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Can subjective evaluation of echograms improve correlation between bottom trawl and acoustic densities?

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ABSTRACT

Direct comparison of acoustic densities and trawl catches involves fundamental difficulties related to species and size selectivity of the trawl and efficiency of the acoustic instrumentation. In some surveys, therefore, accumulated experience on the visual appearance of various species on the echograms combined with species and size information from the trawl is used to scrutinize the echogram and split the observed total acoustic density to species or groups of species.

In this paper, combined bottom trawl – acoustic survey data collected by Scotland and Norway from the North and the Barents Seas are used to study correlations between bottom trawl catches and the acoustic density measures logged from vessel mounted transducers during the trawl operations. We want to evaluate if classifying echo traces by species or groups of species prior to the analysis can improve the correlations between trawl catches and acoustic densities. Although the classification process contains elements of subjectivity, it is based on characteristics of the echo traces, temporal changes in the echograms, geographic location and time of day as well as species and size compositions of the trawl catches.

Initial results indicate that scrutinized information improves the correlation between trawl and acoustic density information and that harmonized rules for the scrutinizing procedures should be developed.

Keywords: Acoustics, bottom trawl, correlation, survey assessment

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Introduction

Norway has collected acoustic data during the annual surveys in the Barents Sea since the 1970s (Dalen and Smedstad 1979). The data have been routinely used in the ICES standard assessment process for Northeast Arctic cod and haddock since the mid 1980s (Godø and Wespestad 1993; Jakobsen et al 1997). The data were collected as part of a combined bottom trawl - acoustic survey and time series are established from 1982. Similarly, such studies have been used in assessment of Alaska pollock (Karp and Walters 1993) and in this case directly combined with bottom trawl estimates. Any kind of integration of results from the two survey types requires correlation between comparable measures of density.

In later years several nations have collected acoustic data during bottom trawl surveys in the North Sea. This has been done because correlation was noticed between the catches and the echo recordings, and because the aggregation patterns of some demersal species allowed for clear detection and identification of the traces. The greater volume of information offered by the echo sounders is tempting, and it is likely that the acoustic data can offer new insight and quantitative improvements to the traditional swept area method in the annual stock assessment. It seems appropriate, therefore, that a study be conducted on the data available from different areas in order to assess their potential application in stock assessment.

At the outset the aim of our study was to model the relationship between the bottom trawl catches and the acoustic data returned from layers above the bottom. A robust model would provide a useful tool for the assessment, and would not require an experienced person in the analysis of the acoustic data set. Using the acoustic data would have the added advantage of providing a broader coverage of the studied area by including data from the miles steamed between stations. The several modelling techniques used still proved unsuccessful (Beare *et al.* 2004).

In the Barents Sea assessment the acoustic data are routinely scrutinized during the survey. Thus backscattering by species or group of species are produced and used as input for the stock assessment. Characteristics of the echo traces and catch composition support the classification but some subjectivity in the process is inevitable. In this paper we compare density measures from catch and acoustics before and after classification of the acoustic data. The main goal is to explore the impact of the classification approach and evaluate the potential for application in stock assessment.

Materials and Methods.

The data.

Bottom trawl and acoustic data were gathered during regular January/February groundfish stock assessment surveys in the Barents Sea (IMR) and North Sea (FRS). The Barents Sea survey design follows a systematic grid, with samples regularly spaced over depths ranging from 50-500m Fig. 1). The surveys run around the clock, implying that most observations are recorded during darkness, due to the short days at high latitudes in winter. The Norwegian survey methodology is described by Jakobsen *et al.* (1997). The North Sea survey design consists of a broadly repeat station, rectangle stratified design (Heessen *et al.* 1997) covering depth ranges of between 45m and 145m (Fig. 2). All the North Sea samples are taken only during daylight hours. The analysis includes data from 1997 - 2002 for the Barents Sea, and from 2002 to 2003 in the North Sea.

In the North Sea a Standard Grand Ouverture Verticale (GOV) bottom trawl net was towed at 4 knots, at half hour intervals (Heessen *et al.* 1997). Similarly, the Barents Sea standard tow used a Campelen sampling trawl over 1.5 n.miles at 3 knots (Jakobsen *et al.* 1997). Acoustic data were gathered with Simrad EK500 scientific echosounders at a frequency of 38kHz. Calibration parameters for the transducers used were retrieved from the last acoustic survey done by the vessel/transducer in question. Sound speed and absorption coefficients were adjusted, according to the temperature and salinity measurements made during the groundfish surveys. Procedures adopted for transducer calibration are described in Foote *et al.* (1987).

The main species in the catches (e.g. herring, sprat, mackerel, cod, haddock, whiting, Norway pout) were measured, weighed, and their densities estimated based on the trawl swept area estimates. To facilitate direct comparison with the acoustic data the density for each species in the catch was converted to **Eq**uivalent **N**autical **A**rea **S**cattering **C**oefficient (*eqnasc*).

$$\text{eqnasc} = 4\pi \cdot 1852^2 A^{-1} \sum_{L=1}^{\max} n_L (L+0.5)^2 10^{TS/10}$$

where L is fish length in cm, n_L number of length L fish, A is the swept area in nm^2 and TS is the target strength.

The Norwegian acoustic data were evaluated and scrutinized during the survey using the BEI (Foote *et al.* 1991) post-processing software. Similarly the Sonardata Echoview © software was used for the scrutiny process of the British data during the preparation of the paper. In both cases spurious contributions (noise or contributions from bottom echoes) have been removed, and the remaining *nasc* values have been allocated to different categories (species or groups of species) on the basis of trawl samples and experience in classifying echo traces.

In the Barents Sea, the main categories used in these surveys were cod, haddock, redfish, capelin, herring, polar cod, other fish and plankton. The scrutinized data have been stored with a vertical resolution of 10 m and a horizontal resolution of 1 nautical mile (n. mile). The lower 10 m above bottom had a vertical resolution of 1 m. In this paper we use the categories *cod*, *haddock*, *redfish*, and in addition the group category "*demersal*" defined as the sum of all scrutinized categories except capelin, herring and plankton. . For the North Sea a 20cm backstep from the corrected bottom line was introduced to exclude any possible contamination remaining from the seabed. The regions in the echograms corresponding to the area over which the GOV had operated (*i.e.* 'touch down' and 'lift off') were isolated, taking into account the distance between vessel and trawl. School traces were identified by scrutiny based on the trawl data and from experience, and the density values for each category extracted and averaged over the haul.

Scrutinizing echograms is a relatively subjective process, conditioned in part to the experience of the scrutinizer. It is not based on an individually localized process of identification. Rather, it relies on a contextualized ‘scenery’ that takes into account the shape and position of the echo trace in the water column and of those around it, including immediately before and after the tow, as well as those present in other tows in the vicinity. Different aggregation patterns for the same species can occur for a number of reasons, changing the appearance of their echo traces. These must be taken into consideration. The species composition in the catch plays a role in classification, but is not the only clue, as gear selectivity and the fact that not all fish present in the catch are necessarily available to the echo sounder and vice-versa. Other variables such as depth and time of day can be of relevance to the process but, again, few ‘rules’ can be established governing all species.

Combining trawl data and acoustic data.

In the North Sea, the acoustic samples and the trawl samples cover the same area, and it is straightforward to combine them. In the Barents Sea an acoustic sample covers a distance of 1 n. mile, whereas the towed distance for a trawl station is typically 1.5 n. mile. Further, the starting positions for the trawl stations are independent of those for the acoustic samples. Thus, there is no exact match between the area covered by the two sample types. To obtain a rough estimate of the acoustic density corresponding to each trawl station the value of the ship log has been used. This is recorded at the start of each acoustic mile, as well as at the start of each trawl station. The distance between the vessel and the trawl, estimated as $(\text{warp out}^2 – \text{depth}^2)^{1/2}$, has also been taken into account, by subtracting this distance from the trawl log. The following example illustrates this: Three subsequent acoustic miles (1,2 and 3) produce the s_A-values 4, 9 and 7, respectively. A 1.5 n. mile trawl station starts at log=1.8, and the trawl is estimated to be 0.2 n. miles behind the vessel, which means that the trawl is positioned at log=1.6 at the beginning of the haul, and at log=3.1 at the end of the haul. That implies that 40 % of the first acoustic mile is covered, 100 % of the second, and 10 % of the last mile. The acoustic density allocated to this trawl station is then (4*0.4 + 9*1.0 + 7*0.1)/1.5 = 7.5. To explore the effect of variation in vertical efficiency of the trawl and vertical distribution of the fish the acoustic data were organized in bottom related channels. The acoustic data could thus be accumulated to various heights above bottom and compared to the trawl catch (see below). To explore the effect of variation in vertical efficiency of the trawl and vertical distribution of the fish the acoustic data were organized in bottom related channels. The acoustic data could thus be accumulated to various heights above bottom and compared to the trawl catch (see below).

Correlation analysis.

Due to the lack of knowledge of the exact efficient height of the bottom trawl (Godø and Wespestad 1993; Aglen 1996), we examined the relationship between catch and acoustic backscatter by calculating the correlation on the log-scale between *eqnasc* and the cumulative *nasc* values up to 150 m above bottom:

(1) $$\rho_k = cor\left[\log(eqnasc + 1), \log(nasc_k^{cum} + 1)\right], \quad k = 1, \ldots, 15$$

where

$$nasc_k^{cum} = \sum_{K=1}^{k} nasc_K$$

is the cumulative *nasc* value for the *k* deepest 10 m channels, that is, from the bottom and up to 10*k* m.

For the different species, we compared the *eqnasc* from the catch to the *nasc* allocated to that species, and to the *nasc* allocated to its group (demersal or pelagic).

Results

Barents Sea

The three most important demersal species or groups of species that can be evaluated by acoustics are cod, haddock and redfish. The redfish is composed by two species, *Sebastes marinus* and *Sebastes mentella* but has here been treated as one category. Figure 3 demonstrates that in all cases the scrutiny elevated the correlation between trawl and acoustics. For most years the correlations for haddock and redfish rose to between 0.7-0.9 when including acoustic recordings up to 30 m or higher from bottom. The results from cod are similar but in general correlations are lower and more variable. Further, there is a tendency to reduced correlations when including recordings too high in the water column. The clear maximum found in many of the curves indicates that the trawl efficiently catches fish up to approximately 40 metres above bottom. For cod and haddock it should also be mentioned that correlations are synchronised, i.e. years with high and low correlations are the same.

North Sea

The most important demersal species in this study were haddock, whiting and Norway pout. The main pelagic species present were herring and sprat. Figure 4 shows the correlation found between catches and acoustic backscatter at different heights off the bottom. Herring and sprat are pooled into pelagics and haddock and whiting into demersals. In the case of pelagics and Norway pout correlation can be improved by scrutinizing the echograms, whereas for the demersal species this is not the case, with correlation remaining low.

As the scrutinized data is not divided in layers but rather in groups, the coefficients are shown as a constant in figure 4.

Discussion

In the North Sea

Echo traces for herring and sprat were easy to identify and showed much higher densities than those recorded by trawl. Although a demersal species, Norway pout on occasion appeared to aggregates into ‘schools’. Hauls where this species was present in large quantities held positive correlation with the acoustic data and the *nasc* values suggest that the trawl gear undersamples the abundance for this species.

Haddock and whiting, on the other hand, did not show clear echo traces on the echograms. This could be in part due to their low abundance in this area and also because they are in the dead zone and do not present high density schooling behaviour. Godø and Ona (1999) show in preliminary studies that low acoustic abundances for cod can be an early signal to a declining stock. It was not unusual to find high catches of haddock or whiting and no echo traces in the corresponding echograms.

A major difficulty remains in distinguishing different pelagic species and norway pout when they co-occur in the haul sample. It is also not possible to tell demersal species apart in a scattering layer close to the seabed, when large catches of haddock, whiting and norway pout occur.

In the Barents Sea
The scrutiny process has been carried out routinely during all surveys since the 1970ies. With the introduction of the post processing software the process has become more standardized and comparability among scientists and years has probably improved. Nevertheless, subjectivity still represents a major problem. In recent years, scrutiny teams independently going through the same data sets have been used to test the effect of subjectivity. The results so fare show that the evaluation of the echograms are fairly consistent among scientists. Other major problems are associated with:

- Splitting cod and haddock.
- Distinguishing demersals from schools of capelin
- Distinguishing small gadoids from other demersals (e.g. redfish, blue whiting)
- Vertical and horizontal gradients in species and size composition

The results from both areas demonstrate that the scrutiny process improves correlation between trawl and acoustics. Even though the process involves an individual taint to the results, the overall outcome underlines a significant probability of recognizing the acoustic traces to species or group of species. The correlations in the Barents Sea are substantially higher than in the North Sea. Several potential reasons for this difference are discussed below.

The depth of the two areas is very different. The average depth of the Barents Sea survey area is about 250 m, which is more than 100 m deeper than the maximum depth of the North Sea (145 m). Shallow waters may influence the correlation in several ways: The effect of the survey vessel on the target species during cruising and trawling may be significant (see e.g. Ona and Godø 1990; Fernø and Olsen 1994). Therefore, at shallow waters trawl catches may increase beyond the expected due to vertical herding into the catching zone of the trawl, and acoustic recordings may be reduced due to fish escapement into the acoustic dead zone (Ona and Mitson 1996). Also, there might be a higher tendency for fish to be distributed close to the bottom in shallow waters (Godø and Wespestad 1993). This depth effect is also confirmed from the Barents Sea data as correlations are reduced in the shallow areas.

The complexity associated with the scrutiny process will increase with higher biodiversity. The Barents Sea is a simple ecosystem with few dominant species. To distinguish among species appearance on the echograms in this area is thus comprehensible compared to the more complex mix of species in the North Sea. Also, taking into account the longer experience with routine scrutiny of acoustic data during combined surveys in the Barents Sea, the lower correlations in the North Sea are not unexpected.

Although there seems to be an immediate gain from the scrutiny process there is a large potential for improvement. Such improvements must come from more objective methodology for distinguishing among species. The result from SIMFAMI is an example in that respect. Underway analysis and presentation of frequency responses that improve the spatial resolution of the species identification may not only be a substantial improvement of combined surveys, but also support an improved strategy for allocation and optimisation of fishing effort.

Another factor that will support the quality of combined surveys is the establishment of reliable operational models for fish behaviour (see e.g. Handegard 2004). Such models will give realistic sampling volumes of the trawl and may assess escape of fish from the acoustic sampling volume. Thereby we can improve comparability of density measures from the two methods and establish reliable models for combined stock assessment.

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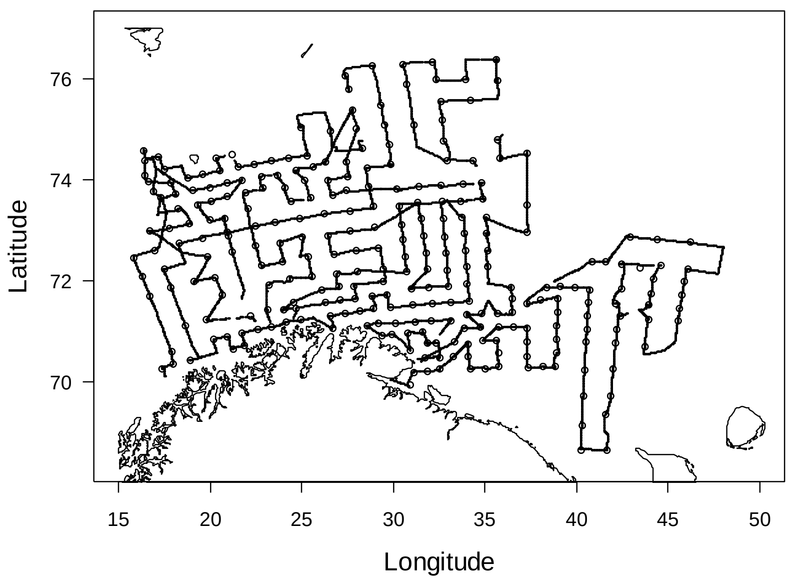

Figure 1. Cruise tracks 2002. Trawl stations are indicated by circles.

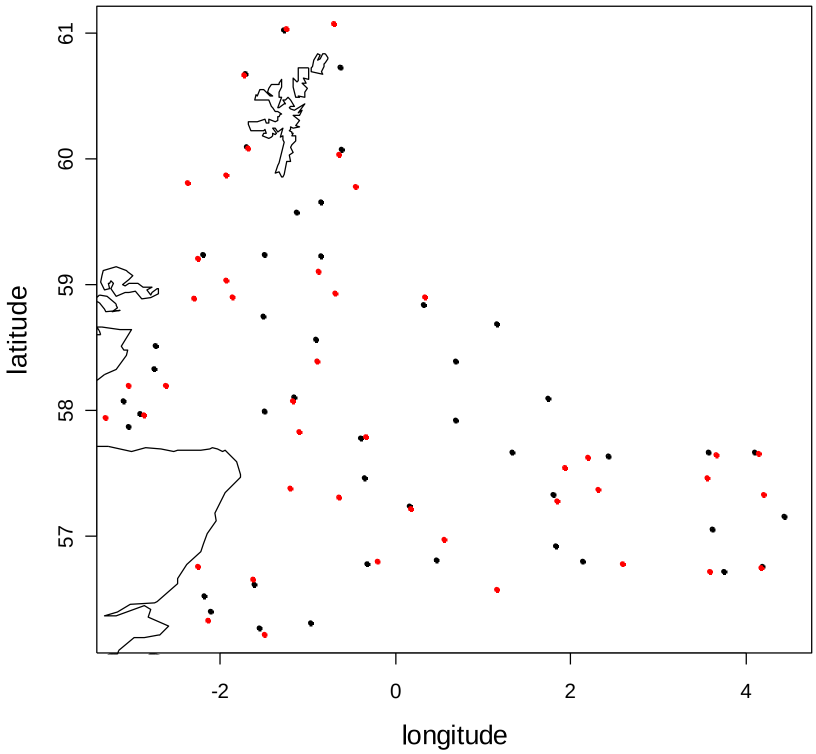

Figure 2. Trawl stations in the North Sea. Black points indicate 2002 and red points indicate 2003.

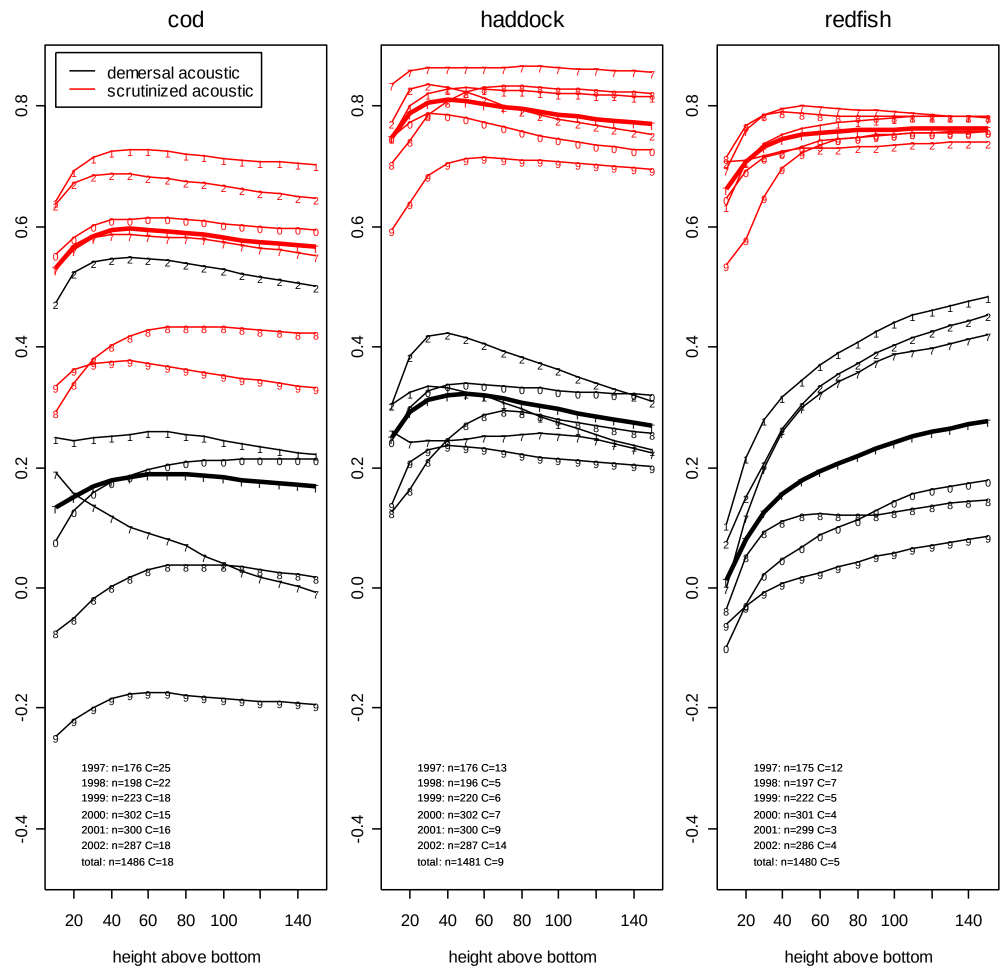

Figure 3. Correlation for the Barents Sea between trawl and acoustics related to the accumulation height of the acoustic values. Results for both accumulated demersal acoustics and species specific acoustics are shown. The number given at each observation point denote the last digit of the observation years (1997-2002). Average catch (C) and number of hauls (n) included in the analysis are given.

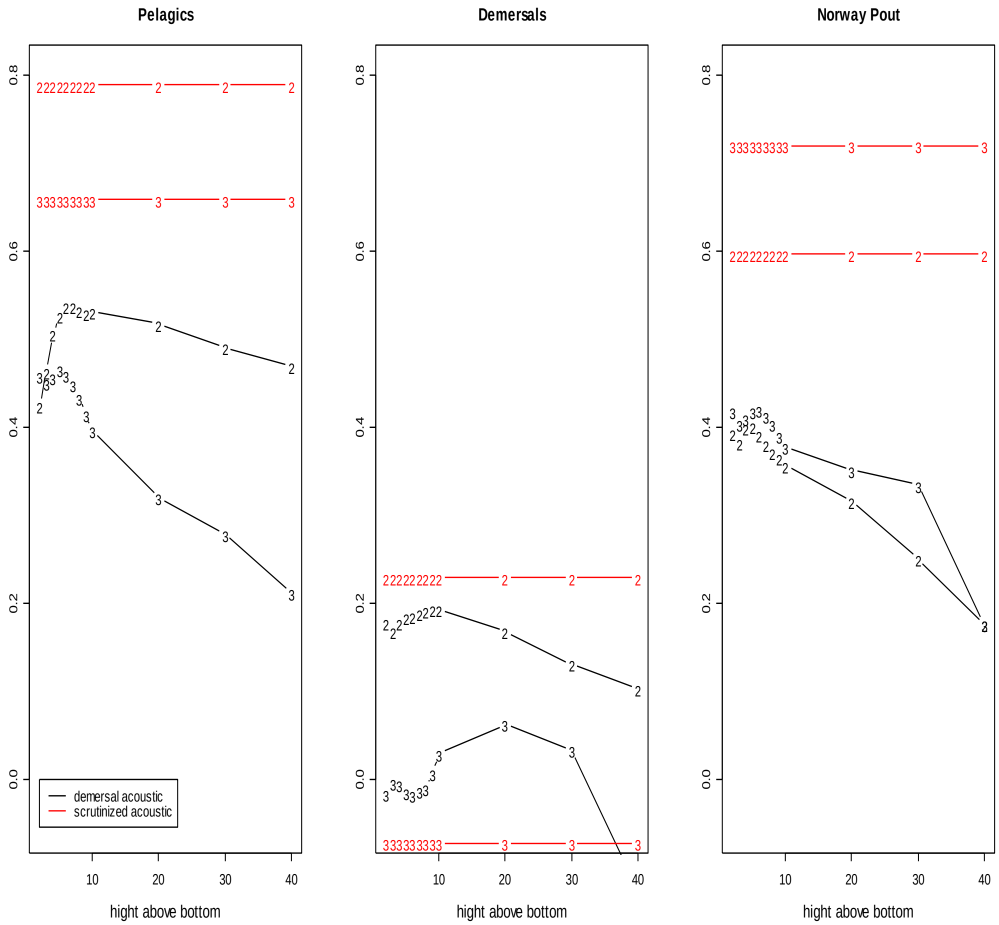

Figure 4. Correlation for the North Sea between trawl and acoustics related to the accumulation height of the acoustic values. The scrutinized information is not depth discriminated in this case. The numbers on the lines denote the last digit of the year they correspond to (2002-2003)