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A COMPARISON OF THE RELIABILITY OF ACOUSTIC ESTIMATES OF FISH STOCK ABUNDANCES AND ESTIMATES OBTAINED BY OTHER ASSESSMENT METHODS IN THE NORTHEAST ATLANTIC

by

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SUMMARY

The basic data for this analysis are various fish stock abundance estimates presented in annual reports of ICES stock assessment Working Groups and other literature. These estimates are obtained by using various observation- and assessment methods; acoustic surveys, use of commercial catch and effort data, tagging experiments, egg and larvae surveys and fishing surveys. The values are analyzed with respect to the relative and absolute errors and the results for the different assessment methods are compared. It is shown that although one particular method might give fairly presice estimates of certain parts of a stock, in most cases a complete and reliable estimate of the total stock must be based on several methods. In particular, judging from the results achieved, acoustic surveys are potentially a key method for assessing stocks of small short-living pelagic fish and also for estimating young fish component of some other stocks.

INTRODUCTION

The main problem in evaluating errors in fish stock assessments is that the true stock size is seldom or never known. All what exists is a series of estimates based on one or several methods.

Reliable acoustic estimates of stock sizes should be expected when the following requirements are met:

1. Sufficient knowledge is available of the scattering properties of the species and size groups which are being recorded.

2. Representative samples of the scatterers are being collected.

3. The survey coverage is sufficient regarding the geographical distribution patterns of the fish.

4. The survey is "synoptic", i.e. fish migrations within the survey area during the survey can be neglected.

In all practical survey work one will have to accept limitations regarding these points and errors will thus be introduced to the estimates. It is difficult to obtain quantitative information of the errors involved. The estimates originate from a variety of data and information - species and size compositions in trawl catches, empirical or in situ measurements of scattering cross sections, knowledge of fish migration and behaviour patterns in relation to survey grids - which all may introduce both biases and variances of often unknown magnitudes. Thus estimates of errors, or confidence limits to stock estimates, can seldomly be given for each particular survey. However, when different independent assessment methods are applied for the same stock, and/or when the stock is surveyed and assessed several times, for instance in subsequent years, likely sizes of errors or variances can be estimated.

In this paper stock sizes estimated during some previous years have been compared with estimates for the same years in the

latest assessments available, the latter ones being taken as
"true" stock sizes. The stocks and methods which have been con-
sidered are:

Stocks	Assessment method
North-east arctic cod	Virtual population analysis (VPA) Acoustic surveys
North-east arctic haddock	Virtual population analysis Acoustic surveys
North-east arctic saithe	Virtual population analysis
North Sea cod	Virtual population analysis
Barents Sea capelin	Acoustic surveys
Blue whiting	Acoustic surveys
North Sea mackerel	Virtual population analysis
Western mackerel	Virtual population analysis

The procedure which has been applied utilizes the convergence
nature of VPA estimates. Relative errors in estimated stock sizes
from VPA decrease towards fairly small values as one calculate
the strength of a year class backwards, the rate of convergence
towards the true value being dependent on the level of fishing
mortality (POPE 1972). However, there are several factors which
could disturb this convergence. POPE (1972) discussed the effect
of sampling (random) errors in catch in number by age data which
will cause a variance on estimated stock sizes. ULLTANG (1977)
discussed the effect of errors in the assumed value of natural
mortality, M, and of stock migration. Such errors will result in
systematic errors in the estimates. This would also be the effect
of a bias in the catch data, e.g. underreporting of catches.

For some stocks where the acoustic technics has been extensively
used, e.g. blue whiting and capelin, no reliable VPAs or other
measures of stock size exist. In such cases, only the consistency
in the acoustic estimates between surveys or years can be ana-
lysed. Such analysis gives an idea about the variance on the
estimates, while large systematic errors may exist without being
discovered.

ACOUSTIC ESTIMATES

North-east arctic cod and haddock (Tables 1, 2 and 3). Since 1976
acoustic surveys have been carried out in the Barents Sea in
order to estimate the abundance of demersal fish (DALEN and
SMEDSTAD 1979). The main objectives of these investigations have
been to obtain estimates of young cod and haddock. DALEN and
SMEDSTAD 1979 have given a detailed description of these cruises;
the design, instrumentation, sampling and data analyzing proce-
dures. In 1981 two commercial trawlers were used in addition to
the research vessel in order to increase the number of trawling
stations.

The yearly results of these cruises are given as number of indi-
viduals in each age group for all age groups of cod and haddock
observed in the investigated area. Cod and haddock reach maturity
at an age of 7-8 and 6 years respectively. The bulk of mature
fish of both species will be on their spawning migration during
the period of investigation (February-March) and therefore mainly
being distributed outside the area of investigation. Consequently
the estimates of the adult age groups will only amount to a
fraction of the "true" numbers, and are therefore excluded from
the present analysis.

Two years, 1976 and 1980, have not been considered in this paper.
In 1976 the survey time allocated for the investigations was too
short to permit a complete coverage of the young fish distri-
bution area. In 1980 the performance of the integration system
was not good enough to allow a reliable collection of data. The
results from the remaining years are shown in table 1 and 2 for
cod and haddock respectively. It should be noted that the 1981
VPA ("true" values) was calibrated to the results of the 1981
acoustic survey for cod but not for haddock.

Table 1 shows clearly that all age groups of young cod have been
underestimated in the acoustic surveys each year although the
variation from age group to age group is large. The percentage
underestimation tend to be highest for the less numerous age

groups, while the 1975 year class which is the most abundant year class throughout the period, seems to be less underestimated. The total stock of young cod were underestimated by 25-48 percent in the acoustic surveys in 1977-1979.

In table 2 a similar analysis is presented for haddock. As for cod the variation in errors from age group to age group is large, but generally the acoustic surveys have overestimated the numbers of haddock; the total stock of young fish being estimated to about twice the "true" value in 1977 and 1978.

Young cod and haddock will to a large extent occur together in the catches. The same age groups of the two species have also nearly equal sizes up to an age of 5 years. Therefore it might be convenient to consider the sum of cod and haddock in each age group. This is done in table 3. Still there is a rather large variance between different age groups, but the large systematic errors which were experienced when considering the two species separately, have disappeared. The total stock of 2-5 years old fish seems to have been very precisely estimated acoustically all the years, except in 1979 when it is underestimated by approximately 30 per cent. The "true" 1979 stock depends, however, critically on the VPA input.

Why have the acoustic surveys resulted in an underestimation of cod and an overestimation of haddock? In our opinion the main reason must be sought in the representativity of the trawl catches. It has been assumed (DALEN and SMEDSTAD 1979) that the trawl catches reflect the "true" species and length (age) composition of the acoustically measured population. Judging from the results obtained above, this assumption has hardly been met. The relative large error of 32 per cent underestimation in 1979 also need some comments. During that winter a severe cooling of water masses took place in the area of investigation. This lead to a westward displacement of the young fish from 1978 to 1979 (MIDTTUN, NAKKEN and RAKNES 1981) and it is thus possible that fish consentrations in the western Barents Sea were not covered satisfactorily by the survey that year.

Barents Sea Capelin (Table 4). The stock of Barents Sea Capelin
has been assessed on the basis of annual acoustic surveys since
1971 (NAKKEN and DOMMASNES 1977, DOMMASNES 1981). Capelin has a
short life span. Most of the Barents Sea stock spawn at an age of
4 years along the northern coasts of Norway and the USSR in
March-April. The acoustic survey, which since 1975 has been a
joint Norwegian-USSR survey, is undertaken each year in September-
October. All age groups are partly covered by the survey, but due
to the behaviour patterns of 0- and 1-group fish and because of
different trawl selectivity of these two age groups as compared
to larger fish, these age groups are excluded from the estimates
(NAKKEN and DOMMASNES 1975 and 1977, DOMMASNES 1981). The results
of the surveys are reported as number of individuals in each age
group for fish which is 2 years and older.

Capelin suffer a mass mortality after its first spawning. Since
most of the fish spawn at an age of 4 years and the first reli-
able estimate of a yearclass is obtained when the fish is 2 years
old, an error analysis must be based on the comparison between
the estimates of 2 and 3 years old fish in two successive years.
DOMMASNES (1981) has made such a comparison for estimating the
natural mortality of capelin from 2 to three years of age. He
arrived at estimates of natural mortality, M, between 0.35 and
1.03, most of the estimates being within the range, 0.6-0.7. The
ICES working group has used a monthly natural mortality of 0.05
in the assessment of the stock. In the present paper we have
adopted a constant natural mortality of 0.05 per month for the
entire period between two surveys. Using this value and the catch
in number by age data we have calculated the expected number of 3
year old fish from the observed number of 2 year old fish the
previous year. The results are given in table 4. The deviations
are the differences between the acoustically measured and expected
number of 3 year old fish.

Table 4 shows no systematic trend but large variances appear
between different years (yearclasses); the deviations varying
from +51 per cent to -71 per cent. However, in 5 of the 10 years
the survey has been carried out, the deviations are less than 11

per cent, and these small discrepancies might probably be within
the variations in the natural mortalities. The deviations of 30-
50 per cent which occurred in 1978, 1979 and 1981 can probably
not be explained by variations in natural mortality. For these
years the sources of errors should be sought in the survey me-
thodology and design, in the performance of the integration
system or in the scattering cross sections which have been applied.

Table 4 may give the impression that systematic errors have been
small and negligible, but this is not necessarily true. Since the
catches only amount to 12-30 per cent of the yearly reduction of
a year class, the estimates of abundance may be scaled up or down
without influencing the computed deviations significantly. Conse-
quently, systematic errors, for instance caused by the appli-
cation of too low or too high scattering cross sections, cannot
be detected in the present analysis. However, comparison of
acoustic estimates of the spawning stock of capelin with estimates
obtained from tagging experiments and eggs and larvae surveys for
the period 1972-1975 (ULLTANG 1977), indicated that no large
systematic errors occurred during that period.

In some of the years incomplete area coverage might have been a
significant source of error. In 1979 the lack of 3 year old fish
in the acoustic survey was probably caused by insufficient cover-
age of the south easternmost areas of the Barents Sea.

Blue whiting (Table 5). Acoustic estimates of biomass of spawning
blue whiting have been worked out every year since 1972. The
estimates originate from surveys of the spawning area west of the
British Isles within the period February-May. Several vessels
from various research laboratories have contributed to the surveys.
The results of the surveys are summarized by the Blue whiting
assessment Working group and given in table 5.

The estimates in table 5 vary considerably both within and bet-
ween years, and the Working Group (1981) being aware of the
potential sources of errors, considered as a minimum estimate the
spawning stock biomass to be in the range 5.7-8.7 million tonnes,

with a mean of 7.2 million tonnes; which corresponds to errors of
± 21 per cent. Unfortunately there is no available data which
enable us to break down the total estimates into estimates for
each age group. Hence, it is impossible to analyze the results in
the same manner as for capelin and North-east arctic cod and
haddock in the preceeding sections. However, several workers have
been aware of the difficulties involved regarding incomplete area
coverage and fish migration in connection with the blue whiting
surveys. The fish migrate quickly both into and out of the main
spawning area (BUZETA and NAKKEN 1975) and many of the surveys
thus cover only a minor part of the total spawning stock. The
various laboratories have also in the past used different tech-
niques and different conversion factors (scattering cross sections)
which has made it difficult to obtain comparable results. Never-
theless, during the two last years the acoustic estimates obtained
seem comparable between laboratories and the errors involved are
now probably at a level which require more knowledge of the
traditional population parameters (growth, age, maturity, recruit-
ment) in order to increase the precision in the estimates.

ESTIMATES BY OTHER ASSESSMENT METHODS

In this section stock size estimates for each year during the
period 1975 - 1978 as given in the relevant ICES Working Group
report the next year are compared with estimates of stock size
for the same years as given in the VPA's carried out during the
1981 round of working group meetings. The latter ones are for
convenience called "true" values. It should however be noted that

(i)   The final year in these VPA's is 1980. Therefore, the
        estimate for 1978 is based on only 3 years catch data and
        may still be somewhat dependent on input fishing mortality
        or stock size for 1980. The likely errors from this source
        will decrease as one goes back to 1977, 1976 and 1975.

(ii) Disregarding the effect of wrong input values in 1980, the
        "true" values should rather be read as "the best estimate
        consistent with the value of natural mortality assumed in
        the VPA".

The comparisons have been carried out for the following stocks:
North-east arctic cod, haddock and saithe, the North Sea and
Western stock of mackerel, and North Sea cod.

For these stocks a variety of data have been used in the assess-
ments: Commercial catch per unit of effort data (cod, haddock and
saithe), young fish trawl survey data (cod and haddock), data
from egg surveys (mackerel) and tagging results (mackerel).

Before discussing the results it should be pointed out that the
only objective of the present work is to illustrate the problems
and likely size of errors connected with the various assessment
methods. Further, it has not been possible or even attempted to
fully reflect the discussion and possible reservations to the
estimates given in the various Working Group reports.

Data on catch in number by age have been an essential part of the
input in all the assessments discussed. For all stocks have been
stated the kind of additional data which were utilized without
repeating the existence of the basic data on catches and age
compositions.

North-east arctic cod (Table 6). The north-east arctic cod is
coming into the fishery in significant numbers as 3 year old. It
recruits to the spawning stock around an age of 8 years. Most of
the catch of young (immature) cod is taken in trawl fisheries
while a significant part of the catch of older fish is taken by
other gears.

The data available to, and used by the Working Group over the
period considered were mainly catch per unit of effort (CPUE) in
various trawl fisheries, CPUE in the spawning fishery with long
line, hand line and gill net at Lofoten, and abundance indices
from pre-recruit trawl surveys.

Table 6 shows that the mature stock (N_{8+}) has been fairly accu-
rately estimated over the whole period considered, the errors
ranging from 0 to +20 per cent. However, great difficulties have

apparently been experienced in estimating the younger part of the stock, errors ranging from -42 to +121 per cent on 3 year old fish. Errors were consistently positive except in the 1979 assessment (1978 stock). For 1975 - 1976 the average exploitation pattern for the years 1970 - 1974 was assumed, which in retrospective can be seen resulted in too high stock sizes for the younger age groups, especially in 1976.

This was even more pronounced for 1977 in an assessment carried out by the working group in March 1978. However, that assessment was revised in September 1978. In the latter assessment, which is the one which has been used in Table 6 for 1977, the Working Group did not assume an average exploitation pattern but studied in more detail CPUE-data from the various fisheries. By this procedure, fishing mortality in 1977 was estimated separately for the younger and older component of the stock, and for the younger part the fishing mortality was estimated separately for each age group. Although this still resulted in heavy overestimation of one age group, the 4 year olds, the results improved significantly. The procedure was continued in 1979 when estimating the 1978 stock, resulting in fairly good estimates of all age groups except for the 3 year olds which appearantly was underestimated.

It should be noted that doubts have been expressed about the validity of the data on catch in number by age in 1978. Errors in those data would invalidate both the 1979 assessment and 1981 assessment of especially the 1978 stock.

To summarize, although detailed analysis of CPUE-data seemed to improve significantly the estimates of 5 year old and older cod, great difficulties are still experienced in estimating the number of 3 and 4 year olds, i.e. cod which have been in the fishery for only 1 or 2 years.

North-east arctic haddock (Table 7). Also the haddock is recruiting to the fishery in significant number as 3 year old. The spawning stock consists of 6 year old and older fish. Assessments for the years 1975 - 1978 were mainly based on CPUE-data from trawl fisheries and abundance indices from pre-recruit trawl surveys.

Errors in spawning stock estimates ranged from -36 to +19 per cent, i.e. somewhat larger than for cod. This is not surprising since there is no separate spawning fishery with an extensive data base for haddock as it is for cod.

Also for the younger age groups the errors are larger for haddock than for cod, ranging from -25 to +192 per cent for the 3 year olds, and +1 to +125 per cent for the 4 year olds.

In contrast to the cod assessments, the Working Group continued to use the average exploitation pattern for the years 1970 - 1974 over the whole period. The large errors in the assessment of the 1977 stock are of similar magnitude as those for cod in the March 1978 assessment which was later revised for cod but not for haddock.

The comment made about 1978 catch data for cod concerns haddock as well.

In the preceeding discussion emphasis has been laid on the difficulties arising from changing exploitation pattern. Such difficulties can to a large extent be overcome if catch per unit of effort data are broken down on age groups provided the appropriate data base for doing this exists. The large errors in especially the 1976 stock estimate for cod and the 1975 - 1977 stock estimates for haddock should therefore not be taken as estimates of likely errors when making optimal use of CPUE-data covering the main fisheries.

North-east arctic saithe (Table 8). The saithe recruits to the fishery in significant number as 2 year old. The spawning stock consists of 6 year old and older saithe. There are two distinct main fisheries, a purse seine fishery which mainly exploits 2-4 year old fish and a trawl fishery where 4 year old and older fish dominate.

Assessments have generally been made by making judgements about changes in fishing effort in the different fisheries and selecting values of fishing mortality for the last year on the different

age groups which in the VPA gave trends which were in agreement with these changes. Details on this procedure are not given in the Working Group reports, and it is not known what data the judgements about changes in fishing effort really were based on.

The errors are relatively small which probably can be explained by the fact that, according to the last VPA available, this has been a fishery without too large changes in effort over the period considered and the immediate preceeding years, except for a drop in fishing effort in the trawl fishery in 1977 as a result of extended coastal state jurisdiction. The working group was able to take account of that in its assessment of the 1977 stock in 1978.

The errors in the assessment of the 5 year olds in 1976 and 4 year olds in 1977 are, however, large (about +60 per cent). The 5 year olds in 1976 was a weak year class and the error may simply be a result of variance in estimated age composition of the catches. The error in the assessment of the 4 year olds in 1977 could have another explanation: Judged from the VPA given in the 1978 report the Working Group assumed that the drop in fishing effort in 1977 affected 4 year old and older fish. The 1981 VPA indicates that the 4 year olds in 1977 were not affected, or the reduction was compensated for by increase in for example purse seine effort on 4 year olds.

The problem of measuring _effective_ purse seine effort is well-known. Since the fishing mortality on younger age groups of saithe mainly is generated by the purse seine fleet, and since in addition the purse seine effort may affect the various age groups differently in different years, depending on the geographical and seasonal distribution of the fishery, large errors could be expected in assessment of the younger age groups by the method used by the Working Group. Indeed, except for the two cases discussed above, the authors found the errors surprisingly small.

North Sea cod   (Table 9). North Sea cod recruits to the fishery as 1 year old and to the spawning stock mainly as 3 year old.

In its assessments the Working Group has used abundance indices
from young fish trawl surveys and CPUE-data from the commercial
fishery. Values of fishing mortality the most recent year have
been selected to give VPAs consistent with calculated trends in
effort. However, for all the years considered, except when esti-
mating the 1975 stock in 1976, the fishing mortality on the 1-
group has been adjusted to give year class strength consistent
with the young fish trawl survey data.

The 1-group has been fairly accurately estimated over the period,
errors ranging from -30 to +8 per cent while the 2-group was
overestimated by as much as 44 and 80 per cent in 1978 and 1976
respectively, and the number of older fish by 53 and 88 per cent
in 1975 and 1976.

North Sea mackerel (Table 10). North Sea mackerel recruits to
the fishery at an age of 2 years and to the spawning stock at age
3.

Assessments have almost entirely been based on tag recaptures.
Egg surveys to monitor changes in the spawning stock have been
carried out since 1973, but data from these have only been used
as supporting evidence for estimated trends in spawning stock
from VPAs where the input fishing mortalities have been based on
tagging results. Since the tag recaptures give no estimates for
the youngest age groups, these have been estimated by assuming
certain relative values of fishing mortality compared to the
older ones.

Some reservations should be made to the estimated "errors" in
Table 10.

(i) North Sea and Western mackerel are during summer mixed in
     feeding areas in the northern North Sea. Catches have been
     allocated to stocks by utilizing tagging data, but large
     uncertainties exist in the estimated proportions. VPA
     estimated stock sizes backwards are valid only as far as the
     allocation of catches to stocks are valid. Therefore the
     term "true" stock is even more obscure in this case.

(ii) Tag recaptures from 1979 onwards have been too few to give a
valid estimate of fishing mortality in 1979 or 1980. The
fishing mortalities for 1980 in the last VPA were selected
to give values for previous years similar to those estimated
by the 1979 Working Group. The small "error" in the 1978
stock estimate of ages 3 and older therefore only reflects
the calibration of the 1981 assessment to the 1979 assess-
ment, although the egg data were found to give supporting
evidence for the resulting estimated trend in the spawning
stock. It should also be noted that with the relative low
fishing mortalities in recent years, the convergence of the
VPA will be slow.

(iii) The analysis for 1975 and 1976 was based on values of
natural mortality, M=0.2, while in subsequent years M=0.15
was used in accordance with estimates from tagging data.

Having made these reservations, it should be noted that the
estimated errors of the 3+ stock were small also in 1977 and
1975. The error in 1976 was larger, +44 per cent. The working
group says in its 1978 report that some overestimation had taken
place because wrong proportions of catches were allocated to the
North Sea stock for 1976 at the 1977 meeting.

It appears that the number of 2 year old fish has been signifi-
cantly underestimated in three of the years.

Western mackerel (Table 11). The Western mackerel recruits to
the fishery in significant numbers already as 1 year old, and to
the spawning stock as 3 year old.

In the assessment of the 1975 and 1976 stock in 1976 and 1977
respectively, terminal fishing mortalities and resulting stock
sizes of one particular year class, the 1969 year class, were
estimated from North Sea tagging data, assuming that the propor-
tions of this year class from the two stocks in the mixing area
around Shetland reflected its strength in the two stocks. The
other year classes were then estimated from assumed relative

values of fishing mortality. It is seen that this resulted in
underestimation of the adult stock of Western mackerel in both
years.

The problem of allocating catches to stock in the mixing area
also have consequences for assessment of the Western mackerel,
especially when using the method described above. Thus, the wrong
allocation of 1976 catches to stock which led to overestimation
of the North Sea stock in 1976 contributed to the underestimation
of the Western stock.

In 1977 a large scale egg survey was carried out, and the spawning
stock in 1977 was calculated from that survey. Also the spawning
stock in subsequent years was indirectly estimated from that
survey by calibration of the VPA to give a backcalculated 1977
stock equal to the survey estimate. The VPA carried out in 1981,
the "true" stock, was calibrated to a new egg survey carried out
in 1980. The results indicate that such large scale egg surveys
can give rather precise estimates. The main problem in the Western
stock assessment, as for the North Sea stock, seems to be the
estimation of younger age groups where changes in relative fishing
mortalities from year to year may heavily bias the results.

By basing the assessment of the Western stock on the egg surveys,
errors in assessment arising from uncertainties in allocation of
catches to stock in the mixing area have been strongly reduced
since most of the western mackerel is caught in other areas.

DISCUSSION AND CONCLUSIONS

In the preceeding analyses errors on separate age groups in the
young fish stocks have been given. In Fig. 1a· is plotted for the
four demersal stocks the percentage error in the VPA-assessments
of total young fish stock and adult stock while Fig. 1b shows the
percentage error in the acoustic estimates of the young fish
stocks of N-E arctic cod and haddock and for the total of the two
species. Considering N-E arctic cod and haddock it is seen that
large problems have been experienced by both methods in the

assessment of the young fish stocks. Yet, when grouping cod and haddock the acoustic results are surprisingly good. Thus it might be concluded that the acoustic surveys seem to produce fairly reliable information about the state of the total young fish stock of cod and haddock in the Barents Sea.

From Fig. 1 it is also seen that the VPA-assessments of the adult stocks of N-E arctic cod and haddock have been more precise than for the young fish stock and regarding N-E arctic saithe and North Sea cod the errors seem to be of about the same level for the two components. It should, however, be pointed out that for predictive purposes a much higher precision may be required for the assessment of the young fish stock than for the adult stock.

The errors in the acoustic estimates of Barents sea capelin have varied considerably over the period. Yet, on an average, the number of capelin seem to have been estimated acoustically with a precision comparable to that for the young fish stocks of N-E arctic cod and haddock when these two species are grouped. The lack of other measures of capelin abundance precludes an evaluation of the accuracy of the acoustic estimates.

Of the acoustically measured stocks which have been treated in this paper, blue whiting seems to have been the most difficult to deal with. A major reason for this might be that all surveys in the past have been carried out in the spawning season when the requirements both regarding coverage and weather conditions are difficult to meet.

For the two mackerel stocks, disregarding the years 1975-1976 for the western stock, the adult stocks have been estimated with rather high precision while the results for the younger age groups are more variable. This is not surprising since the adult stocks have been estimated from tagging experiments and egg surveys while the younger age groups have been estimated by making assumptions on fishing pattern.

It is of course impossible from the analysis carried out in this paper to rank one assessment method above the other, in general. Each method has its strength and weaknesses depending on the behaviour, availability to gears and instruments and migration patterns of the fish stock in question. Further, limitations of man power as well as limitations due to vessel and instrument costs will highly influence the results obtained by any assessment method. However, judging from the results presented here it seems that abundance estimates from acoustic surveys have reached a precision and accuracy which significantly could improve the assessment of some fish stocks or stock components which previously, with large errors, have been assessed mainly by fishery dependent data and methods.

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Table 1. North-east arctic cod. Number of individuals $(N \cdot 10^{-7})$ in each age group estimated from acoustic survey each year and from virtual population analysis 1981 ("True" values) and percentage error.

	1977					1978					1979					1981				
	N_2	N_3	N_4	N_5	N_6	N_2	N_3	N_4	N_5	N_6	N_2	N_3	N_4	N_5	N_6	N_2	N_3	N_4	N_5	N_6
Acoustic estimates	88	10	32	14	5	24	80	15	17	3	1	11	50	8	5	7	6	12	24	27
"True" value	101	35	44	29	12	47	82	25	21	11	19	39	60	16	9	6	10	13	24	27
Per cent error	-13	-70	-28	-51	-56	-50	-2	-39	-17	-78	-93	-72	-16	-53	-50	+11	-42	-2	+2	0
Sum of 2 age groups																				
Acoustic estimates	98		42	46	19	104		95	32	20	12		61	58	13	13		18	36	51
"True" value	136		79	73	41	129		107	46	32	58		99	76	25	16		23	37	51
Per cent error	-28		-47	-37	-54	-19		-11	-30	-38	-79		-38	-24	-48	-19		-22	-3	0
Sum of 3 age groups																				
Acoustic estimates		130		56	51		114		112	35		62		69	63		25		42	63
"True" value		180		108	85		154		128	57		118		115	85		29		47	64
Per cent error		-28		-48	-40		-23		-13	-39		-47		-40	-26		-14		-11	-2
Sum of 4 age groups																				
Acoustic estimate			144		61			136		115			70		74			49		69
"True" value			209		120			175		139			134		124			53		74
Per cent error			-31		-49			-22		-17			-48		-40			-8		-7
Sum of 5 age groups																				
Acoustic estimate			149					139					75					76		
"True" value			221					186					143					80		
Per cent error			-33					-25					-48					-5		

Sources: ICES C.M. 1982/G:2, DALEN and SMEDSTAD (1979).

Table 2. North-east arctic haddock. Number of individuals ($N \cdot 10^{-7}$) in each age group estimated from acoustic surveys each year and from virtual population analysis 1981 ("True" values) and percentage error.

	1977				1978				1979				1981			
	N_2	N_3	N_4	N_5	N_2	N_3	N_4	N_5	N_2	N_3	N_4	N_5	N_2	N_3	N_4	N_5
Acoustic estimate	76	20	6	1	15	74	6	+	1	18	25	1	3	1	7	16
"True" value	28	12	4	2	20	26	5	1	6	16	13	2	10	5	4	8
Per cent error	+169	+71	+71	-33	-27	+185	+22	-89	-82	+10	+90	-35	-75	-72	+61	+105
Sum of 2 age groups																
Acoustic estimate	96	26	7		89	80	7		19	43	26		4	8	23	
"True" value	40	16	6		46	31	6		22	29	15		15	9	12	
Per cent error	+140	+63	+17		+93	+158	+17		-14	+48	+73		-73	-11	+92	
Sum of 3 age groups																
Acoustic estimate	102	27			95	81			44	44			11	24		
"True" value	44	18			51	32			35	31			19	17		
Per cent error	+132	+50			+86	+153			+26	+42			-42	+41		
Sum of 4 age groups																
Acoustic estimate	103				96				45				27			
"True" value	46				52				37				27			
Per cent error	+124				+85				+22				0			

Sources: As for table 1.

Table 3. North-east arctic cod and haddock. Number of individuals ($N \cdot 10^{-7}$) in each age group estimated from acoustic surveys each year and from virtual population analysis in 1981 ("True" values) and percentage error.

	1977				1978				1979				1981			
	N_2	N_3	N_4	N_5	N_2	N_3	N_4	N_5	N_2	N_3	N_4	N_5	N_2	N_3	N_4	N_5
Acoustic estimates	164	30	38	15	38	153	21	17	3	29	75	9	10	7	19	40
"True" values	129	46	47	30	68	108	29	22	25	55	73	18	17	15	17	32
Per cent error	+27	−35	−21	−51	−43	+42	−29	−20	−90	−47	+3	−51	−41	−52	+14	+28
Sum of 2 age groups																
Acoustic estimates		194	68	53		191	174	38		32	104	84		17	26	59
"True" values		175	93	77		176	137	51		80	128	91		32	32	49
Per cent error		+11	−27	−31		+ 9	+27	−25		−60	−19	−8		−47	−19	+20
Sum of 3 age groups																
Acoustic estimate			232	83			212	191			107	113			36	66
"True" values			222	123			205	159			153	146			49	64
Per cent error			+ 5	−33			+ 3	+20			−30	−23			−27	+ 3
Sum of 4 age groups																
Acoustic estimate				247				229				116				76
"True" values				252				227				171				81
Per cent error				− 2				+ 1				−32				−6

Table 4. Estimates of number of Barents Sea capelin ($N \cdot 10^{-9}$).

	Year of observation										
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Acoustic estimates 2 year old fish	220	141	240	550	361	241	181	371	334	199	195
Number of months between surveys	10	14	12	12	12	12	12	12	12	12	
Number of 3 year old fish estimated from $N_{t+1} = N_t \cdot e^{-M}$, $M = 0.05$ per month		133	86	132	301	198	132	99	204	183	109
Catch of year class between surveys		0	[18]	13	28	24	37	33	36	31	[30]
Expected number of 3 year old fish		133	68	119	273	174	95	66	168	152	69
Acoustic estimate of 3 year old fish		140	20	160	304	167	102	100	113	154	48
Per cent deviation		+ 5	-71	+34	+11	- 4	+ 7	+51	-32	+ 1	-31

Numbers in brackets are stipulated. The catch is mainly taken at the end of the period.

Sources: NAKKEN and DOMMASNES (1977). DOMMASNES (1981).

Table 5. Acoustic estimates of spawning stock biomass
         (million tonnes) present in the area west of
         the British Isles, 1972-1981.

		Norwegian surveys	UK surveys	USSR surveys
1972	28 Feb. - 15 Mar.	2.6		
	12-26 Mar.	1.6		
1973	12-30 Mar.	6.6		
	31 Mar. - 11 Apr.	2.4		
1974	15-29 Mar.	2.3		
	31 Mar. - 8 Apr.	2.3		
	6-22 Apr.		10.5	
1975	15 Mar. - 7 Apr.		9.3	
	9-27 Apr.		44.7	
	6-14 May	1.8		
	11-27 May		6.6	
1976	22 Mar. - 11 Apr.		16.8	
	23 Mar. - 12 Apr.	3.1		
	10 Apr. - 2 May		11.2	
1977	23 Mar. - 1 Apr.		3.8	
1978	1-7 Apr.		13.8	
	8-25 Apr.		5.3	
1979	8-21 Apr.		14.8	
	18 Apr. - 4 May	7.9		3.4
1980		5.4	2.9	0.8
1981		6.9	5.3	

Sources: ICES C.M. 1980/H:5, C.M. 1981/H:12.

Table 6. North-east arctic cod. Stock size (N · 10^{-6}) year t + 1 (WG estimate), corresponding estimate for year t as estimated by Working Group year t + 1 (WG estimate), corresponding estimate from 1981 VPA ("true" value) and per cent "error".

1975

	N_3	N_4	N_5	N_6	N_7	N_{8+}
WG estimate	1048	426	778	336	78	38
"True" value	629	351	620	256	64	36
Per cent "error"	+67	+21	+25	+31	+22	+6

1976

	N_3	N_4	N_5	N_6	N_7	N_{8+}
WG estimate	1384	761	370	448	167	46
"True" value	627	474	234	305	104	41
Per cent "error"	+121	+61	+58	+47	+61	+12

1977

	N_3	N_4	N_5	N_6	N_7	N_{8+}
WG estimate	419	708	339	119	121	58
"True" value	348	437	286	120	144	58
Per cent "error"	+ 20	+62	+19	- 1	-16	0

1978

	N_3	N_4	N_5	N_6	N_7	N_{8+}
WG estimate	476	193	245	135	56	98
"True" value	816	249	207	112	51	81
Per cent "error"	- 42	-22	+18	+21	+10	+21

Sources: ICES C.M. 1976/F:10   ICES C.M. 1977/F:6
       "   C.M. 1978/G:64 Revised   "   C.M. 1979/G:20
       "   C.M. 1982/G:2

Table 7. North-east arctic haddock. Stock size ($N \cdot 10^{-6}$) year t as estimated by Working Group year t + 1 (WG estimate), corresponding estimate from 1981 VPA ("true" value) and per cent "error".

	1975				1976			
	N_3	N_4	N_5	N_{6+}	N_3	N_4	N_5	N_{6+}
WG estimate	108	46	73	109	150	55	17	168
"True" value	51	36	100	170	58	33	17	142
Per cent "error"	+112	+28	-27	-36	+159	+67	0	+18

	1977				1978			
	N_3	N_4	N_5	N_{6+}	N_3	N_4	N_5	N_{6+}
WG estimate	339	78	19	77	193	45	7	28
"True" value	116	35	15	66	257[1]	45	9	39
Per cent "error"	+192	+123	+27	+17	-25	0	-22	-28

1) Based on revised VPA, ACFM November 1981.

Sources: ICES C.M. 1976/F:10   ICES C.M. 1977/F:6
     " C.M. 1978/G:64 Revised   " C.M. 1979/G:20
     " C.M. 1982/G:2

Table 8. North-east arctic saithe. Stock size ($N \cdot 10^{-6}$) year t as estimated by Working Group year t + 1 (WG estimate), corresponding estimate from 1981 VPA ("true" value) and per cent "error".

	1975					1976				
	N_2	N_3	N_4	N_5	N_{6+}	N_2	N_3	N_4	N_5	N_{6+}
WG estimate	455	141	41	81	121	308	273	85	30	85
"True" value	404	177	35	60	100	378	257	91	18	91
Per cent "error"	+13	-20	+17	+35	+21	-19	+ 6	- 7	+67	- 7

	1977					1978				
	N_2	N_3	N_4	N_5	N_{6+}	N_2	N_3	N_4	N_5	N_{6+}
WG estimate	142	290	158	46	61	264	104	88	61	56
"True" value	194	261	99	47	62	287	131	125	50	71
Per cent "error"	-27	+11	+60	- 2	- 2	- 8	-21	-30	+22	-21

Sources: .ICES C.M. 1976/F:2   ICES C.M. 1977/F:3
          " C.M. 1978/G:3   " C.M. 1979/G:6

Table 9. North Sea cod. Stock size ($N \cdot 10^{-6}$) year t as estimated by Working Group year t + 1 (W.G. estimate), corresponding estimate from 1981 VPA ("true" value) and per cent "error".

	1975			1976			1977			1978		
	N_1	N_2	N_{3+}	N_1	N_2	N_{3+}	N_1	N_2	N_{3+}	N_1	N_2	N_{3+}
WG Estimate	196	99	98	119	284	109	273	94	58	163	378	65
"True" value	226	93	64	110	158	58	386	84	68	233	262	53
Per cent "error"	-13	+ 7	+53	+ 8	+80	+88	-29	+12	-15	-30	+44	+23

Sources: ICES C.M. 1976/F:9   ICES C.M. 1977/F:8
       " C.M. 1978/G:7   " C.M. 1979/G:7
       Working Document, ACFM Nov. 1981.

Table 10. North Sea Mackerel. Stock size ($N \cdot 10^{-6}$) year t as estimated by Working Group year t + 1 (W.G. estimate), corresponding estimate from 1981 VPA ("true" value) and per cent "error".

	1975		1976		1977		1978	
	N_2	N_{3+}	N_2	N_{3+}	N_2	N_{3+}	N_2	N_{3+}
WG estimate	80	2504	819	2784	141	1605	72	1350
"True" value	444	2305	548	1933	313	1796	137	1481
Per cent "error"	-82	+ 9	+50	+ 44	-55	- 11	-47	- 9

Sources: ICES C.M. 1976/H:3   ICES C.M. 1977/H:2
   " C.M. 1978/H:4   " C.M. 1979/H:3
   " C.M. 1981/H:7

Table 11. Mackerel, Western stock. Stock size ($N \cdot 10^{-6}$) year t as estimated by Working Group year t + 1 (W.G. estimate), corresponding estimate from 1981 VPA ("true" value) and per cent "error".

	1975			1976			1977			1978		
	N_1	N_2	N_{3+}	N_1	N_2	N_{3+}	N_1	N_2	N_{3+}	N_1	N_2	N_{3+}
WG estimate	192	1521	6145	4143	1877	5419	4000	6093	8974	517	3642	9699
"True" value	2619	3034	11638	4021	2205	10442	4217	3202	9952	531	3487	9625
Per cent "error"	- 93	- 50	- 47	+ 3	- 15	- 48	- 5	+ 90	- 10	- 3	+ 4	+ 1

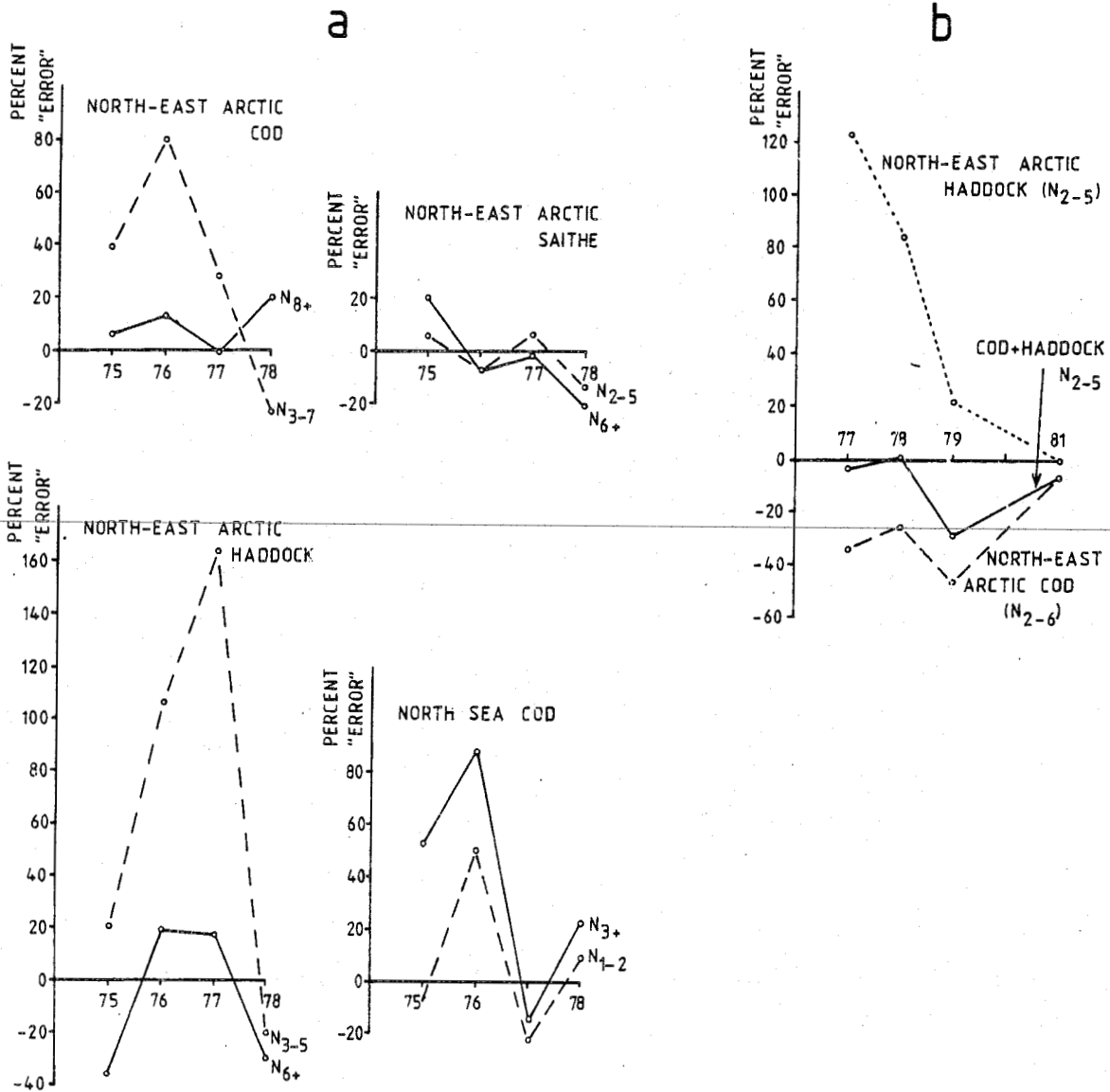Sources: As Table 10.

Fig. 1. a) Per cent "error" in Working Group estimates of young fish
            stock (dotted line) and spawning stock for the years
            1975-1978.

         b) Per cent "error" in acoustic estimates of young fish
            stock for the years 1977-1981.