

# Use of data from the commercial fishing industry in the management of Norwegian spring spawning herring (*Clupea harengus* L.).

By Aril Slotte

## Abstract

Every year the commercial fish industry of Norwegian spring spawning herring collects a severe amount of data for sales purposes that in fact could be very useful for scientific and management purposes too. The present paper describes a new method for estimation of catch at age, which takes advantage of information of catch by size groups collected by **The Norwegian fishermen's sales organisation for pelagic fish**. At landing herring catches for human consumption are divided into 5 size groups by individual weights as follows: group 1 (>333 g), group 2 (200-333 g), group 3 (125-200 g), group 4 (83-125 g) and group 5 (<83 g). Annually many thousands of catches and hundred thousands of tonnes are sampled in this way. In the new method these data on size group composition are combined with biological samples with age readings in a similar way as with the traditional method using age at length keys. Comparisons between the new and the traditional sampling of the fishery suggest that the new method is more reliable, mostly due to the enormous amounts of size group samples used in the calculations. The ICES Northern Pelagic and Blue Whiting Fisheries Working Group has accepted the new method. There are also other useful commercial data on Norwegian spring spawning herring. One example is data on proximate composition (fat and water content) analysed at meal and oil factories and local processing plants, which could be used to analyse seasonal and annual variations in energy loss. Another example is data on individual weights and gonad weights, which could be used to assess the maturation process and reproductive investment using indexes like GSI. The mentioned data on size groups, proximate composition and GSI is also available for species like North Sea herring and mackerel. In addition data on size groups is available for groundfish like cod, saithe and haddock. However, the usefulness of these data remains to be evaluated.

Keywords: commercial data, size groups, proximate composition, maturation process.

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## Introduction

A crucial factor in fisheries management is information on the stock size. A general technique for estimating the numbers at age in a stock is «Virtual Population Analysis, (VPA). The ICES Northern Pelagic and Blue Whiting Fisheries Working Group, which performs the assessment of Norwegian spring spawning herring, has since 1993 utilised a stock estimation method where the VPA is tuned with data from acoustic surveys and tagging (Anon. 1994).

The precision of VPA is dependent on the accuracy of the catch at age data. Traditionally the Norwegian catches of Norwegian spring spawning herring are summarised per month and statistical area. Then the catch at age is estimated after analyses of biological samples, which are assumed to be representative for the total catch in given areas and periods. For a given area and period the catch in numbers by an age group is estimated by the following equation.

$$(1) N_A = C \cdot \overline{W}_A^{-1} \cdot P_A$$

Where N=number, A=Age, C=catch (t).  $\overline{W}$  =mean individual weight (t) in the representative samples and P=proportion in the representative samples.

The accuracy of this method is highly dependent on the sampling strategy, particularly the number of samples. However, Institute of Marine Research's (IMR) resources for collecting and **analysing** biological samples are limited. Ideally ICES has decided that there should be one biological sample per 1000 tonnes of catch. Consequently, **IMR** would have to analyse around 800 samples every year, which is just not possible. Thus, one may conclude that the increased abundance and fishery of the stock in recent years have lead to a higher degree of uncertainty in VPA due to limited sampling resources. Indeed there is need for other methods or new data, which could overcome these uncertainties in the catch at age estimate without increasing **IMR's** own sampling activities

## Material and methods

In order to establish a better method for estimation of age specific catch, new parameters were required. Such parameters were gained after looking for data gathered by the fish processing companies. All herring catches landed in Norway are recorded with the following: catch size (kg), catch position in terms of statistical area and geographical location (Fig. 1), and date of capture. In addition, in all catches landed for human consumption the proportion of different size groups is calculated by taking from one to several sub samples of the catch at landing. The size groups are recorded by individual body weights as follows: group 1 (>333 g), group 2 (200-333 g), group 3 (125-200 g), group 4 (83-125 g) and group 5 (<83 g). The size group composition in the catch is reported to *The Norwegian fishermen's sales organisation for pelagic fish*, where it is stored in a database.

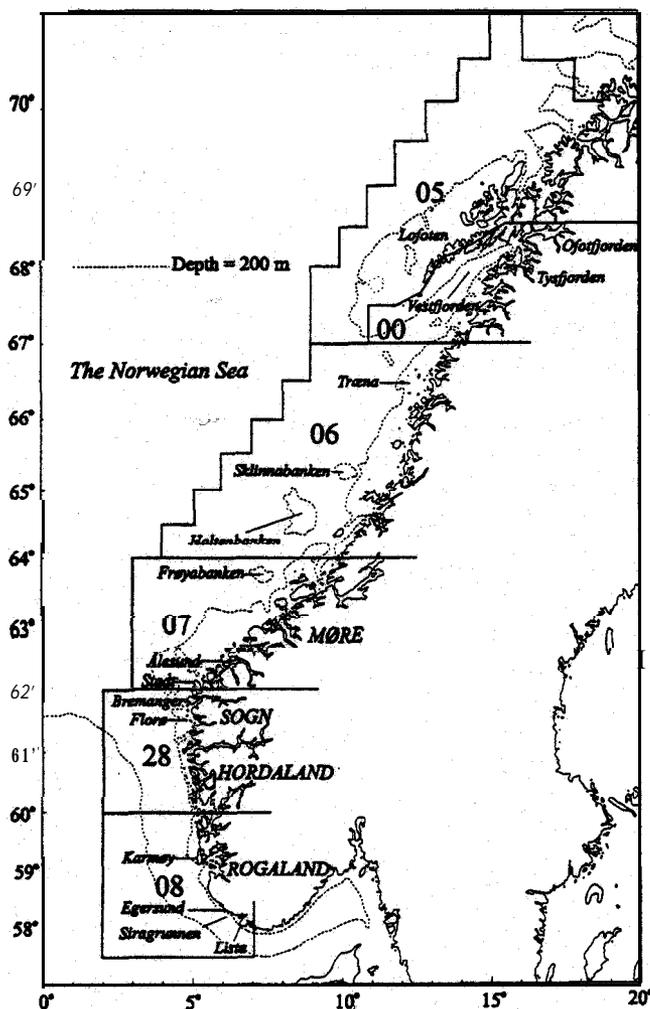


Fig. 1. Map of the Norwegian coastline with statistical areas (two digits), and important herring districts (capitals) and locations.

**Table 1.** Temporal and spatial distribution of samples from the Norwegian seine fishery of Norwegian spring spawning herring in 1995-1996. Area refers to statistical areas given in Fig. 1 and N=number of individuals in the sample. Age readings were conducted on all specimens.

Date	Area	N	Date	Area	N	Date	Area	N
06.01.95	00	100	11.03.95	06	<b>90</b>	05.02.96	07	100
12.01.95	00	100	<b>14.03.95</b>	07	<b>100</b>	05.02.96	07	100
13.01.95	00	100	14.03.95	07	<b>100</b>	05.02.96	07	<b>100</b>
14.01.95	00	100	17.03.95	06	100	07.02.96	07	100
<b>17.01.95</b>	00	100	17.03.95	07	100	<b>08.02.96</b>	07	100
<b>23.01.95</b>	00	100	18.03.95	07	100	11.02.96	07	92
24.01.95	00	100	22.03.95	07	100	11.02.96	07	100
27.01.95	00	100	22.03.95	07	100	13.02.96	07	100
27.01.95	06	<b>100</b>	25.03.95	07	100	14.02.96	07	100
28.01.95	00	100	26.03.95	07	80	17.02.96	07	100
30.01.95	00	98	27.03.95	07	100	17.02.96	07	93
30.01.95	06	100	<b>30.03.95</b>	06	90	18.02.96	07	<b>100</b>
30.01.95	00	81	06.04.95	07	100	<b>19.02.96</b>	07	100
01.02.95	00	80	12.08.95	00	100	23.02.96	07	100
05.02.95	00	80	15.08.95	00	100	23.02.96	07	100
<b>06.02.95</b>	00	80	28.09.95	00	98	24.02.96	07	87
<b>07.02.95</b>	00	81	30.09.95	00	95	24.02.96	07	100
08.02.95	00	100	02.10.95	00	100	26.02.96	07	100
08.02.95	00	90	11.10.95	00	91	26.02.96	07	99
13.02.95	06	99	14.10.95	00	90	27.02.96	28	98
10.02.95	07	100	19.10.95	00	99	01.03.96	28	100
15.02.95	06	100	23.10.95	00	100	04.03.96	28	<b>100</b>
15.02.95	07	100	25.10.95	00	100	05.03.96	28	100
16.02.95	00	90	31.10.95	00	100	07.03.96	07	100
<b>16.02.95</b>	06	100	04.11.95	00	90	<b>07.03.96</b>	07	100
<b>18.02.95</b>	07	100	06.11.95	00	100	07.03.96	07	100
20.02.95	07	85	06.11.95	00	100	14.03.96	06	100
22.02.95	07	100	<b>13.11.95</b>	00	100	14.03.96	28	96
24.02.95	07	91	17.11.95	00	100	15.03.96	28	100
26.02.95	07	100	17.11.95	00	94	18.03.96	06	97
26.02.95	07	87	17.11.95	00	100	19.03.96	06	100
27.02.95	07	100	27.11.95	00	100	<b>22.03.96</b>	07	100
02.03.95	07	90	11.01.96	00	100	22.03.96	07	100
02.03.95	07	100	16.01.96	00	100	27.03.96	07	100
03.03.95	07	89	17.01.96	00	100	23.03.96	07	98
03.03.95	07	100	17.01.96	00	100	15.09.96	00	100
04.03.95	07	100	18.01.96	00	100	26.09.96	00	100
04.03.95	07	100	18.01.96	00	100	30.09.96	00	100
04.03.95	07	100	23.01.96	06	50	04.10.96	00	100
05.03.95	07	100	23.01.96	06	<b>100</b>	21.10.96	00	99
06.03.95	07	99	29.01.96	06	100	26.10.96	00	100
06.03.95	07	100	29.01.96	06	100	30.10.96	00	97
06.03.95	07	100	30.01.96	06	100	01.11.96	00	100
07.03.95	07	100	30.01.96	06	100	<b>05.11.96</b>	00	100
07.03.95	07	<b>100</b>	31.01.96	06	100	13.11.96	00	100
08.03.95	07	95	01.02.96	06	100	20.11.96	00	100
10.03.95	07	81	02.02.96	07	<b>100</b>	23.11.96	00	100

The data on size group composition in the catches were made available to **IMR** for further analyses, and a method for estimation of age specific catch was established by combining these data with data from biological samples in a similar way as done with age at length keys. For a given area and period the catch in numbers by an age group of herring landed for human consumption was estimated as follows:

$$(2) N_A = \left( \sum_{S=1}^5 W_{AS} \cdot W_S^{-1} \cdot C_S \right) \cdot \overline{W}_A^{-1}$$

Where N=number, **A=age**, **S=size** group, **W=weight** (g) in the samples, **C=catch** (t) and  $\overline{W}$  =**mean** individual weight (t). Usually a smaller part of the catches are landed for reduction purposes, and for instance in 1995 and 1996 this part contributed with 25% and 15% respectively. The age group composition as estimated from the catches for consumption, was also utilised on the catches reduced to meal and oil, in order to obtain total number caught by age.

The estimate of catch at age is a summary of estimates obtained from different periods and statistical catch areas (Fig. 1) based on migrations and maturation. The Norwegian fishery on Norwegian spring spawning herring is carried out throughout most of the year, and there are four main catch periods: 1) the late wintering period in area 00 (Vestljorden, Tysfjorden, **Ofotfjorden**) in January-February, 2) the pre-spawning period in areas 06 (**Træna-Haltenbanken**), 07 (**Møre**), 28 (**Sogn-Hordaland**) and 08 (**Karmøy**) in January-February 3) the spawning period in areas 06, 07, 28 and 08 in March-April and 4) the early wintering period in area 00 September-December. A small fishery is also conducted in the Norwegian Sea and along the coast during summertime.

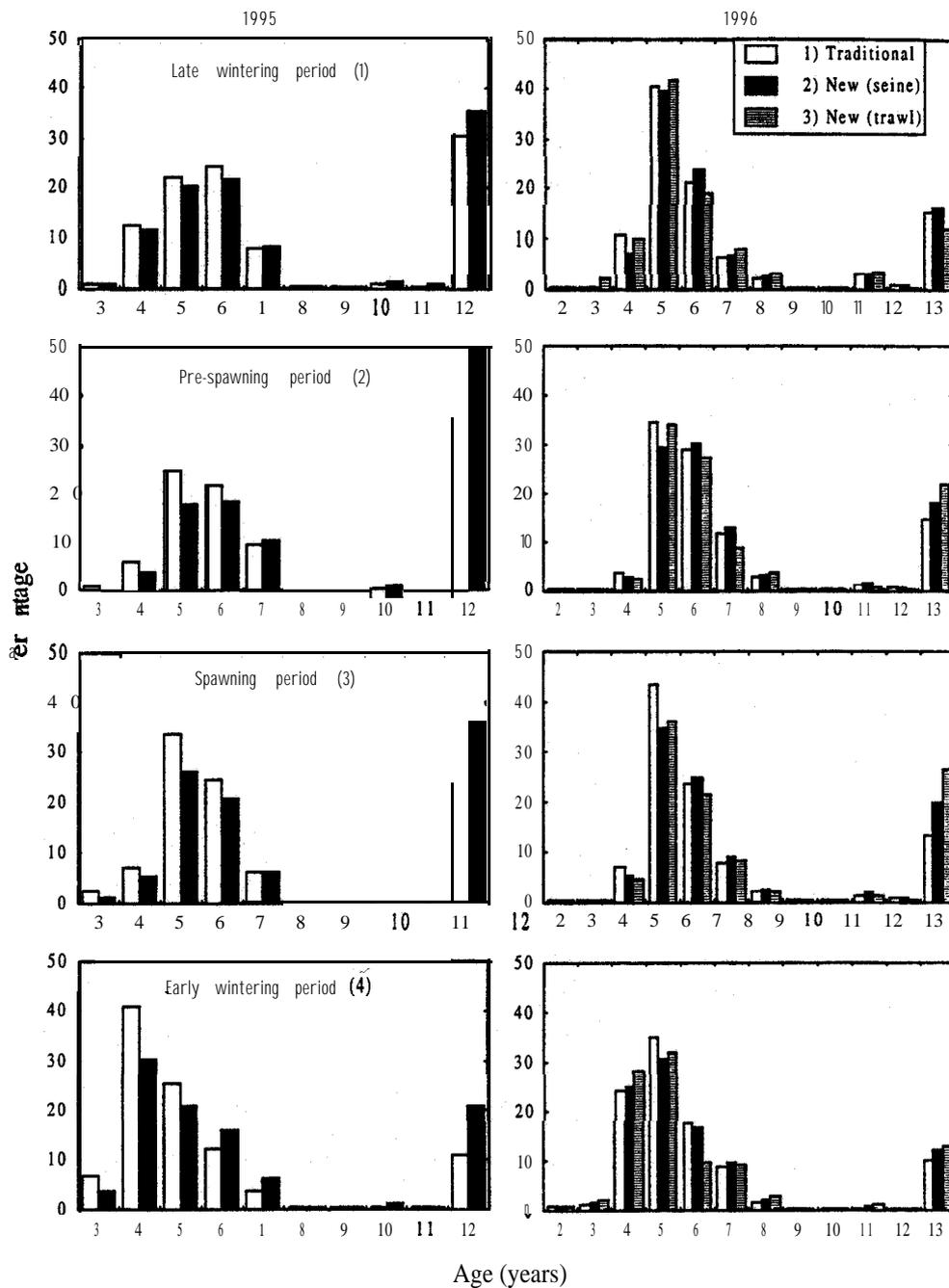
The data used to compare the results of the new methodology (2) with the traditional one (1) were collected in 1995 and 1996. In both the traditional and the new method, data from biological samples of the fishery were applied. The fishery is regularly sampled and the temporal and spatial distribution of purse seine samples in 1995 and 1996 are given in Table 1. In these years the numbers of samples from the fishery were on the average more than 5 times higher than in previous and future years, due to detailed studies on migrations (Slotte 1.998, Slotte **1999a** b, **Slotte** and Fiksen 2000, Slotte et al. 2000). Thus, the estimates using the traditional method should be at the best during this period, but still they will represent the results of an effort that IMR could not put in every year. In addition trawl samples collected during research surveys in 1996 (Table 2) were compared with seine samples from the fishery as input in the new method.

Table 2. Number (**N**) of trawl samples and individuals collected by research vessels of the Institute of Marine Research within the four main catch periods. See materials and methods for information of catch periods. For information on statistical areas, see Fig. 1.

Vessel	Catch period	Time period	N (samples)	N (individuals)	Statistical area
<b>R/V Johan Hjort</b>	1	<b>16.-27.01</b>	22	1974	00
<b>R/V Michael Sars</b>	2	<b>20.-28.02</b>	16	972	06 and 07
<b>R/V Michael Sars</b>	3	01.-14.03	17	<b>1000</b>	07 and 28
<b>R/V Johan Hjort</b>	4	<b>05.-15.12</b>	21	2013	00

## Results

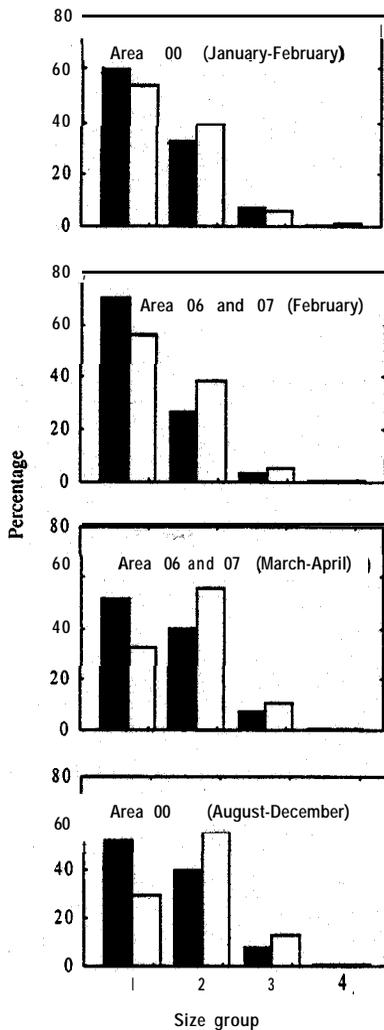
The comparison between the traditional and new method for estimation of age specific catch for the main catch periods in 1995 and 1996 (Figs. 2 and 3, Table 3) demonstrated that the traditional method underestimates the proportion of the oldest fish and thus overestimates the total catch in numbers, compared to the new method. This seems quite clear despite the large amount of biological samples collected. The difference was not as pronounced in 1996 as in 1995. The new method gave reliable estimates even when trawl samples **from** research surveys were utilised instead of representative samples **from** the seine fishery. However, utilisation of trawl samples resulted in increased catch by numbers.



**Fig. 2.** Comparison between 3 different methods of estimation of catch by age group in the main catch periods in 1995/1996 (see Table 3 for comparison by numbers by period and method, also total numbers). 1) The traditional method, using only data from representative samples of the seine catches. 2) The new method combining data from the size group distribution in the fishery with representative samples of the seine catches. 3) The new method, but using trawls samples from research surveys instead of representative samples from seine catches. The catch by size group is exemplified by 1995 in Fig. 3.

**Table 3.** Comparison between 3 different methods for estimation of total catch in numbers (millions) using data from the four main catch periods in 1995 and 1996 (see materials and methods for information of catch periods): 1) The traditional method using only data from representative samples of the seine catches. 2) The new method combining data from the size group distribution in the fishery with representative samples of the seine catches and 3) The similar method as in 2), but trawl samples from research surveys are utilised instead of representative samples from seine catches.

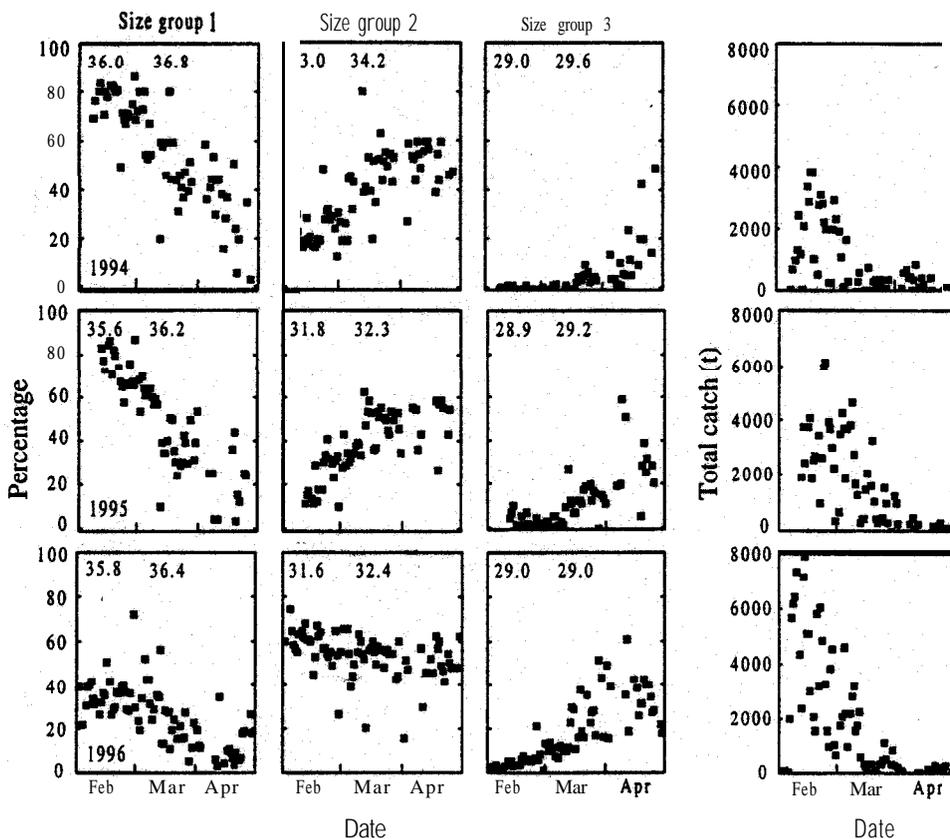
Method	Year	Period 1	Period 2	Period 3	Period 4	Total
1) Traditional	1995	632.1	203.3	248.3	676.1	1759.8
2) New (Seine)	1995	625.5	194.9	231.4	602.3	1654.1
1) Traditional	1996	643.9	587.1	277.7	1095.6	2604.3
2) New (Seine)	1996	623.3	568.0	259.4	1063.5	2513.7
3) New (Trawl)	1996	679.7	612.1	269.5	1183.1	2744.4



**Fig. 3.** Catch by size group and period in 1995 (Black bars). Comparison with size group composition in the biological samples (White bars).

## Discussion

Why does the traditional **method** underestimate the catch of older herring compared to the new method even when **IMR's** sampling effort is at the highest? The answer to this question lies mainly in the fishing pattern and migration pattern of the stock. The fishery for consumption is size specific (Slotte and Johannessen 1997). There is a commercial motivation for catching the largest, better paid herring. The selection of larger herring is possible because the fish have a size dependent migration pattern leading to higher proportions of large individuals in certain periods and areas (Slotte and Johannessen 1997, Slotte 1999b, Slotte and Fiksen 2000, Slotte et al. 2000). For instance, the herring arrive at the main spawning area off Mare by decreasing sizes and condition (Fig. 4), while they arrive in the wintering area in **Vestfjorden** in autumn by increasing sizes (Slotte and Johannessen 1997b). These differences are suggested to be results of energetic considerations based on life history theory (Slotte 1999a b, Slotte and Fiksen 2000). Fig. 4 also demonstrates how useful “free” data on size group composition could be for studies on migration patterns.



**Fig. 4.** Temporal variations in daily size group composition (group 1-3) and total catch in the spawning area off More (area 07) during February-April in the years 1994-96. Mean lengths (cm) of each size group are given for February and March (upper part of each graph). From Slotte et al. (2000).

The traditional method will be very sensitive to these temporal variations in age compositions. For instance, calculating mean weight and age composition off Mere in February during a period with decreasing proportions of older age groups and decreasing fishing intensity, will result in underestimation of the older fish if the samples are spread throughout the period. It would have been optimal if estimates based on the traditional method could have been done for every week with in each area and not just for longer periods of months or quarters. Than again, this would have demanded to much effort for IMR. In 19% the young 1991 and 1992 year classes started to predominate in the spawning stock (Anon. 1997). This resulted in less distinct temporal variances in age composition, which explains why the underestimation of older fish by the traditional method was less pronounced in 1996 compared to 1995.

There seems to be three main advantages by the new method. Firstly, it is probably more precise than the traditional one, because the temporal variations in age composition and fishing intensity is **recognised**, when

utilising the information on size **group** composition. Secondly, the number of samples from the fishery may be reduced without significant effects on the estimate, because while the proportion of age groups varies in the samples taken within a given area and time period, the age composition within the size groups will not vary similarly. For instance, in 1995 the 1983 year **class** always contributed with a high proportion in size group 1, even though the total proportion was low. Thirdly, trawl samples **from** the fishery may be used as substitutes for samples of the fishery, and still the estimate will be reliable. It would be possibility to ignore the sampling of the fishery. However, the trawl samples will on the average represent smaller individuals of the given year classes than the in the seine samples, due to the size specific fishery (Slotte and Johannessen 1997). Thus, **utilisation** of trawl samples will probably overestimate the total number of fish caught. Also the trawling could be very intense on particular age groups. This is a fact during surveys in the wintering area, where a multitrawl (tree nets) is used to collect herring from different layers or parts of layers on a vertical scale, and where the proportion of older herring and size at age increases with depth (Foote et al. 1996). The conclusion is that trawl samples should not substitute the seine samples, but only be utilised in periods with no or few samples from the fishery.

There is one source of error in the utilisation of the new method, which is connected to the minor proportion of the total catch landed for reduction purposes. In 1995 (Slotte and Rottingen 1996) and 1996 (Slotte 1997), when the new method was introduced in The ICES Northern Pelagic and Blue Whiting Fisheries Working Group, the same age composition as calculated on the fishery for consumption was utilised on the fishery for reduction purposes. This was done because no samples were taken from this fishery. However, the fishery for reduction purposes is not size specific, and these catches could therefore contain herring of smaller size than the catches landed for consumption.

There are also other useful commercial data on Norwegian spring spawning herring. One example is data on proximate composition (fat and water content) analysed at meal and oil factories and local processing plants, which could be used to analyse seasonal and annual variations in energy loss (Fig. 5)(Slotte 1999a). The effort needed to analyse the proximate composition in fish is very high, and therefore it must be considered a great advantage if such data is available for "tree". Slotte (1999a) also utilised "free" proximate composition data to estimate the energy loss of non-feeding herring migrating from the wintering areas in **Vestfjorden** to Mere. This has furthermore lead to models of the spawning migration in which the data on energy loss is of great importance. Another example of "free" data is individual weights and gonad weights, which could be used to assess the maturation process and reproductive investment using indexes like GSI (Fig. 6). In fact these data on GSI shows the same as those collected and analysed by IMR by use of an enormous effort (Slotte 1999a).

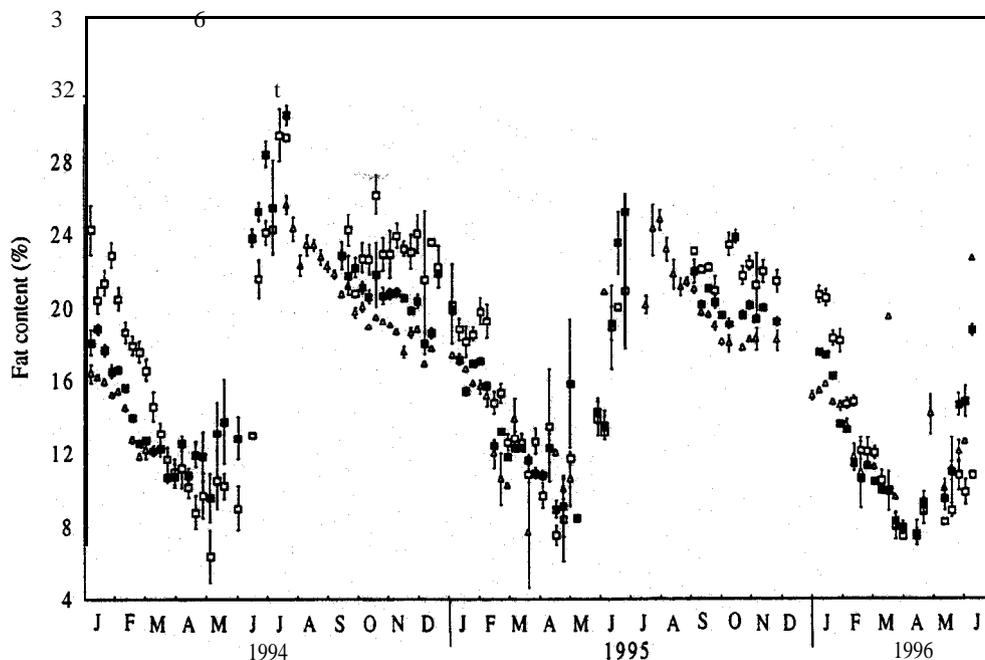


Fig. 5. Temporal variations in fat content during 1994-95 and 1995-96. Comparison between instrumental analyses (filled squares = whole individual herring, open squares = batches of fillets) and chemical analyses (open triangles = batches of whole herring). Mean values per week  $\pm$  SE are given. Skaarfisk Group A/S for provided data on fat content in round herring and fillets, whereas The Norwegian Sales Organisation for Pelagic Fish provided data on fat content **from** batches of herring. From Slotte (1999a).

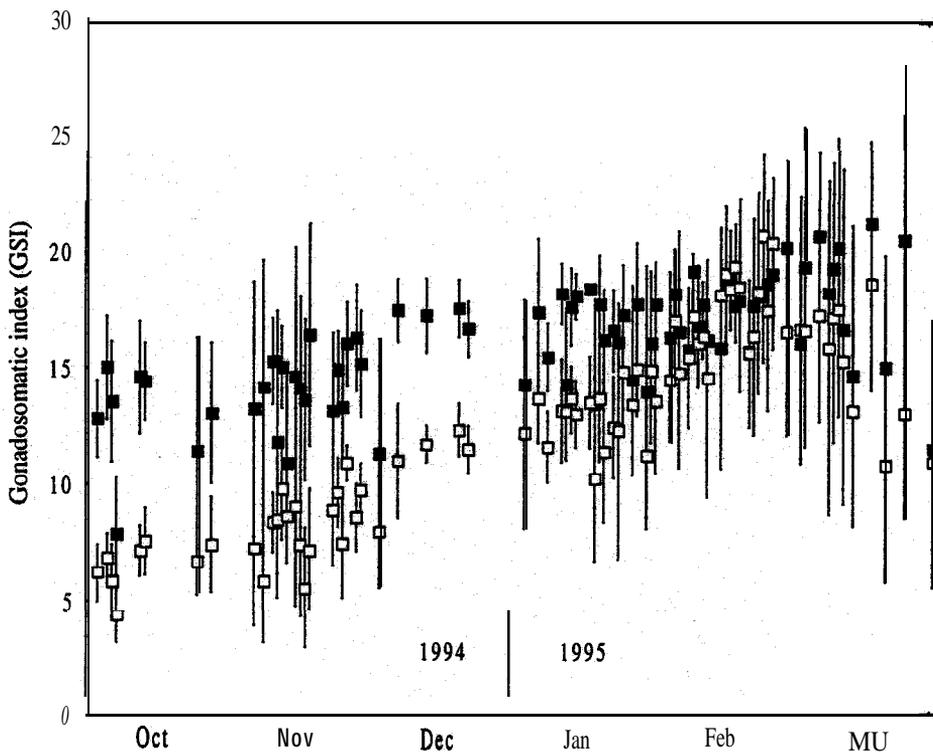


Fig. 6. Temporal variations in GSI (total weight/gonad **weight\*100**) content during 1994-95. Comparison between males (filled squares) and females (open squares). Mean values per week  $\pm$  SD are given. **Skaarfisk** Group **A/S** provided the data.

## Conclusions

It is likely that the enormous amount of size group data included in the new method for estimation of age specific catch in Norwegian spring spawning herring has contributed to a significant reduction of uncertainty in these estimates. A comparison between the new and traditional methodology based on statistical modelling, would eventually prove how significant the reduction of uncertainty would be. However, this remains to be done. It is furthermore important to emphasise that the mentioned commercial data on size groups, proximate composition and GSI are also available for species like North Sea herring and mackerel. In addition data on size groups are available for **groundfish** as cod, saithe and haddock. This author has suggested that the available data on these other species should be evaluated, but scientists seem to have doubts about the accuracy of such data and therefore hesitate to take action. Hopefully this paper could encourage the search for similar data collected by the fish industry in other countries. This author will at least keep on evaluating the data available in Norway. After all, you never know if the “free” data are useful for scientific or management purposes until a thorough evaluation has been conducted.

## Acknowledgements

The results presented are a product of a project funded by the Norwegian Research Council, «**Population** structure and spawning migration in Norwegian Spring Spawning Herring, of the Institute of Marine Research. The author are indebted to all the assistants involved in the measuring of the biological data, to the fish food company **Skaarfisk** for collecting samples from the fishery and providing data on proximate composition and GSI, and to **The Norwegian sales organisation for pelagic fish** for making data on catch by size group and proximate composition available for analysis.

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