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ESTIMATING THE MATURITY OGIVE FOR NORTHEAST-ARCTIC COD BY A MODIFIED MESH ASSESSMENT MODEL

by

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ABSTRACT

The exploitation (1967-77) of the Northeast Arctic cod is splitted in 12 different fisheries. The mesh assessment model is modified in order to estimate the maturity ogive on the basis of the length and the age distributions of the catches from these fisheries. The key fishery in the estimation is the gill net fishery in Division IIa which mainly takes part during the spawning season. The resulting ogives are similar to those derived by other methods for the same period. Although the estimated statistical variations of the results are underestimates due to unaccounted uncertainties in the fixed input parameters in the model, the present method may be an alternative or a check on other methods.

INTRODUCTION

The working group on Arctic fisheries (Anon. 1983) estimated the spawning stock of Northeast Arctic cod for each of the years 1946-1982. In doing so the working group used different maturity ogives for different periods as derived from Rollefsen (1954), Garrod (1967), Hylen and Dragesund (1973), Ponomarenko,

Ponomarenko and Yaragina (1980), Ponomarenko and Yaragina (1981), Ponomarenko (1982), and Hylen and Nakken (1982).

Garrod (1967) and Hylen and Dragesund (1973) based their ogives on the age compositions of the catches from the spawning fishery. The maturation curve given by Ponomarenko et al. (1980, 1981) and Ponomarenko (1982) are based on trawl sampling in the Barents Sea in period November-February. Hylen and Nakken (1982) based their maturation curve on acoustic surveys in February-March 1982 that covered the main areas of the distribution of the immature as well as the mature part of the stock. There are problems with all of these methods used for estimating the maturity ogives, and it is difficult to evaluate the size of the possible biases.

From the maturity curves summarized by Anon. (1983) there seems to be a gradual shift towards an earlier onset of maturity in the post-war years, which may correspond to an increasing growth rate (see Anon. 1983; Ponomarenko 1981). However, the different methods used to establish the different curves makes it difficult to assess accurately how much the maturation process actually has changed over the years.

The present paper do not address the problem of a change of the maturity ogive through time. We only intend to estimate the average maturity ogive for the period 1967-1977 using a method not applied before to this problem, i.e. a modification of the mesh-assessment method as described by Høydal, Rørvik and Sparre (1980, 1982).

METHOD

The core of the method is a model that simulates biological characteristica of a fish stock and the individual fisheries on the same stock. The model takes into account the selective properties of the gears, the discard practice and the recruitment of the fish to the individual fisheries. This model has previously been used to estimate the effective mesh sizes in some fisheries (Høydal 1977; Anon. 1979; Anon. 1980), and with slight modifications on a stock of lobster (Tveite and Rørvik 1982).

The basic model is STEP 1 as it is written out in mathematical details by Høydal, Rørvik and Sparre (1980, 1982). Here we will only describe the modifications of this model as used in the present paper. In doing so we will use the same symbols as Høydal _et al_. (1982, p. 84-86). There are four modifications:

1. Høydal _et al_. (1980, 1982) simulate the relative age- or length-distributions of the catches. We use the absolute catch distributions and introduce the size of the initial stock N(TI) as an additional free parameter to be estimated.

2. Høydal _et al_. minimize the sum of squares of the difference between the observed and the estimated relative catch distributions. We prefer a modified chi-square function:

$$\text{OBJECT FUNCTION} = \sum_{e} \sum_{i} \frac{(CL(e,i)-OBSCL(e,i))^2}{OBSCL(e,i)}$$

CL(e,i) and OBSCL (e,i) are the estimated and the observed number of fish (in thousands) respectively in length (or age)-group i that are caught by fishery e. In the calculation of the object function, we have only included length- or age-groups containing 5 (thousands) or more fish.

Both the least square function as used by Høydal _et al_. (1982), and the modified least chi-square function are strongly consistent estimators. However, contrary to the minimum least square the minimum chi-square estimator is asymptotically efficient. Therefore the latter estimator is to be preferred (Kirkwood 1982).

The chi-square estimator allows confidence intervals of the parameters to be calculated (Kirkwood 1982; James and Ross 1977; James 1978). However, these confidence intervals are only minimum intervals as they require that the fixed input parameters in the model are true and not subject to uncertainty. The only uncertainty is supposed to be due to the variations in the observed length- (age-) distributions with a standard deviation = $OBSCL(e,i)^{\frac{1}{2}}$. The true errors of the estimated parameters are likely to be considerably larger.

The parameters and their confidence intervals are estimated by a program called MINUIT-S that is developed at CERN in Geneva (James and Ross 1977; James 1978).

3. We have simplified the mesh assessment model as described by Høydal et al. (1982) in that we only estimate (or use as input parameters) the 50% selection length of the individual gears. However, the ratio between the length at 75% selection and the 50% selection (FAC), as estimated in selection experiments, has to be given as fixed input parameters in the model.

4. For two fisheries, gill-net in Sub-area I and gill-net in Division IIa, the selection curves are fixed on the basis of the work by Hylen and Jakobsen (1979). Instead the lengths at 50% recruitment (RL50%) to the fisheries and the RL75%/RL50% ratio are estimated.

   The recruitment curve that minimize the difference between the observed and the estimated catch at age (or length) distribution of gill-net in Division IIa is an estimate of the maturity ogive, since this fishery is mainly taking place in Lofoten during the spawning season.

MATERIAL

Catch distributions

The working group on Arctic fisheries (Anon. 1983) utilized in their virtual population analysis (VPA) catch at age data splitted on 17 different fisheries for each of the years 1967-1982. These being:

Number	Fishery
1.-3.	USSR trawl, Sub-area I; Division IIa; Division IIb
4.-6.	UK trawl, - " - " -
7.	Federal Republic of Germany, Sub-areas I-II
8.	Other countries (except Norway), - " -
9.-11.	Norway trawl, Sub-area I; Division IIa; Division IIb
12.-13.	Danish seine, Sub-area I; Division IIa
14.-15.	Gill net, - " -
16.-17.	Long- and Hand-line, - " -

In the present study, however, only the years 1967-1977 are considered as also done in a preliminary mesh assessment (Anon. 1979). The length distributions for these fisheries are available for this period as well.

In the simulations only the age-groups 1-14 are included, ignoring the insignificant 15+ group. The simulations based on the length-distributions cover the range 15 to 130 cm.

In order to reduce the number of free parameters to be estimated several fisheries were pooled. The Norwegian trawl fishery in Division IIb was pooled with the UK fishery in the same area since data from the UK fishery is to a large extent used to calculate the catch distributions of the Norwegian trawlfishery in this Division.

The USSR fishery in Division IIa, which only took 0.35% of the total catch by number (1967-1977), were pooled with the Other countries' fishery.

A closer scrutiny of the basic data indicated large sampling variation of Danish seine. This gear only accounts for 1.3% of the total catch by numbers in the period 1967-1977. Therefore the two categories of Danish seine were pooled with Other countries' fishery.

The age compositions of the trawlers from the Federal Republic of Germany (2.2% of total catch by numbers, 1967-77) are not available for bottom trawl and midwater trawl seperately, both gears being important in this fishery in the relevant period. Therefore the FRG data were pooled with the Other countries' fishery.

The Other countries' fishery thus become a kind of "rag-bag" category containing several less important fisheries that together make up 9.6% of the total catch by numbers (1967-1977).

By these poolings the catch compositions of the total fishery become divided in 12 categories. Thus for each simulation there are 15 parameters to be estimated, i.e. three more than in an ordinary mesh assessment with 12 fisheries (STEP 1) as described by Høydal et al. (1982).

Input parameters

The fixed input parameters that are used are summarized in Table 1. The same parameters are used both in the simulation of the age- and the length-distributions of the catches. The reason for choosing these parameters are summarized below:

a) Von Bertalanffy parameters

The parameters are based on a combined set of data from the USSR fishery in Sub-area I and from the spawning fishery in Division IIa.

b) Selection factor (SEL(e)) and steepness of the selection curve (FAC(e))

As we are interested in the length at 50% selection and not the effective mesh sizes, SEL(e) is set equal to 1.00 for all fisheries (e). The ratio between the length at 75% and 50% selection (FAC(e)) is set equal to 1.09 for all of the eight trawl fisheries on the basis of the results from the joint

USSR-Norwegian trawl experiments in 1977 (Hylen and Olsen 1977; Ponomarenko, Nikeshin and Sakhno 1978).

Hook selection curves seems to be less sharp than those for trawls. On the basis of the experiments reported by Sætersdal (1963) FAC(e) was taken to be 1.13 for the two long-line fisheries.

In the case of gill-net Hylen and Jakobsen (1979) give a selection curve for nylon material, which dominated in the actual period (1967-1977). The solid line in Fig. 1 is the curve fitted by Hylen and Jakobsen (1973), and it should according to the authors approximate the selective properties of gill-net for fish caught with the head first in a single mesh, ignoring other ways of being caught.

The open circles in Fig. 1 represent points not included in the fitting of the solid line. Although these circles partly represents observations with few observations, they as well as other data given by Hylen and Jakobsen (1979), indicate that less steep selection ogives should be applied for representing the total selectivity of gill-net.

We have applied the curve with the broken line (Fig. 1) which we fitted by eye. This curve has a 50% and 75% selection at 73 cm and 80 cm respectively, and a subsequent decreasing selection with the 75% and the 50% lengths at 97 cm and 105 cm respectively. These data stems from nets with a 190 mm mesh size (nylon) which was the most common mesh size used in the spawning fishery (Division IIa) and should also be fairly representative for the gill-net fishery in Sub-area I.

c) Recruitment

The recruitment curves should not be regarded in absolute terms as a fix proportion of an age- or length-group in the stock that is recruited to the area of fishing for a particular fishery. They express the proportion available to the fishery in relation to the maximum availability to the same fishery, which may only be a small percentage of the whole stock.

The parameters for the recruitment curves are difficult to assess. In general terms the younger age-groups tend to be in the eastern part of the Barents Sea (Sub-area I) or in Division IIb. The older age-groups tends to be farther west and south, in particular the mature part which have the main spawning grounds in Lofoten (Division IIa).

The later the fish recruit the lower the estimated selection ogive becomes and vice versa. None-recruited fish are not subject to fishing mortality. The model also assumes that all of the fish that escape through the trawl net survive. Therefore, possibly wrong recruitment parameters for the eight trawl fisheries, the two long- and hand-line fisheries, and gill-net in Sub-area I, are compensated for by the estimated selection curve of the gears. The fixed recruitment parameters therefore have little effect on the estimated parameters for gill-net in Division IIa.

The recruitment parameters for gill-net are not input parameters (except for a first quess) as that is what is to be estimated by these simulations.

The figures for de-recruitment (Table 1) are of little importance in the present context. We do, however, believe that they are not biological unreasonable, and they generally give a better fit between the observed and estimated distributions, i.e. the catches by age or length, or the fishing mortalities.

d) Discard parameters

In the case of the two USSR trawl fisheries no discards are assumed to take place.

No discards were assumed to take place in the case of "Other countries" either, although this is hardly the case for all of the fisheries included in this "rag-bag" category. However, due to the relative small importance of this category this error is regarded as neglectable.

Observations on discard from Norwegian trawlers can be found in Hylen (1965, 1967 and 1969) and Hylen and Smedstad (1974). On the basis of the latter reference which reports on investigations in 1973, a discard curve with 50% and 25% discards at 41.5 cm and 43.5 cm respectively was established. This discard curve was applied to the three UK and the two Norwegian trawl fisheries as well as the four gill-net and line fisheries.

Considerable uncertainties are connected with the discard curves as it probably vary much between fisheries, areas, years and seasons, and it problably depends on the the catch rates. This add much uncertainty to some of the the estimated lengths at 50% selection of the different fisheries. There are, however, probably five exceptions to this reservation. The two first being the USSR trawl fisheries where discards are minimal or none-existent. Furthermore the two gill-net fisheries and the long- and hand-line fishery in Division IIa land few fishes below 50 cm. This is not due to a seperate discard practice, but mostly due to minimal availability of the smaller fishes in Division IIa to these gears.

e) Fishing mortalities (EF(e))

The maximum fishing mortalities (EF(e)) for the individual fisheries (e) were adjusted so that the estimated number caught in proportion to the total number caught by all fisheries (Table 2) corresponded to the observed proportion in 1967-1977 (Table 1). The obtained values of EF(e) which were based on simulating the age data, are given in Table 1. These values of EF(e) were also applied to the length data.

f) Natural mortality (M)

A constant M of 0.20 for all age-groups was chosen. This is in line with the practice by the Arctic fisheries working group (Anon. 1983).

RESULTS

The estimated lengths at 50% selection of the fisheries, the estimated yield and the contribution to the object function (chi-square) from the individual fisheries are given in Table 2.

The observed and the estimated age and length distributions are shown in Figs. 2-13 for the individual fisheries, and in Fig. 14 for the total fishery. Figs. 2-14 also show the estimated and the observed fishing mortalities. The observed fishing mortalities are the average for the years 1967-1977, and are derived from a VPA by splitting the total F's (Anon. 1983) between the individual fisheries on the basis of the catch at age data.

In the case of the two gill-net fisheries the estimated recruitment parameters are given in Table 3. The maturation ogive (MAT(L)) as a function of length L is given by the equation:

MAT(L) = 1/(1 + EXP(-(L-RL50%)Log3/(RL75%-RL50%)))

RL50% and RL75% are the lengths at 50% and 75% recruitment in Division IIa as derived from the gill-net fishery in this area (Table 3, Fig. 15).

DISCUSSION

The estimated catch distributions follow the observed catch distributions relatively good, both in the case of the age data (Figs. 2a-14a) and the length data (Figs. 2b-14b).

The fit between the estimated and the observed fishing mortalities (Figs. 2c-14c), which are not part of the simulations, are more variable. In the case of the total fishery (Fig. 14c) the estimated fishing mortalities on 10 to 13 year olds are about 0.5 higher than the observed one. This is mainly due to the estimated fishing mortalities for long-line and gill-net in

Division IIa (Fig. 11c and Fig. 13c). In order to get a simulated catch close to the observed one (Tables 2, 3) the fishing mortalities on these two spawning fisheries had to be increased considerably over the observed ones (Fig. 11c, 13c).

It is also seen (Table 2) that the estimated length at 50% selection generally tends to be lower for the simulations based on the length data than on the age data.

The initial stock estimates (1 year olds) are 1176 x 10^6 and 1083 x 10^6 in the case of the age- and the length-distributions respectively. It is the 1953-1976 year-classes that contribute to the age composition data (1-14 year olds, 1967-1977), the average of these being 678 x 10^6 at the beginning of age 3 (Anon. 1983, Table 18). Correcting for the assumed natural mortality at 0.2 this figure becomes 1011 x 10^6 at age 1. A minor addition (15 x 10^6) to this figure is due to discards (estimated from simulations) and catches of 1 and 2 year olds with some correction for natural mortality. The corrected total from VPA is thus roughly 1025 x 10^6, i.e. 5-13% below the initial stock figure as derived from these simulations. Considering the equilibrium assumption on which the mesh assessment model is constructed, we do not consider this to be an unacceptable difference.

The observed total number caught in the years 1967-1977 is 463,062 x 10^3 (Table 1), fairly close to the estimated total catch of 449,791 x 10^3 and 443,131 x 10^3 for the two catch distributions respectively (Table 2).

There are two problems with the way the von Bertalanffy equation is used in the present study. The first being that the same equation is applied to all of the fisheries, while fishes of the same age that occur in different parts of the Barents Sea may have different growth rates. Our intention of using data from the eastern part of the Barents Sea in the case of the younger age-groups and combine them with data from the Lofoten for the older ones in order to estimate the parameters in the von Bertalanffy equation was to establish a kind of "average" curve for the fish that dominates the catches.

A second problem would be that the von Bertalanffy curve is applied in a deterministic way, while in reality there is a scatter around the "average" curve. This becomes a problem when there is a considerable overlap of the length distributions for the different age-groups. As Jones (1974) notes the relationship between the mean length and the age, versus the relationship between the length and mean age are not neccessarily the same, the latter one generally shows a greater growth rate. This factor problably being the main reason why the estimated parameters depends somewhat on whether the basis for the simulation is the observed age- or the length- distributions. However, the length distributions and the age distributons give similar recruitment curves for gill-net, in particular in Division IIa. This indicate to us that the von Bertalanfffy parameters used are reasonable "averages".

There are a more general problem with the estimation of parameters that are pertinent to this study. That is the effect of correlations between the estimated parameters, which are always to increase the errors on the other parameters. If any of these two-by-two correlations get close to plus or minus one, that increase the difficulty to get an unique set of parameters from the model or the data available.

In the present case the great majority of the two-by-two correlations were close to zero (<0.20). However, in the case of gill-net, in particular for the gill-net fishery in Division IIa, there were rather high correlations between the parameters, i.e. r(RL50%, RL75%/RL50%) = 0.81 and 0.82 on the basis of the age data and the length data respectively. This is also reflected in the global correlations (Eadie et al. 1971, p. 23) as given in Table 4.

In the case the gill-net fishery in Division IIa, the high correlations indicate that an increase in the length at 50% recruitment (RL50%) is to a large extent compensated by a less steep slope (RL75%/RL50%). These high correlations are also reflected by the elongated shape of the confidence regions for these two parameters (Fig. 16).

The standard deviations of the lengths at 50% selections (Table 2) are in the range 0.1 to 2.5 mm. These standard deviations assume that all of the input data, except for the observed age- (or length-) distributions are correct and not subject to uncertainty. The estimates of the lengths at 50% selection are on the average about 5 cm larger when using the age data than the length data. This as well as our own experience from preliminary simulations with different fixed input parameters indicate that the true standard deviations of the length at 50% selection (or recruitment) may well be an order higher than those given in Table 2. Although the estimated standard deviations indicate that the coefficient of variation of the estimated parameters varies considerably between the different fisheries (Table 2).

Contrary to some of the other fisheries the parameters for discards are not important in the case of gill-net, as also mentioned earlier. Since the selection parameters could be fixed from independent experiments for gill-net, the recruitment curve could be estimated rather than fixed on the basis of circumstantial evidence. This should give the estimated parameters for gill-net (Table 3) more trustwórthiness than those for the other fisheries. However, the the considerations on the von Bertalanffy equation given above, the relatively high correlation coefficients for the four estimated parameters of the gill-net fishery (Table 4), and finally the relatively poor fit between the observed and estimated fishing mortalities (Fig. 11c) errode some of our confidence in the estimates.

As also mentioned earlier, the two recruitment curves which are derived from the age composition and the length-composition of the gill-net fishery in Division IIa, may be considered as maturity ogives.

In Fig. 15 the two maturity ogives as derived from the present investigations are drawn together with the maturity ogive given by Hylen and Dragesund (1973) which should represent the years 1967-1969, and data from Ponomarenko et al. (1980, 1982) which apply to the period 1967-1977. They are all similar except for the younger age-groups (≤9 years) where our model suggest about 1 year's later maturation. However, our estimates of the onset of maturation is to a large extent determined by the selection curve for gill-net. It should be evident from Fig. 1 that this curve is not very well defined for length-groups up to about 80 cm, i.e. fishes 8 years or younger.

CONCLUSION

We are unable to assess which of the maturity curves (Fig. 15) reflects the situation in the period 1967-1977 most accurately. However, depending on an independent assessment of input parameters this study does indicate that a modified mesh assessment model may be an useful approach to estimating maturity ogives in some cases.

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Table 1. North-east Arctic cod. Input parameters in model for the each of the 12 fisheries into which the total fishery is splitted. (S.-a. = Sub-area, Div. = Division)

Von Bertalanffy parameters: TO = 0.226, K = 0.0677, L8 = 200 cm. Natural mortality (M) = 0.20

Fishery		"steepness" of selection curve	Recruitment[1] 50% (cm)	Recruitment[1] 75% (cm)	Derecruitment[1] 50% (cm)	Derecruitment[1] 75% (cm)	Discard 50% (cm)	Discard 75% (cm)	Maximum fishing mortality	Observed catch in numbers ($x\ 10^{-3}$)
USSR trawl	S.-a. I	1.09	16.5(1.5)	28.5(2.5)	103.6(11)	96.8(10)	no discard		0.179	206 318
USSR trawl	Div.IIb	1.09	34.2(3)	45.1(4)	131.3(16)	118.6(13.5)	no discard		0.084	60 023
UK trawl	S.-a. I	1.09	34.2(3)	45.1(4)	89.6(9)	73.6(7)	41.5	43.5	0.063	37 215
UK trawl	Div.IIa	1.09	64.7(6)	81.8(8)	no derecruitment		41.5	43.5	0.039	8 917
UK+Norway trawl	Div.IIb	1.09	34.2(3)	45.1	96.8(10)	89.6(9)	41.5	43.5	0.015	12 959
Other countries trawl		1.09	81.8(8)	115.8(13)	no derecruitment		no discard		0.069	44 488
Norway trawl	S.-a. I	1.09	50.2(4.5)	60.1(5.5)	89.6(9)	73.6(7)	41.5	43.5	0.087	38 984
Norway trawl	Div.IIa	1.09	64.7(6)	81.8(8)	115.8(13)	103.6(11)	41.5	43.5	0.047	9 815
Gillnet	S.-a. I	2)	73[3]	80[3]	105[3]	97[3]	41.5	43.5	0.130	2 352
Gillnet	Div.IIa	2)	73[3]	80[3]	105[3]	97[3]	41.5	43.5	1.523	14 388
Long- & hand-line	S.-a. I	1.13	50.2(4.5)	60.1(5.5)	109.9(12)	96.8(10)	41.5	43.5	0.037	17 937
Long- & hand-line	Div.IIa	1.13	81.8(8)	89.6(9)	no derecruitment		41.5	43.5	0.509	9 666
Total										463 062

1) The corresponding age in years are given in brachets.

2) To be estimated by the model.

3) Not recruitment parameters, but parameters describing the ascending and decending selectivity of gillnet as determined by experiments (Hylen and Jakobsen 1979).

Table 2. North-east Arctic cod. Results from simulation based on the 1967 - 1977 catch data.

Fishery		AGE DATA			LENGTH-DATA		
		50% Selection ± S.D. (cm)	Estimated catch in numbers ($x10^{-3}$)	CHI-SQUARE	50% Selection ± S.D. (cm)	Estimated catch in numbers ($x10^{-3}$)	CHI-SQUARE
USSR trawl	S.-a. I	42.10 ± 0.02	201 265	4476.6	35.89 ± 0.01	213 289	5747.6
USSR trawl	Div.IIb	49.67 ± 0.03	58 773	1306.9	43.27 ± 0.04	62 410	2052.9
UK trawl	S.-a. I	49.72 ± 0.04	36 186	2085.0	45.51 ± 0.07	34 275	927.3
UK trawl	Div.IIa	51.61 ± 0.15	8 471	519.0	43.35 ± 0.07	7 983	437.8
UK + Norway trawl	Div.IIb	43.83 ± 0.13	12 583	331.8	41.38 ± 0.07	10 574	873.3
Other countries' trawl		35.37 ± 0.09	43 207	1561.2	28.23 ± 0.10	36 082	3410.8
Norway trawl	S.-a. I	49.84 ± 0.06	37 966	1107.0	47.14 ± 0.03	32 513	1808.3
Norway trawl	Div.IIa	53.11 ± 0.12	9 488	407.4	49.42 ± 0.16	8 119	561.1
Gillnet	S.-a. I	-[1)]	2 136	130.3	-[1)]	2 194	103.3
Gillnet	Div.IIa	-[1)]	13 224	326.7	-[1)]	12 028	1399.7
Long- & Hand-line	S.-a. I	50.72 ± 0.09	17 667	405.1	45.93 ± 0.17	15 917	461.1
Long- & Hand-line	Div.IIa	92.63 ± 0.08	8 825	545.4	86.07 ± 0.25	7 747	2144.7
TOTAL			449 791	13202.6		443 131	19928.1
Number of 1 year olds		$1175.9 \times 10^6 \pm 0.8 \times 10^6$			$1082.8 \times 10^6 \pm 1.0 \times 10^6$		

1) The length of 50% selection by the gear is not estimated. Instead the 50% and 75% recruitment is estimated (See Table 3).

Table 3. Estimated recruitment curves for the gillnet fisheries. Length ± S.D. at 50% recruitment, and the ratio between the length at 75% and 50% recruitment ± SD.

	Age data		Length-data	
	50% (cm)	75% / 50%	50% (cm)	75% / 50%
S.-a. I	99.8 ± 1.9	1.1238 ± 7×10^{-4}	92.8 ± 0.6	1.119 ± 2×10^{-3}
Div. IIa	94.5 ± 0.5	1.0603 ± 2×10^{-4}	93.3 ± 0.1	1.0681± 3×10^{-4}

Table 4. Global correlation coefficients of the estimated parameters as derived from the two sets of catch distributions.

Parameter		Age-data	Length-data
USSR, trawl	S.-a. I ; L50%	0.12	0.01
" "	Div.IIb ; L50%	+	0.03
UK, trawl	S.-a. I ; L50%	0.01	+
" "	Div.IIa ; L50%	0.01	+
UK + Norway trawl	Div.IIb ; L50%	0.08	0.01
Other countries' trawl	; L50%	0.05	+
Norway trawl	S.-a. I ; L50%	0.07	+
" "	Div.IIa ; L50%	0.01	+
Gill-net	S.-a. I ; RL50%	0.55	0.34
"	Div.IIa ; RL50%	0.68	0.69
Long- and hand-line	S.-a. I ; L50%	+	+
" " "	Div.IIa ; L50%	0.17	0.03
Gill-net	S.-a. I ; L75%/L50%	0.52	0.32
Gill-net	Div.IIa ; L75%/L50%	0.69	0.69
Stock estimate (1 year olds; 15 cm); N(TI)		0.01	+

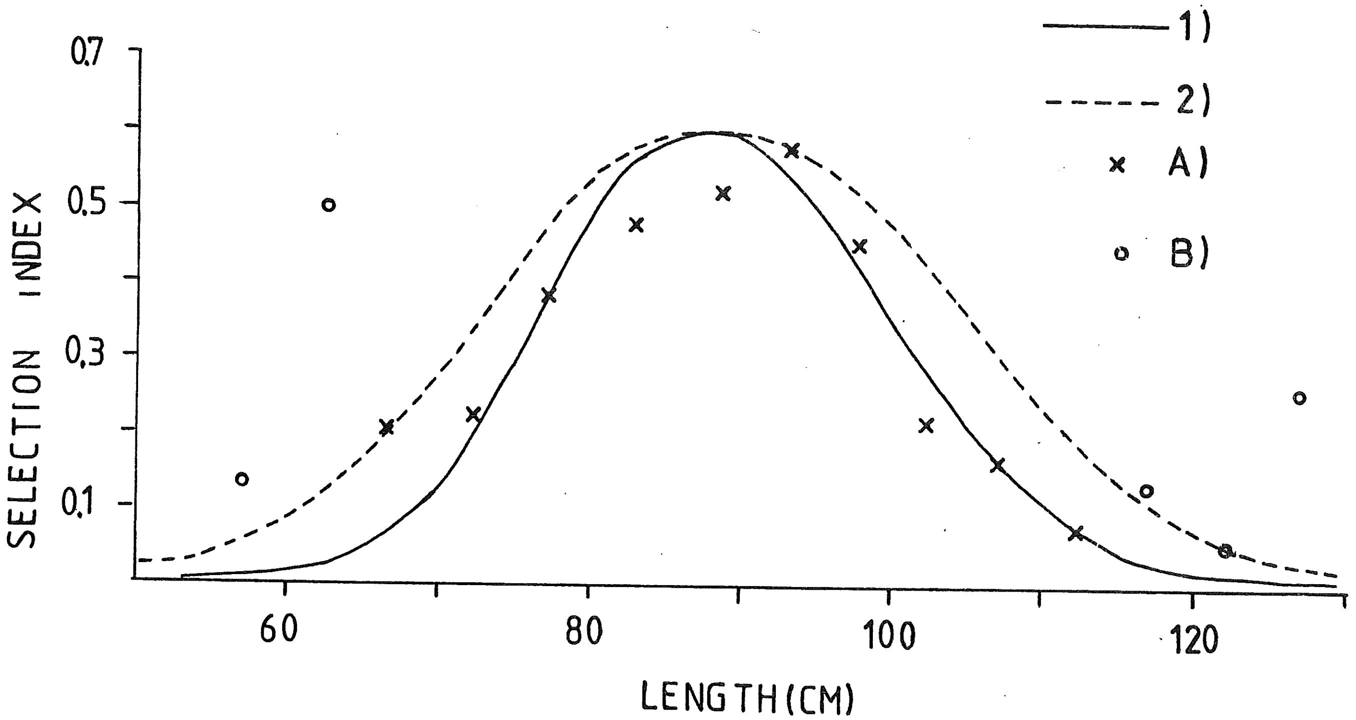

Fig. 1. Northeast Arctic Cod. Selection index for nylon gill nets. Redrawn from Hylen and Jakobsen (1979). Legend: 1) Line fitted on the basis of points A (Hylen and Jakobsen 1979). 2) Refitted line based on both sets of points A and B.

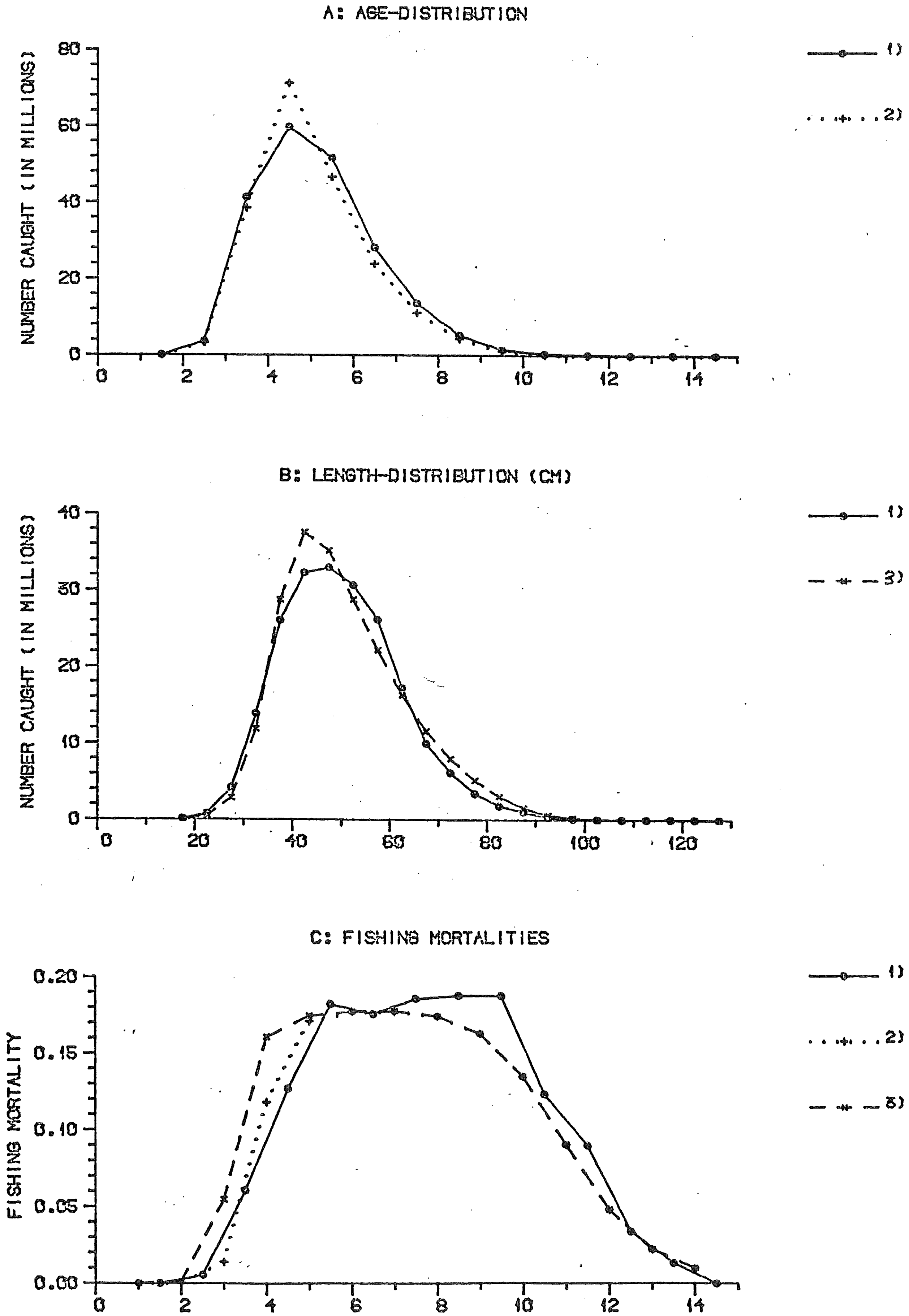

FIG.2. USSR TRAWL SUB-AREA I. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

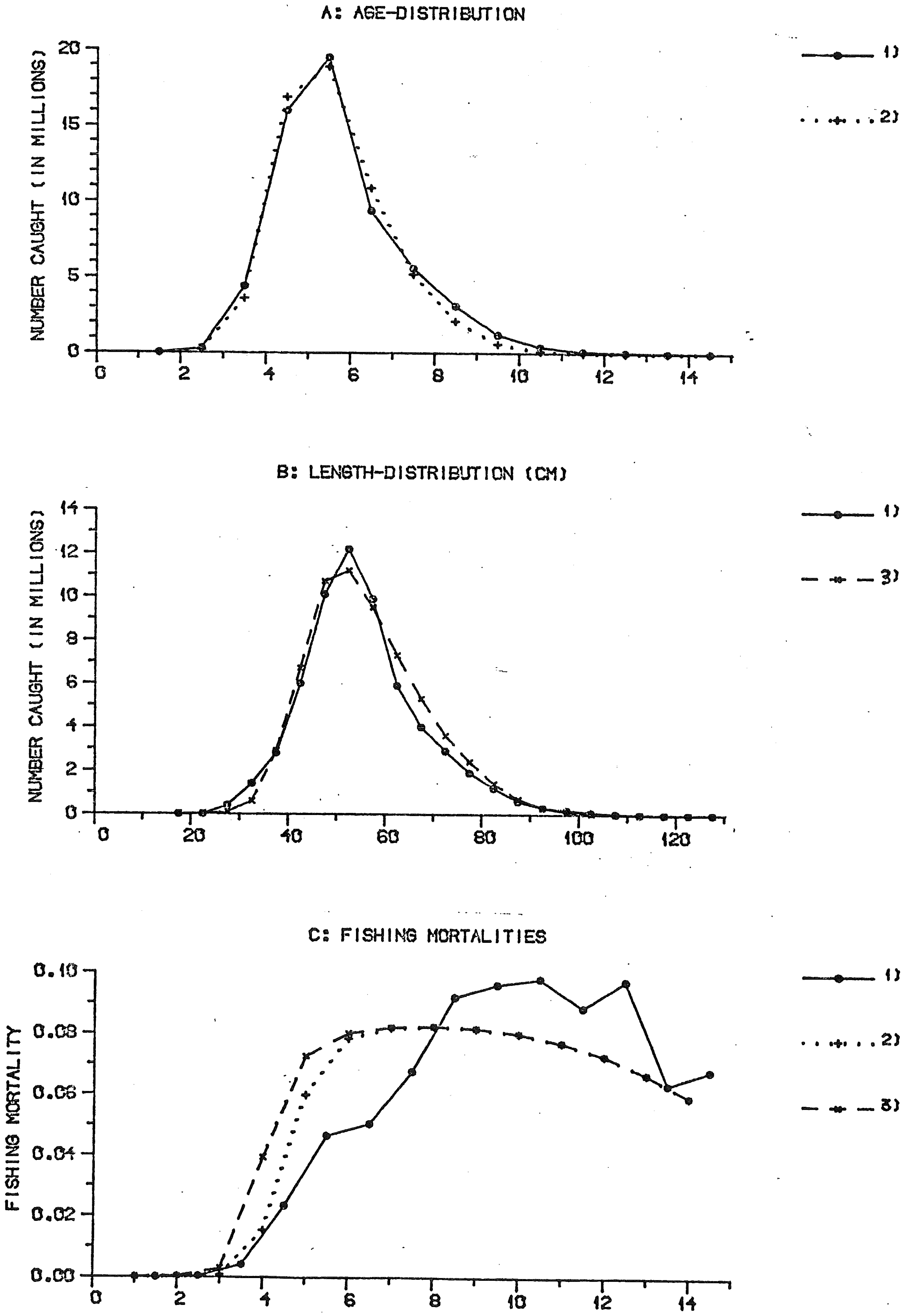

FIG.3 . USSR TRAWL DIV. IIB. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

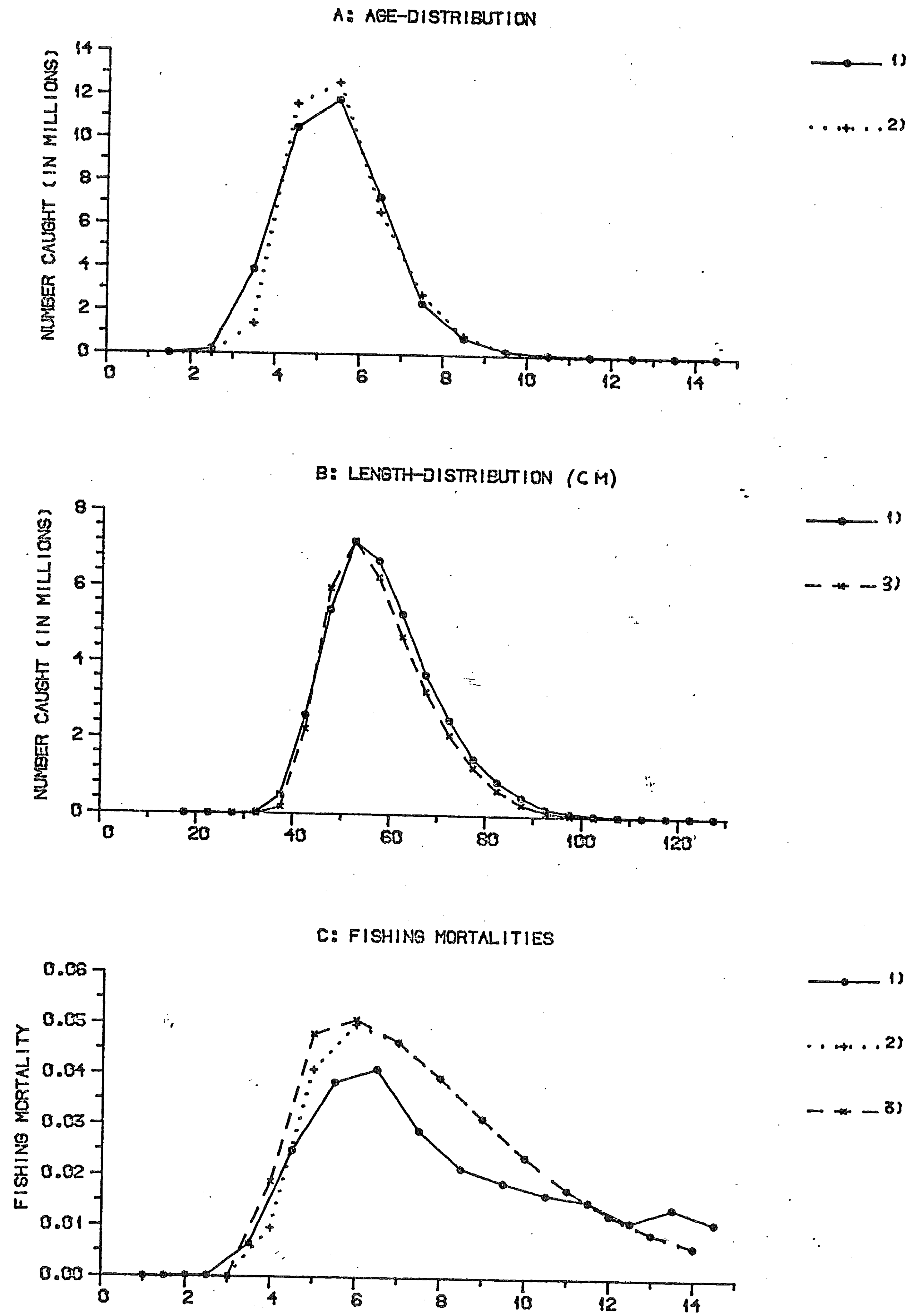

FIG. 4. UK TRAWL SUB-AREA I. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

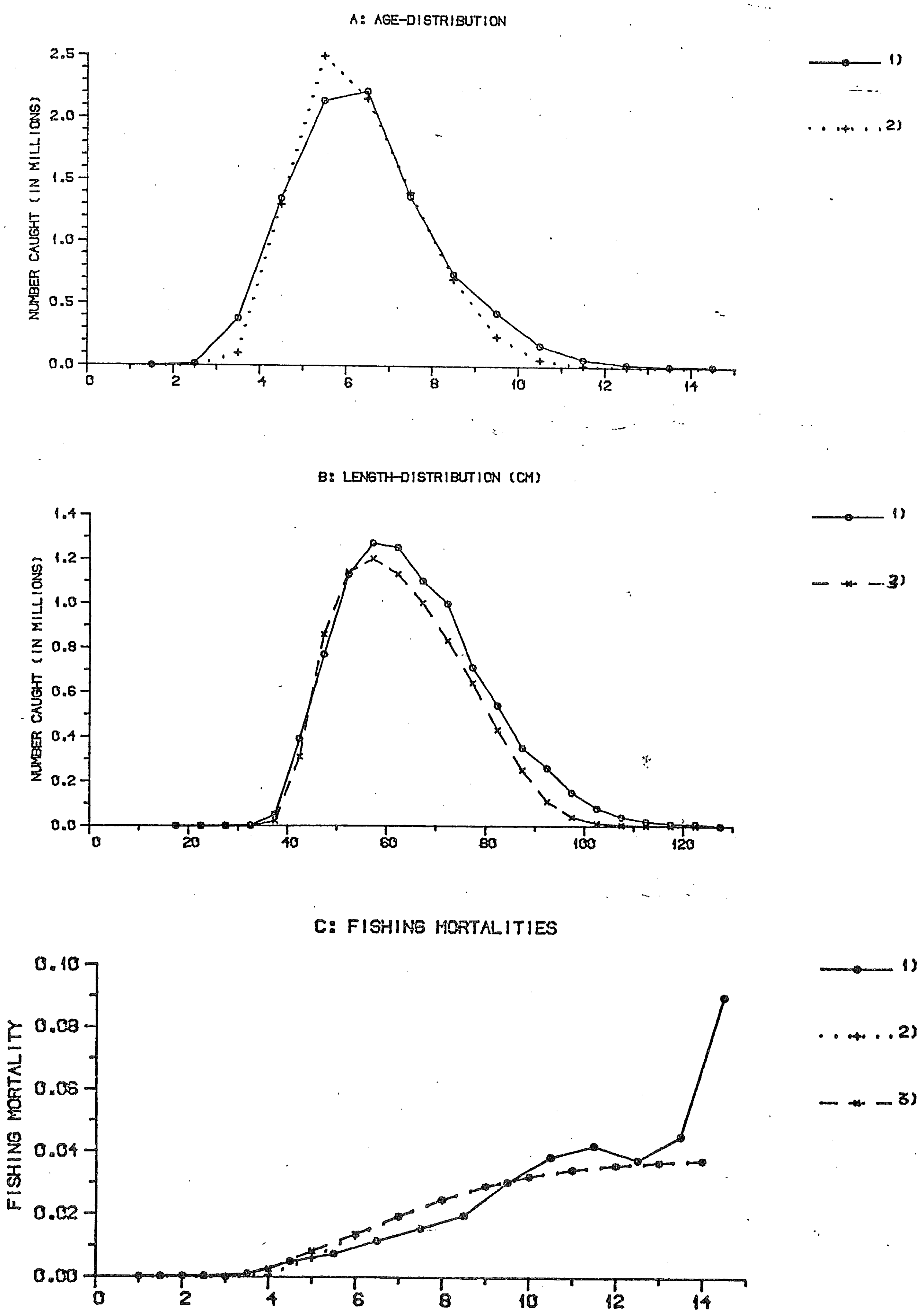

FIG.5 . UK TRAWL DIV.II A. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

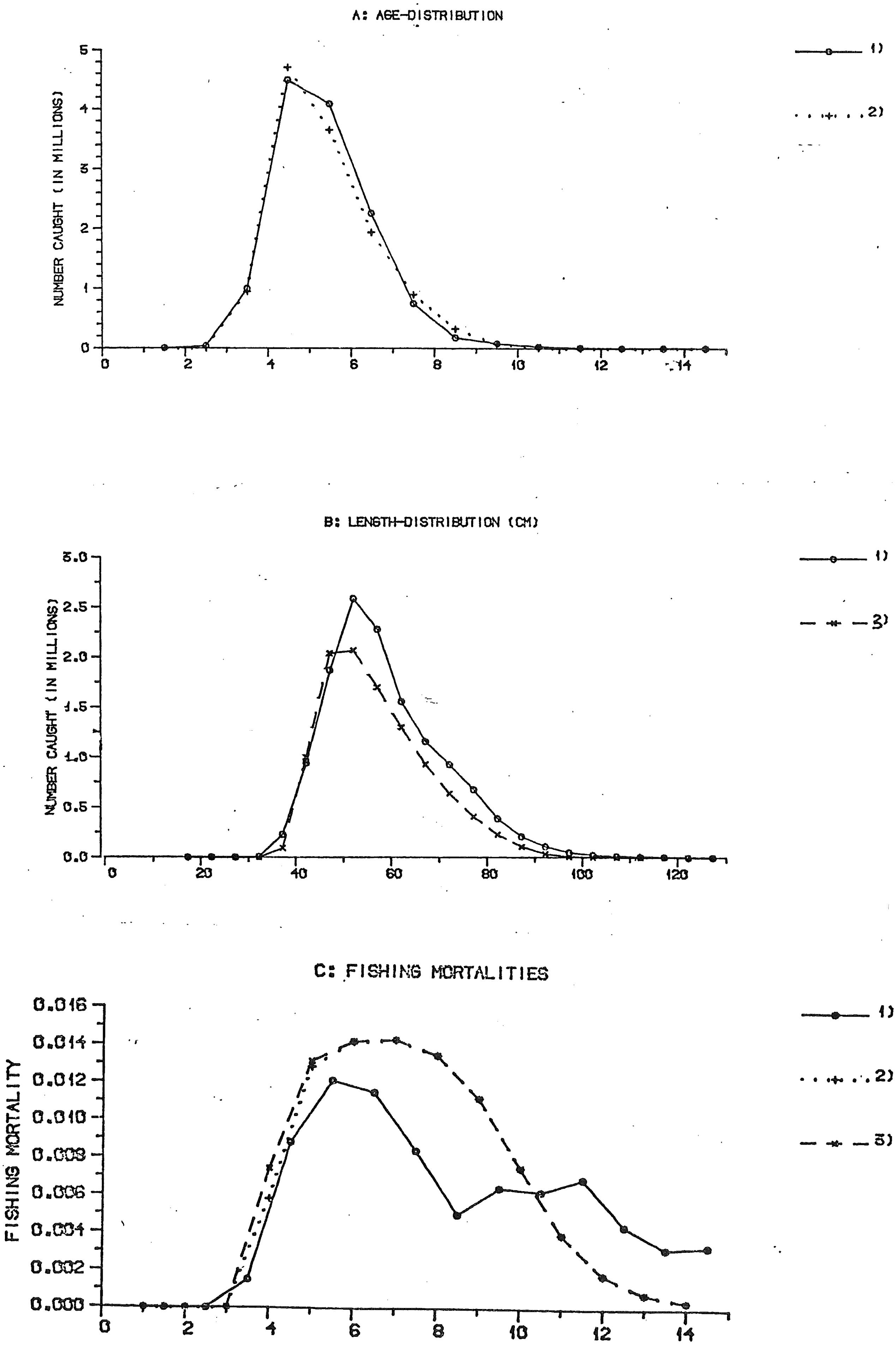

FIG. 6. UK + NORWAY TRAWL DIV. IIB. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

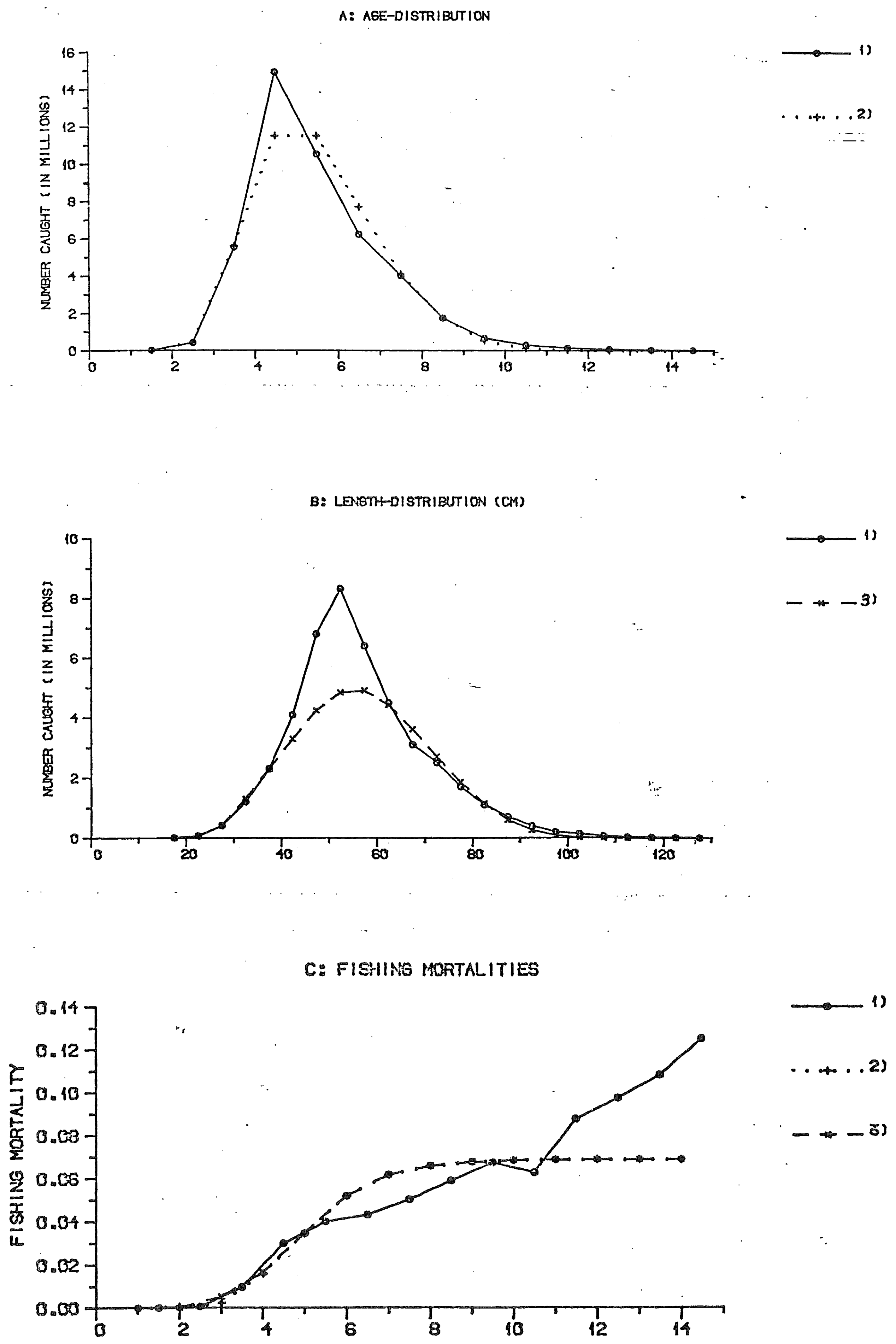

FIG. 7. OTHER COUNTRIES' TRAWL. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

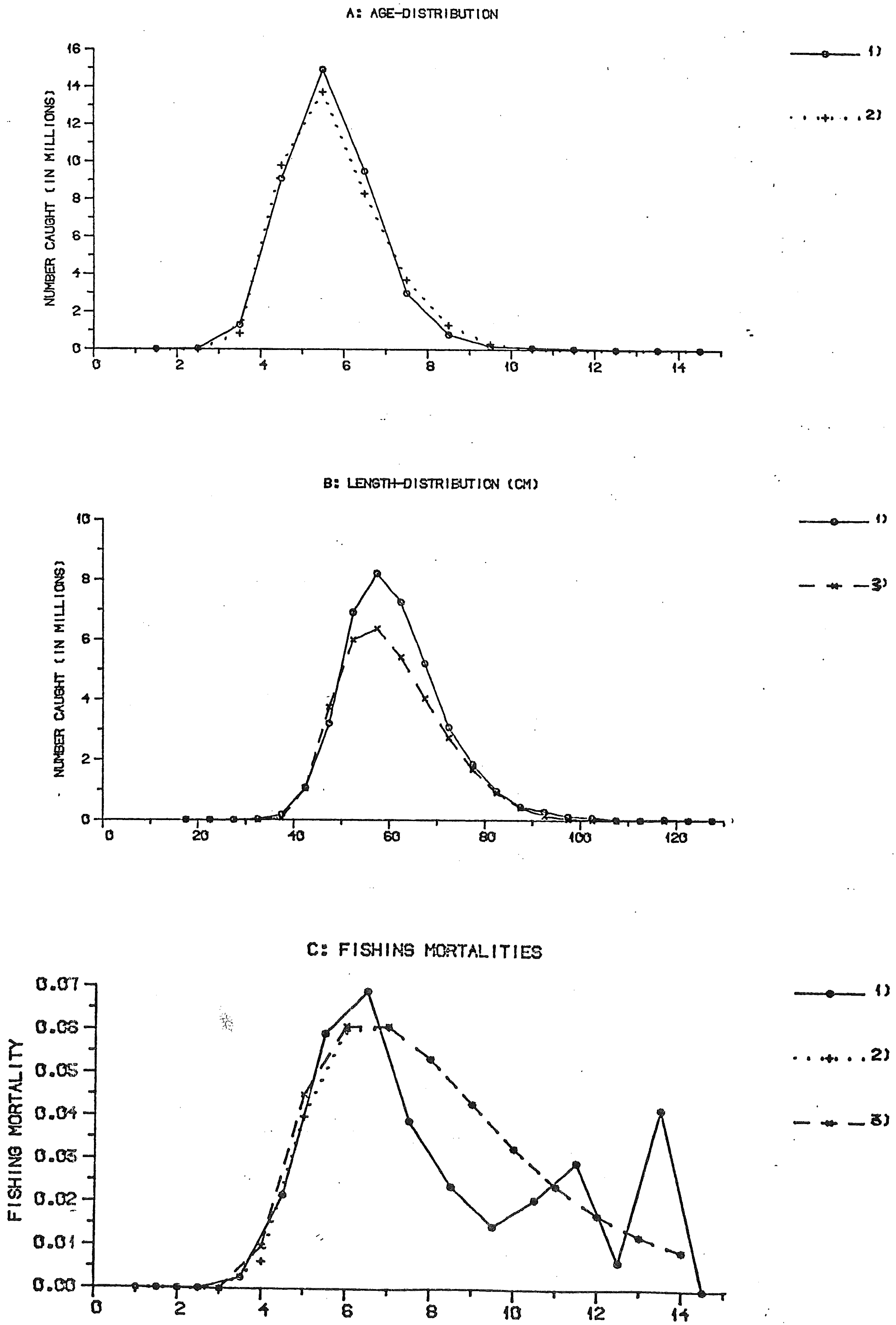

FIG. 8. NORWAY TRAWL SUB-AREA I. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

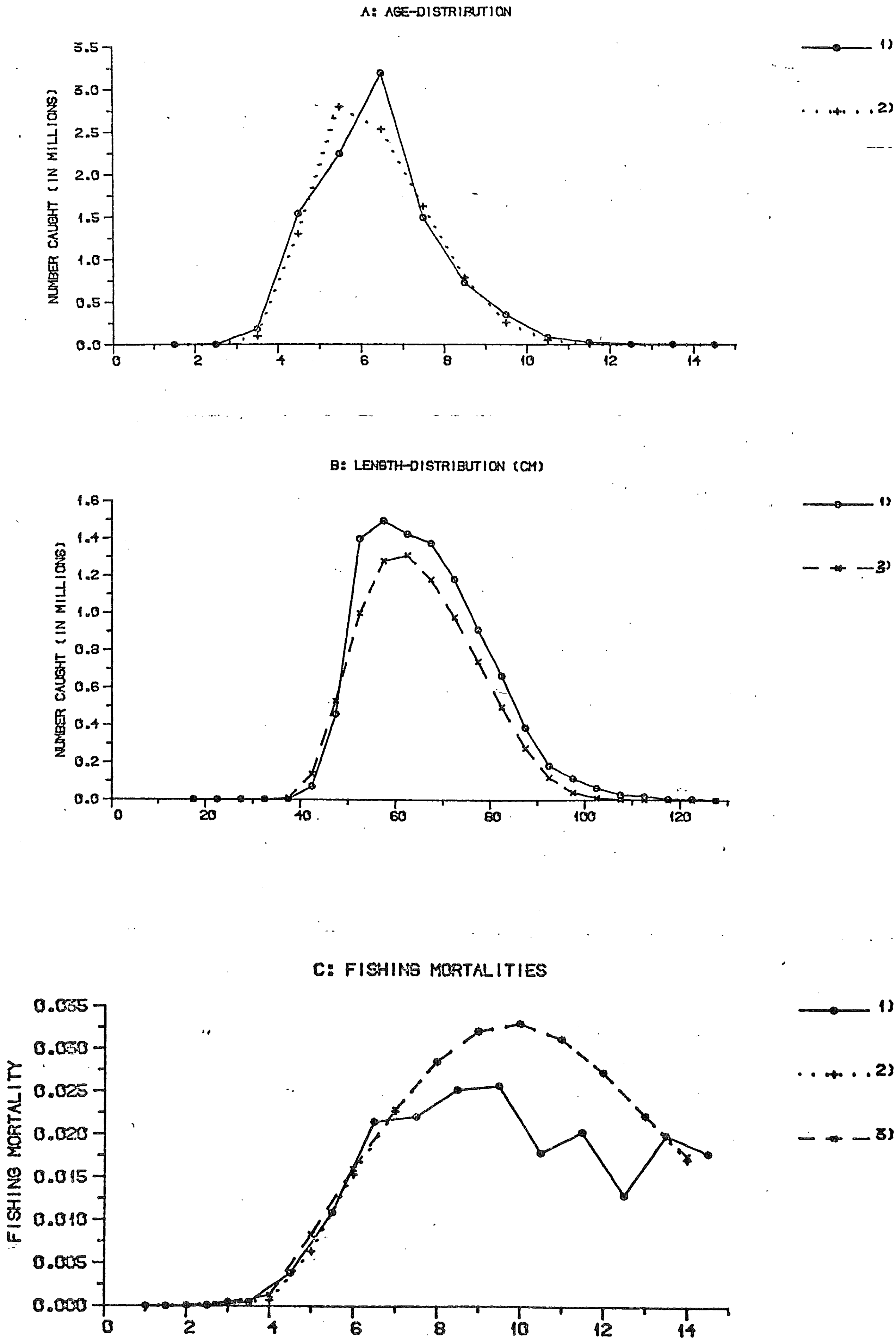

FIG.9 . NORWAY TRAWL DIV.IIA. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

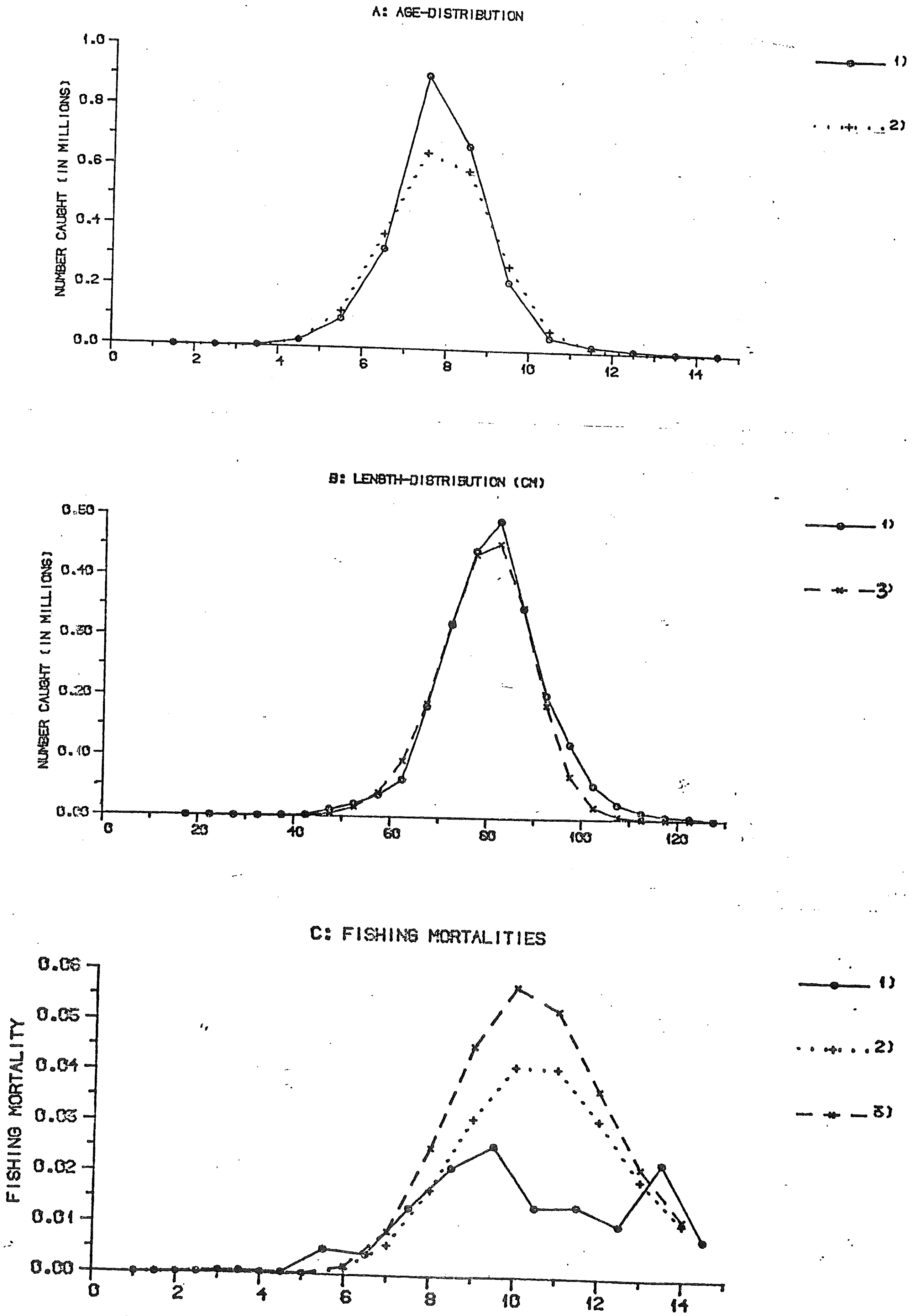

FIG.10. GILLNET SUB-AREA I. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

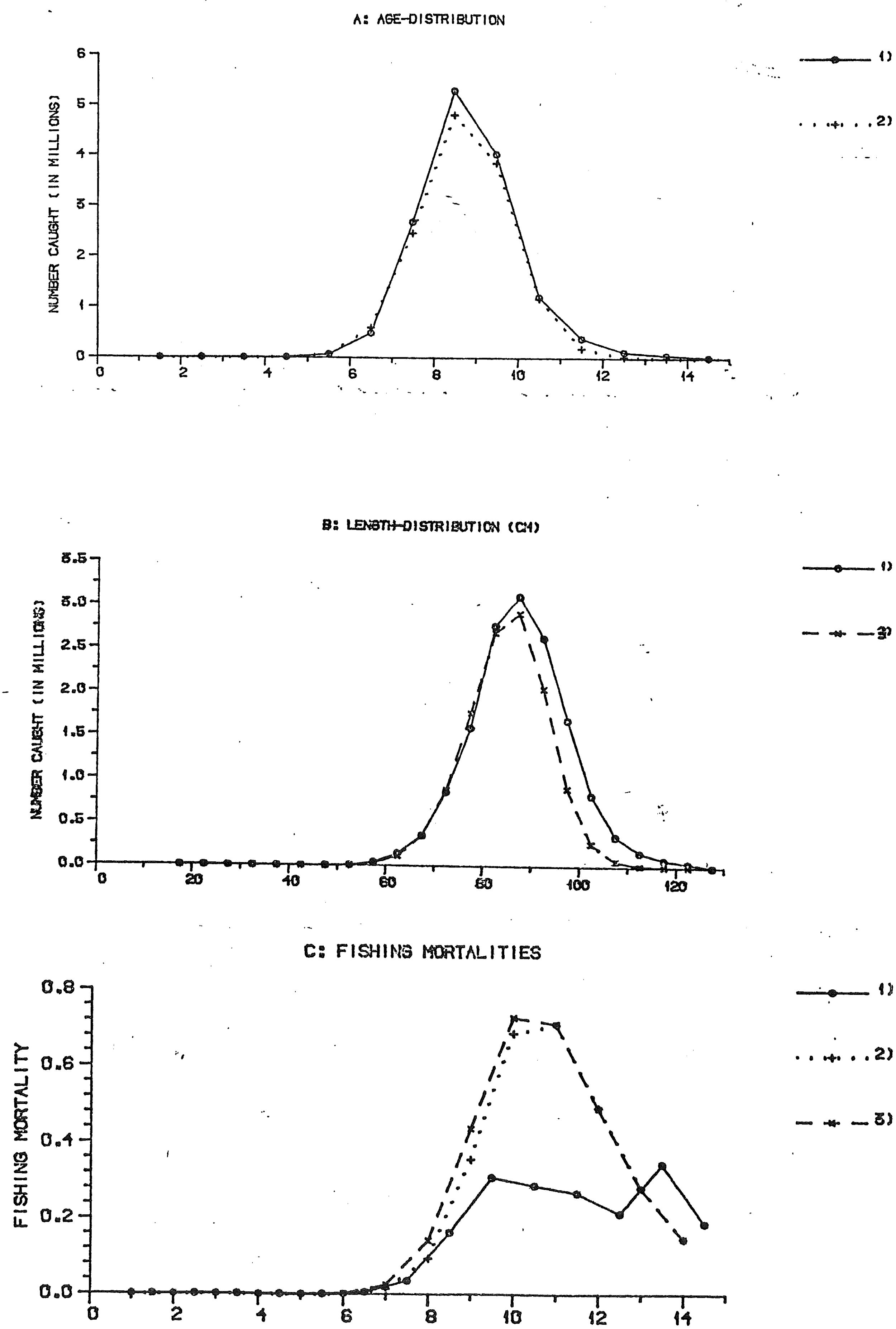

FIG.11. GILLNET DIV. IIA. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

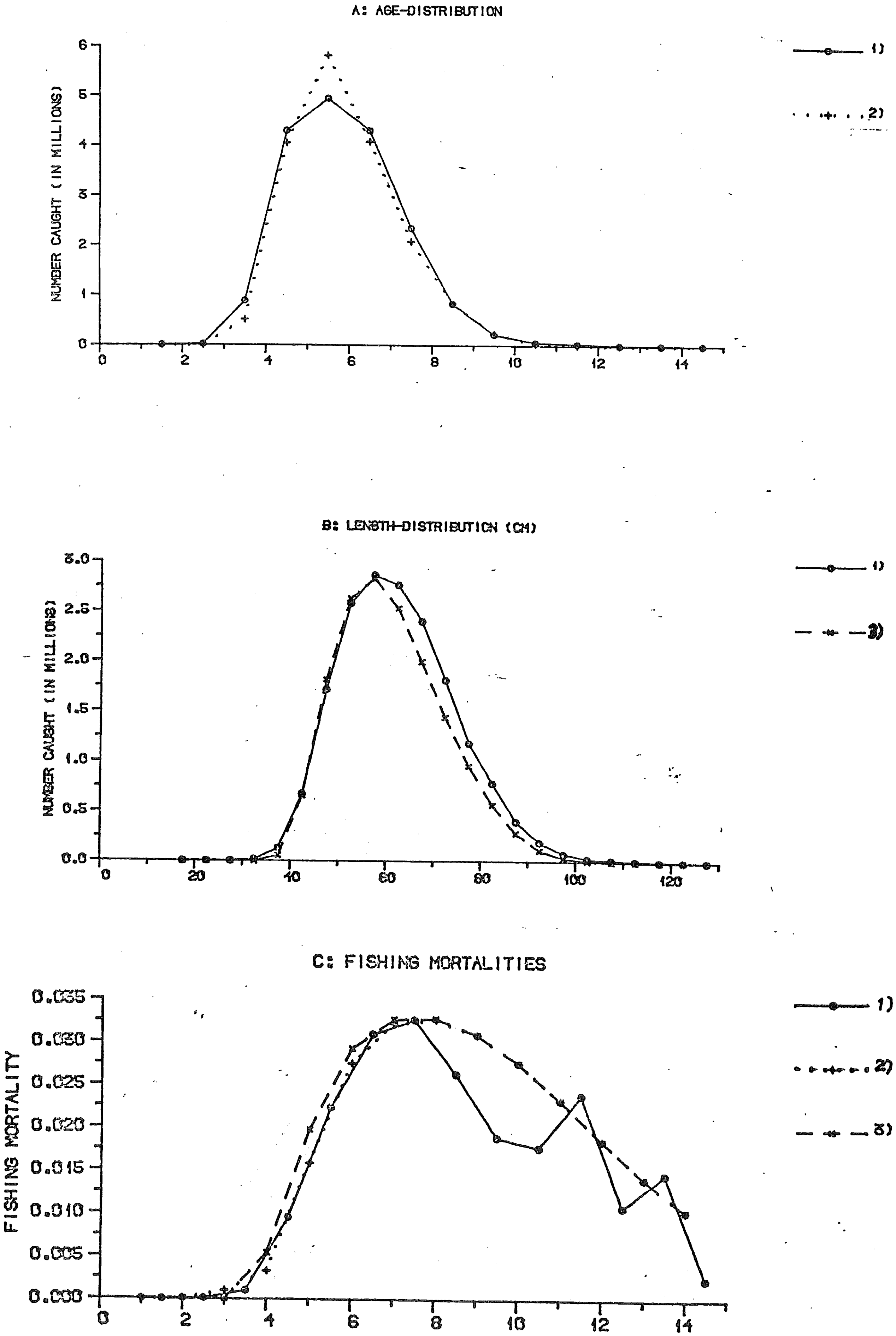

FIG.12. LONG & HAND-LINE SUB-AREA I. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

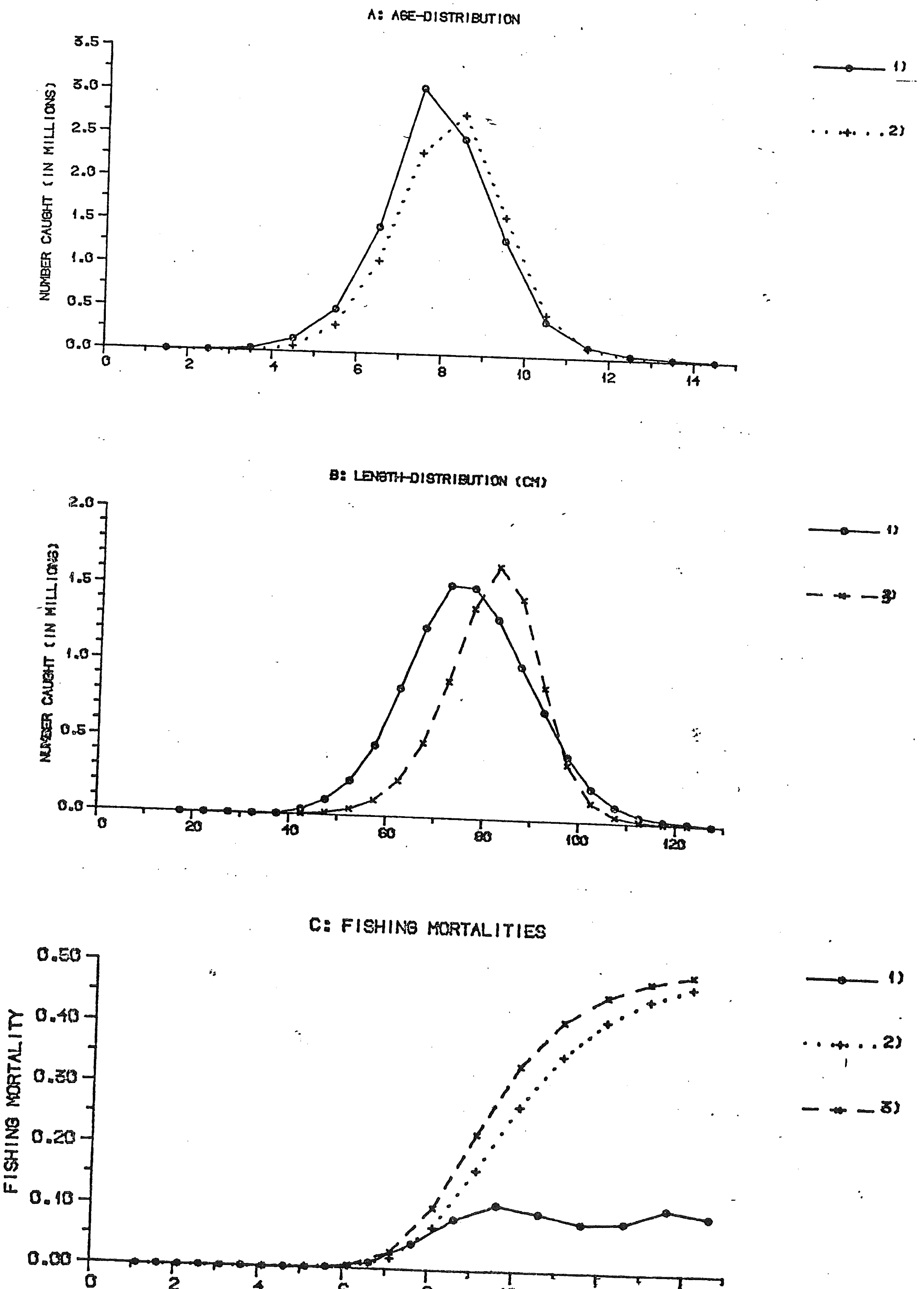

FIG.13. LONG & HAND-LINE DIV. IIA. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

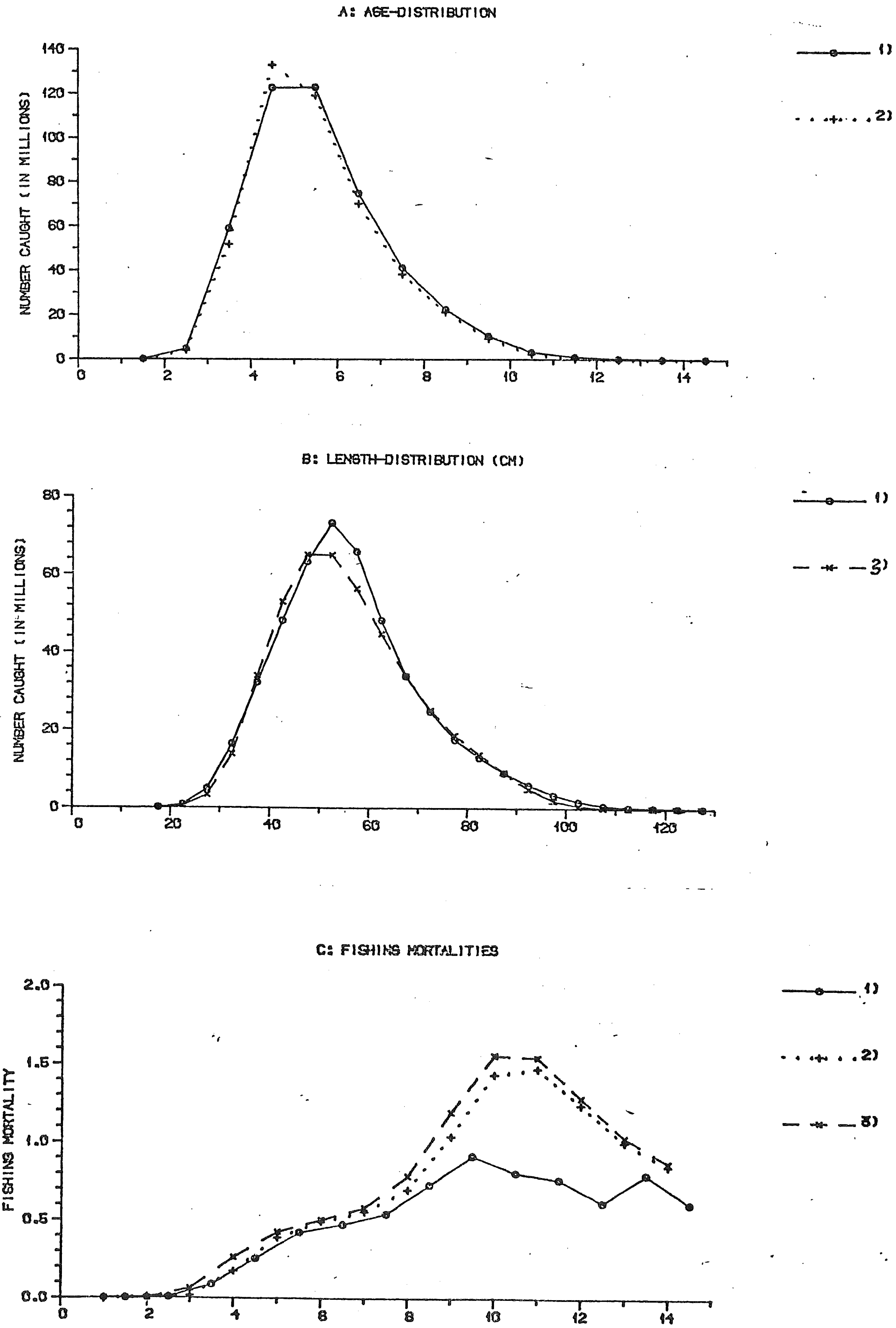

FIG.14. TOTAL FISHERY. 1) OBS. 2) EST. (AGE) 3) EST. (LENGTH)

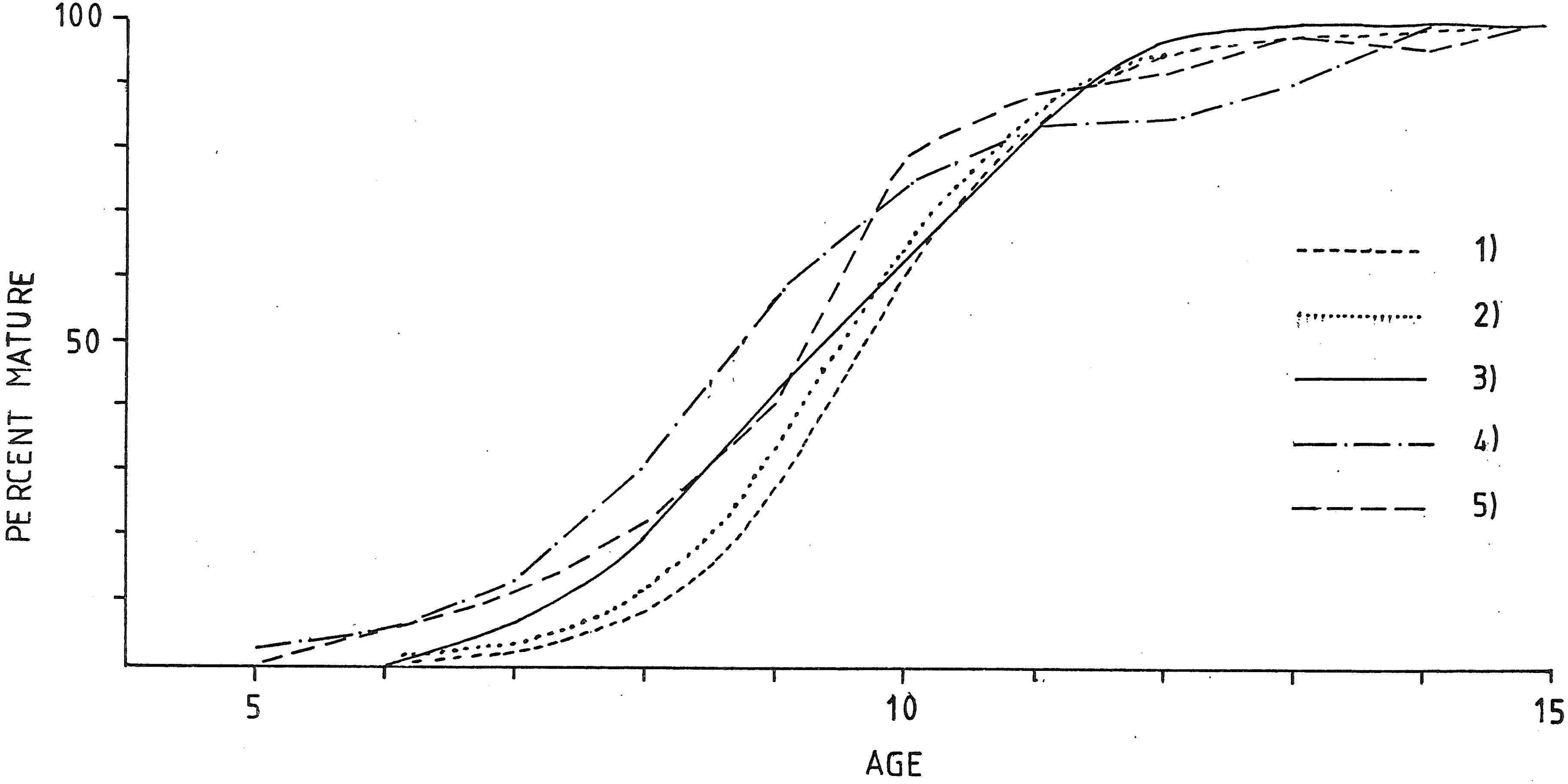

Fig. 15. Northeast Arctic Cod. Maturity ogives. Legend: 1) From catch at age data. 2) From catch at length data. 3) From Hylen and Dragesund (1973). 4) From Ponomarenko <u>et al</u>. (1980). 5) From Ponomarenko (1982).

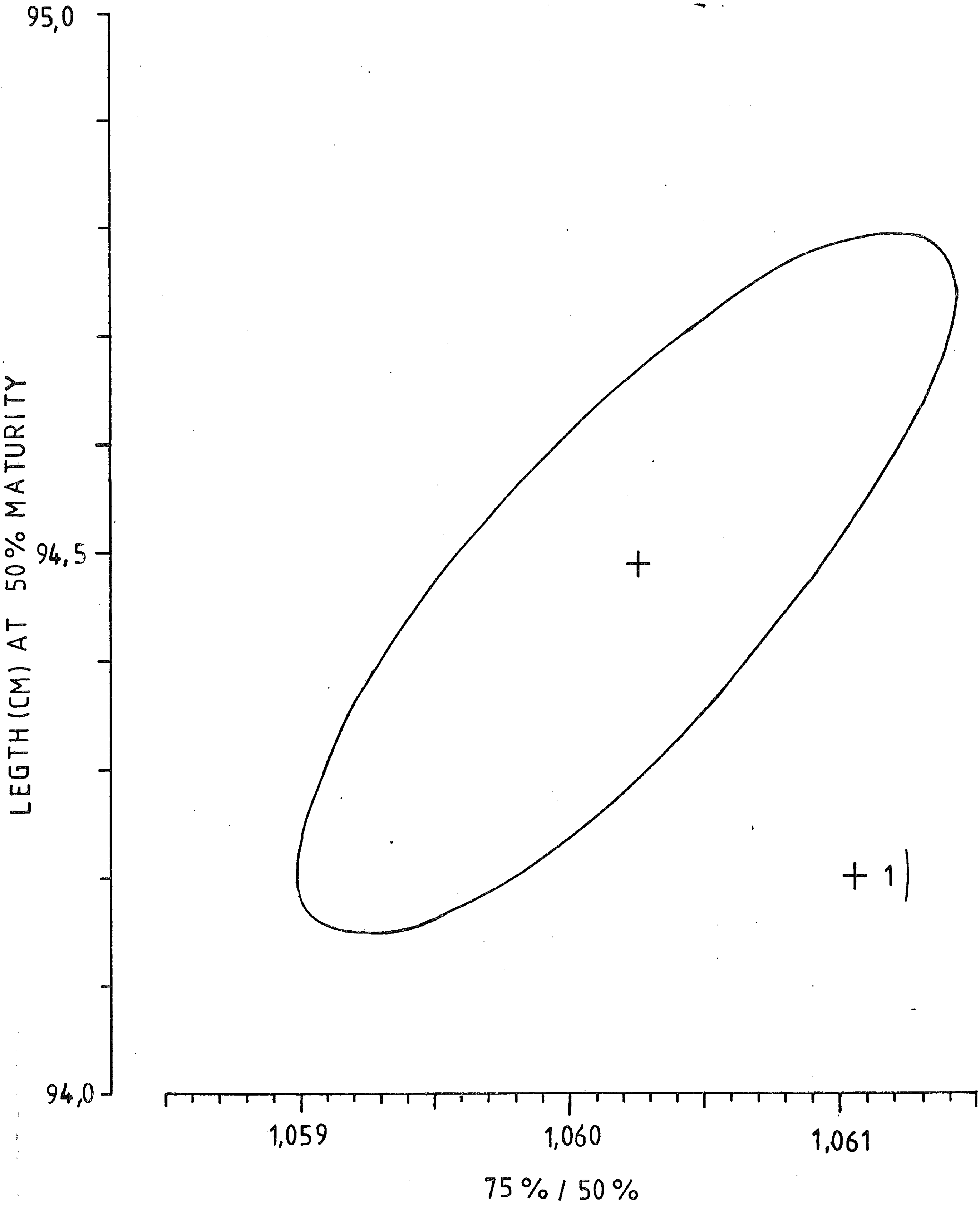

Fig. 16. 95% confidence region of the length at 50% maturity versus the slope of the maturity curve at the inflection point. Legend: 1) Best estimate.