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International Council for the Exploration of the Sea

C.M.1974/ H:27
Pelagic Fish (Northern)Committee
Ref. Statistics Cttee

# Report on the Norwegian sampling programme for industrial catches of herring, mackerel and caplin

by

J. Hamre, Ø. Ulltang and O.J. Østvedt,
Institute of Marine Research,
Bergen/Norway

## INTRODUCTION

The 61st. statutory Council meeting recommended that member countries should nationally institute a statistical evaluation of the adequacy of the number and the size of samples taken from individual fisheries and report the results to the relevant Committees of the 62nd Statutory Meeting(C.Res.1973/4:8).

In response to this resolution the present paper deals with sampling of the Norwegian catches of North Sea herring, mackerel and caplin used for reduction, which contribute with the bulk of the total catch.

Fish used for reduction purposes is paid according to the fat content of individual landings. According to agreement between the fishermen union and the industri, three samples of each landing are drawn, one from the top of the fishhold, one from the middle and one from the bottom, each sample containing one bucket of fish (approxemately 10 kg). The fat analysies is organized by the Directorate of Fishery, and the field work is carried out by selected people stationed at the various landing ports.

In resent years the Directorate of Fishery has in cooperation with the fishermens sales organisations enitiated a new data recording system with the aim of establishing a data bank in which all relevant data on catch statistics and trade are collected. For the industrial fisheries of North Sea herring, mackerel and caplin, the new system was introduced in 1973. The sampling programme for the fat analyses constitutes the main sourse of information on the catch, but in addition to the fat analyses, the samples are now measured for length distribution and the total weight of the samples is recorded. Details appears from the recording sheet shown in figure 1.

The data bank provides outprints of the catch statistics by time, area and length groups. In order to convert the length distribution to age, the catches taken during peak season are sampled randomly for establishing relevant age-length keys. Some principals of the validety of this procedure are dealt with below.

## METHOD

As every catch landed is sampled for length composition while the age-length keys are based on a relative few samples, the variance in the estimated length distribution will contribute relatively very little to the variance of the final estimate of the age composition of catch landed. Of practical reasons it will therefore be assumed that all variance in estimated number landed by age comes from variance in the estimated age-length key rather than in the abundance of each length-group. This means that the estimated length distribution is considered to be the true length distribution of the catches.

If a percentage $p_{l_i}$ of the fish caught have length $l_i$ and a percentage $\hat{p}_{a,l_i}$ of those are estimated to be of age a, then

$p_{l_i} \cdot \hat{p}_{a,l_i}$ = estimated percentage landed of length $l_i$ and age a

$$\text{var}\,(p_{l_i} \cdot \hat{p}_{a,l_i}) = p^2_{l_i}\ \text{var}\,(\hat{p}_{a,l_i})$$

$p_a = \sum_i p_{l_i}\ \hat{p}_{a,l_i}$ = estimated percentage landed of age a

$$\text{var}\,(p_a) = \sum_i p^2_{l_i} \cdot \text{var}\,(\hat{p}_{a,l_i})$$

In the following the theory of two-stage subsampling is used. The formulas used are mainly based on COCHRAN (1963). If n samples for age-length key are taken, an unbiased estimate of $p_{a,l_i}$ is given by

$$\hat{p}_{a,l_i} = \frac{1}{n} \sum_{j=1}^{n} {}_j\hat{p}_{a,l_i}$$

where ${}_j\hat{p}_{a,l_i}$ = percentage of age a and length $l_i$ in the $j^{th}$ sample.
Var $\hat{p}_{a,l_i}$ may be estimated by

$$\text{var}\ \hat{p}_{a,l_i} = \frac{1}{n} \sum_{j=1}^{n} \frac{({}_j\hat{p}_{a,l_i} - \hat{p}_{a,l_i})^2}{n-1} = \frac{1}{n} s_1^2 \qquad (1)$$

Var $\hat{p}_{a,l_i}$ is made up of two parts

$$\text{Var}\ p_{a,l_i} = \frac{s_1^2}{n} + \frac{s_2^2}{mn} \qquad (2)$$

where

$s_1^2$ = variance between primary units means (primary unit = catch sampled)

$s_2^2$ = variance among elements within primary unit

m = number of elements in the actual lengthgroup taken in each sample

n = number of samples.

If m differs from sample to sample, then m in (2) should be substituted by

$$m_o = \left( \sum_{j=1}^{n} m_j - \sum_{j=1}^{n} m_j^2 \Big/ \sum_{j=1}^{n} m_j \right) / (n-1)$$

(SNEDECOR and COCHRANE, 1967)

where

$m_j$ = number of elements in the $j^{th}$ sample (in the actual length-group).

$S_2^2$ may be estimated from the binominal distribution by

$$\hat{S}_2^2 = s_2^2 = \frac{1}{n} \sum_{j=1}^{n} \frac{m_j \; {}_j\hat{p}_{a,l_i} (1 - {}_j\hat{p}_{a,l_i})}{m_j - 1}$$

$S_1^2$ may then be estimated by

$$\hat{S}_1^2 = s_1^2 - \frac{s_2^2}{m}$$ ( $s_1^2$ as defined by equation (1) above).

Often age-length keys are estimated by lumping together all samples from a certain time period and area. If there are all together m fish of length $l_i$ of which $m_a$ are of age a, $p_{a,l_i}$ is estimated by

$$\hat{p}_{a,l_i} = \frac{m_a}{m}$$

with variance

$$\text{var } \hat{p}_{a,l_i} = \frac{\hat{p}_{a,l_i} (1 - \hat{p}_{a,l_i})}{m - 1}$$

Using this method, n different simple random samples are considered as making one big simple random sample. This is only justified if the variance between primary unit means, $S_1^2$, is 0 or very small compared with the $S_2^2$, i.e. if the differences in $p_{a,l_i}$ from sample to sample may be explained by the variance in the estimation of each $p_{a,l_i}$. If this is not true, Var $\hat{p}_{a,l_i}$ may be seriously underestimated if the last method is used.

Some preliminary investigations on herring and mackerel have been carried out in order to study the relative strength of the two components of variance, the level of precision given by the present sampling effort and methods and how improvements in the precision most efficiently could be gained.

NORTH SEA HERRING

The samples for age-length keys are taken randomly and not stratified by length. There are therefore rather few age-readings in the poorly represented length groups. (Table 1). The analysis of the relative size of the two components of variance therefore had to be limited to the more abundant length groups. Only samples which contained 10 or more fish in the length group under consideration were incorporated in the analysis. Results of the analysis for herring of length 26-, 27-, and 28 cm are shown in the table below (notation as in the paragraph Method).

| Length group | age *) | n | $m_o$ | $\hat{p}_{a,l}$ | $\hat{S}_1^2$ | $\hat{S}_2^2$ | $\hat{S}_1^2 / \hat{S}_2^2$ |
|---|---|---|---|---|---|---|---|
| 26 | 2 | 6 | 27 | 0.26 | 0.0118 | 0.1824 | 0.065 |
| 27 | 3 | 6 | 17 | 0.75 | 0.0241 | 0.1692 | 0.142 |
| 28 | 3 | 6 | 20 | 0.84 | 0.0183 | 0.151 | 0.151 |

It is seen that $\hat{S}_1^2$ is between 5 % and 15 % of $S_2^2$ in these three cases.

In fig. 2 is illustrated how the standard deviation of $\hat{p}_{a,l}$ will vary with n and m if $S_1^2$ and $S_2^2$ have the values estimated for the percentage of 2-group herring in length group 26 cm given in the table above, using the formula

$$Var\ (p_{a,l_i}) = \frac{S_1^2}{n} + \frac{S_2^2}{nm}$$

The standard deviation decreases rather slowly when m, the number in a length group per sample, increases above 5-10. If one then wants the precision to be increased considerably, the number of samples (n) has to be increased. In the case illustrated $\hat{S}_1^2$ was 6.5 % of $\hat{S}_2^2$. In the two other examples given in the table $\hat{S}_1^2$ is 14.2 % and 15.1 % of $\hat{S}_2^2$. For those cases the precision of the estimated $p_{a,l_i}$ is thus even more dependent on n.

The results show that it is of great importance to get good estimates of the relative size of the two components of variance if one wants to improve the sampling scheme.

*) All references to age refer to winter-rings.

One finds it perhaps a little surprising that the variance between samples should be of that great size as indicated here for age-length keys. However, autumn- and spring spawning herring have not been separated and the percentage of spring spawning herring differs from sample to sample. In addition the autumn spawning herring consists of several spawning populations. If the age-length keys are different for the various spawning groups, this may explain the great variance between samples.

Using the same age-length samples as in the analysis above and the length composition of the catch landed from the same area in June 1973, the precision of the estimated age composition of the catch landed was studied. The relative precision of the estimated number landed by age is greater for the abundant yearclasses than for the weaker ones. Because the age-length samples are taken randomly and not stratified by length the estimated age-length key will have the greatest precision for the abundant length groups.

The percentage of 2 years old herring was estimated to 23,9 % with a standard deviation of 2.1 %, i. e. a coefficient of variation of 8.8 %. The 5 years old herring was estimated to make 3.9 % of the total number landed and the standard deviation was 0.8 %, i.e. a coefficient of variation of ca. 20 % .

Fig. 2 indicates that little is gained by increasing the number of age-readings per sample and length group above 10. By stratification of the age-length sampling one could therefore probably increase the relative precision of the estimated number landed of the weaker yearclass considerably without increasing the total sample size and with only a slight decrease in the relative precision for the stronger yearclasses. To increase the precision of the estimated age composition, the number of samples should be increased instead of increasing the sample size. By increasing the number of samples and taking a fixed number of herring for age-reading in each length group in each sample, this itself would provide for better estimates of the relative size of the two components of variance. For the future one would then have a better basis for chosing the "best" ratio between number of samples and size of samples.

MACKEREL

Two sets of sampling data were analyzed to estimate the two components of variance: 6 samples from the North Sea (south of $60^{\circ}$N) in September - October 1973 and 8 samples from the Shetland area in August 1973 (Table 1).

The samples from the North Sea indicated that the variance between samples is very small or practically zero compared with the within unit variance. This means that the number of samples is of less importance, the main objective of the sampling should be to get many fish in each lengthgroup age-determined. The samples from the Shetland area however, showed that the variance between samples may be considerable, giving an estimated $S_1^2$ as great as 37 % of $S_2^2$ for the percentage of 4 years old in the 36 cm group. Using the actual values found for $S_1^2$ and $S_2^2$ for this percentage in the formula

$$\text{Var } \hat{p}_{a,1} = \frac{S_1^2}{n} + \frac{S_2^2}{nm}$$

the standard deviation of the estimated percentage will be 0.135 if n = 5 and m = 10, 0.105 if n = 10 and m = 5 and 0.074 if n = 20 and m = 5. The number of samples is thus of great importance for the precision in this case.

The high variation between samples in the Shetland area compared with the North Sea may easily be explained by the fact that the mackerel in the Shetland area consists of two components, North Sea mackerel and Irish mackerel. These two components have a different growth pattern, the former being more fastgrowing than the latter one. Since the percentage of Irish mackerel seems to have increased with time in the actual fishing season, this resulted in a high variance between samples in the age-length key. The mackerel in the North Sea (south of 60$^\circ$N) consists of North Sea mackerel mainly and one would therefore expect low variance between samples as observed.

The relative precision of the estimated age composition of the total catch of mackerel in the Shetland area and in the North Sea was estimated by the same method as described for North Sea Herring and the main conclusion is the same: The relative precision is highest for the most abundant yearclasses. For the catch in the Shetland area, the percentage of 4 years old mackerel was estimated to 21 % with a standard deviation of 2.8 %, i.e. a coefficient of variation of 13.3 %. The percentage of 7 years old mackerel was estimated to 9.3 % with a standard deviation of 1.9 %, i.e. a coefficient of variation of about 20 %. For the strong 1969 yearclass (4 years old) in the North Sea catch the estimated percentage is 64.2 % with a standard deviation of 2.9 %, i.e. a coefficient of variation of 4.5 %. The 7 years old are estimated to make 2.3 % of the catch with a standard deviation of 1.0 %, i.e. a coefficient of variation of 43 % .

CONCLUSIONS

Only a small part of the material has yet been analysed. Further analysis is necessary before any decisiveconclusions can be drawn. However, the preliminary result presented in this paper illustrates the necessity of getting good estimates of the relative size of the two components of variance, the variance between unit means and the variance within units. When a stock consists of two or more components with different growth pattern the variance in the age-length key between samples is often of a considerable magnitude, especially when the relative strength of the different components varies with time and area. In such cases it should be taken many samples distri - buted in time and area in a similar way as the catches.

By the present sampling scheme the estimated number landed by age has a coefficient of variation of 5 - 10 % for the dominant yearclasses and a higher one for yearclasses which is poorly represented in the catch. If this level of precision is sufficient depends on the use of the estimates. This is a question which has to be answered from an asessment or management point of view. The different assessment working groups have to define the level of precision needed before one can make a proper evaluation of the adequacy of the number and size of samples.

The main conclusion from this study is that to fully utilize the existing sampling for length composition introduced on Norwegian industrial fisheries, the number of samples for age-length keys should be increased, especially for North Sea herring and the mackerel fishery in the Shetland region.

REFERENCES:

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Snedecor, George W. and Cochrane, William G. 1967. Statistical
Methods, 6th ed.
The Iowa State University Press, Ames, Iowa.

Table 1. <u>Number per length group in the samples used in the analysis of age-length keys</u>

a. North Sea Herring

| Length | Sample no. | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| 23 | 7 | 2 | | | | 1 | | | | 1.1 |
| 24 | 9 | 19 | 1 | | 4 | 8 | | | | 4,6 |
| 25 | 38 | 45 | 7 | | 10 | 26 | 2 | | | 14.2 |
| 26 | 27 | 23 | 24 | 1 | 28 | 32 | - | | 2 | 15.2 |
| 27 | 11 | 5 | 33 | 9 | 24 | 14 | 7 | 10 | 16 | 14.3 |
| 28 | 5 | 2 | 19 | 30 | 15 | 8 | 32 | 22 | 28 | 17.9 |
| 29 | 1 | 2 | 10 | 23 | 12 | 6 | 32 | 28 | 26 | 15.6 |
| 30 | 1 | | 2 | 19 | 6 | 3 | 16 | 23 | 19 | 9.9 |
| 31 | | | 1 | 8 | 1 | 1 | 6 | 12 | 1 | 3.3 |
| 32 | | | 1 | 4 | | 1 | 3 | 4 | 3 | 1.8 |
| 33 | | | | 1 | | | | - | | 0.1 |
| 34 | | | | | | | | 1 | | 0.1 |
| | 99 | 98 | 98 | 94 | 100 | 100 | 98 | 100 | 95 | 98.0 |

b. Mackerel (Shetland)

| Length | Sample no. 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
|---|---|---|---|---|---|---|---|---|
| 31 | 7 | 1 | 1 | | 1 | | | 1.4 |
| 32 | 6 | 6 | 3 | 3 | 2 | | | 2.9 |
| 33 | 10 | 6 | 10 | 9 | 7 | | | 6.0 |
| 34 | 10 | 10 | 8 | 8 | 6 | | 1 | 6.3 |
| 35 | 23 | 16 | 12 | 12 | 10 | | - | 10.4 |
| 36 | 16 | 17 | 16 | 14 | 19 | 2 | 5 | 12.7 |
| 37 | 10 | 10 | 13 | 10 | 10 | 6 | 7 | 9.4 |
| 38 | - | 6 | 9 | 10 | 11 | 8 | 7 | 7.3 |
| 39 | - | 3 | 2 | 3 | 6 | 21 | 5 | 5.7 |
| 40 | - | 4 | 2 | 1 | 3 | 12 | 7 | 4.1 |
| 41 | 1 | 2 | | 1 | | 10 | 4 | 2.6 |
| 42 | | 1 | | 1 | 2 | 13 | 6 | 3.3 |
| 43 | | | | | | 5 | 2 | 1.0 |
| 44 | | | | | | 1 | 1 | 0.3 |
| 45 | | | | | | - | 1 | 0.1 |
| 46 | | | | | | 1 | | 0.1 |
| | 83 | 82 | 76 | 72 | 77 | 78 | 46 | 73.4 |

c. Mackerel (North Sea)

| Length | Sample no. | | | | | | Mean |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| 31 | | | 1 | | | 1 | 0.3 |
| 32 | | | 1 | | 2 | 3 | 1.0 |
| 33 | 5 | | 3 | | 4 | 15 | 4.5 |
| 34 | 11 | 1 | 10 | 1 | 10 | 21 | 9.0 |
| 35 | 14 | 8 | 23 | 10 | 24 | 20 | 16.5 |
| 36 | 25 | 14 | 25 | 21 | 30 | 11 | 21.0 |
| 37 | 18 | 12 | 13 | 27 | 11 | 5 | 14.3 |
| 38 | 5 | 4 | 4 | 7 | 2 | | 3.7 |
| 39 | 1 | 6 | 5 | 5 | 1 | | 3.0 |
| 40 | - | - | 1 | 3 | | | 0.7 |
| 41 | 1 | 1 | - | 4 | | | 1.0 |
| 42 | | | 1 | 1 | | | 0.3 |
| 43 | | | | 1 | | | 0.2 |
| | 80 | 46 | 87 | 80 | 84 | 76 | 75.5 |

# RÅSTOFFDATA FOR INDUSTRIFISK

1465

| | | |
|---|---|---|
| ANALYSESTASJON | 1 | 5 |
| FABRIKK *Factory* | 3 | 21 |
| PRØVE *Sample no.* | 5 | 164 |
| RÅSTOFF *Species* | 10 | 107 |
| *Fishing date* FANGSTDATO | 13 | ÅR 84, MND 8, DAG 13 |

BÅTENS NAVN *Name of vessel*

FANGSTDATA *Catch date*

| | | |
|---|---|---|
| REGISTRERINGS-MERKE | 19 | FYLKE H, NUMMER 30, KOMM AV |
| *Date of delivery* LEVERINGSDATO | 27 | MND 8, DAG 14 |
| FANGTSFELT *Fishing area* | 31 | OMR 42, LOK 73 |
| REDSKAP *Fishing gear* | 35 | 11 |
| SALGSLAG *Sales company* | 37 | 08 |
| SLUTTSEDDEL | 39 | 83147 |

RÅSTOFFKONTROLL

| | | |
|---|---|---|
| KONTROLL TYPE | 45 | 6 |
| RÅSTOFFKVALITET | 46 | 1 |
| AVSILING | 47 | 1 |
| KONSERVERINGSMÅTE | 48 | 1 |
| ANVENDT DOSE | 49 | |
| KONSERVERINGSUTSTYR | 51 | |
| ANVENDELSE | 52 | 1 |
| VOLUM % UNDER MINSTEMÅL | 53 | 0 |

ANALYSEDATA *Chemical analysis*

| GRUPPE 55 | ANTALL HL 56 *Catch in HL* | % FETT 61 | %TØRRSTOFF 64 | % FFA 67 | ANALYSE NR 70 | ANALYSE DATO MND | ANALYSE DATO DAG |
|---|---|---|---|---|---|---|---|
| 1 | 2157 | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |

| FISKER | PRØVETAKER | ANALYTIKER |
|---|---|---|
| [signature] | [signature] | |

VURDERING (Havf.inst.) *Data control* 19

VEKT AV LENGDEMÅLT RÅSTOFF *Weight of samples* 21 280

LENGDEMÅLING *Length measurement*

CM – GRUPPER

| <30 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | /// | ~~////~~ // | ~~////~~ ~~////~~ /// | ~~////~~ ~~////~~ ~~////~~ // | ~~////~~ /// | // | // | | |
| | | | | | | 3 | 7 | 14 | 17 | 8 | 2 | 2 | | |

53

Fiskeridirektoratet

F. BEYER - BERGEN

*Fig. 1. Data sheet for Industrial catches*

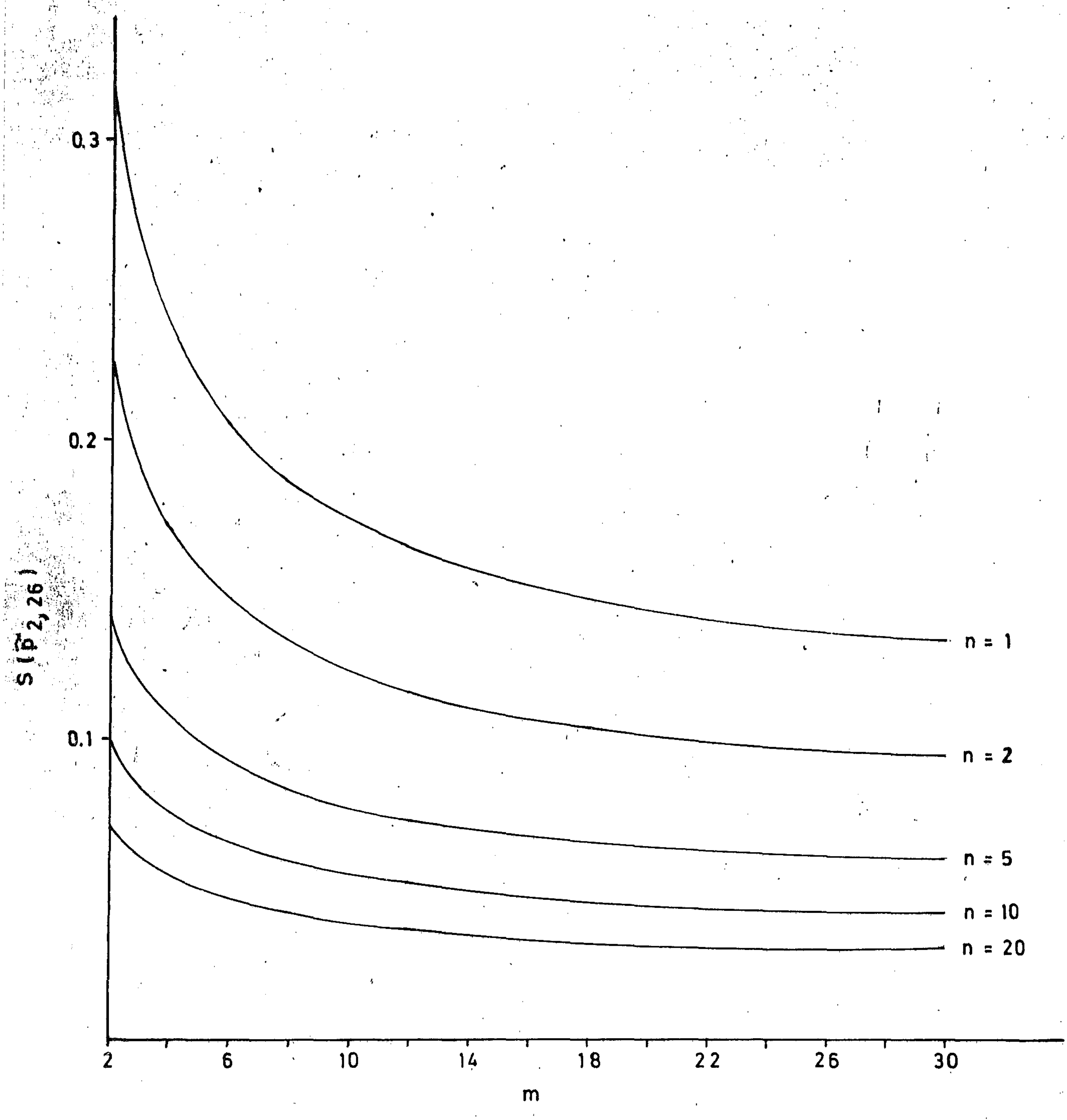


Fig. 2. Standard deviation of estimated percentage of 2 years old herring in the 26 cm group against m for different values of n.

m = number of aged herring in each length group per sample.
n = number of samples