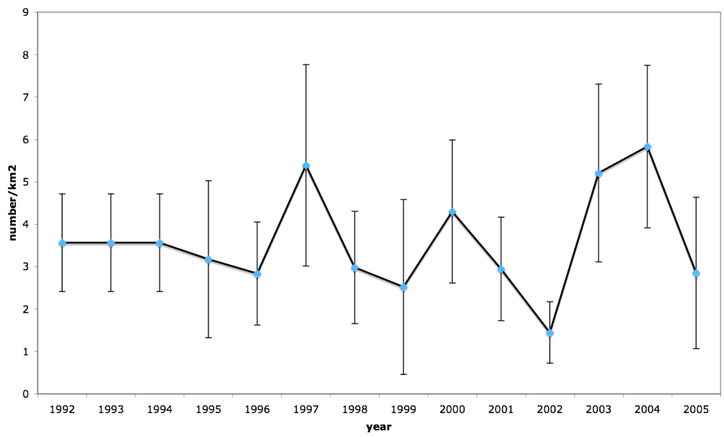


Figure 23. Average annual mean densities in number km^{-2} (with 95% confidence intervals) for thorny skate *(R. radiata)* (1992-94 given as one average).

Table 4. One-way single factor ANOVA schemes (where p=0.05) for determining the significance of temporal differences in abundances of the listed species.

Species	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rabbitfish	3717741.6	11	337976.5	0.98	0.473	1.88
Velvet belly lantern shark	893976.4	11	81270.6	0.58	0.840	1.88
Black-mouth catshark	231510.3	11	21046.4	0.68	0.751	1.88
Piked dogfish	5282.6	11	480.2	0.76	0.675	1.88
Thorny skate	184.2	11	16.7	1.92	0.044	1.88
Longnosed skate	52.4	11	4.8	1.00	0.449	1.88
Thornback ray	19.1	11	1.7	1.85	0.055	1.88
Round skate	14.0	11	1.3	1.61	0.107	1.88

Spatial differences in abundance were showed to be significant for all species excluding thornback ray (see Table 5, next page). Distribution of abundances is presented in Figure 25, page 32, for each of these species. Thorny skate was observed to be present in each range of latitude. Abundances were highest in the two areas (approximately 5 individuals km^{-2}) between the latitudes of 69° to 71°N and decreased at lower latitudes to approximately 1 individual km^{-2}. A secondary peak in abundance (3 individuals km^{-2}) appeared at 63°N although the effect of this latitude in relation to the adjacent latitudes was not shown to be statistically significant. Round skate was not observed to be present within latitudes 63°N, 65°N, 66°N, and 69°N. Abundances were highest for this species at latitudes 67°N and were approximately 1 individual km^{-2}. The remaining species were shown to have increasing abundances with lower latitudes. Black-mouth catshark and velvet belly lantern shark both had peaks in abundances at 63°N, while rabbitfish and longnosed skate abundances were highest at 62°N. Analysis using the student t-test (where p=0.05) with the assumption of equal means showed that the effect of the difference in latitudes between 62°N and 63°N was not statistically significant. All had significantly lower or zero abundances at latitudes greater than 64°N. The mean bottom depth of the trawl sample stations was highest (306m) in area 65°N. All other areas were less than 250m (see figure 24 below).

Table 5. One-way single factor ANOVA schemes (where p=0.05) for determining the significance of spatial differences in abundances of the listed species.

Species	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rabbitfish	7537614.7	8	942201.8	2.8	0.007	2.03
Velvet belly lantern shark	5141623.0	8	642702.9	6.0	2.53E-06	2.03
blackmouth catshark	1078162.9	8	134770.4	5.5	9.93E-06	2.03
Piked dogfish	13594.7	8	1699.3	2.8	0.007	2.03
Thorny skate	294.3	8	36.8	5.3	1.49E-05	2.03
Longnosed skate	162.5	8	20.3	5.0	2.84E-05	2.03
Round skate	10.3	8	1.3	2.8	0.008	2.03
Thornback ray	7.3	8	0.9	1.3	0.245596	2.03

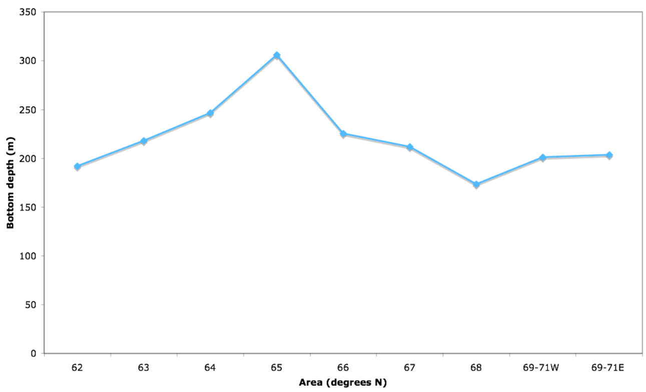


Figure 24. Average bottom depth of trawl samples taken for each area

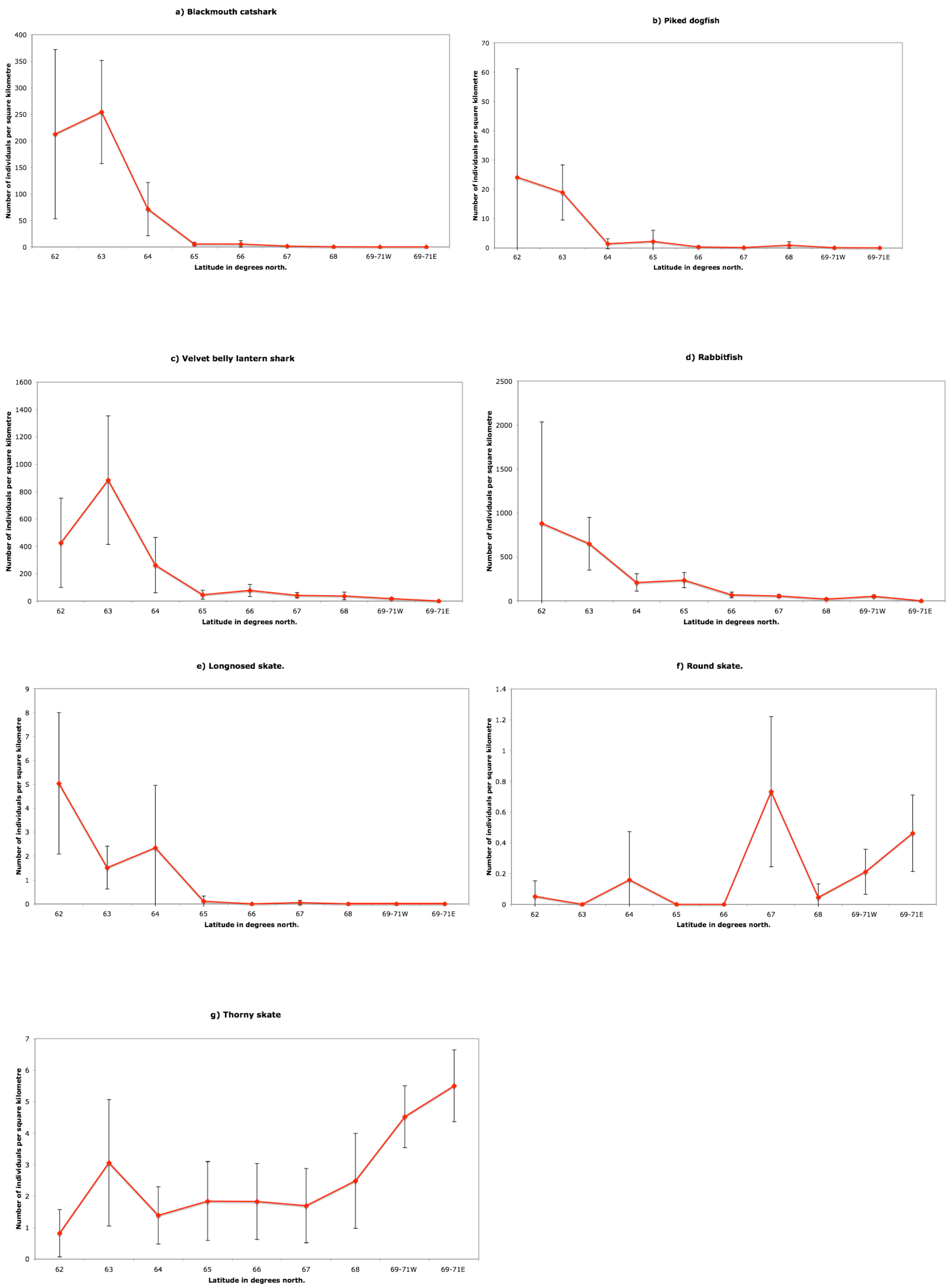


Figure 25. Mean distribution densities (with 95% confidence intervals) along the North Norwegian coast for a) Black-mouth catshark, b) Piked dogfish, c) Velvet belly lantern shark, d) Rabbitfish, e) Longnosed skate, f) Round skate and g) Thorny skate. Areas separated by latitude below 69°N and above by longitude 25°E.

Scatter-plot graphs appear to show that the highest abundances of rabbitfish are at depths greater than 400m; velvetbelly lantern shark and blackmouth catshark at depths greater than 150m; thornback ray at depths less than 500m; and round skate below 450m deep. Average abundances for all other species did not appear to be depth dependant (see figure 26, next page). The 50m depth intervals from 550m to 700m were not included in the statistical analysis due to the low number of samples (between 1 and 6 for each interval). Differences in depth dependant abundances were only shown to be statistically significant for blackmouth catshark (see table 6).

Table 6. One-way single factor ANOVA schemes (where p=0.05) for determining the significance of depth dependant differences in abundances of the listed species.

Species	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
rabbitfish	40047077	9	4449675.2	1.46	0.170	1.95
velvetbelly	1386782	9	154086.9	1.69	0.098	1.95
catshark	352063	9	39118.1	3.23	0.001	1.95
Piked	4807	9	534.1	1.65	0.107	1.95
Thorny	155	9	17.2	1.21	0.297	1.95
longnosed	135	9	15.0	0.97	0.469	1.95
thornback	14	9	1.5	1.05	0.405	1.95
Round	5	9	0.6	1.81	0.072	1.95

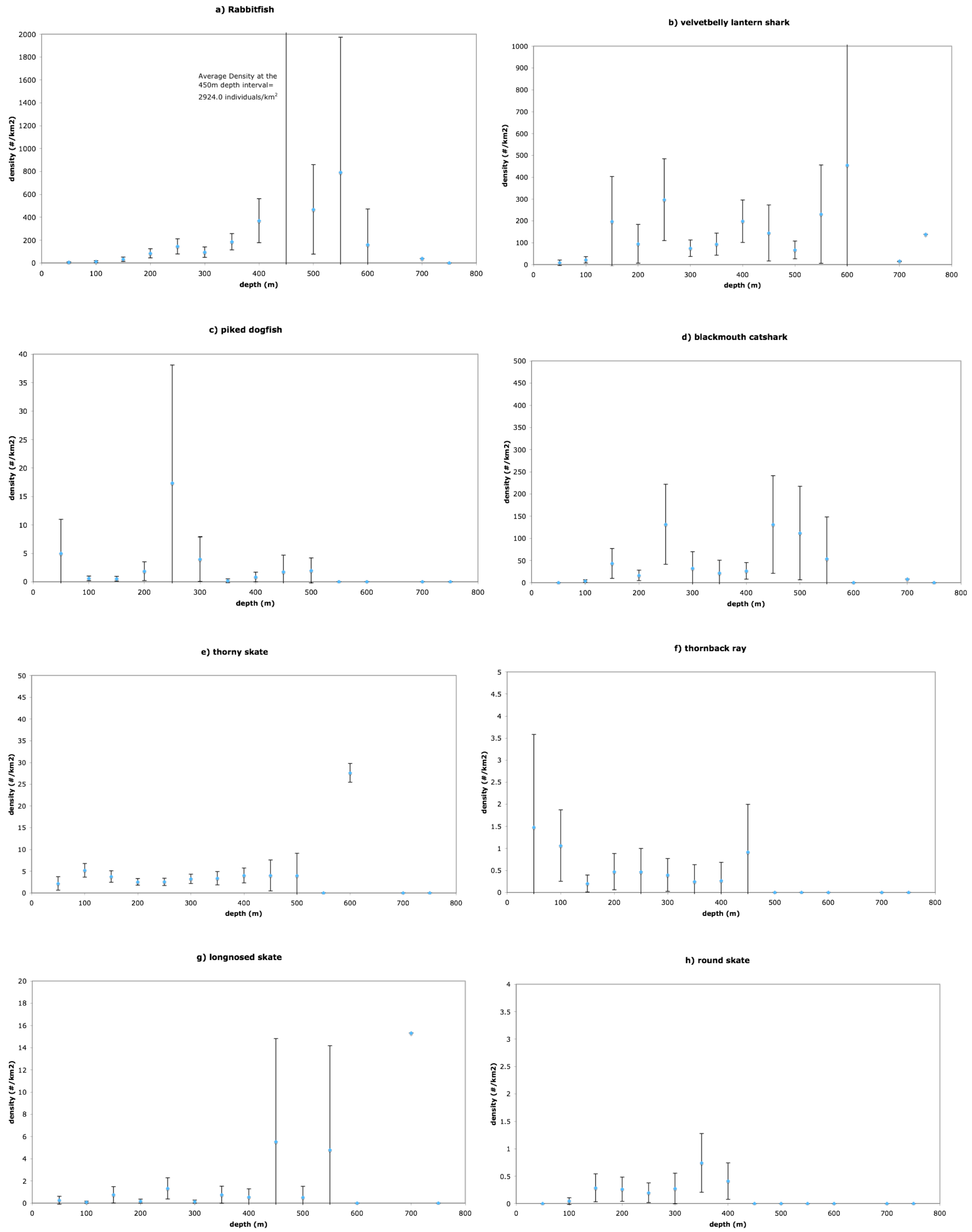


Figure 26. Average abundances (number km^{-2}) for each 50m depth interval (given by the maximum depth) for a) rabbitfish, b) velvetbelly lantern shark, c) piked dogfish, d) blackmouth catshark, e) thorny skate, f) thornback ray, g) longnosed skate and h) round skate.

3.2.3 Abundance overview.

Greenland shark *(S. microcephalus)*, Arctic skate *(A. hyperborean),* Blonde ray *(R. brachyura),* Spotted ray *(R. montagui),* Blue skate *(D. batis),* Sailray *(D. linteus),* Spinetail ray *(B. spinicauda),* Norwegian skate *(D. nidarosiensis),* Sandy ray *(L. circularis)* and Shagreen ray *(L. fullonica)* were all confirmed as occurring within the North Norwegian coastal area (62°00'N 4°50'E to 69°50'N 30°50'E). There were too few observations of these species to determine distribution patterns or temporal variations in abundances.

Rabbitfish *(C. monstrosa)* was shown to have the highest overall average abundance of all species with an estimated mean density = 161.01 individuals km^{-2}. Distribution was shown with highest abundances at the lowest latitudes and decreasing in a northerly direction. Abundances north of 66°N were less than 10% of the estimated abundance within the 62°N latitude range. No rabbitfish were observed above 71°N. Velvet belly lantern shark *(E. spinax)* also was estimated to have an overall average abundance higher than 100 individuals km^{-2}. The population was unevenly distributed with the greater proportion of individuals inhabiting the lower latitudes between 62°N and 65°N. Again none were observed above 71°N. No other species was estimated to have overall abundances in excess of 4 individuals km^{-2}. Piked dogfish *(S. acanthias)*, black-mouth catshark *(G. melastomus)* and longnosed skate *(D. oxyrinchus)* were all shown to be more strongly distributed in the south and absent north of latitudes: 71°N, 69°N and 66°N respectively.

Thorny ray *(R. radiata)* was the most abundant of the skate (Rajidae) species with an overall mean density of 3.57 individuals km^{-2}. This species was found to be more highly abundant at the most northerly latitudes, but occurred in all latitude ranges along the coastline. Thorny skate was the only species shown to have significant annual changes in average abundances over the total survey area. From 2002 until 2003, abundances were shown to have increased from 2 to 5 individuals km^{-2}. Thornback ray *(R. clavata)* was neither shown to vary in abundance annually, or be unevenly distributed throughout the different ranges of latitude.

Although abundances for some species appeared to be depth dependent, only the higher abundances of blackmouth catshark below 150m deep was shown to be statistically significant.

For some of the species mentioned, the observed distribution was different to that given previously in literature (Pethon, 2005). These differences are summarised in table 7 below.

Table 7. Differences in species distributions between survey data and the literature (Pethon, 2005)

No difference: Observations consistent with known distribution	**Northern shift:** One or more observations occurring north of known distribution	**Shift to coastal areas:** Observations occurring in coastal areas, whilst known distribution is offshore
Blue Skate	Blonde Ray	Arctic Skate
Black-mouth catshark	Norwegian Skate	Spinetail ray
Greenland Shark	Sandy ray	
Rabbitfish	Spotted ray	
Longnosed Skate	Thornback ray	
Piked dogfish		
Round Ray		
Shagreen ray		
Thorny Skate		
Velvet Belly Lantern Shark		
Other shifts in distribution:	The sailray was observed in only one location (68°N 16°E), which was not consistent with the two areas given in the literature (see figure 10)	

3.3 Species Abundance and Shrimp Trawl Effort

For the Statistical Areas 03, 04, 05 and 37 combined, four species were calculated as having annual average frequencies greater than 5 individuals yr^{-1} (see table 8.). These were rabbitfish (*C. monstrosa*), velvet belly lantern shark (*E. spinax*), thorny skate (*A. radiata*) and thornback ray (*R. clavata*).

Table 8. Mean annual frequencies (number yr^{-1}) of all cartilaginous species in Statistical Areas 03,04,05 and 37 combined.

Species	Mean annual frequency (number yr^{-1})	Standard deviation
Rabbitfish	316.31	227.10
Velvet belly lantern shark	107.54	109.62
thorny skate	45.46	18.38
thornback ray	5.31	8.18
Round skate	3.15	4.06
Piked dogfish	1.62	3.59
spinetail ray	0.77	1.36
blue skate	0.62	0.65
shagreen ray	0.46	1.39
Arctic skate	0.31	0.85
spotted ray	0.08	0.28
greenland shark	0.08	0.28
Black-mouth catshark	0	0
sand skate	0	0
longnosed skate	0	0
norwegian skate	0	0
Blone ray	0	0
Sailray	0	0

Spearman's rank-order correlation tests and predictive regression analysis showed that there was no significant (α=0.05) correlation between effort and mean abundances for any of the selected species (see table 9, next page).

Table 9. Shrimp trawl effort versus mean density (number km^{-2}) for the selected species in Statistical Areas 03.04,05 and 37.

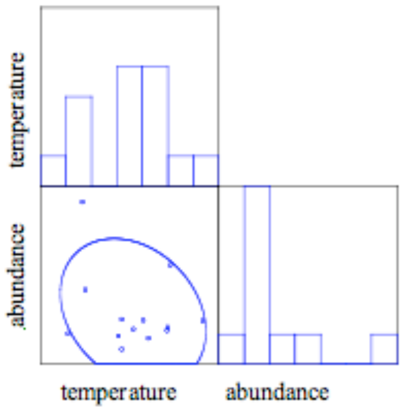
Species	ρ	p-value	R^2
Rabbitfish	-0.264	0.25	0.12
Velvet belly lantern shark	-0.099	0.63	0.02
Thorny skate	0.099	0.95	0.0004
Thornback ray	0.266	0.66	0.02

3.4 Species Abundances and Sea Temperature

For 5 of the 6 species with significant distribution patterns (as shown in figure 25, page 32), Spearman rank analysis showed strong correlations between average latitudinal differences in bottom temperature and with the respective average species abundances, for all years combined. Abundances of velvetbelly lantern shark, rabbitfish, piked dogfish and blackmouth catshark were positively correlated with bottom temperature ($\rho>0.9$). Thorny skate abundance was negatively correlated to temperature ($\rho>-0.9$). Round skate was the exception with no correlation ($\rho<\pm0.5$).

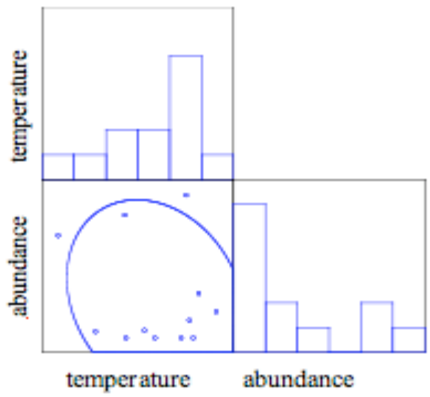
With regards to temporal changes in abundances for each area, Kruskal-Wallis tests revealed no significant variations for any species in the areas 64°N and 67°N. Annual abundances of Longnosed skate were shown to vary significantly in area 62°N ($p>0.05$ assuming Chi-square distribution(Chi^2) with 11 df). Within area West(69-71°N) significant annual variation was seen for rabbitfish ($p=0.01$with Chi^2 12df) and velvetbelly lantern shark ($p=0.008$ Chi^2 with 12df). Only thorny skate abundance varied significantly ($p<0.05$ Chi^2 with 11df) in area East(69-71°N).

With the exception of area East(69-71°N), all areas appeared to show an overall increase in temperature between 1992 and 2005 (see figure 28). Annual variations in sea temperature were not shown to significantly effect species abundances in each area. Spearman rank analysis showed a weak correlation ($\rho<\pm0.5$) between the two variables (see figure 27). 95% confidence intervals of annual densities for each species showed that for each year, other factor(s) had a greater effect than temperature on species abundances (see figure 28).



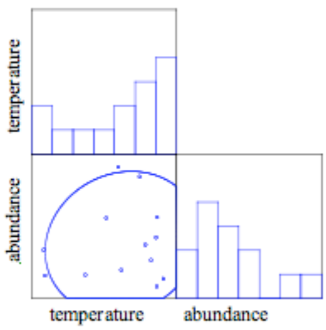
	Temperature	Abundance
Temperature	1	
Abundance	-0.018	1

a) Longnosed skate in area 62°N



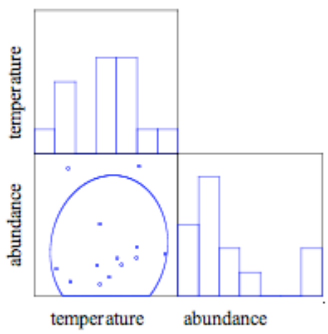
	Temperature	Abundance
Temperature	1	
Abundance	0.05	1

b) Rabbitfish in area West(69-71°N).



	Temperature	Abundance
Temperature	1	
Abundance	-0.088	1

c) Thorny skate in area East(69-71°N)



	Temperature	Abundance
Temperature	1	
Abundance	0.451	1

d) Velvetbelly lantern shark in area West(69-71°N)

Figure 27. Spearman rank correlation values (ρ) and scatter-plot matrix for the two variables: temperature and species abundance. The categories are: a) longnosed skate in area 62°N, b) rabbitfish in area West(69-71°N), c) thorny skate in area East(69-71°N) and d) velvetbelly in area West(69-71°N).

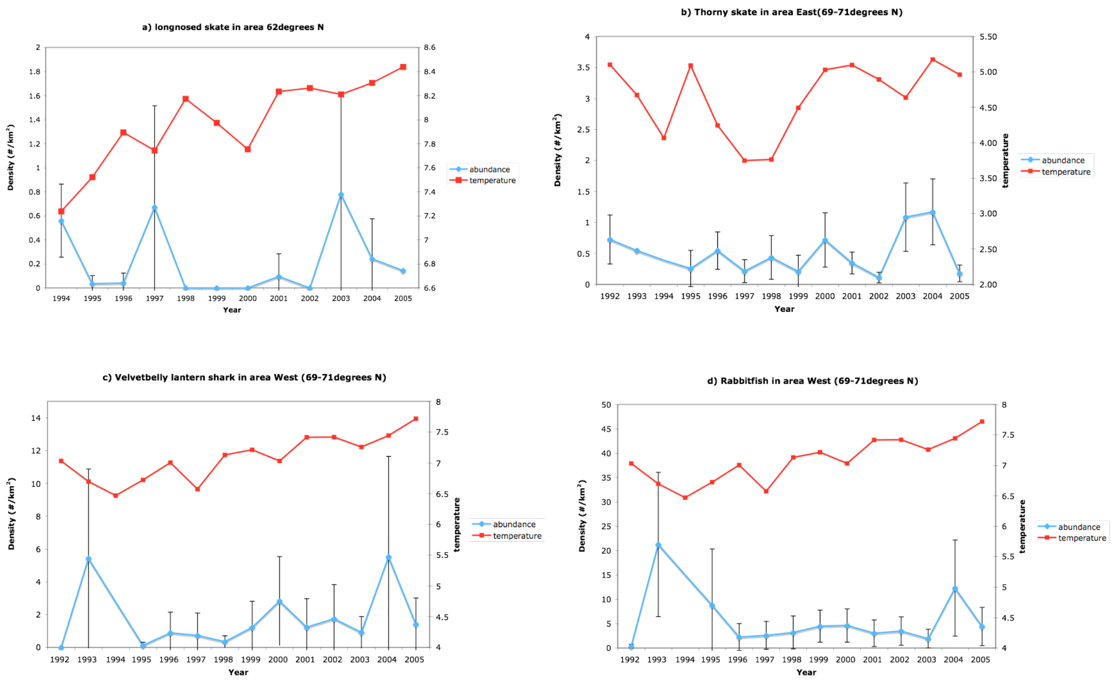


Figure 28. Species abundance with 95% confidence intervals against temperature for a) longnosed skate in area 62°N, b) thorny skate in area East(69-71°N), c) velvetbelly in area West(69-71°N) and d) rabbitfish in area West(69-71°N).

4 Discussion

4.1 Evaluation of the Survey

Fishery independent surveys are often favoured for making stock assessments because measurements are derived from scientific sampling, which eliminates many of the unknown factors associated with fishery dependent surveys (Bonfil and Musick, 1994). However, using this approach means that the findings are totally dependent upon the quality of the survey itself. Most fishery-independent surveys are designed to estimate abundances for more than one species. In most cases it is unlikely that the survey design is optimal for all (Bonfil and Musick, 1994) and even less likely for additional species recorded during the survey. This assumption is particularly relevant for the species investigated in this study. A study of commercial and survey catches in the Mediterranean showed that bottom trawl was not the most efficient gear type for catching skates. It was suggested that skates often bury themselves in the bottom strata whilst the gear passes over them (Abella and Serena, 2005).

Selection of trawl survey stations was partly random and partly determined by the suitability of the bottom substrate for demersal trawl gear. The accuracy of the survey in reflecting actual abundances was therefore influenced by the habitat preferences of each species and whether distributions were more patchy or homogenous.

The preferred habitats for most of the species were accounted for in the survey design (Pethon, 2005, Teresa et al., 2005, Froese and Pauly, 2007). The bottom trawl gear could only be used in certain permitted areas where the bottom substrate was soft. Most are primarily found in this habitat. However, owing to how little knowledge there is regarding some of the species, higher preferences for other habitats cannot be ruled out.

The pattern of localised distributions within soft bottom areas can have a strong influence on the power of surveys to detect trends in abundance. Any changes in distribution may reflect distribution - abundance relationships, with populations being confined only to habitats with high suitability as abundance falls (Ellis et al., 2005). Species that have a more homogenous distribution in soft bottom areas will therefore be better represented in the survey data.

The survey was conducted during the latter part of each year, however the actual period differentiated by up to nearly 3 months between years. If any of the species were to undergo seasonal migrations, this could influence the survey data. The trawl samples were taken at irregular intervals 24hours a day. Therefore samples were influenced by diurnal variations in light, and in greater contrast at lower latitudes and later in the season. Casey and Myers (1998a) stated that skate species use visibility as a means to escape trawl gear and were caught in higher proportions at night. This may be also true for other species.

4.2 Evaluation of the Method

The largest possible source of error in abundance estimations is associated with the assumptions made regarding the catch efficiency of the survey gear. To allow for a certain percentage that escape capture, it is normal to use an effective catching width that is less than the spread of the doors. The effective catching width is based on prior analysis using a variety of techniques, which takes into account the behavioural and physical characteristics particular to a single or group of species and environmental considerations (Dickson, 1993).

For investigations using the same trawl gear as used in this survey but to monitor other species, effective catching widths that were less than the spread between the doors were applied. The precise value used was dependent on the knowledge available for each species. An example is the abundance analysis of Greenland halibut (*Reinhardtius hippoglossoides*) and redfish species (*Sebastes marinus* and *S. mentella)* in the Barents Sea, which applied a standard catching width of 25m for all catches. During the same survey, more precise length dependant catch widths were applied to estimates of the better known species, cod (*Gadus morhua)* and haddock (*Melanogrammus aeglefinus*)(Jakobsen et al., 1997, Aglen et al., 2005) . The literature used in this study makes no references to any standard catching width size that can be used for determining abundances of cartilaginous species. Given the little knowledge available for cartilaginous species, the catching widths used for other species could not be considered (with any certainty) compatible for this study.

This study assumed that the catching width was constant for all species, was equal to the spread between the doors, and was 100% effective. It is more likely however, considering the reasons given earlier, that a certain percentage avoided capture. The spread between the doors represents the upper limit of possible values that could best represent the mean effective catching width of the gear. With respect to this, possible errors in the analysis cannot lead to overestimations of species abundances.

Neither the survey design, nor the analysis of abundances accounted for species habitat preference or expected distribution. Closer consideration to these factors could have helped to reduce the high level of variance associated with estimated average abundances, and allowed the results of the survey to be more representative of actual abundances. Stratifying the sampling frame (the total area considered for a given mean abundance) into sets of sampling units with more homogenous properties (e.g. depth) is a means to reduce variance (Bonfil and Musick, 1994). However this requires the proportional values of each sample unit within the sampling frame, which was beyond the scope of this study.

4.3 Abundances and Distribution Patterns

For the less abundant species (less than 5 individuals observed per year), insufficient data was available to confirm whether abundances significantly changed with time between areas of latitude. However, some of these species were shown to be present in areas outside their respective known distributions (Pethon, 2005). For blonde ray, Norwegian skate, sandy ray, spotted ray and thornback ray, the perceived distribution shift was in a northerly direction. With the exception of Norwegian skate, these are southern species more commonly associated with the North Sea and Atlantic areas south of 62°N. Arctic skate and spinetail ray are associated with offshore areas, but were observed in coastal areas. It is beyond the scope of this study to determine the reason for this apparent shift. Because these species are so poorly understood in this area, it is impossible to rule out the theory that there has been no actual shift in distributions.

A more suitable survey design may have shown a higher abundance of blue skate. Although most literatures describe this species as preferring soft or mixed bottom areas(Pethon, 2005, Teresa et al., 2005, Froese and Pauly, 2007), reports by sports anglers state that in other areas of the East Atlantic, this species is territorial and found in highest abundances where the benthos is rocky (http://www.wreckfish.com/skate.htm). In addition, abundances of the Greenland shark could well be higher than estimated, because it is possible they avoid being caught by swimming faster than the trawl is towed. No literature could be found to directly support this argument, but the Greenland shark is known to prey on highly mobile species such as seal, which suggests this species is capable of swimming at high-speed (Fisk et al., 2002).

Distinct patterns of distribution were seen for the more abundant species (more than 5 individuals observed per year). Rabbitfish, velvetbelly lantern shark, piked dogfish, blackmouth catshark and longnosed skate have more southerly distributions. With the exception of longnosed skate, changes in abundance correlated well with latitudinal changes in temperature. Abundances for all of these species appeared to decrease dramatically above 65°N. It was not determined whether this was directly caused by changes in temperature or whether other factors played a significant role. Although the area surveyed within the 65°N latitude ranges is generally deeper than all other areas, it is unlikely that depth was the critical factor because high abundances of these species in other areas appeared to be concentrated toward the deeper sample stations. Thorny skate was distributed along the whole coastal area, but the warmer waters in the south were shown to have a negative effect on abundance. This correlates well with the findings of Dolgov et. al. (2005), which showed the distribution of skate species (including thorny skate) in the Barents Sea appears to be related to temperature. Round skate was distributed throughout all latitudes, but was most abundant at 67°N. Temperature was not shown to be a critical factor. All these findings correlated well with the previous knowledge given for each species by Froese and Pauly (2007) and Pethon (2005).

From 1992 to 2005, the distributions of the more abundant species appeared to be stable. Overall abundances within the North Norwegian coastal area did not appear to have significantly changed over time. However, the choice of survey design and method of analysis may have masked actual trends in abundances.

More localised temporal differences in species densities were detected for rabbitfish, velvetbelly lantern shark, longnosed skate and thorny skate. These differences were related only to one or two years rather than the whole time series, and sea temperature did not appear to be the influencing factor. Because spatial variations in species distributions do correlate well with corresponding changes in temperature, it is likely that annual temperature changes do actually affect species abundances, at least near the limits of their distributions.

The analysis of the effects of fishing effort was completely inconclusive. The choice of fisheries to include in this analysis was limited by the data available. The shrimp trawl fishery used in this study was not sufficiently suitable to make accurate comparisons between the survey and effort data. The area represented by the shrimp trawl effort data was too large and so unable to measure more localized effects this fishing activity may have created. In addition, most of the trawling activity occurred in areas away from the coastline that were not included in the survey (M. Aschan, personal communication, 05 Mar. 2007). Tagging experiments in the North Sea indicate that skates are quite sedentary and form local sub-populations with limited exchange of individuals (Walker et al., 1997). Therefore, any changes in abundances in distributions directly relating to fishing pressure, are more likely to be caused by the fishing activities occurring in the same area.

The use of sorting grids to reduce bycatch became compulsory for the shrimp trawl fishery in 1990 (Isaksen et al., 1992), and the bottom trawl fishery for gadoid species in 1996 (Isaksen, 1997, quoted in, Dingsør, 2001). These recent developments are designed to reduce catches of bycatch, such as the cartilaginous species. Both of these fisheries harvest the offshore areas bordering the North Norwegian coastline. In this study, the populations of the more abundant cartilaginous species appeared not to have significantly changed over time. This indicates that even if these developments affected offshore populations, they most likely had no significant effect on the coastal populations.

This study has not been able to investigate the changes and developments that may have occurred in the coastal fisheries. Fishing pressure has been shown to affect many of the species in other areas (Casey and Myers, 1998b, Dulvy et al., 2000, Stevens et al., 2000), so it is likely that the abundances and the community structures of cartilaginous fishes along the North Norwegian coast are affected coastal fishing activities. However, the most dramatic alterations of stock structures in response to fishing activities in general, probably occurred before 1992, at times when other significant developments in the fisheries occurred. The low abundances of the larger skate species and the Greenland shark may be representative of populations that have been depleted over a longer time scale. It is not clear from this study whether current fishing activities or other factors are causing any further alterations to these populations. Abundances of the more abundant species were shown to have significantly increased or decreased over time. This maybe because these populations are fairly stable, and have not been significantly affected by any developments in the coastal fisheries that may have occurred during the survey period.

4.4 Evaluating Species Identification

To this point, this discussion has not considered the possibility of species misidentification. The difficulties associated in identifying skate species are a serious concern when considering the validity of the data. Bearing in mind the observations made during the 2006 coastal survey regarding the identification practices used, it is fair to assume that generally skate species were identified accurately, but potential misidentification cannot be ruled out (with perhaps the exception of Norwegian skate and spotted ray, which are both visually more distinctive).

The issue of misidentification has also caused problems for estimations of abundances in other areas. Daan (2001) highlighted the limitations regarding skate misidentifications that occurred during surveys of the North Sea and the Skagerrak/Kattegat region. He suggested that the data be thoroughly evaluated before considering it suitable as a reliable indicator of changes in abundances and distributions. The same is true for this study.

The skate catches that were identified only as far as the 'Family' taxon were excluded from this study. This may have affected the perceived distributions of the less abundant skate species. However, if this data were representative of the more abundant species (thorny skate, thornback ray, longnosed skate and round skate), its inclusion would not have significantly influenced the respective estimated abundances, because these catches made up only a small percentage (less than 1%) of the total survey.

The corrections made to the data exemplify the possible extent of identification inaccuracies. These were based purely upon the previously known distributions for thorny skate and thornback ray, and the apparent inconsistencies in the survey data (see appendix). Taking into account these issues, the apparent distributions and abundances of skates given in this study cannot be considered as definite without further examination. The non-skate species are easier to differentiate and during the 2006 coastal survey the participants showed no difficulties in identifying them. Abundances and distributions of the non-skate species can therefore be considered to reflect accurate identifications made during the survey.

4.5 Possibilities for improvement and further investigation

Future improvements in analysis of abundance should focus on finding more precise catchability indices and reducing sample variances. Catchability indices should take into consideration the physical and behavioural characteristics of each species, diurnal and depth variation in light and water clarity. More appropriate survey techniques would also give a better indication of species abundances. The use of beam trawl has been suggested as generally more effective at catching skate (Rajidae)(Abella and Serena, 2005). However, because this gear can be very destructive to benthic communities, it is widely considered inappropriate for survey work. Including rocky bottom areas in a survey design for blue skate and using passive gear, such as bottom long-line, for Greenland shark may present a clearer picture of abundance for these two species. Sample variances could be reduced by stratifying the survey area into sets of sample units with more homogenous properties (Bonfil and Musick, 1994). Stratifying sample units into depth intervals could be advantageous because depth remains constant over time and it appears to influence habitat preference for a number of the species included in this study.

Further investigations could always be improved by including reliable fisheries dependent data, in particular for the most infrequently observed species. The current survey design is insufficient for estimating the distribution patterns of these species with any degree of certainty. Comprehensive and reliable bycatch data, collected by observers onboard commercial vessels, would be very beneficial for assessing distributions.

Finding relevant temperature data proved to be difficult. The temperature data used in this study was taken from only 5 sample stations and were assumed to reflect actual trends in temperature throughout the survey area. The study of skate stocks in the Barents Sea by Dolgov et. al. (2005) was more effective at indicating how temperature affects species abundances. The survey used a CTD system to measure temperature immediately before or after each trawl haul. This however can be time consuming, a SCANMAR sensor mounted to the trawl gear to measure sea temperatures during each haul may be more appropriate.

The analysis of shrimp trawl effort and species abundance was completely non-conclusive. Further research requires effort data from the demersal fisheries that actually harvest the coastal areas, rather than the nearby offshore areas.

Temperature was shown to influence the overall distributions of rabbitfish, velvetbelly lantern shark, piked dogfish, blackmouth catshark and longnosed skate. However this study could not fully explain why abundances dramatically decreased north of 65°N. Further research is needed to conclude whether temperature was the dominant factor or if other variables played a more significant role. Depth and fishing effort certainly must be considered as other possible variables. Also density-dependant relationships with prey, predator and other species competing for the same resources could have a significant effect. The studies of skate community structures in the coastal areas around the British Isles has shown that the populations of a number of the smaller species included in this study (spotted ray, blonde ray and thorny skate), are growing in response to declining numbers of the larger skate species (blue skate and thornback ray) (Dulvy et al., 2000).

Similar interactions could be occurring between cartilaginous species, or with non-cartilaginous species, within the North Norwegian coastal area.

Lengths and/or weights obtained from the survey could be used to estimate age structures of the cartilaginous populations within the North Norwegian coastal area. This may also be useful for explaining the effects of size selection by commercial fishing gear upon populations of cartilaginous species, and how each species is influenced by the other variables mentioned. However, this task was beyond the scope of this study.

Finally, future surveys should place more emphasis on ensuring that species identifications are accurate. Reliable data is better achieved if the literature and methods used are suitable and consistent throughout all surveys. Data from the previous surveys requires closer scrutiny in order to assess what can be trusted and what cannot. Useless and unreliable data is a waste, so effort should be focused toward correcting dubious data to make it sufficiently accurate for indicating changes in abundances and distributions.

5 Conclusion

It was concluded that at least for some of the species, abundances and distributions were affected by changes in temperature. No conclusion could be made as to whether fishing activities did have a significant effect.

Rabbitfish, velvetbelly lantern shark, piked dogfish and blackmouth catshark are all found in higher abundances at lower latitudes. Their distributions appear to be related to spatial variations in temperature. Whether temporal changes in temperature affect distribution remains inconclusive.

Thorny skate is distributed along the entire coastline, but was found in higher densities at northern latitudes. Its distribution also appears to be related to temperature.

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7 APPENDIX

CORRECTIONS TO THE SURVEY DATA

<u>Summary of findings from investigations made during the 2006 IMR coastal survey onboard R/V Jan Mayen.</u>

Investigations were undertaken whilst the survey covered the coastal area from Tromsø (69° 42' N, 19° 00'E) to Sandnessjøen (12°37'E, 66°01'N). The diversity and quantity of cartilaginous fishes observed during this investigation was too low to comprehensively detail the accuracy species identification methods used. Despite this fact a great deal of knowledge was gained from the crew, the scientists and through the survey work itself relating to the reliability of sampling techniques used in the previous surveys. From this the following conclusions were made:

1. There was consistency in the literature available for classifying Elasmobranch species on the surveys.
2. The literature was not always used to identify species. This may have lead to misidentification of skate (Rajidae) species which were commonly classified without literature and using invalid information.
3. There was a general consensus that information regarding skate species may be very inaccurate and at least must be treated with a high degree of uncertainty.
4. There were no resources available to identify juvenile skate species onboard. It is highly likely that in previous surveys such specimens were either misidentified or ignored.
5. All Elasmobranch species identified during the survey were found in areas that were in accordance to their stated ranges of distribution (Pethon, 2005).
6. Elasmobranch diversity increased as the survey moved further south, as predicted by the research team.

<u>Alterations made to the survey data.</u>

A bias in the data occurred between thornback ray and thorny skate during the 1992 survey than was shown to satisfy the criteria set out in the method. All observations of thornback ray during September were registered by shift B. 9 individuals were identified at 70°N in one trawl, whilst the other observations were at 69°N. All observations of thorny skate in this period were registered by shift A. Figure 1 graphically shows the bias that occurred during a 5-day period at 69°N where specimens of thornback ray were identified by shift B whilst shift A simultaneously registered only thorny ray. No thornback ray was registered by shift A during the 1992 survey (see Figure 2). Observed distributions were only consistent with the known distribution for thorny skate (Pethon, 2005). All observations of thornback ray were therefore assumed to actually represent thorny skate and the necessary alterations to the data were made.

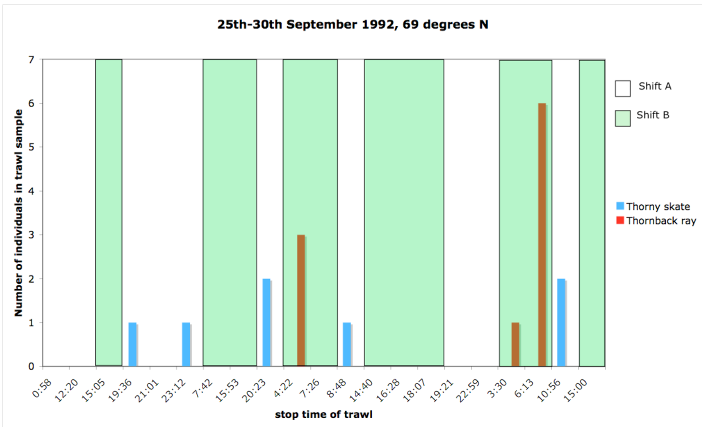

Figure 1. Pattern of identifications of thornback ray and thorny ray between shifts over a 5-day period in 1992.

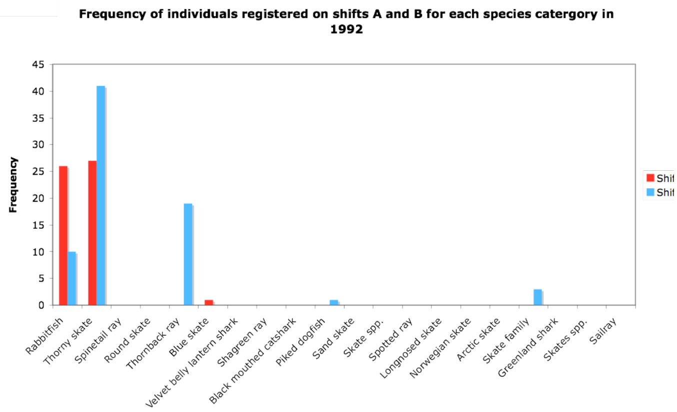

Figure 2. Frequency of observations registered by each shift during the 19992 survey.

<u>Referance</u>

Pethon, P. 2005. Aschehaugs store Fiskebok, 5 edition. H. Aschehaug & Co.