Investigation of the relationship between hidden mortality of Icelandic haddock and fishing effort

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Working paper 34 for the North Western Working Group 2003

Höskuldur Björnsson
(hoski@hafro.is)
MRI, Reykjavík

15th May 2003

1 Introduction

Results from the Icelandic groundfish survey show that all age groups of haddock are much more available to the survey than corresponding age groups of cod as seen in figure 1, the difference most notable for younger fish. Assuming $M = 0.2$ the catchability of age 1 haddock in the survey is 30% of that of age 3 and older, catchability of age 2 haddock 80% and the relationship betweeen age disaggregated indices and number in stock is linear for all agegroups. This high catchability of small haddock in the groundfish survey combined with the common perception that small haddock is relatively sensitive to handling could point to hidden mortality caused by the fisheries being a potential problem.

Discard analysis comparing length measurements from landings and from inspectors aboard the fishing vessels indicate that discard of undersized haddock is a considerable problem in the haddock fishery, proportionally larger than in the cod fishery. (Pálsson 2003). The problem seems to be largest when the adult stock is small and the recruiting yearclasses large (Pálsson 2003) Results from the discard analysis have shown that haddock discarding has reduced considerably in recent years (Pálsson et.al 2003a). This reduction in haddock discard could be driven by changes in distribution of small haddock with larger part of the incoming yearclasses inhabiting the waters north of Iceland where fishing effort is only a fraction of what it is in the areas south and west of Iceland (Figures 2 - 4 This change in spatial distribution can be seen in the groundfish surveys in March and October (figures 8 - 16 as well as in the shrimp surveys north of Iceland.

Although the estimated discard numbers are high they are not high enough to explain the discrepancies seen in the survey in recent years when recruiting yearclasses have become progressively larger with every new survey. Figures 5- 7. The most striking discrepancies are those seen for yearclasses 1998 and 1999 between the 2002 and 2003 survey (figure 6) and the catchcurves from the survey have been flat for the same yearclasses (figure 7).

For towed gears and danish seine the discard number do not have to tell the whole story as they do not include the fishes that escape through the meshes of mobile fishing gear, as applies for example to all age 1 haddock which is hardly seen in in the discards . The mortality of those fishes is not well known but if it is high this part of the hidden mortality could be a major problem.

To investigate the problem further the spatial distribution of number of age 1 haddock was matched against the fishing effort by demersal trawl, danish seine, neprops trawl and long line. For each grid cell the number of haddock caught per hour in the survey was estimated. Then the numbers of hours towed by neprops trawl and bottom trawl and the number of settings by daninsh seine was calculated for each gridcell. The analysis were both done using a $9x9$ miles grid and a kringing method as well as using directly means from each statistical square which is 1/2 degree latitude x 1 degree longitude. The results from both gridding methods were similar but use of statistical squares makes longer timeseries available as most of the logbook data prior to 1991 are only available by statistical square.

Results from the 2003 survey are available now but distribution and magnitude of fishing effort for 2003 is of course not available. To be able to use the 2003 numbers from the survey fishing effort from 2002 is used for 2003, having in mind that the distribution and magnitude of fishing effort is less variable than distribution of recruiting haddock.

The estimated number of fishes “filtered” and caught by the different types of gear are estimated from the following equations.

$$N_{bt,y,age} = \sum_{gridcells} N_{survey,y,square,age} E_{bt,y,square} \quad (1)$$

$$N_{ne,y,age} = \sum_{gridcells} N_{survey,y,square,age} E_{ne,y,square} 0.6 \quad (2)$$

$$N_{ds,y,age} = \sum_{gridcells} N_{survey,y,square,age} E_{ds,y,square} 1.3 \quad (3)$$

Where $N_{survey,y,square,age}$ is the mean number of haddock per hour towed of age age in square $square$ in year y in the March survey.

All these numbers are based on the assumption that to "filtering" takes place in the survey trawl, which is probably not the case. That the catchability of age 1 haddock is $\frac{1}{3}$ of the catchability of age 3 and older haddock could be and indication that at least 2/3 of the age 1 haddock escape through the gear. The factor 0.6 for the neprops trawl is due to less speed of the neprops trawl and the factor 1.3 for danish seine is based on comparison of the catch per hour in demersal trawl and catch per setting in danish seine. The numbers shown in equations 1 to 3 give an estimate (or indices) of the number of fishes encountered by different types of gear during each year. In the equations *bt* is used for bottom trawl, *ne* for nephrops trawl and *ds* for danish seine. An index of the proportion (index of disturbance) of each yearclass encountered by each type of gear is then estimated by equations 4 to 6.

$$M_{bt,y,age} = \frac{\sum_{gridcells} N_{survey,y,square,age} E_{bt,y,square}}{\sum_{gridcells} N_{survey,y,square,age}} \quad (4)$$

$$M_{ne,y,age} = \frac{\sum_{gridcells} N_{survey,y,square,age} E_{ne,y,square}}{\sum_{gridcells} N_{survey,y,square,age}} \quad (5)$$

$$M_{ds,y,age} = \frac{\sum_{gridcells} N_{survey,y,square,age} E_{ds,y,square}}{\sum_{gridcells} N_{survey,y,square,age}} \quad (6)$$

Figures 17 to 19 show the results of the analysis and how much the index of disturbance has reduced in recent years, both for the demersal trawl, neprops trawl and danish seine, mostly due to changes in distribuition of recruiting haddock. The 2003 survey does on the other hand shows increased potential for problems, especially regarding age 3 haddock in the neprops and danish seine fishery but age 3 haddock early in the year is somewhere on the border "between discard and kept catch ".

The analysis sofar have not included long lines and shrimp trawl. Discard analysis (Pálsson 2003) have shown that discarding of haddock is a problem in the longline fishery as well as in other haddock fisheries. For the longlines reliable measurements of discards are likely to include most of the hidden mortality caused by the gear, unlike what could be the case with mobile fishing gear and mortality of age 1 haddock by longlines is most likely neglible. Figure 20 shows an index of disturbance calculated in the same way as for the other types of gear. For longlines 2 indices are presented, one including longliners > 10 GRT and the other including all longliners. The reason is that prior to September 1st 1999 only vessels larger than 10 GRT were required to return logbooks but since then all vessels have been required to return logbooks. Figure 20 shows clearly that the small longliners are fishing more in areas where small haddock is found.

In May each year a nephrop survey is executed, towing at 50 stations distributed over the nephrops fishing area (figure 4). In this survey a subsample of the haddock at each station is measured and the total number of haddock is counted allowing to get the total number caught in the survey of the youngest age groups of haddock which can be aged via the length distributions. Figure 21 shows the results. They shows that using the number from the neprops survey show the same trend but gives lower numbers for all age groups.

Part of the shrimp fishery has taken place in areas where haddock is found, at least occasionally (figure 2). Those are areas south and west of Iceland, 2 of the West fjords and the fjords north of Iceland. The shrimp fishery in all those areas except the two West fjords, Ísafjardardjup and Arnarfjordur has been more or less closed in last years and shrimp surveys in the shallow water areas north of Iceland have shown increased abundance of haddock. An index of disturbance caused by the shrimp fisheries has not been estimated but would show a drop in recent years in the areas where haddock is to be expected.

2 Use in Assessment

A logical question is to ask if the indices of disturbance or filtering can be included in assessment. In the first attempt to do so a combined index of disturbance for nephrops trawl, bottom trawl and danish seine using the conversion factors that 1 towing hour in nephrops trawl equals 0.6 towing hours in bottom trawl and 1 setting of danish seine equals 1.3 towing hour by bottom trawl. The combined indices obtained this way are shown in figure 22. The indices in the figure are all scaled to a mean of 1. Figure 22 also shows the estimated number of "filtered" haddock.

Adding different types of gear as done here, has of course a number of shortcomings. The neprops trawl for example keeps all age 2 haddock while large part of it slips through the meshes of a demersal trawl and danish seine so most likely the mortality of the haddock encountering neprops trawl is higher.

The indices of disturbance could be calculated back to 1985 but prior to 1985 the mean of the subsequent years was used. For 2003 and later the index based on the 2003 distribution from the groundfish survey and the distribution of the commercial catch in 2002 was used.

In the asssessment model hidden mortality was estimated be 7

$$M_{year,age} = M_{0,age} + \alpha_{age} I_{year,age} + \epsilon_{year,age} \tag{7}$$

Short time did not allow to look at the error term $\epsilon_{year,age}$ which was set to 0. The parameters α_{age} are estimated by the assessment model. In the runs done here the 4 α_{age} were estimated, for age 1-3 and 4+. Of those the parameters for ages 3 and 4+ were close to 0 but the other 2 were larger than 0, α_1 significantly. The value 0.2 was used for $M_{0,age}$ but lower values gave better fit to the data.

That the estimated parameter for age 3 was 0 was not according to expectations but this agegroup is in some years a substantial part of the discards.

Using variable M gave a better fit to the data than fixed M or an improvement of 53 in the likelihood function in a Statictical catch at age model(whatever that means). For comparison using $M = 0.1$ changed the likelihood function by 7 in the model. In an ADAPT type model the change in likelihood was 8 but 2 ny changing M from 0.2 to 0.1. Therefore it seems that calculating M this way improves model fit to the data considerably but what is a "significiant" difference is not clear. Possible difference in catchability between areas is also a factor that needs to be invesigated and could possibly be the factor driving part of the changes seen in recent years.

Figure 23 show the estimated stock biomass from the model with lines from a standard assessment model (using M=0.2) shown for comparison. Figure 24 shows the estimated natural mortality and "number discarded + filtered" according to the model. For comparison the total number discarded (age 2 + age 3) has been in estimated to lie in the range 1-12 million fishes for bottom trawl alone (Pálsson 2003).

The results presented here explain part of the discrepancies seen in the data in recent years and fit available better than $M = 0.2$. Some aspects of the results are though contrary to expectations, especially how much mortality is put on age 1 fish and none on age 3. This might be due to too rigid model as $\epsilon_{year,age}$ in equation 7 is 0. As haddock is relatively stationary in the first years of its life and spatial distribution of fishing effort tends to be stationary, estimates of M on different age groups of the same yearclass could be correlated.

3 Mangagement consideration

The analysis here have indicated the "hidden mortality " of haddock caused by the fisheries could be an important factor in assessment of the stock and reduce the potential yield from the stock by a large proportion.

So what can be done to reduce the "potential hidden mortality". Part of the hidden mortality is caused by fleets targeting haddock but part by fleets that are targeting other species, for example neprops or shrimp. Of the variables that affect hidden mortality spatial distribution of the recruits seems to be the most important one but it is the only one out of our control so the management must concentrate on magnitude and spatial distribution of the fishing effort as well as the types of gear used.

For the fleets targeting haddock a reduction in effort should be the first step. Reduction in effort will lead to less filtering but also there will be more large haddock so captains might have more possibilities to avoid areas where small haddock is to be found which they can not do if there is nothing else available than the small haddock and they still need to catch haddock.

Spatial allocation of effort by closing certain areas and changes in the gears catching haddock by increased use of long lines and possibly using grids in the bottom trawls instead of large meshes in the codend could help in reducing the "hidden mortality" but these measures will not replace "reduced total effort" which seems to be the most obvious management tool.

The fisheries that are not targeting haddock might be more difficult. There are indications from the groundfish survey that bycatch of haddock in the nephrops fishery might become a problem in 2003. There seems to be an urgent need to look more closely at the neprops fishery with regard to bycatch of a number of species.

Part of the bottom trawl, danish seine and long line fisheries are also targeting other species than haddock and get haddock as bycatch. The best way to avoid problems with those fleets is to allocate "comparable quotas" in species in mixed fisheries where comparable quotas means quotas leading to "similar proportion" of the harvestable biomass of the species being caught. Other measures could though need to be incorporated as some stocks are more resilient to fishing than others, long lived stocks should generally be fished more carefully and stocks that are below B_{lim} need special protection.

4 References

Pálsson Ó.K 2002. A length-based analysis of haddock discards in Icelandic fisheries. Fisheries Research 59 p437-466.

Pálsson, Ó.K, Karlsson G, Arason, A, Gíslason G, Jóhannesson G and Aðalsteinsson S 2003a. Mælingar á brottkasti botnfiska 2002. Hafrannsóknastofnunin Fjölrit nr 1994.

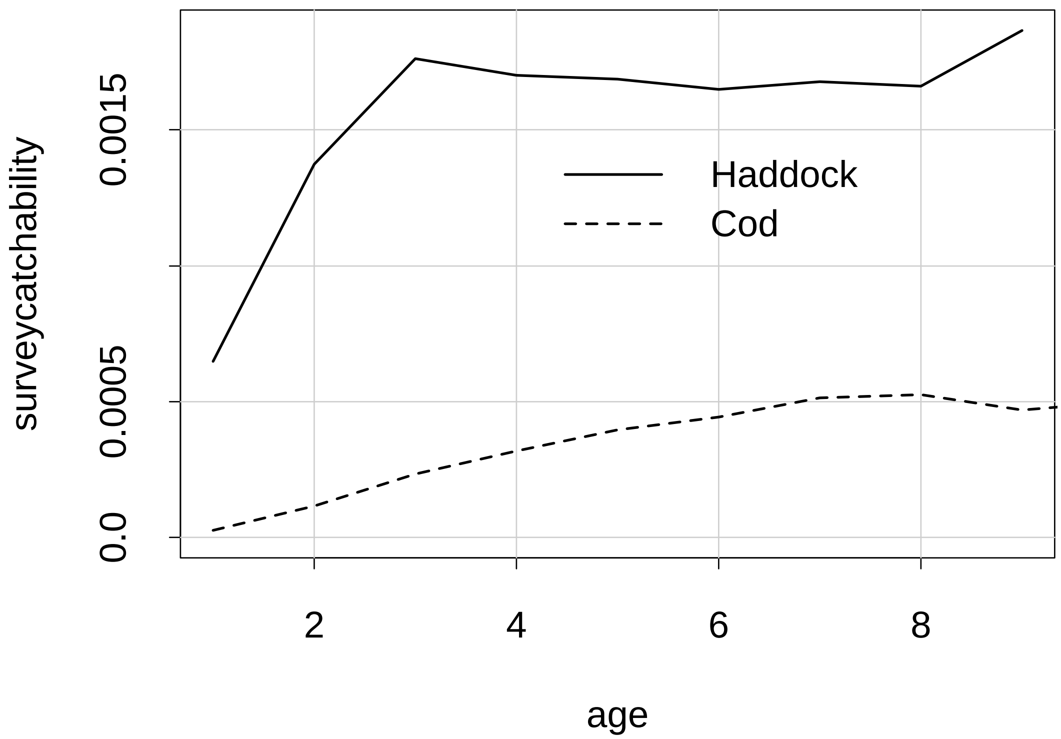

Figure 1: Estimated catchability of cod and haddock in the March survey

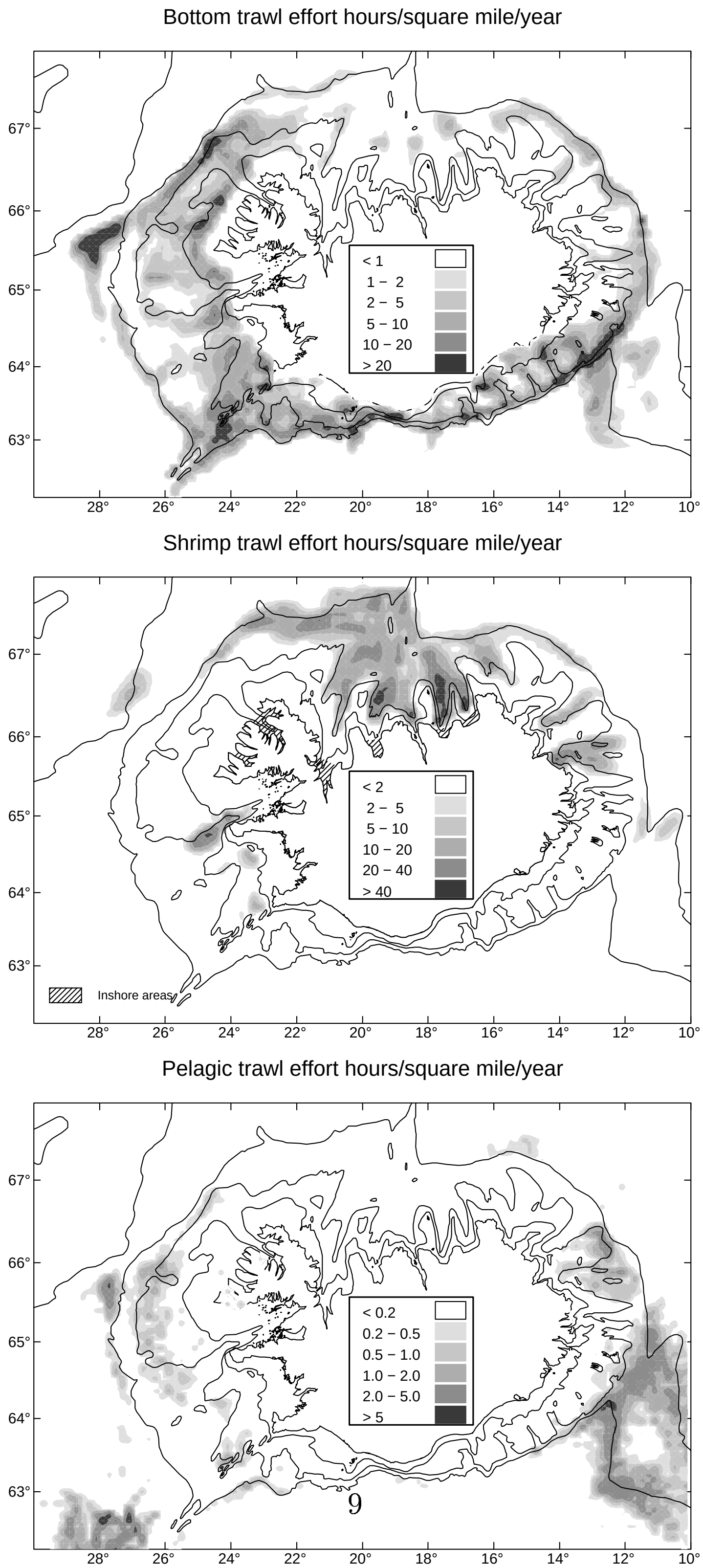

Figure 2: Spatial distribution of fishing effort by demersal trawl (1993-2002), shrimp trawl (19933-2002) and pelagic trawl (2000-2002) in hours towed /square- mile /year.

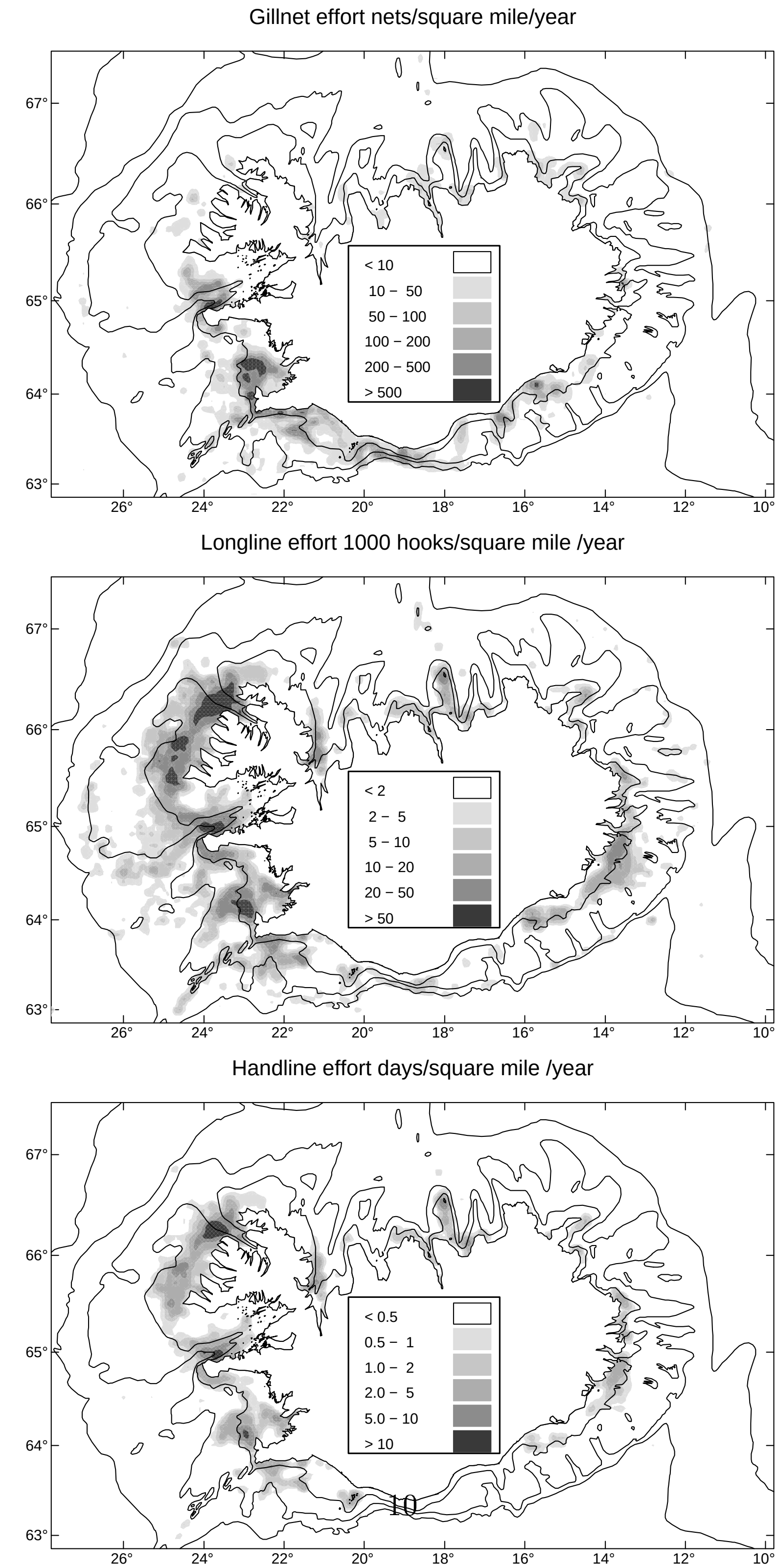

Figure 3: Spatial distribution of fishing effort by longlines (2000-2002) in million hooks/square-mile/year , handlines (2000-2002) in days/square-mile/year and pelagic trawl (2000-2002) in hours towed /square-mile /year.

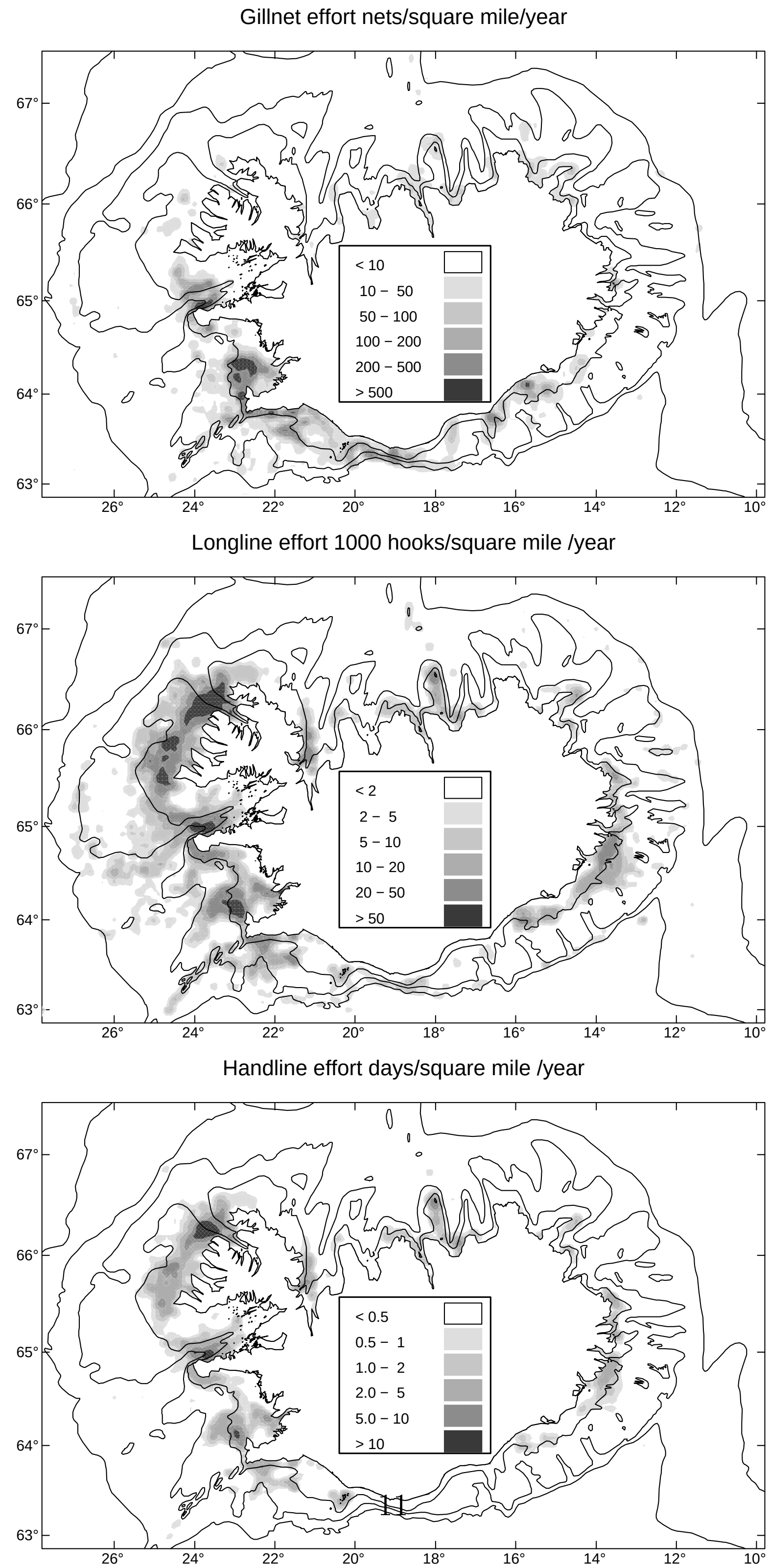

Figure 4: Spatial distribution of fishing effort by danis seine (1993 - 2002) in settings/square-mile/year and nephrops trawl (1993 - 2002) in hours towed/square-mile/year.

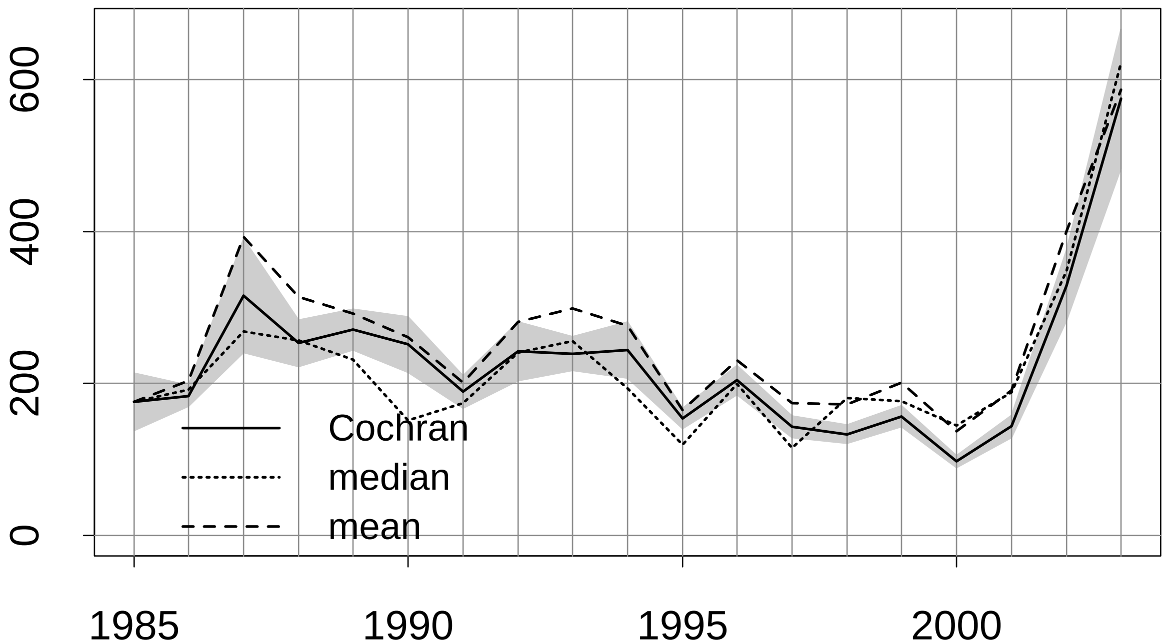

Figure 5: Total biomass index for haddock in the groundfish survey in March. The shaded portion shows one standard error in the estimate of the indices. The dashed line shows an index calculated as the number of stations where haddock was caught times the median of the haddock catch at those stations.

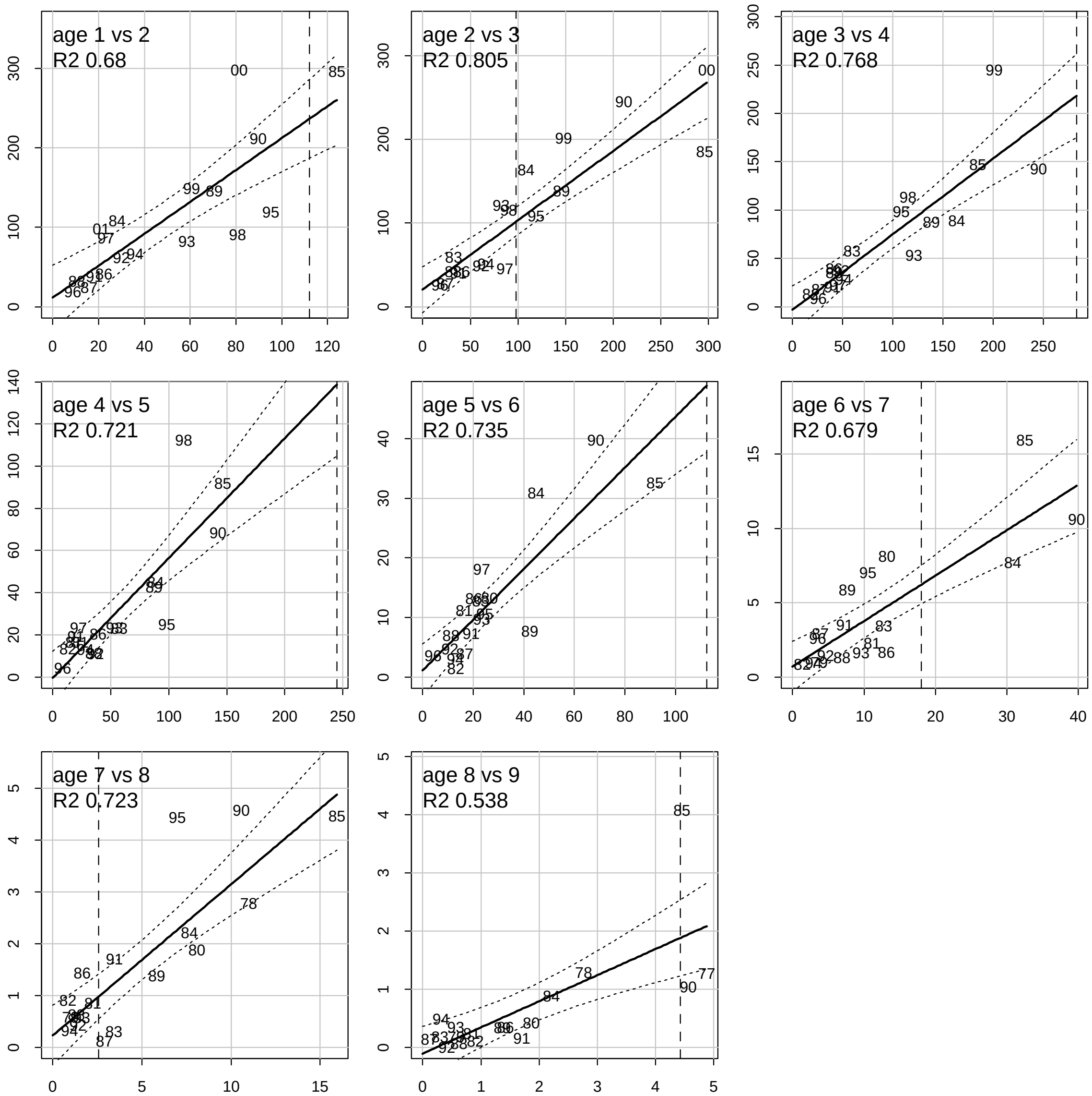

Figure 6: Icelandic haddock. Abundance indices of a yearclass in the March survey plotted against the abundance indices of the same yearclass the year before.

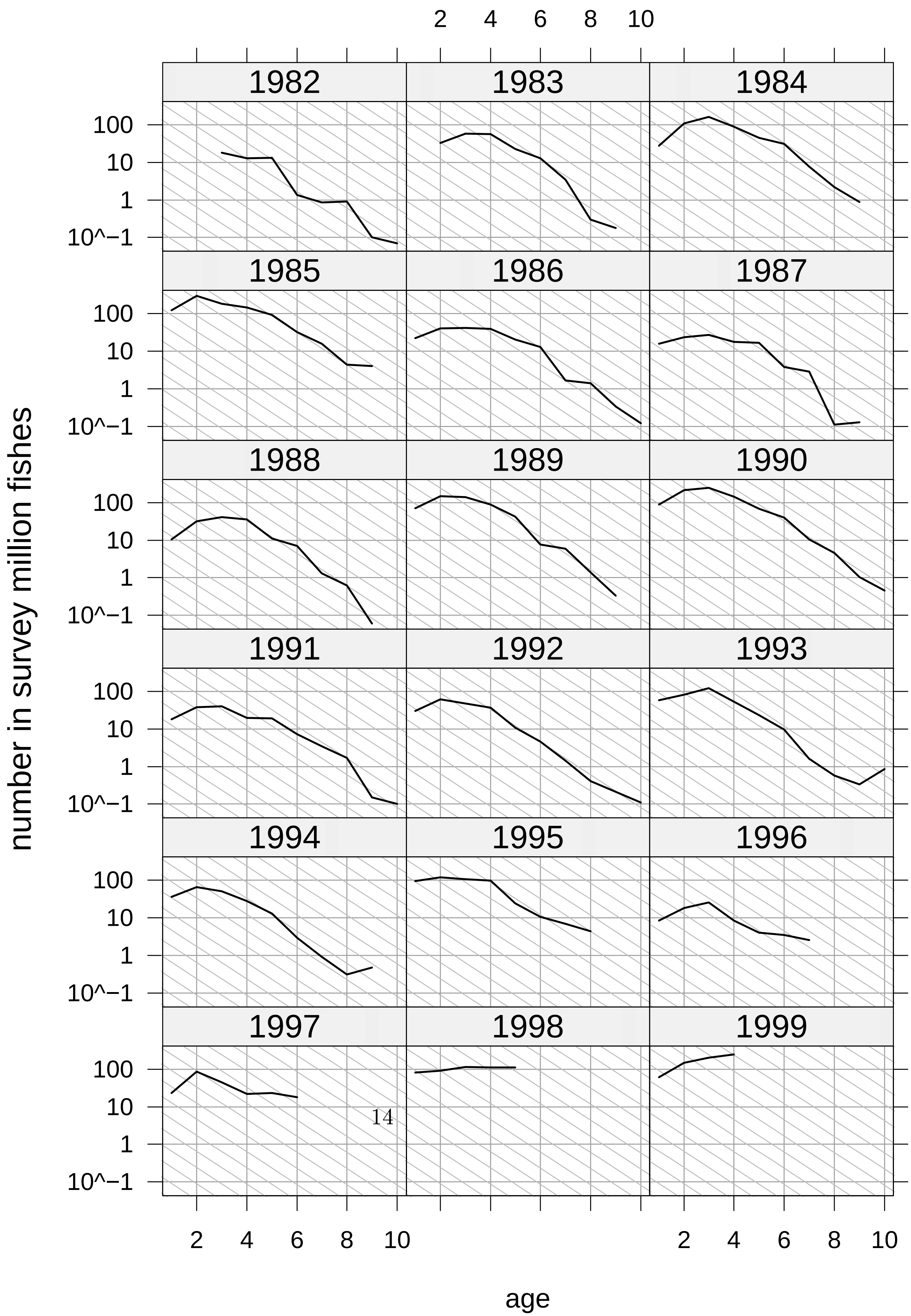

Figure 7: Icelandic haddock. Catchcurves from the March survey

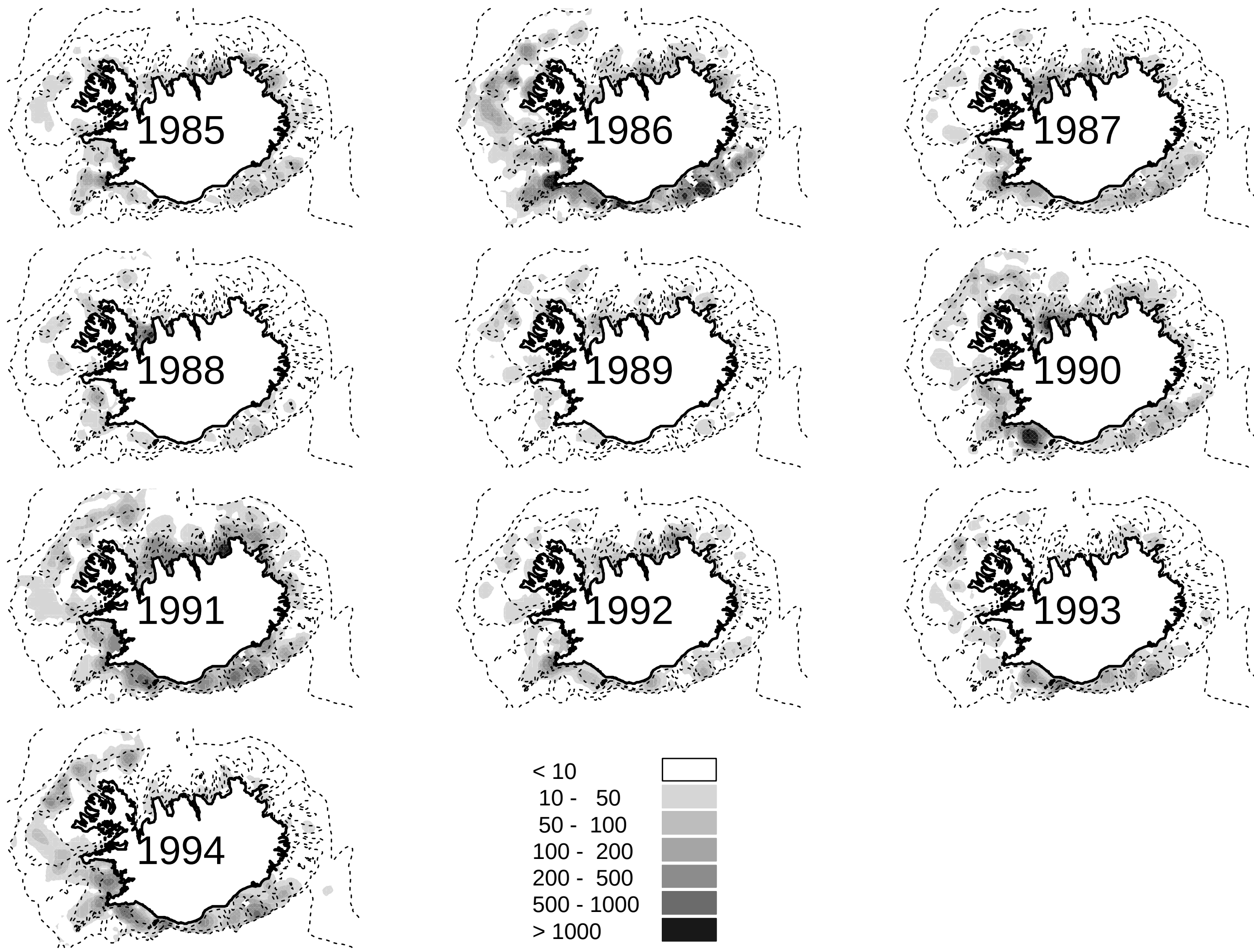

Figure 8: Spatial distribution of age 1 haddock in the groundfish survey in March 1985-1994. The figure shows number per 4 mile tow.

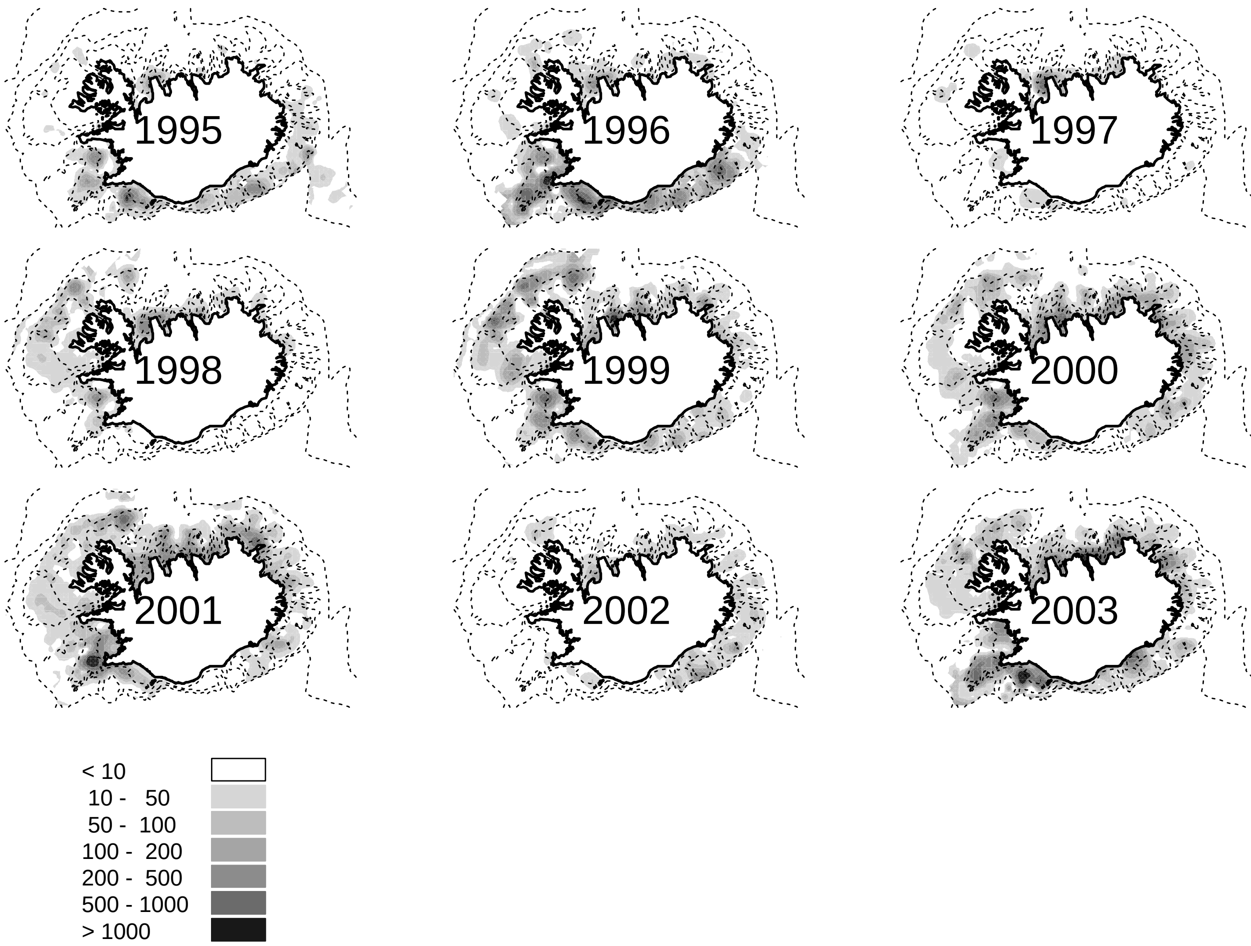

Figure 9: Spatial distribution of age 1 haddock in the groundfish survey in March 1995-2003. The figure shows number per 4 mile tow.

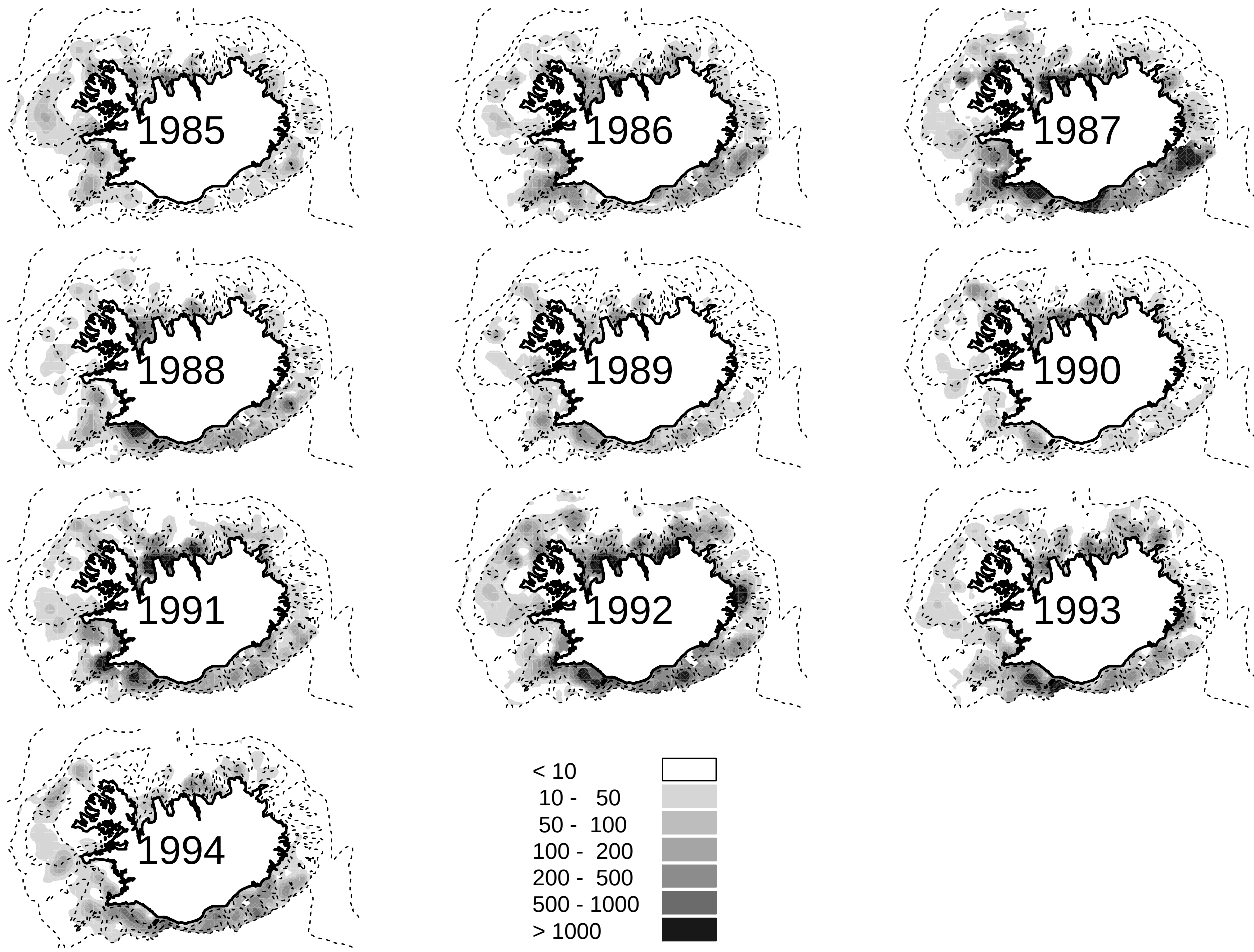

Figure 10: Spatial distribution of age 2 haddock in the groundfish survey in March 1985-1994. The figure shows number per 4 mile tow.

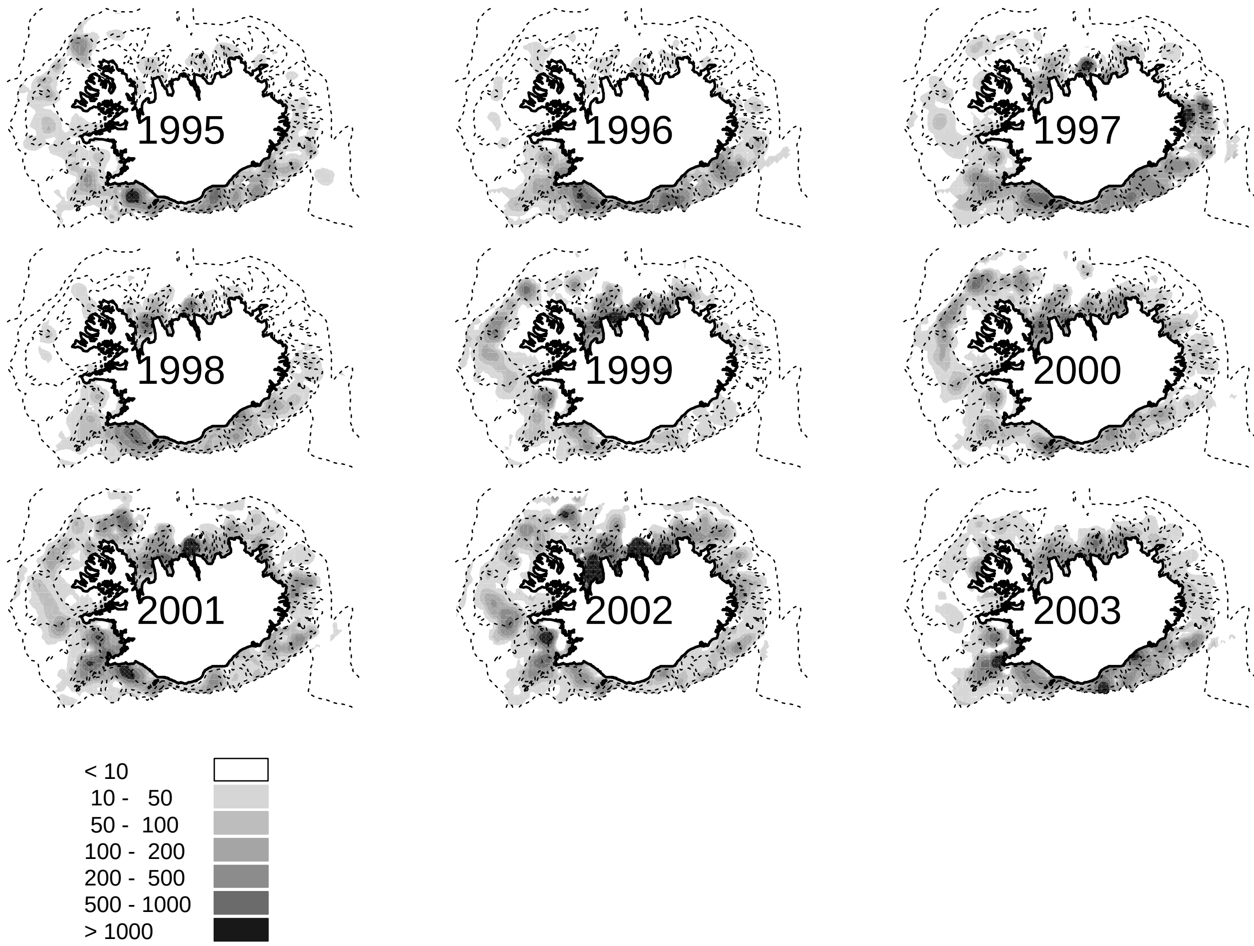

Figure 11: Spatial distribution of age 3 haddock in the groundfish survey in March 1995-2003. The figure shows number per 4 mile tow.

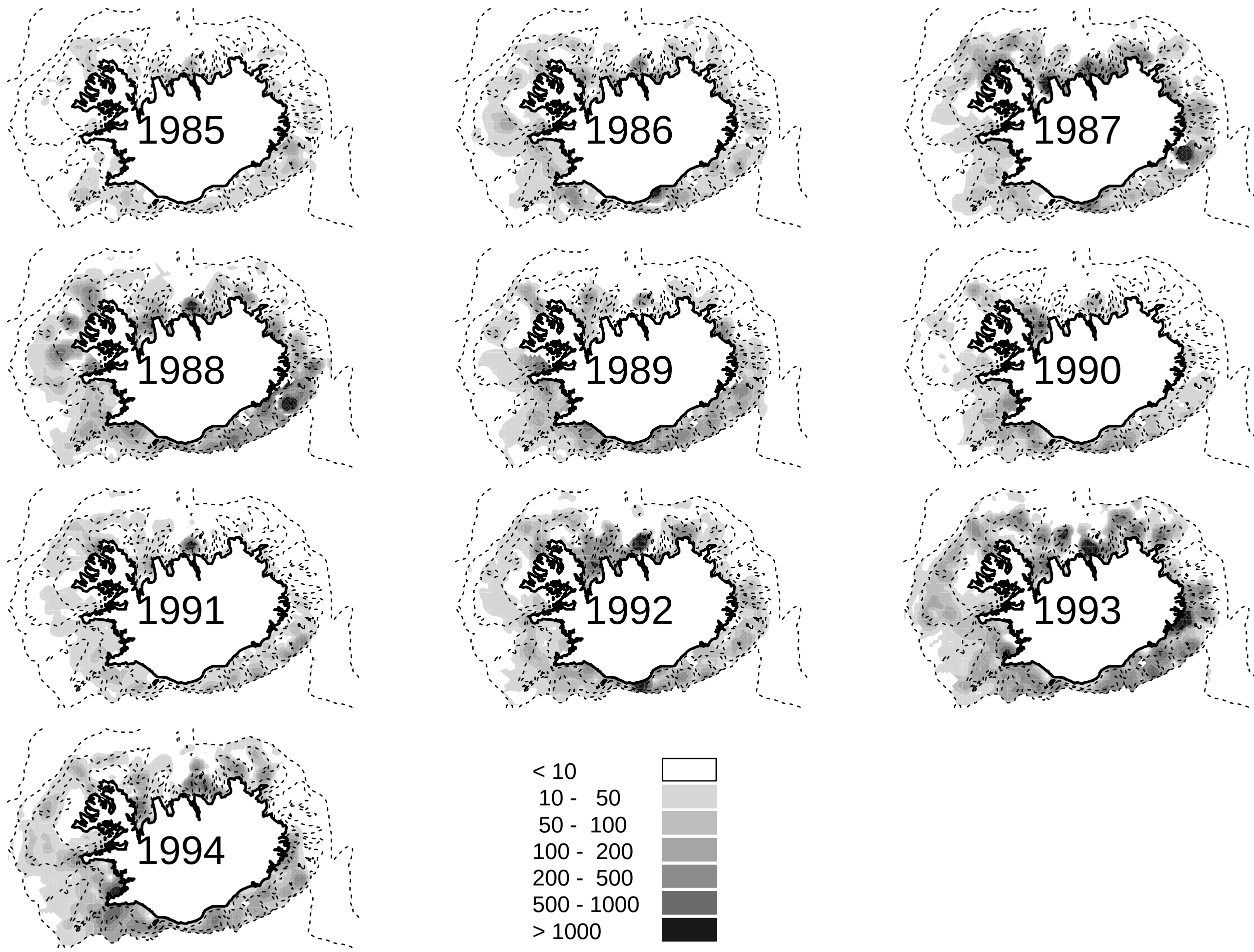

Figure 12: Spatial distribution of age 3 haddock in the groundfish survey in March 1985-1994. The figure shows number per 4 mile tow.

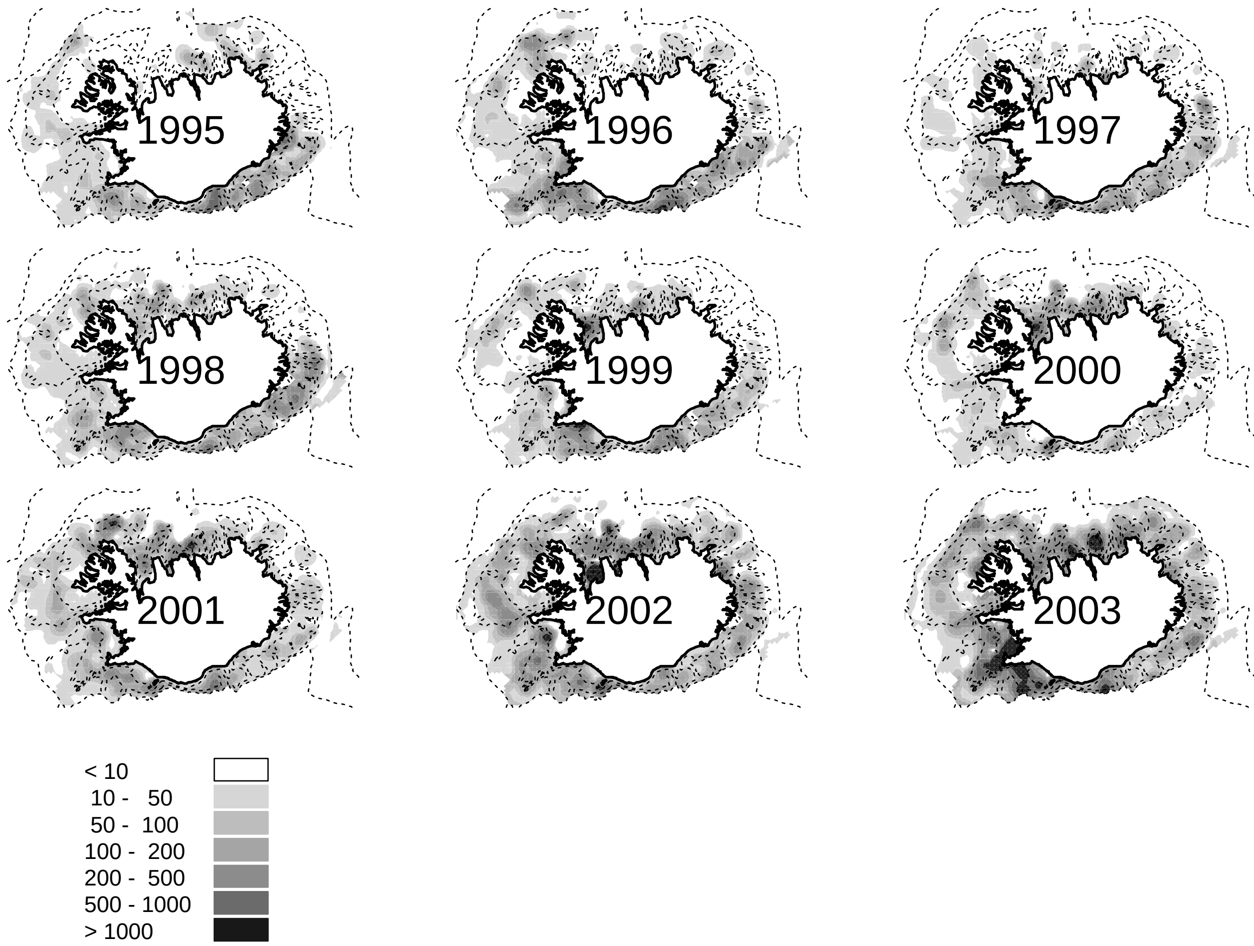

Figure 13: Spatial distribution of age 3 haddock in the groundfish survey in March 1995-2003. The figure shows number per 4 mile tow.

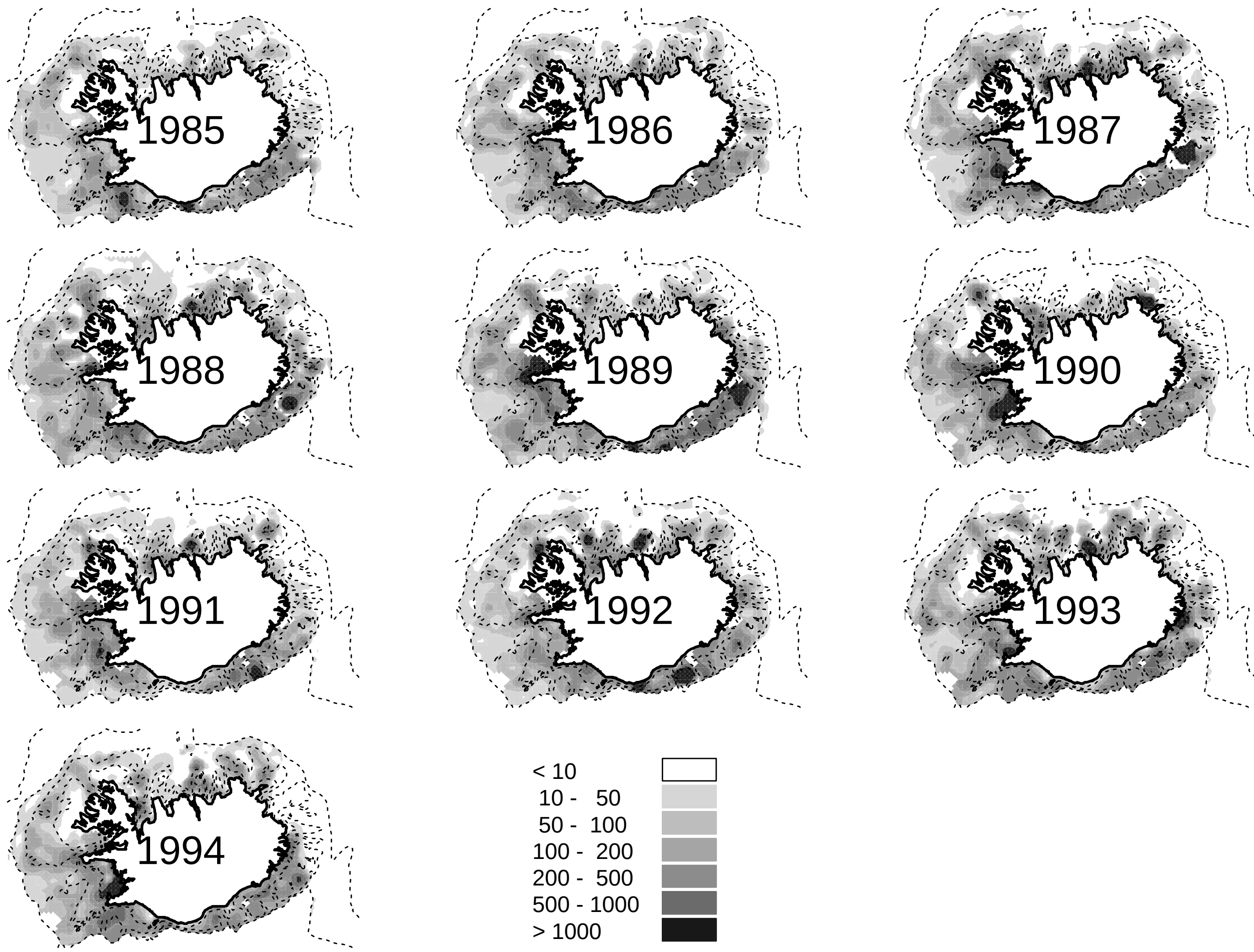

Figure 14: Spatial distribution of haddock in the groundfish survey in March 1985-1994. The figure shows kg per 4 mile tow.

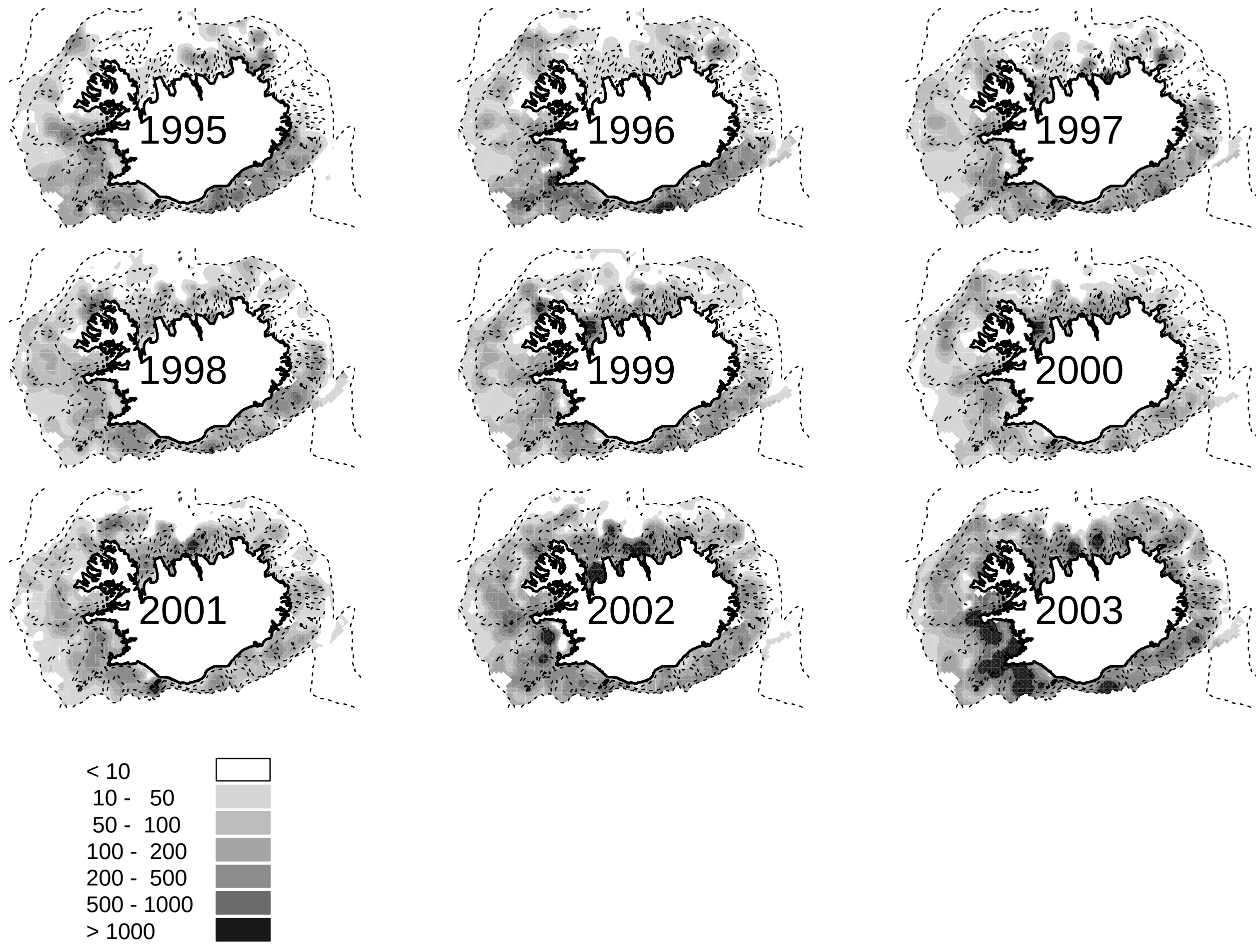

Figure 15: Spatial distribution of haddock in the groundfish survey in March 1995-2003. The figure shows kg per 4 mile tow.

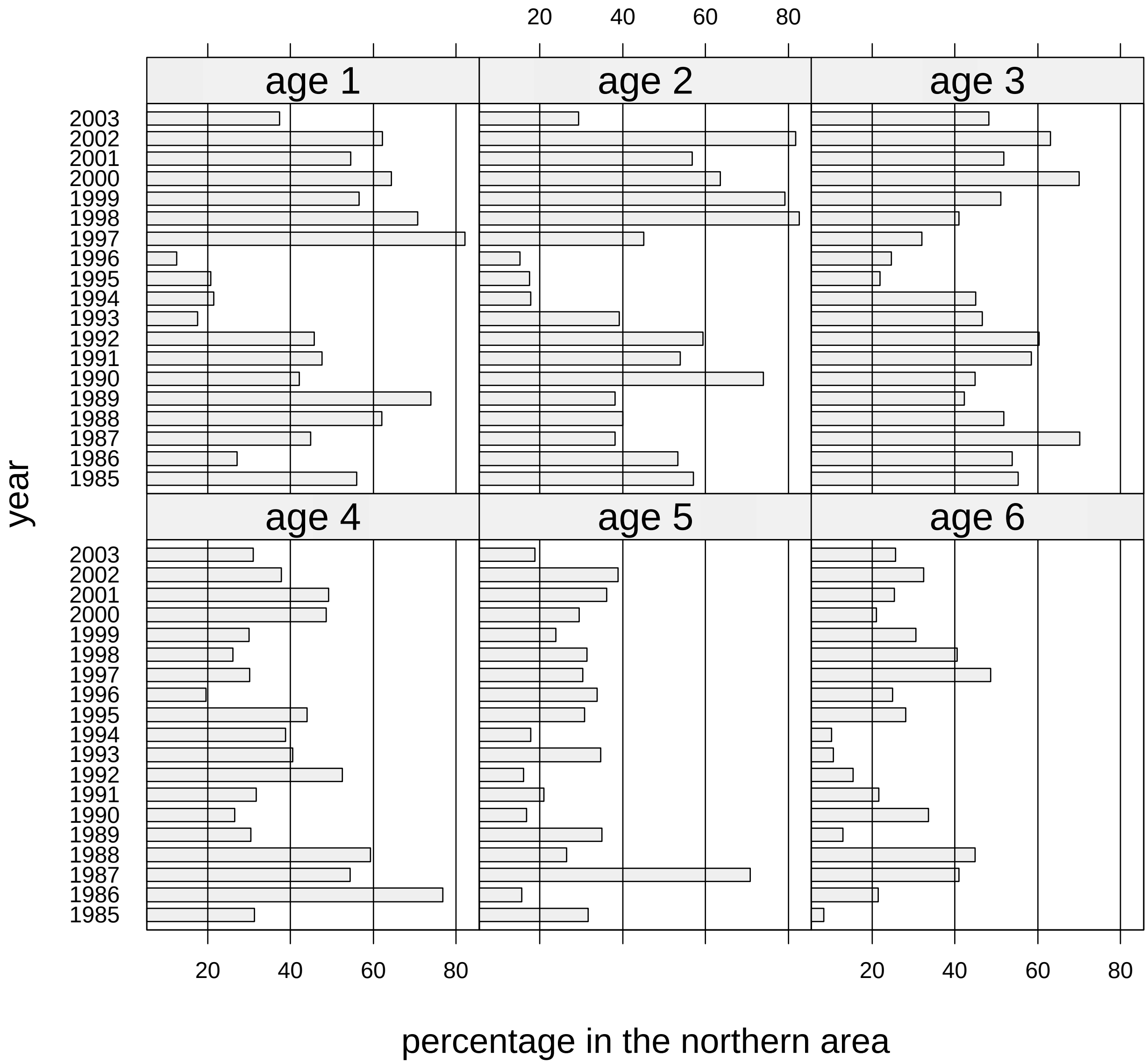

Figure 16: Proportion of haddock caught in the northern part of the survey area in the groundfish survey in March

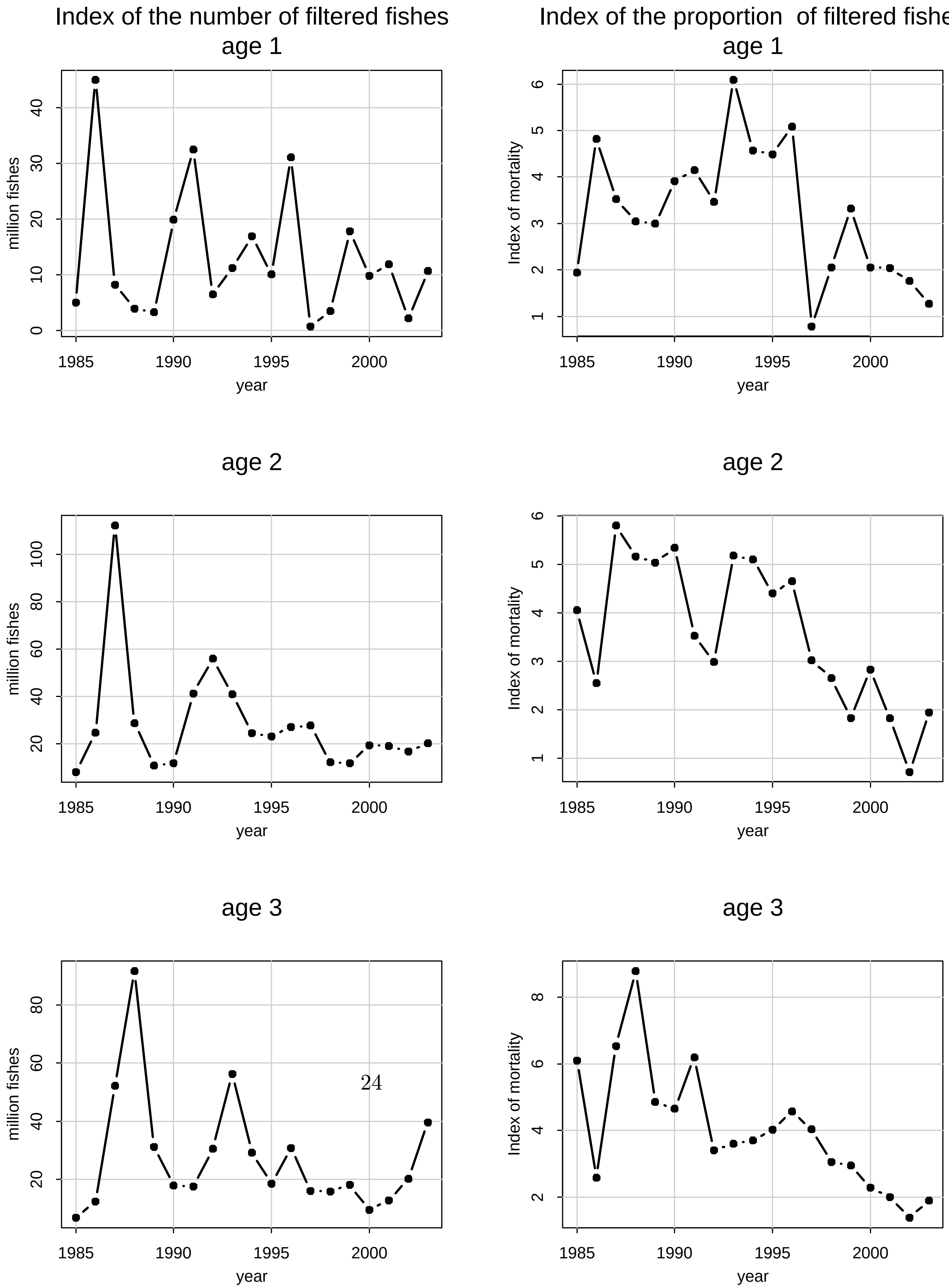

Figure 17: Index on the number and proportion of haddock “filtered” through demersal trawl each year.

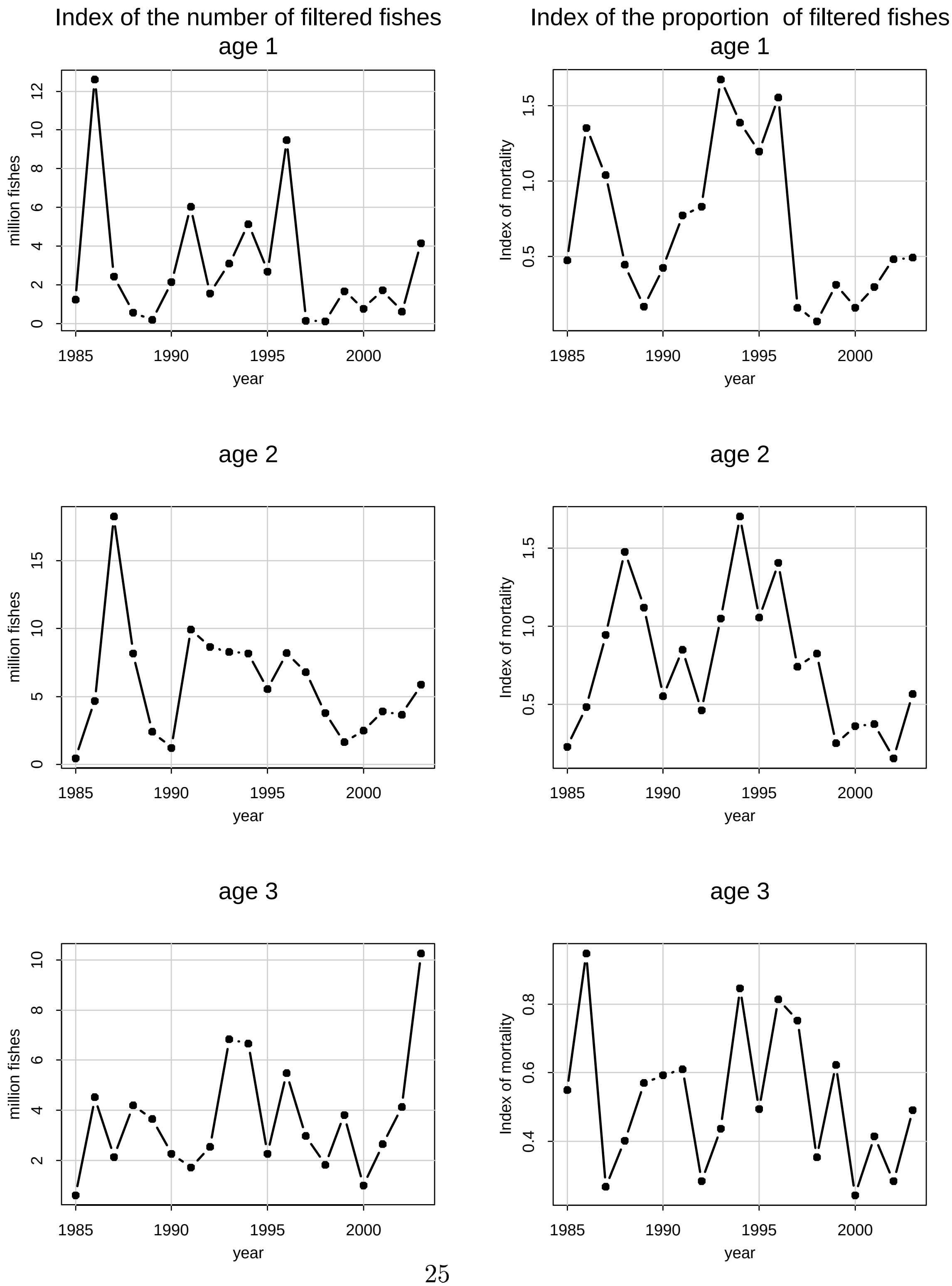

Figure 18: Index on the number and proportion of haddock “filtered” through nephrop trawl each year

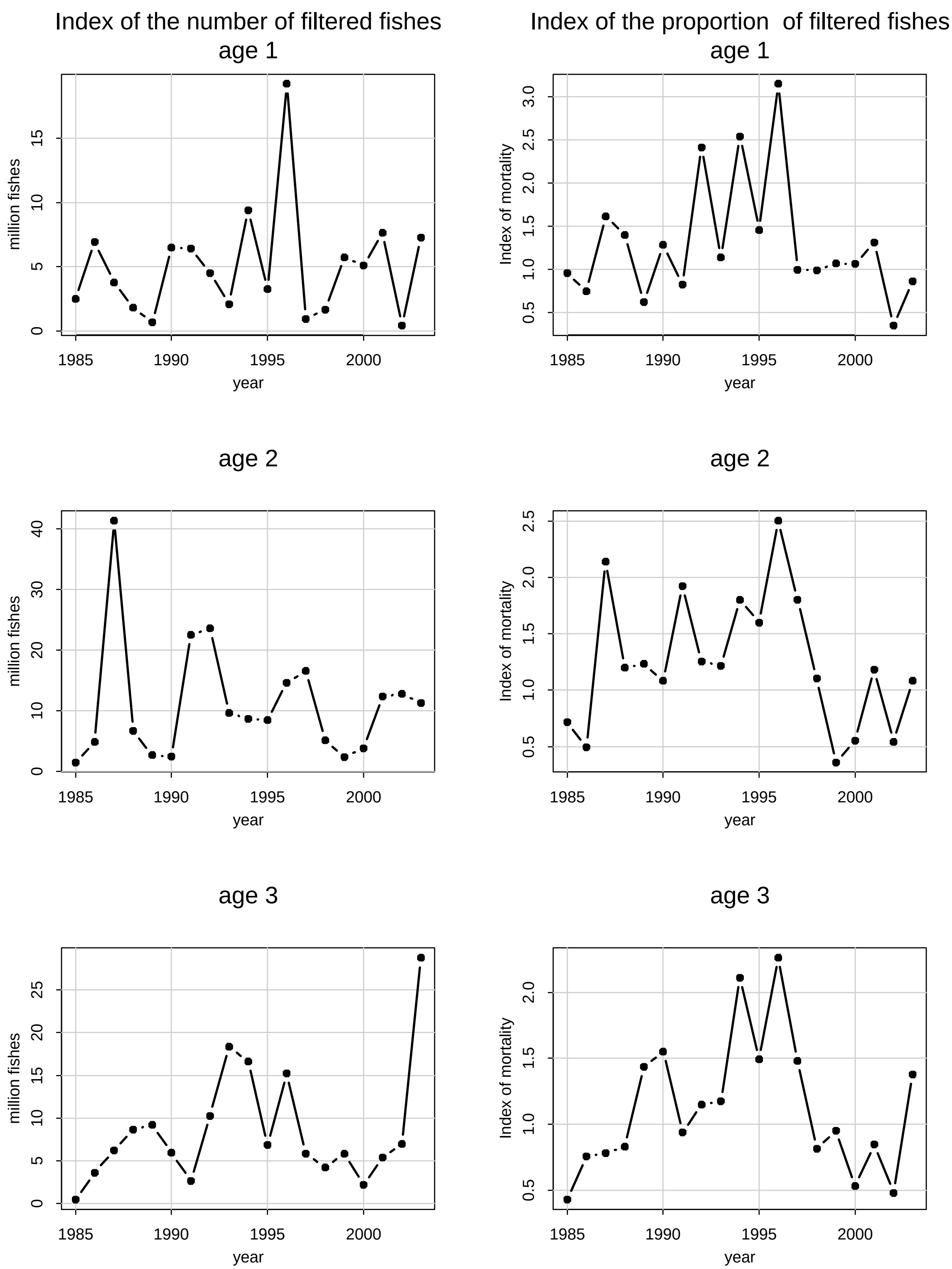

Figure 19: Index on the number and proportion of haddock "filtered" by danish seine each year

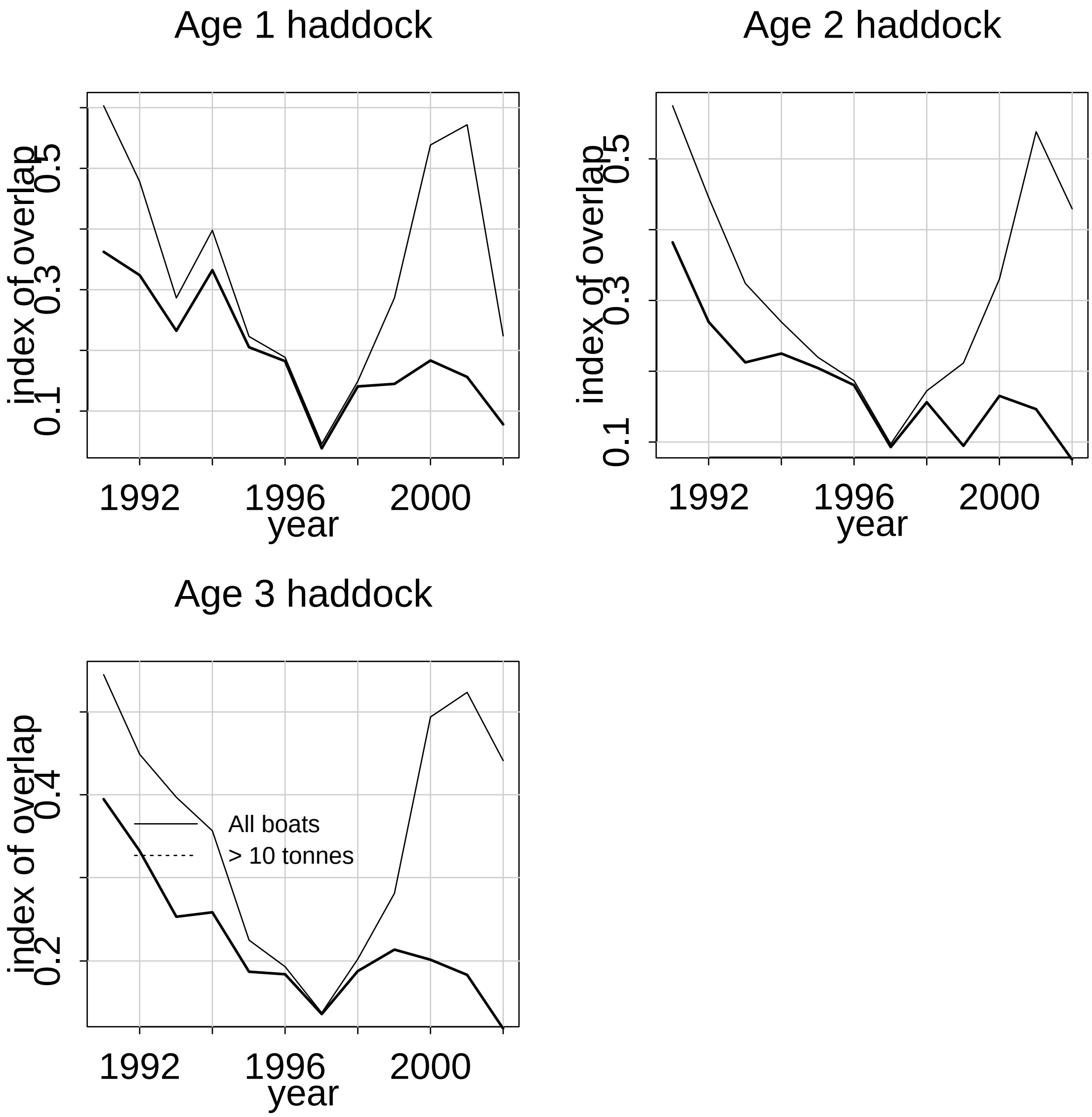

Figure 20: Index of disturbance for the longline fleet. Prior to september 1999 relatively low percentage of the vessels smaller than 10 GRT returned logbooks but after that all vessels have been required to return logbooks

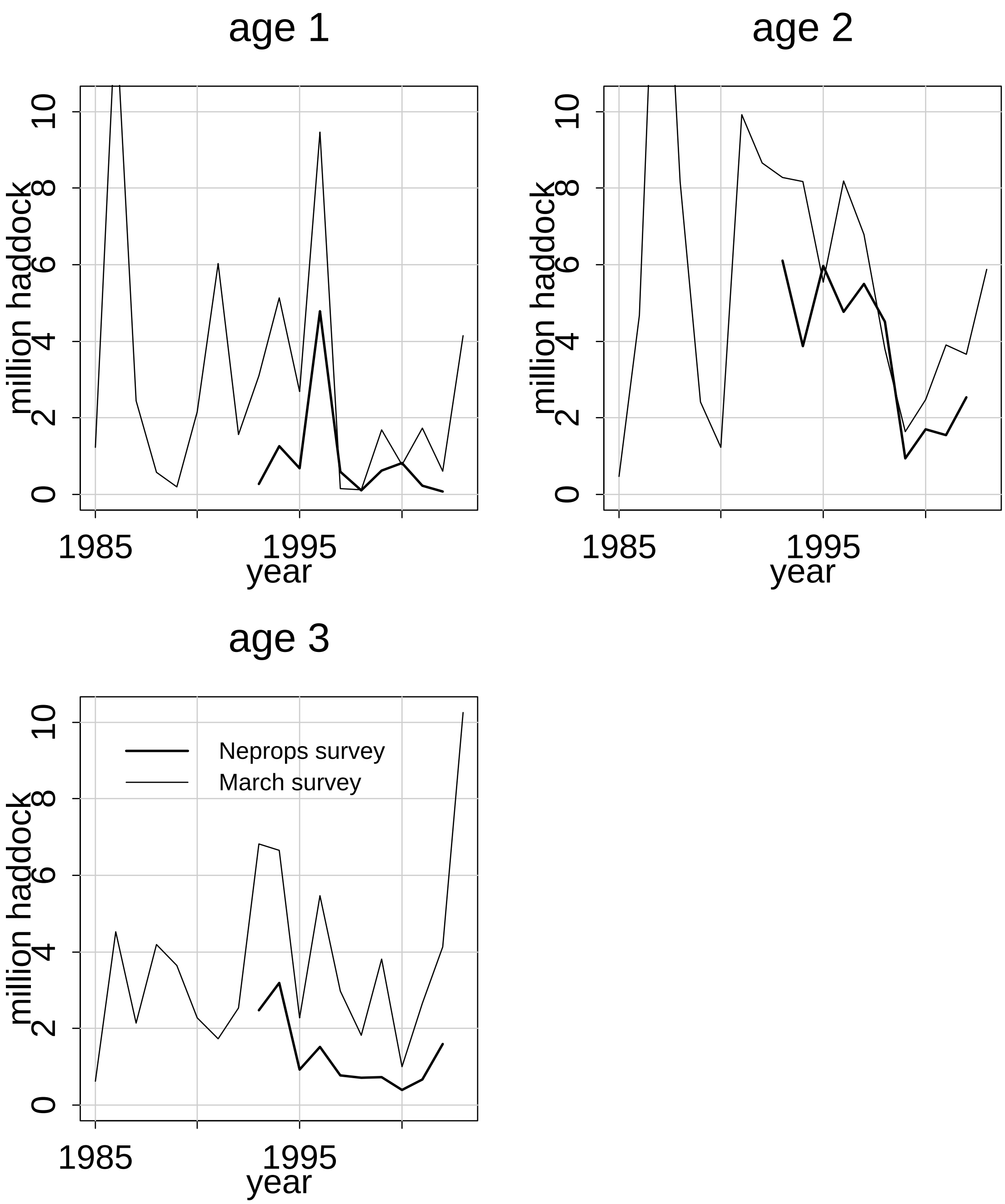

Figure 21: Comparison of the estimated number of haddock "filtered" by the neprops fleet, based on number of haddock caught in the March survey and number of haddock caught in the neprops survey

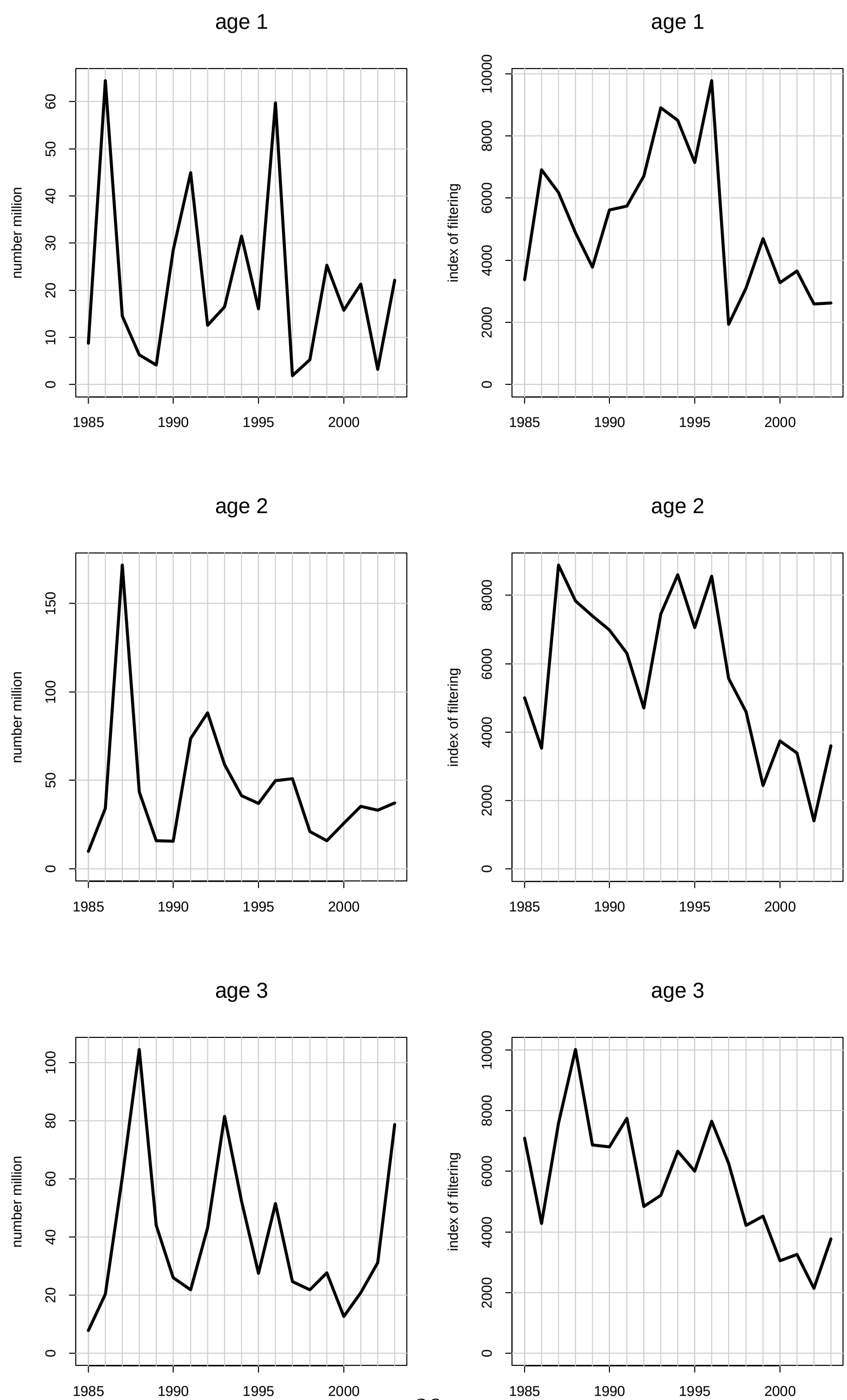

Figure 22: Total number and index of mortality obtained by adding together bottom trawl, danish seine and neprops trawl

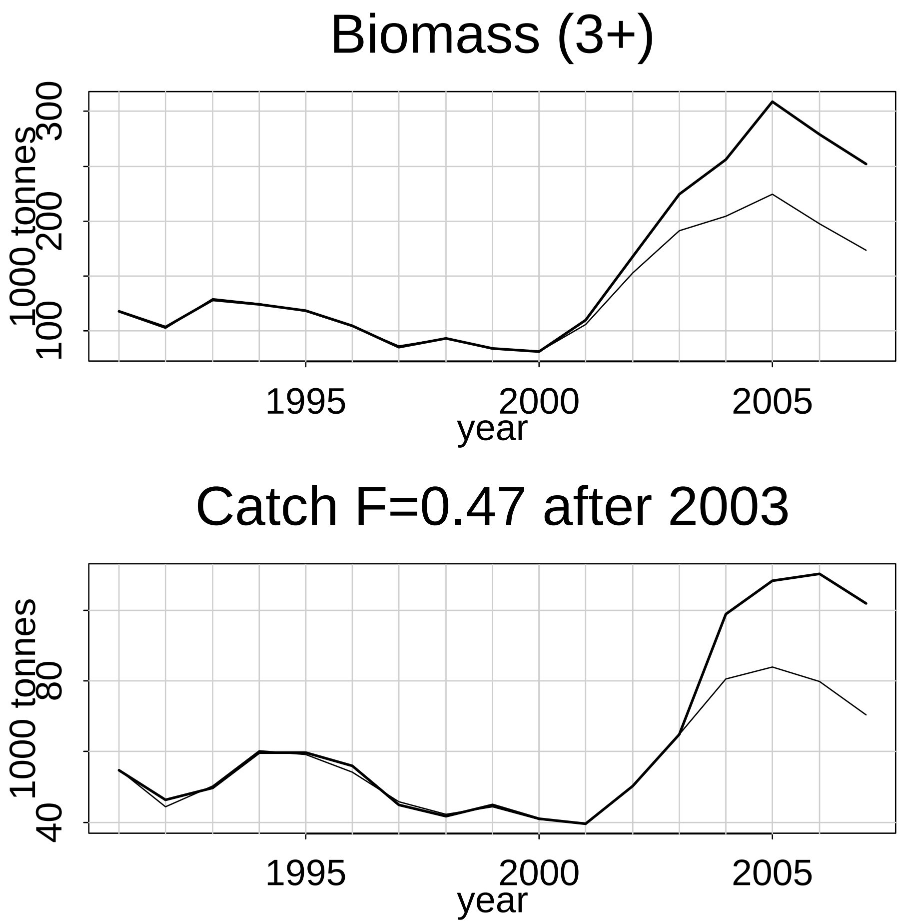

Figure 23: Comparison of results using fixed M (thin lines) and incorportating hidden mortality from the fishery (bold lines)

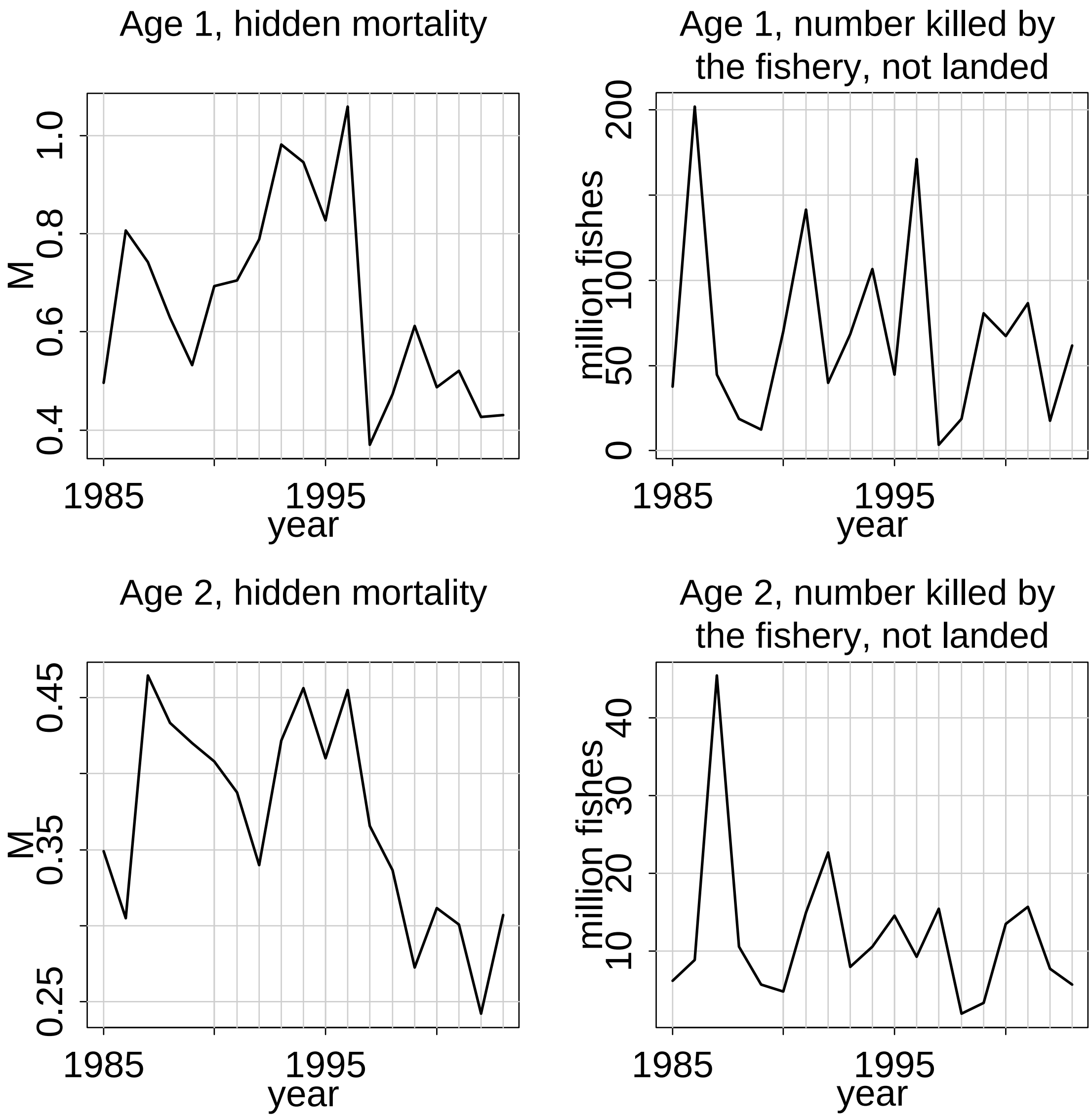

Figure 24: Estimates of hidden mortality and the estimated number of fishes killed by the fisheries but not landed, estimated by $C_{ay} = \frac{M_{ay}-0.2}{Z_{ay}} N_{ay}(1 - \exp^{-Z_{ay}})$