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Selectivity of gillnets in the North Sea, English Channel and Bay of Biscay

by

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Contents

Summary

The gill net selection have been estimated in accordance with the principle of geometrical similarity which imply that selection is determined by the relation between fish size and mesh size. Conceptually the work has been based on the classically methods of indirect estimation of gill net selectivity but the actual estimations have been carried out by the use of non-linear minimizations. Nine different experimental fisheries has been analysed including in some cases the by-catch components. The selection has been described by the use of a common model which was sufficiently flexible to describe the selection of the for species covered (cod, hake, plaice and sole). However, uncertainties were found with regard to the selection towards the the larger individuals which were scarce in the catches.

The selectivity model developed has been implemented to a fleet based prediction model enabling evaluation of the effects of changes of mesh size for North Sea gill net fisheries on yield and biomass of cod, plaice, sole and hake.

The effect of mesh size changes has been evaluated for the Danish North Sea gill net fishery, which is the most important one in that area. The evaluation compared equilibrium yield and spawning stock biomass for a baseline characterized by unchanged mesh size and selectivity with scenarios with mesh size changes. The equilibrium situations occur after about 10 years such that the comparisons should be considered as medium term changes.

1.1 Introduction

1.1.1 Direct and indirect estimation methods.

The size selection of a fishing gear may be defined by a curve expressing for each size group of fish that encounters the gear the proportion of this size group which is being retained. In formal notation the selection curve may be expressed as an array of proportionality constant (S_l) relating the product of fish abundance (N_l)and fishing effort (E) to the catch (C_l) (Hamley, 1975).

$$C_l = S_l * N_l * E \qquad \text{(eq. 1.1)}$$

Selection may be estimated by direct or indirect methods. A method is called direct when an estimate of the fish abundance is available. The most well known example of direct selection estimates are the estimates of trawl selection from covered cod end experiments when the combined catch of the cod-end and the cover is used as an estimate of the fish encountering the gear (N_L). In this case the selection may be directly estimated by $S = C_{codend} / (C_{codend} + C_{cover})$. Direct estimates using the cover approach are, in principle, possible for gears where the catch are encircled by the gear, i.e. trawls, seines, purse seine and traps.

For gears where the catching depends on fish being attached to the gear - jigs, long-line and gill nets the cover approach can not be applied and for these gears the selection must be estimated by the use of indirect methods. The indirect methods requires that several gears differing by hook or mesh size are used simultaneous and further relies on a number of assumptions.

1.1.2 The conceptual framework of the present analysis

The most important assumption commonly made in work on gill net selection is that the selection follows the *principle of geometrical similarity* formulated by Baranov (1948). This axiom states that the selection only depends on the relative geometry of the fish relative to the mesh and implies that the selection only depend on the ratio between fish size and mesh size.

An hypothetical example of three different mesh sizes being in accordance with the principle of geometrical similarity are shown in the upper panel of fig. 1.1. The modal length (the length where full selection occurs which is set to 100%) are found at 25, 30 and 37.5 cm for the mesh sizes 10, 12 and 15 cm, respectively, which implies that full selection are found when the ratio between fish length and mesh size are 2.5. Similarly, the selection is the same for the three curves whenever the ratio between fish length and mesh size are the same. Therefore, when plotting the selection curves against [fish length/mesh size] the three curves will be superimposed (fig 1.1, lower panel). Fish length/mesh size is termed the transformed length. On the transform length axis full selection occurs at the modal value (in some work called the selection factor). The modal length of any mesh-size may be derived by multiplying the modal value by the mesh size.

The selection can not be directly observed. However, if imagining that an equal effort is exerted on a uniform length distribution of fish the catch length distribution in the nets will be proportional to the selection (cf. Eq. 1.1). Considering the principle of geometrical similarity this implies that the length frequency distributions will be identical when plotted against the transformed length. This feature is illustrated in fig 1.2. where catches taken in three length groups are shown. In real life, however, we will expect that the numbers will vary across the length spectre of the stock and in that case the catches in the three length groups will show up as given in the lower panel of fig 1.2. This implies that when plotting the catches taken in different mesh sizes against the transformed length this results in curves of the the same shape but differing with respect to amplitude (in real life a considerable scatter around the curves is to be expected). It should be noted that the relation shown in fig. 1.2 requires that fish of the same size are equally available to all mesh sizes (nets of the different mesh sizes should be of the same size; when tied together different net sections should be randomly permuted to restrict possible border effects).

The simple example given above illustrates the conceptual framework used when basing indirect estimation of gill net selectivity on the principle of geometrical similarity. Many of the classical methods of gill net selection methods are based on drawing the selection curves by eye through the empirical plots similar to fig. 1.2 (e.g. McCombie and Fry (1960) , Kitahara (1970), Jensen (1973).

Fig. 1.1: An illustration of the principle of geometrical similarity. The upper part show the selection curves for three different mesh sizes. The bottom part show than when selection is plotted versus the transformed length (length/mesh size) the three curves have the exact same shape.

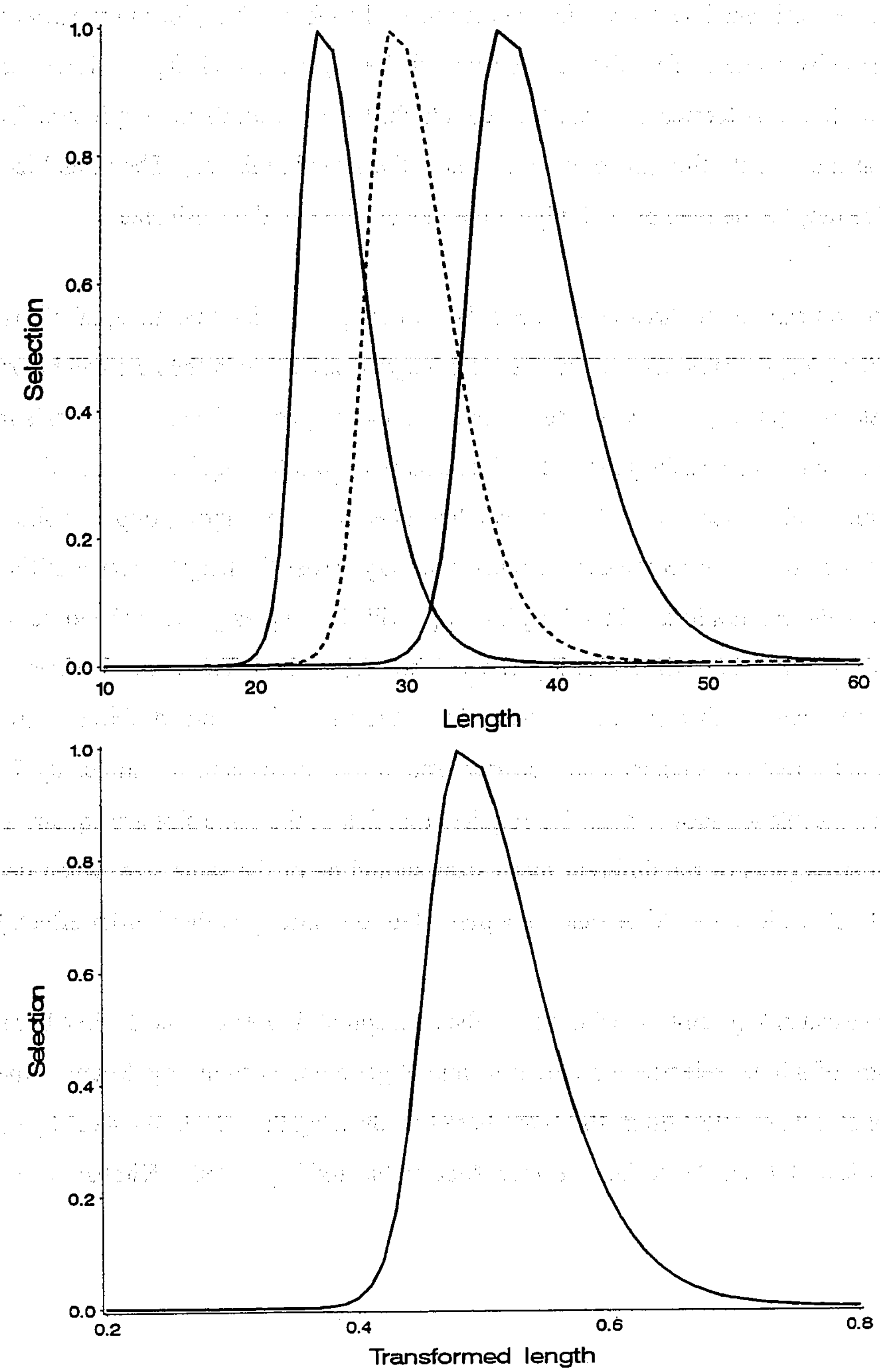
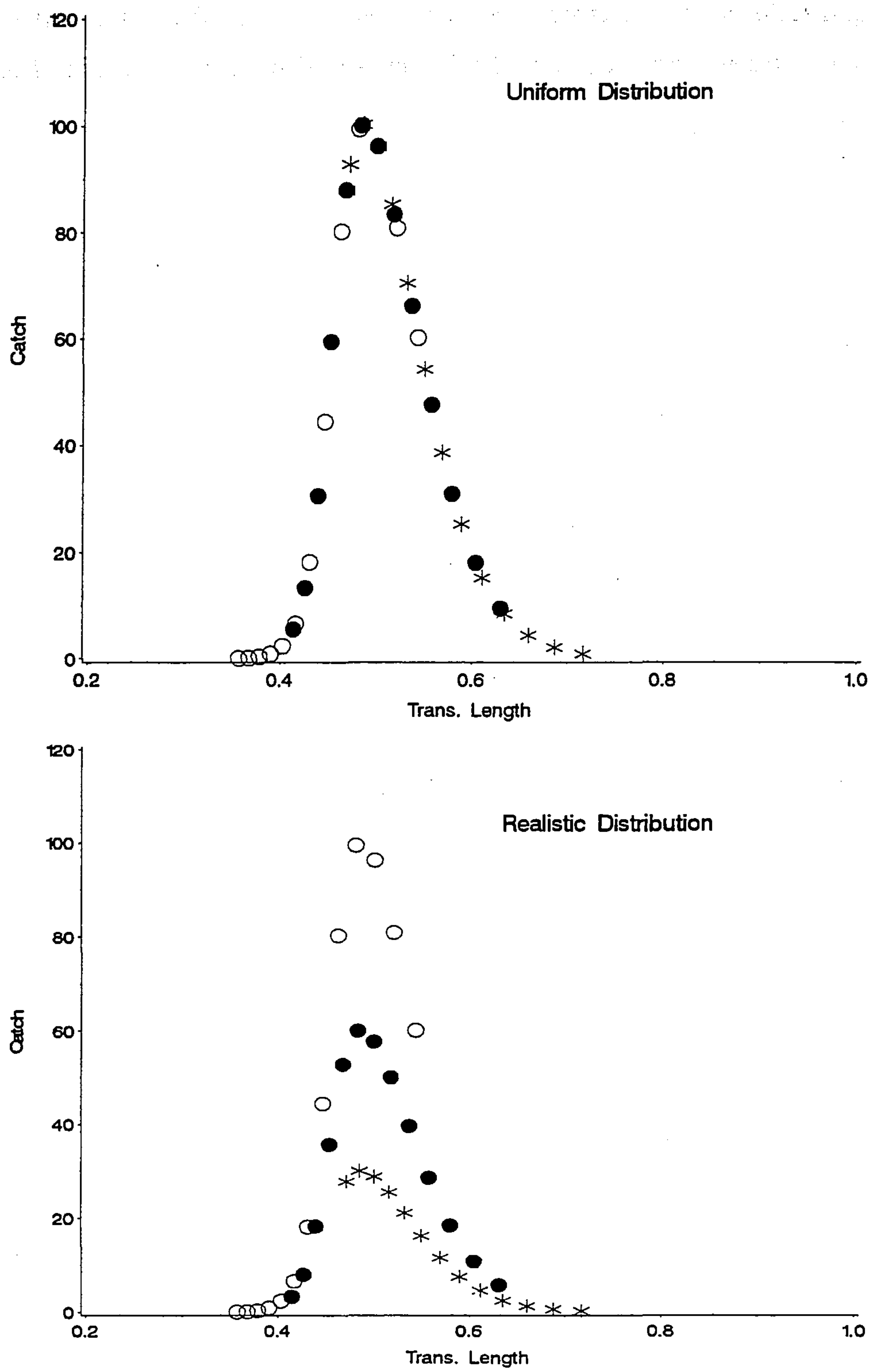


Fig 1.2 : The number of fish caught by different meshes for three length classes of fish plotted versus the transformed length. The upper part show the catches when the length distribution of the stock is uniformly distributed. The lower part show the catches for the more realistic case when the fish abundance differs between length classes.



The present analysis is also based on the principle of geometrical similarity but the estimates of the selection parameters and the stock abundance have been derived by using a non-linear minimization routine.

In the example given in fig. 1.1 all selection curves are given the same hight. This corresponds to assuming that the different nets are of equal efficiency - i.e. that the nets have the same fishing power. In the present work the power of different mesh sizes have been assumed equal.

1.2 Materials and Methods

1.2.1 The experiments.

The experimental fisheries were carried out by DIFTA from Denmark, IFREMER from France and SEAFISH from United Kingdom. Each institute conducted experiments covering three concrete fisheries as defined by target species and by the type of gear used. Two different types of nets were used - gill-nets and trammel nets. The nets were further characterized by the type of material used in the twine (monofil, multimonofile and multifilament). Except for the sole experiments carried out by DIFTA all fisheries were covered by several experiments. The gear used and the operational procedures were kept constant over all the individual experiments. Table 2.1 presents an overview over the experiments listing target species, survey areas, gear-type, the numbers of different mesh-sizes used, the number of experiments and the total number of fish of the target species caught summed over all experiments. More detailed information on the rigging of the different net sections as well as the timing and location of the individual experiments are available in the reports provided by the different institutes.

Table 2.1 : Overview over the experiments carried out on the nine fisheries covered by the project. MM indicate multimonofilament, MF multifilament, Mono monofilament.

Species	Area of In-vestigation	Institute	Gear Type	Twine material	Nos. of mesh-sizes	Nos. of Experi-ments	Total Catch in Nos.
Cod	North Sea	DIFTA	Gill-net	MM	6	4	7949
Cod	North Sea	SEAFISH	Trammel	MF	4	7	3224
Hake	Biskay	IFREMER	Gill-net	Mono	5	2	1694
Hake	W.Channel	SEAFISH	Gill-net	Mono	5	4	2938
Plaice	North Sea	DIFTA	Trammel	MF	6	6	17162
Sole	North Sea	DIFTA	Gill-net	MM	7	1	10547
Sole	E. Channel	IFREMER	Trammel	MF	5	4	4769
Sole	E. Channel	IFREMER	Trammel	MM	5	4	3135
Sole	North Sea	SEAFISH	Trammel	MF	5	4	1945

Except for the experiments carried out by DIFTA the number of fish taken as by catch in the fisheries was too low to alow any evaluation of the gill-net selectivity. For the DIFTA experiments the gear selection were estimated for the by catches of cod, plaice sole. Table 2.2 lists the number of by catches of these species.

Table 2.2 : Number of cod, plaice and sole taken as the targeted species and as by catch in fisheries carried out by DIFTA..

Targeted species	Bycatch species		
	cod	plaice	sole
cod	7949	1473	551
plaice	1488	17162	1701
sole	788	3405	10547

1.2.2 Measurements

Recording of catches

The catches were recorded by mesh-size for each individual net setting. The catch data were subsequently aggregated for each experiment which constitutes the smallest unit used in the analysis. For all species the length of the fish was measured to the nearest cm below. Before the analysis the length were corrected to the midpoint of each cm size-class by the adding of 0.5 cm.

The catch data for each fishery are presented for each individual experiment and aggregated over all experiments in Appendix A. For some of the fisheries the length of the different net-sections differ considerable which hampers a direct comparison of the catch rates between mesh-sizes. For these cases (IFREMER sole both MF and MM nets, DIFTA-plaice) the catch data are also presented by adjusting the catch numbers to the mean net-section length.

Girth and width measurements

In some experiments girth or width was measured for a sub-sample of the catch. For the round fishes (cod and hake) girth measurements were made with a string perpendicular to the length axis of the fish using an instrument designed by IFREMER For both species measurements were made at the distal end of the Maxillae (Jaw), at the distal end of the gill-cover and at the maximal girth. For sole and plaice the width were measured perpendicular to the length axis. For plaice the with was measure at the ventral spine and at the maximum width. For sole the width was measured at the pectoral spine and at the gill.

Except for IFREMER sole, which were recorded in ½ cm, all girth and width measurements were made in mm. The measurements were only carried out on some of the experiments and never for the by-catches. The number measured are given in Table 2.3.

Table 2.3 : Number of fish where girth or width have been measured.

Species	Institute	Experiment no.	Nos. Measured
cod	DIFTA	1 , 3	520
cod	SEAFISH	1	166
hake	IFREMER	1 , 2	607
hake	SEAFISH	1 , 2 , 4	420
plaice	DIFTA	1 , 3	437
sole	DIFTA	1	255
sole	IFREMER	1 , 2 , 3	615
sole	SEAFISH	3	100

Recordings of the way of attachments

Recordings on how fish was caught were made by DIFTA for cod. In the first cod experiment carried out by DIFTA a significant number of cod too small to be gilled in any of the mesh-sizes were caught and it was observed that these cod were attached to the net by their teeth. In DIFTA's 4th cod experiment a formal registration on how individual cod were entangled was recorded. The cod were classified into groups by the following criteria : a) Attached by the teeth,

b) Gilled, c) Attached by the maxillae (jaw) or d) otherwise entangled.

A somewhat different approach to relate mesh-size to the size of fish caught were used by SEAFISH on hake. The mesh-mark left by the net was measured after the fish had been removed and these information were then recorded by mesh size. This procedure enabled a secondary classification of the most likely plaice of entanglement of the individual fishes.

1.2.3 Theory

1.2.3.1 Exploratory analysis

In the indirect estimation of gill-net selection curves the parameters of the selection curve and the size composition of fish available to the gear are estimated concurrently. The functional form of the selection curve must however be specified and it is obvious that the choice of the form of the selection curve will influence all subsequent results.

Finding the proper form of the selection curve is poorly covered in the literature. In most cases the form of the selection curve is pre-assumed as following a normal density distribution (Holt, 1963) or some right skew distribution (eg. a log-normal distribution (McCombie and Fry 1960) a skew normal distribution (Reiger and Robson 1966) or a gamma distribution (Henderson and Wong 1991)).

In the present work the simple non-parametric method suggested by Jensen (1973) was used for an explanatory data analysis prior to the actual analysis. The method utilises that for a given length group the ratio of the selection of two mesh-sizes (a,b) can be written as

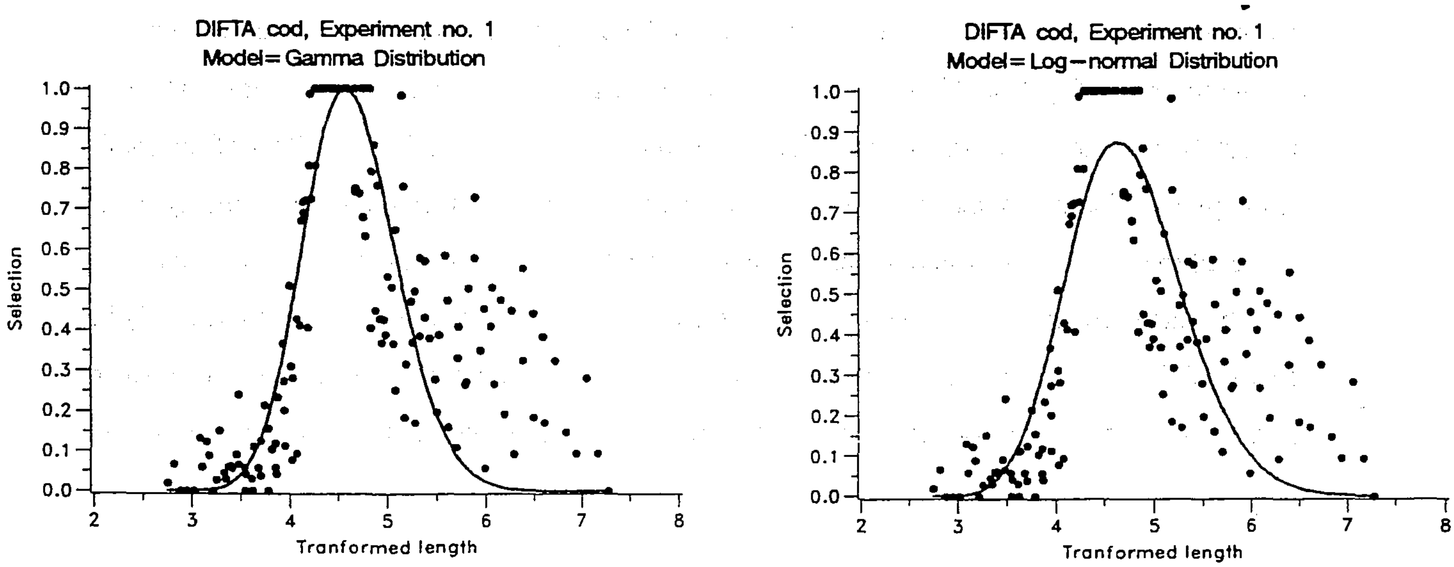
$$S_{a,l}/S_{b,l} = C_{a,l}/C_{b,l} \quad => \quad S_{a,l} = S_{b,l} * C_{a,l}/C_{b,l}$$

which follows directly from eq. 1.1 when effort is the same for the two meshes. This equation can be extended to cover more than two mesh-sizes, i.e. the selection of all mesh-sizes may be related by simply comparing their catches within length groups. Jensen further made the rough approximation that the highest catch within each size class is fully selected (i.e. that $S_{b,l} = 100$ %). This implies that selection can be expressed as $S_{a,l} = C_{a,l} / C_{best\ mesh,l}$). To derive a empirical graph of selection all the $S_{a,l}$ are plotted versus the transformed length (length/mesh size).

The assumption of the highest catch corresponding to a 100% selection is evidently very misleading for some size classes. For instance, the smallest mesh is expected to be most efficient towards all length groups below its modal length but is certainly not catching very small fish with at 100 % selection (see fig. 1.1). However, when omitting length class below the last length where the smallest mesh is most efficient mesh size and all length classes above the first length where the largest mesh size is the most efficient mesh size the method provides a useful tool for over viewing the pattern of selection.

Scrutinizing the Jensen plots for the various experiments showed in many cases a clear right skew pattern in the selection which were poorly described by selection curves following the form of a gamma-distribution or a log- normal distribution (fig. 2.1). The skewness was better described when using a model where the selection to the left and to the right of the modal length are modelled independently.

Fig 2.1 An example of the use of the method given by Jensen (1973) to explore the shape of the selection curves.



One clear limitation with the Jensen screening is that it only can be applied to a subset of length-groups. In the cod example given in fig. 2.1 a significant number of small cod (20-40 cm) were excluded from the Jensen analysis. During the experimental fishing it was observed that these cod, which were to small to be gilled in any of the mesh-sizes used, were attached to the net twine by their teeth and also that these cod occurred in about equal number in the different mesh-sizes. This implies that the catch of these sizes of cod could not be attributed to mesh-size selection. To account for such catches it is necessary to assume some sort of mesh-independent catch capacity of the nets. In selection terms this corresponds to a selection being constant.

1.2.3.2 Formulation of selection models

Gilling , i.e. fish being attached to the mesh somewhere between the gill cover and the location having the maximal girth , is typically the most important catch process and is usually assumed to produce some sort of bell shaped selection. In its clearest form this may be described by a normal distribution as initially done by Baranov (1948) and Holt (1963) but it is more frequently described by use of some right skew distributions. Random entangling is recognized in several works but does not seem to have been included in previous models of gill-net selection (in some case random entangled fish has been omitted from the analysis eg. Helser et al, 1991). The entangling is usually assumed to be an almost non-selective catch process.

For the present study the general form of the selection model was chosen to allow the gilling to be skew to either the right or the left. This was archived by using two normal distributions with a common mean (***k***) describing the modal value but with different standard deviations (***st1, st2***) for fish below and above the modal value, respectively. To this is added the effect of randomly entangling which is assumed to be different for small and large fish as the level of entangling is expected to be smaller for fish of a size that allows them to swim through the meshes as compared to fish which are stopped by the meshes. The entangling catch processes can of course only be discerned for sizes of fish not significantly influenced by the gilling process, i.e. for transformed length < ***k -2*st1*** or transformed length >***k +2*st2.*** In the model the random entangling has been described by a step function assigning levels of random entanglement of *C1* and *C2* for sizes of fish below and above the modal value, respectively. In mathematical notation the basic model is formulated as

Basic model

for Tl < ***k*** Selection= (1-*C1*) * exp $(-\frac{1}{2}*((\mathrm{Tl}-k)/st1)^2) + C1$

for Tl >= ***k*** Selection= (1-*C2*) * exp $(-\frac{1}{2}*((\mathrm{Tl}-k)/st2)^2) + C2$

where the terms (1-*C1*) and (1-*C2*) assures that the maximal selection is scaled to 100%, and TL indicates the transformed length (fish length/mesh size).

The basic model is flexible as the part of the selection curve above and below the modal length is described independently. The basic model contains 5 parameters. One may consider two ways of reducing the number of parameters - by assuming either that ***C1=C2*** or ***st1=st2***.

Model R1 : C1=C2

This model contains 4 parameters : the modal value ***k***, a spread of the selection curve to the left of ***k*** of ***st1***, a spread of the selection curve to the right of ***k*** of ***st2*** and a single constant accounting for all catches taken non-selectively, ***c*** . In formal notation

for Tl < ***k*** Selection= $(1-c)$ * exp $(-\frac{1}{2}*((\mathrm{Tl}-k)/st1)^2) + c$

for Tl >= ***k*** Selection= $(1-c)$ * exp $(-\frac{1}{2}*((\mathrm{Tl}-k)/st2)^2) + c$

Model R2 : st1=st2

In this model the selection is attributed to fish being selected by a normal distribution in conjunction with two levels of the non-selective selection accounting for the catches under and above the modal length, respectively. This implies that any skewness is explained by a different level of the constant (mesh in-dependent) selection on the two sides of the modal length (*C1* and *C2*). In formal notation this model is expressed as for $Tl < k$ Selection= $(1-c1) * \exp(-½*((Tl-k)/st)^2) + c1$

for $Tl >= k$ Selection= $(1-c2) * \exp(-½*((Tl-k)/st)^2) + c2$

The models are formulated by using the formulas of the normal distribution. However, the selection curves are not distributions and to avoid possible confusions ***k*** and the ***st's*** will be termed the *modal value* and the *spread*, respectively.

1.2.3.3 Estimation procedures

None of the three suggested models can be linearized but parameter estimates can be obtained by non-linear regression techniques. Rewriting eq. 1.1 by expanding it to cover several experiments (e) leads to the formulation

$$E(C_{e,ms,l}) = E_{ms} * S_{ms,l} * N_{e,l} \qquad \text{(Eq. 2.1)}$$

The effort component may be written as the product of net-size (length of nets) and time of use. As all net-sections have been used concurrently and for the same duration the time aspect have been disregarded in the model. For some of the experiments there have, however, been substantial difference in the length of the various net-sections. The measured net length have therefore been included as an exogenous parameter. This leaves the length distribution and the parameters describing the selection curve is to be estimated

To estimate the length composition of the fish encountering the nets one may write the least square estimate of equation (2.1), i.e.

$$L = \Sigma_e \Sigma_{ms} \Sigma_l \, (C_{e,ms,l} - N_{e,l} E_{ms} S_{ms,l})^2$$

which is to be minimized with respect to $N_{e,l}$, i.e

$$\delta L/\delta N_{e,ms} = -2 \sum_{ms} (C_{e,ms,l} - N_{e,l} E_{ms} S_{ms,l}) E_{ms} S_{ms,l} = 0 \quad \text{(Eq. 2.2)}$$

Solving equation (2.2) with respect to $N_{e,l}$ leads to

$$\hat{N}_{e,l} = \sum_{ms} (C_{e,ms,l} E_{ms} S_{ms,l}) / \sum_{ms} (E_{ms}^2 S_{ms,l}^2)$$

The estimates of the length distribution within each of the experiments is regarded as a nuisance parameter and is introduced into equation (2.1) for the subsequent estimation of the parameters in the selection models. Equation (2.1) may therefore be reduced to

$$C_{e,ms,l} = E_{ms} * S_{ms,l} * \hat{N}_{e,l} \quad \text{(Eq. 2.3)}$$

Equation (2.3) have been solved by using the procedure NLIN within the SAS software package. Scrutinizing the residuals showed that the variance increased with he size of the catch. In order to keep the variances constant the non-linear regression was carried out after a square root transformation of the data i.e. by the model

$$E (SQRT (C_{e,ms,l})) = SQRT (E_{ms} * S_{ms,l} * \hat{N}_{e,l}) \quad \text{(Eq. 2.4)}$$

which resulted in a more evenly distribution of the residuals. Using a square root transformation corresponds to an underlying assumption of the fish caught follows a Poisson distribution.

As formulated the model estimate the set of selection parameters which fits best to the observed catch distributions as found by the combined experiments but the model may also be applied to single experiments. In most gill net selection work is customary to aggregate all catches over experiments and subsequently to estimate selection on one common mesh-size-length matrix . The by catch data from DIFTA, which were characterized by rather modest catch numbers within experiments were analysed after being pooled. Trials on the main data using either non-aggregated catches or catches aggregated over experiments resulted in almost identical parameter estimates.

The SAS procedure NLIN requires initial guesses of the parameters which are subsequently modified by a number of iterations until convergence or the procedure fails. Provided that not grossly unreasonable initial values were used convergence was easily archived.

The output from the regression analysis contains the estimated selection parameters and the standard errors on the estimates. The removal of the population estimates as nuisance parameters is however not taken into account in the calculation of the standard errors and these are therefore underestimated. The number of nuisance parameters is relatively high (=number of length groups) and will furthermore be correlated with the selection parameters. This implies that the effective number of degrees of freedom will be substantially below the formal values given in the model output. Inference on differences in parameter estimates should therefore not be based on the standard error given in the output.

The length distribution of the fish encountering the gear is finally derived by inserting the selection parameters into equation (2.3.). When the abundance of fish within each length group is estimated the selection by mesh-sizes (ms), length (l) and experiment (e) can be calculated as :

$$\text{Selection}_{ms,l,e} = \text{Catch}_{ms,l,e} / \hat{N}_{l,e} \qquad \text{(eq 2.5)}$$

Plotting the selections from the individual length groups enables an evaluation on the amount of statistical scatter found around the selection curve. These plots are useful in judging the quality of the estimated selection curve.

1.2.4 Analyses of the relationship between Length -girth/width.

Fish is mainly caught in gill-nets by getting stuck by some part of the body in a mesh of a suitable size. Therefore, the best size characteristics of a fish with respect to gill net selection is girth-measures which may directly be related to the mesh perimeter. Compared to length measurements the girth measurements are far more time consuming to carry out and therefore length is the typically size measure used in gill-net selection work. However, if length and girth is not related by proportionality the use of length will introduce biases when using the Baranov theorem in calculating the transformed size. For the flatfishes width were measured instead of girth for reasons of convenience. Width is not as good a measure as girth as it can not be directly related to mesh perimeter and excludes possible differences in the growth in the thickness of the flatfish. However, if width is not proportional to length this may likely indicate a dis-proportionality between length and girth.

It is usually found that the growth of fishes takes place in an approximal isometrical way, i.e. that all body proportions increases proportionally. In such cases girth measurements are expected to be proportional to length i.e. Girth=Constant*length. However, plotting girth against length indicated that the variability in the girth increased with length. For this reason the relationship between length and girth were analysed after a log transformation, i.e. log (girth) = constant + log (length). The analysis of the relationship between girth and length width in this model were carried out an analyse of variance where the constant is spitted into effects of measure (i.e the different positions where girth were measured) and experiments :

$$E\,(\,\log(\text{girth/length})_{m,e}) = M_m + E_e + M{*}E_{m,e}$$

were M_m indicates the site of measurement and the different experiment $(E\,)_e$ accounts for possible differences between experiments attributed to for example season, sub-stock encountered etc. The interaction term $(M{*}E_{m,e})$ allows for differences in the different measurements between experiments. The model was used on the data from each of the different fisheries. In all cases the model was reduced as far as possible by successive removing terms not being statistical different from zero.

However, fish may grow allometrically (i.e. in a non-isometrical fashion) and in that case it will be appropriate to describe the relation between girth and length by a power function, i.e. $girth=a*length^{b}$ which may be linearized by a log transformation. Analysis of the relationship within this model was carried out by the linear model

$$E(\log(girth)) = M_m + E_e + (\beta + \beta_m + \beta_e) * \log(length)$$

where β is the parameter describing the overall slope whereas $\beta_m + \beta_e$ allows the slope to be adjusted between experiments and measures. Also this model were reduced as far as possible by successive removal of non-significant terms.

1.3 Results

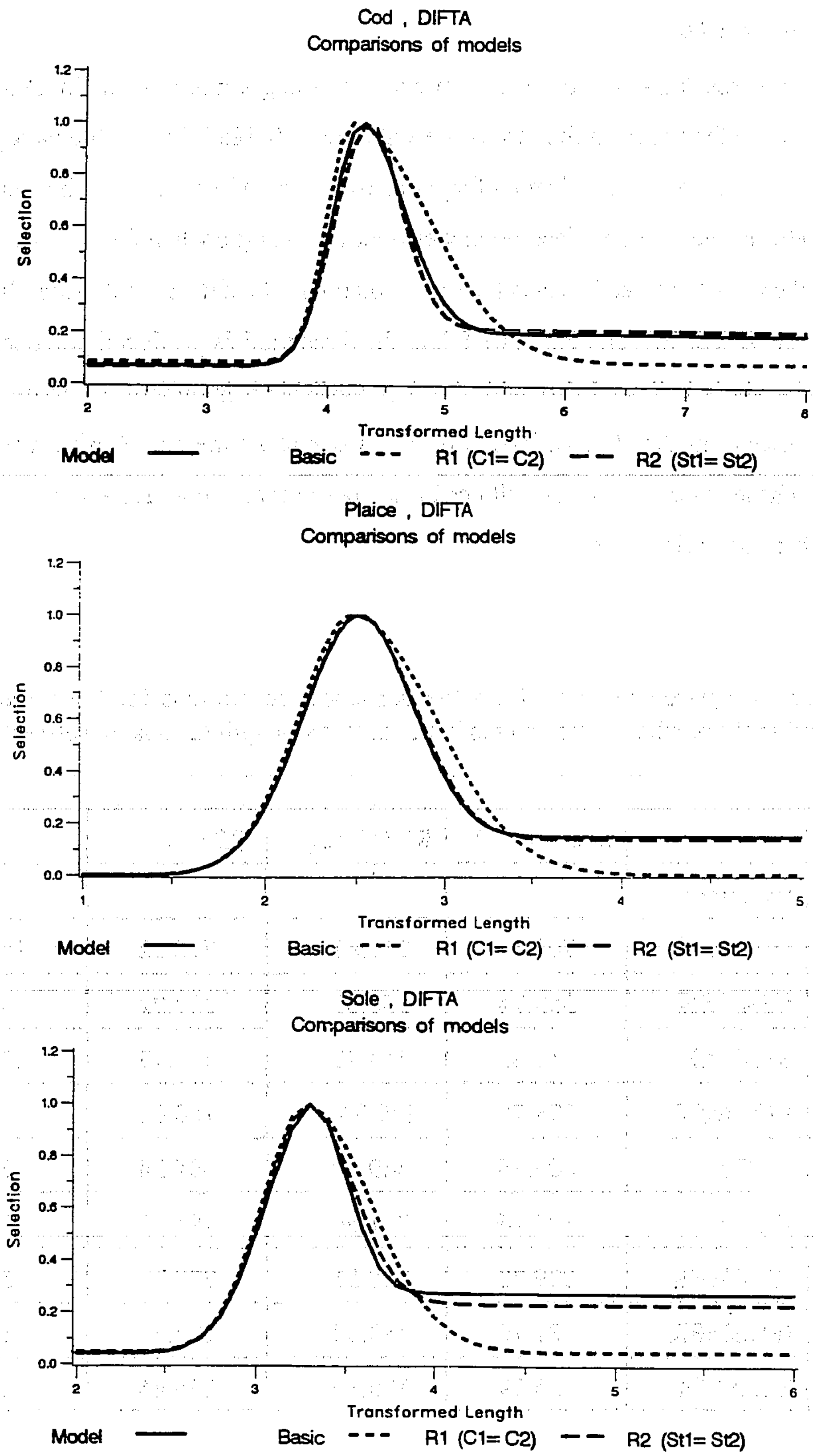
1. 3.1 Choice of model

The sum of squared residuals was used as a measure of the goodness of fit. In general little difference was found in the fits from the three different models (table 3.1). For the data provided by DIFTA an increase in the residual sum of squares were seen when reducing the basic model by assuming a uniform level on non-selective catches over all sizes (i.e when *C1=C2)* whereas the basic model and the model reduced by using the same ***s*** on both side of the modal value differ only marginally. For the IFREMER and SEAFISH data the three models produced practically equal fits. Overall the analysis indicated that with the data available it is difficult to chose between models by their ability to fit the observations. For the final analysis the model using a common ***s*** (model R2) were chosen as this model overall performed better than model R1 and contained one parameter less than the basic mode.

Table 3.1 : Sum of squared residuals from the non-linear regressions for the three models examined. N signifies the number of data points in the analysis (length groups by net-sections and experiments).

Model		Basic model	R1 (c1=c2)	R2 (st1=st2)	N
Species	Institute				
Cod	DIFTA	708.17	731.81	712.52	1440
Cod	SEAFISH	353.74	350.89	357.22	1580
Hake	SEAFISH	413.83	414.43	414.73	1255
Hake	IFREMER	178.78	179.34	180.04	675
Plaice	DIFTA	603.76	649.29	604.24	720
Sole	DIFTA	188.26	211.66	191.27	189
Sole-MF	IFREMER	229.28	228.51	229.43	530
Sole-MM	IFREMER	181.70	183.68	187.44	505
Sole	SEAFISH	135.39	135.39	135.46	481

Fig 3.1. A comparison of the selection curves derived by using three different selection model for DIFTA cod, DIFTA plaice and DIFTA sole.



A scrutinization of the selection curves derived by the three models show that differences in selection is primarily found for fish above the modal value. Fig. 3.1 show this for the DIFTA experiments. It appears that all three models result in an almost identical estimations of the selection at or below the modal length but that substantial difference may be found for sizes well above the mode. The figure also show almost identical selection curves between the basic model and model R2 which indicate that the basic model is over-parameterized.

1.3.2 Presentation of the results of the selection analysis

All fisheries have been analysed with the model given in equation (2.4) thus estimating the set of selection parameters which describes the observed catch distribution over all experiments. This constitutes the main results of the analysis. Besides this all individual experiments have be analysed separately. The individual experiments can be considered as particular realisations of the selection process and these analyses therefore allows for judgement of the between experiment variability in the magnitude of the estimates.

For the ease of the presentation only the main results are presented in the text. The reggresion tables and the fit between the model and the observations for the analysis using all catch information is provided in Appendix A and Appendix B. The lay out of the text section and the appendices is described below.

1.3.2.1 Presentation in the text

In the description of the results the analysis are presented in a condensed form. The estimated selection curve derived from the analysis utilizing the catch data from all experiments are shown together with the estimated selections calculated from the individual length-groups ($Catch_{ms,l}/\hat{N}_l$ -cf. Eq. 2.5). In the majority of the analysis these plots showed a considerable uncertainty on the estimation of the part of the selection curve on the right side of the modal values. This uncertainty derives typically from the fact that the right side of the selection curve is based on a rather low number of fish being caught. This is evaluated by splitting the observed catches into size intervals based on the modal value (***k***) and spread (***st***) as estimated from the analysis using catch data from all experiments. As size classes are chosen intervals of a size of ***st*** ranging from ***k-5st*** and to ***k+5st***. The proportion of the total catch taken above ***k+2st*** is used as a measure of the amount of catch information for estimating the right most side of the selection curve.

A table is provided giving the estimated parameters and the calculated standard errors for the analysis based on all dada as well as from the analysis where the parameters are estimated seperately from each experiment. As noted in section 1.2.2.4 the standard errors are underestimated and should therefore not be used for formal inference on difference in estimates between experiments. However, the calculated standard errors may be interpreted relatively, i.e. that parameters with higher calculated standard errors are determined with a higher relative uncertainty.

Besides the parameters the selection curves for all individual experiments are presented in a figure. As each experiment can be considered as a particular realization of the selection process between experiment differences in the selection curves provides a measure of the uncertainties in the estimated selection.

When judging the parameters it should be noted that the parameters describing the modal value (***k***) and the spread of the selection (***st***) refers to the transformed length. The selection parameters for individual meshes are derived by multiplying these values by the <u>full-mesh given in cm</u>. In the literature selection factors may be given the half-mesh length (bar-length) and the measuring may be done in mm. Half mesh values may be derived by multiplying the values by 2, mm values may be derived by dividing with 10. For instance, the modal value for DIFTA cod ,estimated at 4.33, will correspond to 2*4.33/10= 0.87 when referring to bar-length measurement made in mm. The values of ***C1*** and ***C2*** refers to the vertical axis and is hence not affected by the units used.

1.3.2.2 Tabular output (Appendix A)

The tabular output consist of an analyse of variance table which provides on the sum of squares as derived on the square-root scale. The regression effect is given with 4 Degrees of freedom corresponding to the number of parameters explicitly given in the model. It should be remembered that the analytical procedure contains the implicit estimation of the abundance of fish in all length groups were catches are taken.

Below the ANOVA table the parameter estimates are given with their calculated Std. Error and associated confidence intervals. The last part of the output tables contains the information on the correlation between the parameters.

Tables are provided for each fishery and also includes the analysis of the 6 by catches provide by DIFTA.

1.3.2.3 Graphical output (Appendix B)

Graphical output is produced for all the analysis carried out. The species in question and the institute providing the data are given in the first line of the heading on each sheath. The graphical presentation is separated into sheets presenting catch/stock information and selection information

The graphical sheets of *catch and stock features* includes the following information:

1) The fit between the observed catch (presented as dots) and the catch estimated from the regression analysis (presented by a line). These plots are provided for the individual experiments and by mesh-sizes (the mesh size is labelled as MS and given in mm stretch mesh). These plots enables a evaluation of the quality of the model fit.

2) An residual plot given for each experiment and including information on mesh-sizes. These plots refers to the residuals as given in the square-root scale and enables an evaluation of patterns

in the residuals.

3) A plot of the estimated length distribution of the stock given for each experiment. As the size of net-sections is included in the model the abundance is expressed in nos. of fish per m of net.

The graphical sheets of *selection features* includes the information :

4) A plot of the selection curve (presented by a line) for each mesh-size overlaid with the estimated selection derived from the individual length (observed catch in mesh/estimated stock abundance - presented by dots). The selection axis is constrained to values below 2.0 to facilitate the evaluation between individual data points and the selection curves. A few outlying points were typically found within each fishery deriving from length-classes estimated at very low values.

5) A plot of selection given on the transformed length-scale and showing the selection for all cm-groups and mesh-sizes versus the selection curve. The plot is given in 2 versions. In the first version the selection axis is constrained to values between 0 - 2 as in 4) above. In the second version no constrains was placed on the selection axis which implies that all outlying points within the analysis may be spotted on this graph.

1.3.3 Results of the Length -Girth and Length- Width relationships

The results of the analysis of the relation between length and Girth/width is given in Appendix C. Tables providing the results from the analysis are given for each fishery assuming both isometrical and allometrical growth - these analysis being labelled ANOVA and Regression, runs respectively. Plots of the observations and the estimated values derived from the two analytical approaches is also given for each fishery, experiment and position where the Girth/Width were measured. The estimated values assuming allometrical growth is shown with full lines whereas the estimates based on the the isometrical assumption is marked by the broken lines.

The analysis showed for all fisheries, except for DIFTA plaice, that the relation between log

(Length) and log(Girth) or log (Width) were best described with slopes statistical different from 1.0 - this implying allometrical growth. In four of these seven cases where the slope differt from 1.0 the terms including β_m or β_e were found to be statistical different from zero. This implies that the best statistical fit required adjustment of the slope for individual experiment and/or for the different positions where Girth/Width were measured.

Considerable differences in the slopes was found for the same species when estimated by data from the different institutes. For Hake the analysis of the IFREMER data showed a slope below 1 whereas the analysis of the SEAFISH data resulted in a slope above 1. A similar pattern appeared for sole where the SEAFISH data lead to a slope below 1 whereas the slopes found from DIFTA's and IFREMER's data resulted in a slope above 1.

When scrutinizing the plots showing the observations and the estimated lines from the two sets of analysis it appeared that the fit based on the ANOVA analysis was only marginally inferior to the descriptions from the regression analysis. A measure of the statistical loss associated with using the ANOVA approach can not be directly derived by comparing the multiple correlation coefficients (R-squares) as two analysis uses different dependent variables. However, the squared residuals derived from the fit between the parameters derived from the ANOVA can be used to estimate R-square (table 3.2). The reduction in R-square is generally found to be very small. Larger differences in the two fits was basically confined to the very small and very large fish measured. The small and large fish will have a disproportionate effect on the magnitude of the slope of the regression due to their high leverage and one may question wether fish-size found outside the range delimited by the modal length of the smallest and largest mesh-size should in fact be omitted from the analysis.

Overall, the analysis indicate that the errors associated with assuming a isometrical growth will be small and hence that the Baranov transformation is justified. A slightly better description may be derived when allowing for allometrical growth , i.e. by allowing the slopes between length and girth to deviate from the value of one. Allometrical growth can be included in the selection model by introducing the slopes estimated in the regression as exogenous given parameters. However, as Girth/Width measurements were only available from some experiments this approach was not attempted.

Table 3.2 The R^2 found by the analysis assuming either allometrical or isometrical growth. The analysis and the model fits are shown in Appendix C.

Institute	Species	Allometric growth	Isometric rowth
DIFTA	Cod	0.943	0.938
SEAFISH	Cod	0.951	0.946
IFREMER	Hake	0.845	0.844
SEAFISH	Hake	0.950	0.939
DIFTA	Plaice	0.883	0.882
DIFTA	Sole	0.907	0.900
IFREMER	Sole	0.948	0.944
SEAFISH	Sole	0.907	0.902

The girth/width information has also been used to evaluate at what part of the body that accounts for the majority of catches. For the round fishes this has been done by calculating the ratio between the various girth measurements and mesh-perimeter, whereas for flatfishes the ratio between 2*width and mesh-perimeter was used. These calculations were restricted to the modal length found for each mesh-size and included girth information for the two adjacent length groups. For instance, for DIFTA cod where the modal value were estimated at 4.33 the modal length of the 108 mm mesh may be calculated as 46.7 cm. For this mesh the girth information from the length groups 46.5 and 47.5 were averaged.

1.3.4 Selection estimates for the different fisheries

1.3.4.1 DIFTA cod

The experimental fishery was conducted by multimonofilament gill-nets utilizing six different mesh-sizes ranging from 90 mm to 151 mm stretched mesh. Four experiments were available with a total catch of 7949 cod.

The fit between the observed and the estimated catches may in general be described as being god for all experiments and mesh-sizes (Appendix B). The fit between the selection curve and the selection calculated on individual data points (cf. Eq. 2.5) show the highest amount of variation around the selection curve for cod of a transformed length above a value of approximately 5 (fig. 3.3). A scrutinization of the more detailed diagnostics on the selection of individual mesh-sizes presented in Appendix B show that this high variability can mainly be attributed to cod of sizes above 55 cm . The estimated length distribution of cod available to the nets showed a low abundances of cod above this size for all experiments (Appendix B).

The modal value ***(k)*** were found at 4.33 when being estimated on the data from all four experiments (table 3.3). When estimated on the individual experiments the modal value varied between 4.21 to 4.50. The spread ***(st)*** were estimated between 0.26 to 0.27 in the individual experiment and at 0.28 when being estimated from the catches available from all experiments. That the overall spread is larger than found in any of the single experiments is caused by the fact that the overall spread absorbs the variability found between the modal values in the individual experiments. The constants ***(C1,C2)*** accounting for the non-selective catches below and above the modal values was estimated at 0.07 (range 0.05 to 0.12 in individual experiments) and at 0.21 (range 0.07 to 0.28 in individual experiments), respectively. The estimated selection curves from experiment 1 and 4 and from experiment 2 and 3 were pair-wise found rather similar (fig. 3.3). The selection curve estimated on all data was found in between the selection curve from these two groups of experiments.

Table 3.4 show the proportions of the catches taken in different parts of the selection curve. About

13 % of the total catch were taken above a transformed length of *k+2st* . When multiplying this proportion with the total number of cod caught this imply that about one thousand fish were available to the estimation of the right most part of the selection curve.

The proportionality constants relating length to gill-girth, to maximal girth and to maxillar girth were estimated at 0.47, 0.48 and 0.31, respectively. No statistically significant differences were found between the proportionality constants estimated for different experiments (Appendix C). The ratio between the girth and the mesh perimeter for fish at the modal length show that the maximal girth and the gill girth exceeds the mesh perimeter by 4 and 1 percent, respectively (table 3.5). This indicate that the modal length is composed of cod being entangled at or slightly posterior to the gills.

Table 3.3 : DIFTA cod. Selection parameters estimated from all the available catch information and from the catch information from individual experiments.

	Experiment									
	All		exp_1		exp_2		exp_3		exp_4	
	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter										
K	4.331	0.009	4.495	0.016	4.209	0.012	4.234	0.010	4.520	0.019
ST	0.282	0.007	0.260	0.012	0.265	0.010	0.267	0.008	0.256	0.017
C1	0.065	0.004	0.055	0.005	0.052	0.007	0.050	0.004	0.124	0.015
C2	0.210	0.013	0.282	0.023	0.066	0.011	0.177	0.017	0.158	0.020

Table 3.4 : DIFTA cod. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch proportions by size classes												
	<-5 St	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 5 St	Total
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
Experiment													
no. 1	16.9	5.3	3.9	2.6	4.6	16.3	21.1	9.4	5.1	4.0	3.4	7.3	2608
no. 2	5.0	2.7	3.2	6.2	21.5	33.6	16.4	4.6	2.4	1.6	0.8	1.9	1101
no. 3	5.0	2.4	2.9	5.4	19.8	32.4	20.2	5.4	2.6	1.4	1.0	1.3	3230
no. 4	11.3	5.7	3.8	3.1	6.7	15.0	23.3	11.3	5.5	3.8	3.9	6.6	1010
All	9.7	3.8	3.4	4.3	13.4	25.1	20.3	7.4	3.8	2.6	2.1	4.1	7949

Table 3.5 : DIFTA cod. The ratio between the measured girth at the modal length and the mesh perimeter for the different mesh sizes used. 'Nos' indicate the number of girth measurements.

	Measurement at			
	Max. Girth	Gill Girth	Maxilar Girth	
	Average Ratio	Average Ratio	Average Ratio	Nos.
Mesh-size (mm)				
90	1.040	1.013	0.675	72
99	1.033	1.005	0.665	77
108	1.050	1.021	0.679	39
123	1.072	1.027	0.680	19
134	1.038	1.010	0.693	8
151	1.147	1.084	0.841	2
Overall average	1.043	1.013	0.675	217

Fig. 3.2 : DIFTA cod. A comparison between the estimated selection curve and the selection calculated for individual data points (cf. eq. 2.5) .

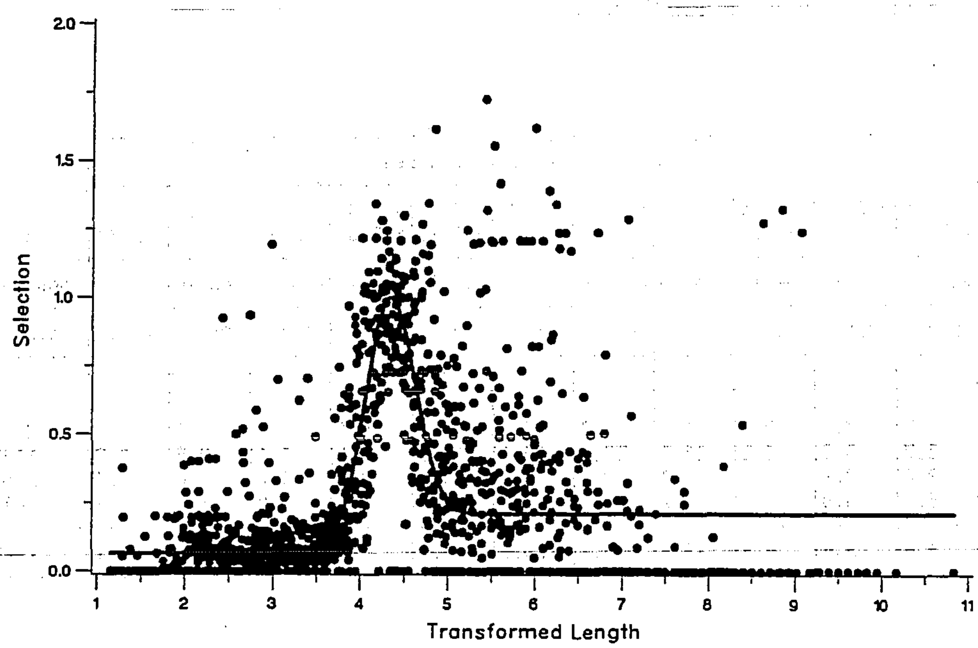
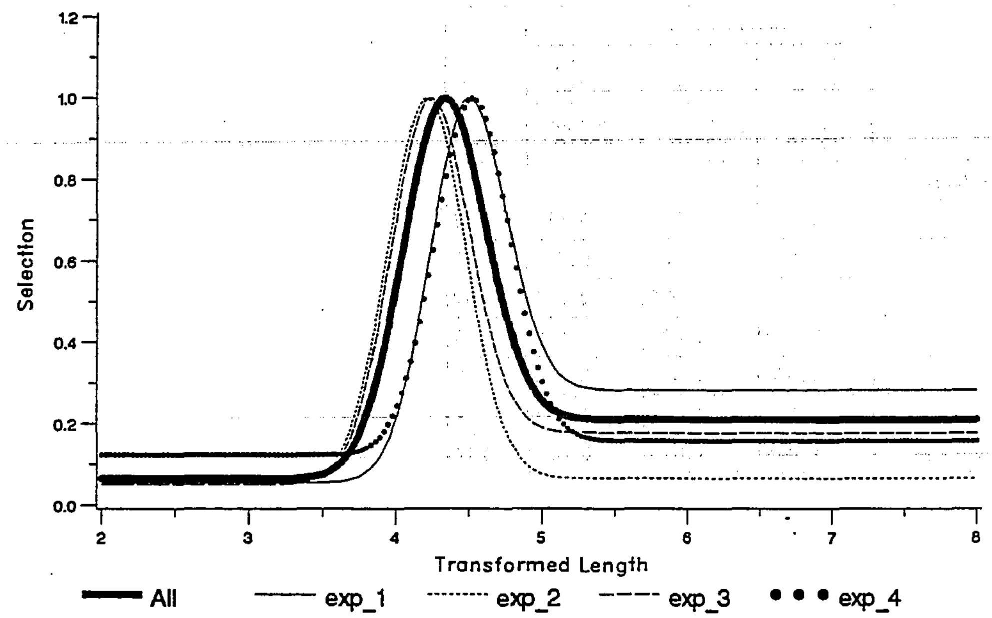


Fig . 3.3 : DIFTA cod. Plots of the selection curve estimated on the basis of all experiments and for the selection curves estimated from the individual experiments.



1.3.4.2 DIFTA cod from fisheries targeting plaice and sole

The plaice fishery, which were carried out with multifilament trammel nets, resulted in a by-catch of 1488 cod. The catch data for the three plaice experiments were pooled prior to analysis. A significant proportion of the catches (approximately 40 %) were cod of a size between 20 and 35 cm which were to small to be gilled in any of the mesh-sizes used. These cod were found across all mesh sizes and in fact dominated the catches in the four largest mesh-sizes (Appendix B).

The sole fishery were carried out with multimono filament gill-nets i.e. with the same gear type which were used in the directed cod fishery. However, the rigging of the nets differ especially in regard to hanging ratio. Only one sole experiment was conducted which lead to a cod by-catch of 788 individuals. Also in the sole fishery a notable number of small cod (20-30 cm in length) were caught in all mesh-sizes (Appendix B).

An evaluation of the fit between the predicted and the observed catches (Appendix B) indicates an acceptable fit for all mesh-size for both species. However, the comparison between the estimated selection curve and the estimated selection for individual data points (cf. Eq. 2.5) reveals a pronounced uncertainty regarding the selection for fish above the modal values (fig. 3.4 and fig 3.5). When evaluating the selection plots from the different mesh sizes (Appendix B) it appears that the high scatter around the selection curve can be attributed to cod above ca. 50 cm. The availability of cod of this size were estimated to be low in both the plaice and in the sole fisheries.

The estimated selection parameters are presented in table 3.6 and the selection curves are shown in fig 3.6. The largest discrepancy between the two selection curves are found on the right side of the curves relating to the constant *C2* . This may be attributed to the low number of cod available to the estimation of the right most part of selection curve (table 3.7) as the split of the catches on relative size categories show that only 70 and 87 cod were useful to estimate the part of the selection curve to the right of ***k+2st*** in the plaice and sole fisheries, respectively.

Table 3.6 : DIFTA cod by-catches. Selection parameters estimated from the by-catches in the plaice and sole fisheries.

	Fishery for			
	Plaice		Sole	
	Estimate	Std. Err.	Estimate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter				
K	4.462	0.036	4.624	0.024
ST	0.211	0.023	0.259	0.020
C1	0.112	0.011	0.104	0.012
C2	0.508	0.093	0.358	0.048

Table 3.4 : DIFTA cod. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes												
	<-5 St	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 5 St	Total
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
Bycatch in													
Plaice fish.	61.8	4.1	2.0	3.2	6.7	7.9	6.2	3.3	1.6	0.5	0.5	2.1	1488
Sole fishery	16.0	3.8	4.3	4.6	10.9	24.7	15.5	9.0	6.1	2.5	1.4	1.1	788

Fig. 3.4 : DIFTA cod by-catch in the plaice fishery. A comparison between the estimated selection curve and the selection calculated for individual data points (cf. eq. 2.5) .

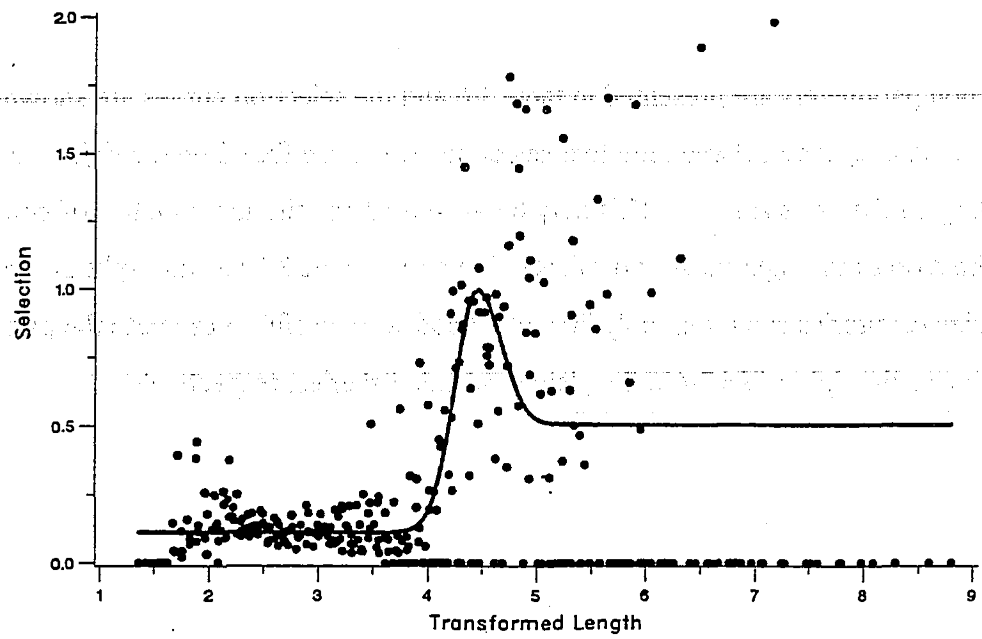


Fig. 3.5 : DIFTA cod by-catch in the sole fishery. A comparison between the estimated selection curve and the selection calculated for individual data points (cf. eq. 2.5) .

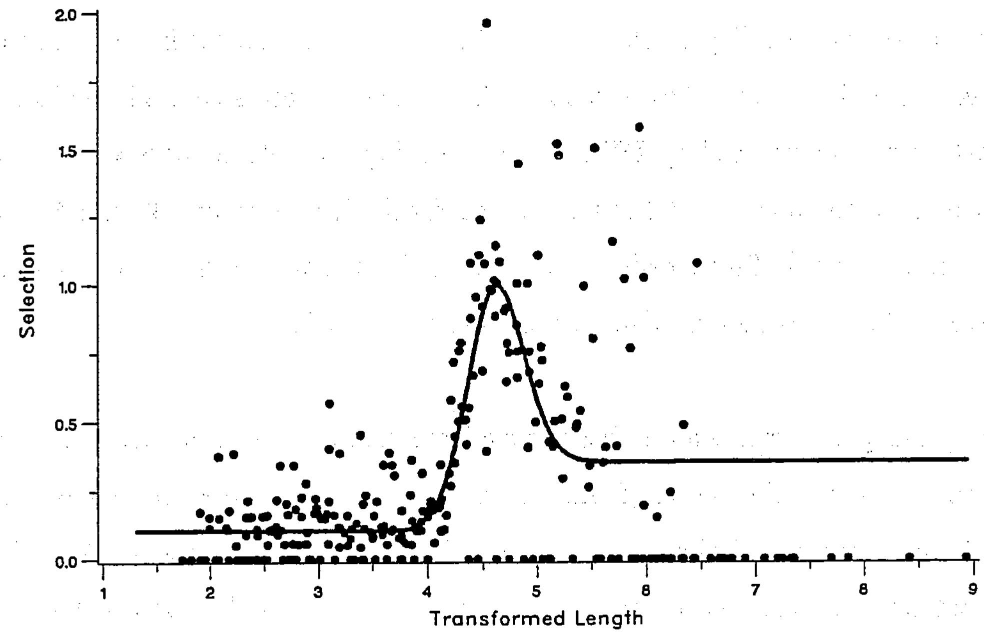
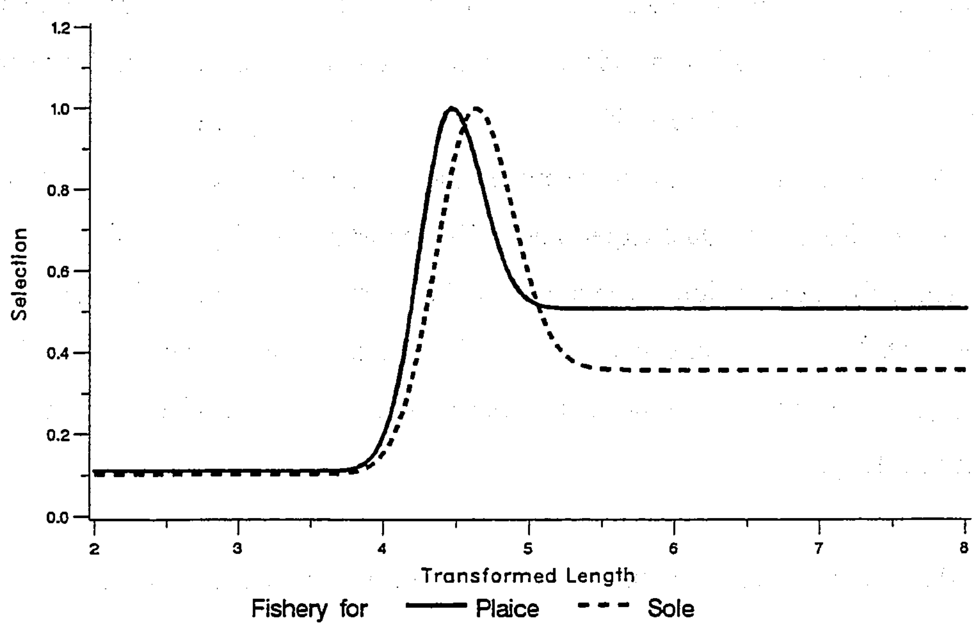


Fig . 3.6 : DIFTA cod bycatches. Plots of the selection curve estimated from the by-catches in the plaice and sole fisheries.



1.3.4.3 SEAFISH cod

The SEAFISH cod experiments were carried out by the use of net-sections of multifilament trammel-net using four mesh-sizes ranging from 103 to 136 m, stretched length. Seven experiments were carried out yielding a total catch of 3224 cod. The catches in some of the experiments were very low - in two cases below 200 fish. The smallest mesh-size used was larger than the two smallest mesh-size used by DIFTA. Scrutinizing the catches pooled over all experiments showed that the highest catches were found for the length groups 42 and 43 cm which is below the modal length of the smallest mesh-size (estimated at 46.8 cm). This indicate a poor match between the mesh-sizes used and the size distribution of the stock.

For the experiments yielding low catches it is difficult to evaluate the fit between the observed and the estimated catches. For experiments 2,4,5 and 7, where the catches were the highest an acceptable fit is found between and observed and the estimated catches (Appendix B). The comparison between the selection curve and the selection values for individual data points (fig 3.7) show a fair correspondence for length below the selection value but a very noisy relation for lengths above this value. Referring to the selection plots from individual mesh-sizes (Appendix B) show that the high variability is found for cod about 50 cm.. The abundance of these size of cod were found to be low in all experiments (Appendix B).

The modal value and the spread, estimated from the data from all experiments , were found at 4.55 and 0.35, respectively (table 3.8). When estimated from the individual experiments ***k*** ranged from 4.42 to 4.90 and ***st*** from 0.28 to 0.50. The parameter describing the non mesh size dependent catches below the modal value (*C1*) were overall estimated at 0.08 - ranging from 0.01 to 0.10 when determined from individual experiments. The constant relating to the non size dependent catches above the modal value (*C2*) were overall estimated at 0.55 but showed very considerable differences between experiments (range 0- 0.9). The estimated selection curves for the various analysis (fig. 3.8) show that the major differences in the estimated selection is found to the right of the modal length.

The distribution of the catches on taken in different part of the selection curve show that 13% , equivalent of some 430 fish, were available to estimate the selection to the right of ***k+2st*** (table 3.9).

The proportionality constants relating length to gill-girth, maximum girth and maxillar girth were estimated at 0.48, 0.48 and 0.32, respectively. The girth measurements show that the girth measured at the gill or at the position where girth was at its maximum exceeded the mesh perimeter by 9% and 10%, respectively (Table 3.10). This indicate that the catch at the modal length correspond to fish being entangled close to the gills.

Table 3.8 : SEAFISH cod. Selection parameters estimated from the total catch information and from the individual experiments.

	Experiment															
	All		exp_1		exp_2		exp_3		exp_4		exp_5		exp_6		exp_7	
	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.
	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale	Tran. Scale
Parameter																
K	4.548	0.025	4.743	0.032	4.431	0.094	4.899	0.064	4.572	0.066	4.424	0.038	4.839	0.069	4.753	0.047
ST	0.354	0.015	0.333	0.019	0.283	0.055	0.478	0.043	0.400	0.040	0.293	0.024	0.431	0.035	0.495	0.028
C1	0.082	0.006	0.005	0.003	0.084	0.018	0.061	0.019	0.096	0.015	0.095	0.011	0.032	0.010	0.072	0.015
C2	0.551	0.041	0.000	0.000	0.904	0.154	0.141	0.072	0.669	0.096	0.561	0.067	0.009	0.040	0.008	0.008

Table 3.9 : SEAFISH cod. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (***st***) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes												
	<-5 St	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 5 St	Total
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
Experiment													
no. 1	0.9	3.6	4.5	5.4	6.3	21.6	28.8	13.5	11.7	2.7	0.9	0.0	111
no. 2	0.4	3.4	4.6	6.5	13.1	28.5	18.8	9.1	7.1	3.4	2.2	2.8	495
no. 3	1.6	1.6	6.5	5.6	9.7	28.2	19.0	11.3	6.9	4.4	2.8	2.4	248
no. 4	1.0	3.4	6.5	8.4	14.2	24.2	16.9	8.9	7.1	3.6	2.8	3.0	774
no. 5	1.1	3.9	5.1	7.6	13.7	32.5	17.0	8.0	4.1	3.1	2.4	1.3	1021
no. 6	1.3	5.8	10.3	7.7	14.8	31.6	12.9	5.8	4.5	2.6	1.9	0.6	155
no. 7	2.1	2.6	6.9	8.3	16.2	27.6	18.3	8.3	3.8	2.6	0.7	2.4	420
All	1.1	3.4	5.9	7.5	13.6	28.5	17.8	8.8	5.7	3.3	2.2	2.1	3224

Table 3.10 : SEAFISH cod. The ratio between the measured girth at the modal length and the mesh perimeter for the different mesh sizes used. 'Nos' indicate the number of girth measurements.

	Measurement at			
	Gill Girth	Max. Girth	Maxil. Girth	
	Average Ratio	Average Ratio	Average Ratio	Nos.
Mesh-size (mm)				
103	1.083	1.092	0.707	18
116	1.119	1.118	0.762	14
128	1.049	1.077	0.708	8
136	1.126	1.129	0.759	6
Overall average	1.093	1.102	0.731	46

Fig. 3.7 : SEAFISH cod. A comparison between the estimated selection curve and the selections calculated for individual data points (cf. eq. 2.5) .

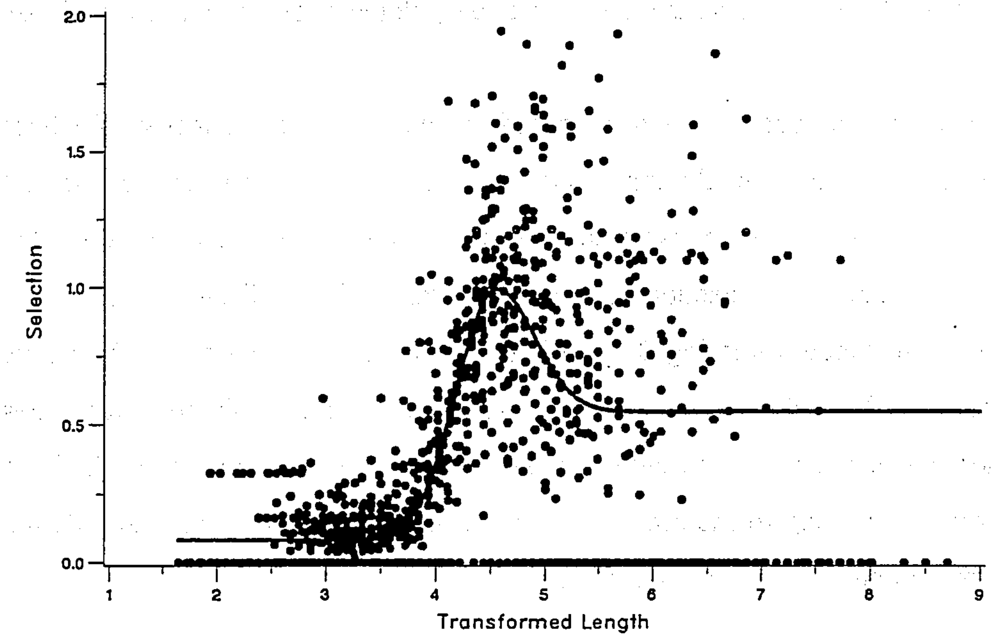
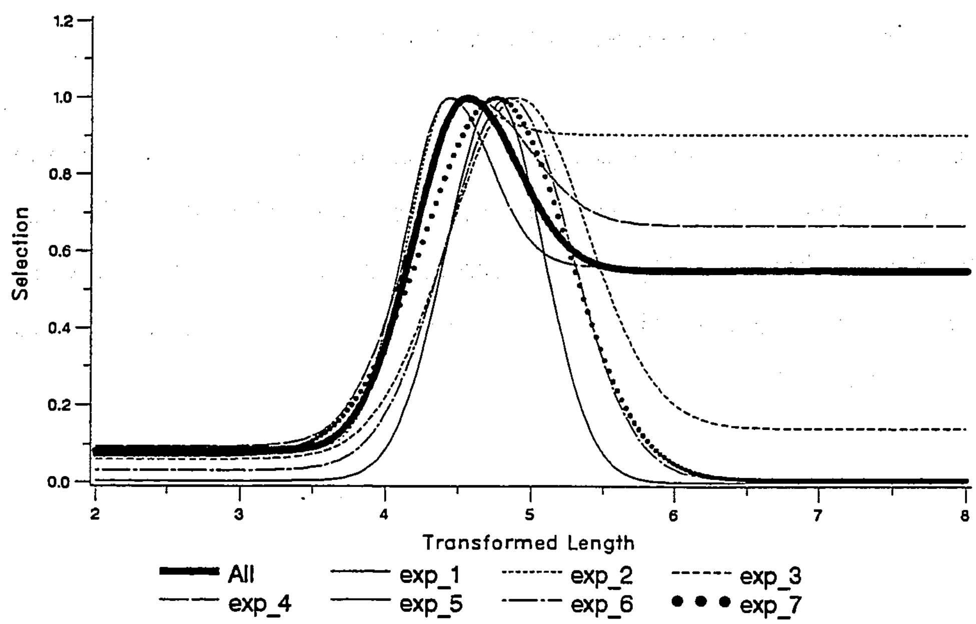


Fig . 3.8 : SEAFISH cod. Plots of the selection curve estimated on the basis of all experiments and from the individual experiments.



1.3.4.4 IFREMER hake

The fishery were carried out by monofilament gill-nets using five mesh-sizes ranging from 80 to 122 mm, stretched mesh. Two experiments were conducted yielding a total catch of 1694 hake.

In general the fit between the observed and estimated catches was found adequate for both experiments (Appendix B). However, the fits found for the two largest mesh-sizes in the first experiment where the catches were low, were somewhat imprecise. The relation between the selection curve and the estimated selection for individual data points indicate a relative fair correspondence below the modal value (fig. 3.9) with somewhat more scatter above this value. This pattern appears more clear when viewing the selection plots from the individual mesh-sizes (Appendix B) where an increase in the scatter around the selection curves is found for hake exceeding ca. 70 cm. According to the estimated population size structure (Appendix B) the number of hake above 70 cm was low in both experiment.

The estimated modal value and spread differed little in the two experiments (table 3.11). A somewhat larger difference were seen in the constants *C1, C2* which were estimated as (0.12; 0.22) and as (0.02 ; 0.35), respectively. However, the selection curves for the two experiments have been estimated to be very similar (fig 3.10).

Few hake were available to estimate the right most part of the selection curve as only 6%, equivalent to 95 hake, were taken at a size exceeding $k+2st$ (Table 3.12).

The proportionality constant between the length and gill-girth, maximum girth and maxillar girth were estimated at 0.34, 0,34 and 0.28, respectively. The girth information showed that the hake caught at the modal length were characterised by a girth to perimeter ratio of 1.10 when measured at the gill or at the maximum (table 3.13). This indicate that the modal values may be related to fish being entangled close to the gill .

Table 3.11 : IFREMER hake. Selection parameters estimated from the total catch information and from the individual experiments.

	Experiment					
	All		exp_1		exp_2	
	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter						
K	6.429	0.049	6.381	0.068	6.442	0.060
ST	0.771	0.036	0.805	0.059	0.707	0.040
C1	0.049	0.010	0.122	0.025	0.015	0.007
C2	0.299	0.045	0.216	0.057	0.350	0.056

Table 3.12: IFREMER hake. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (***st***) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes												Total
	<-5 St	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 5 St	
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
Experiment													
no. 1	0.0	1.1	3.1	9.2	21.7	32.9	21.3	6.2	3.0	1.0	0.4	0.1	794
no. 2	0.2	0.3	1.6	2.3	19.1	32.7	26.3	10.9	4.2	1.8	0.4	0.1	900
All	0.1	0.7	2.3	5.5	20.3	32.8	24.0	8.7	3.7	1.4	0.4	0.1	1694

Table 3.13 : IFREMER hake. The ratio between the measured girth at the modal length and the mesh perimeter for the different mesh sizes used. 'Nos' indicate the number of girth measurements.

	Measurement at			
	Gill Girth	Maxil. Girth	Pect. Girth	
	Average Ratio	Average Ratio	Average Ratio	Nos.
Mesh-size (mm)				
80	1.104	0.906	1.099	34
89	1.093	0.887	1.086	42
99	1.130	0.915	1.143	52
110	1.069	0.883	1.102	27
122	1.023	0.846	1.059	5
Overall average	1.101	0.898	1.109	160

Fig. 3.9 : IFREMER hake. A comparison between the estimated selection curve and the selections calculated for individual data points (cf. eq. 2.5) .

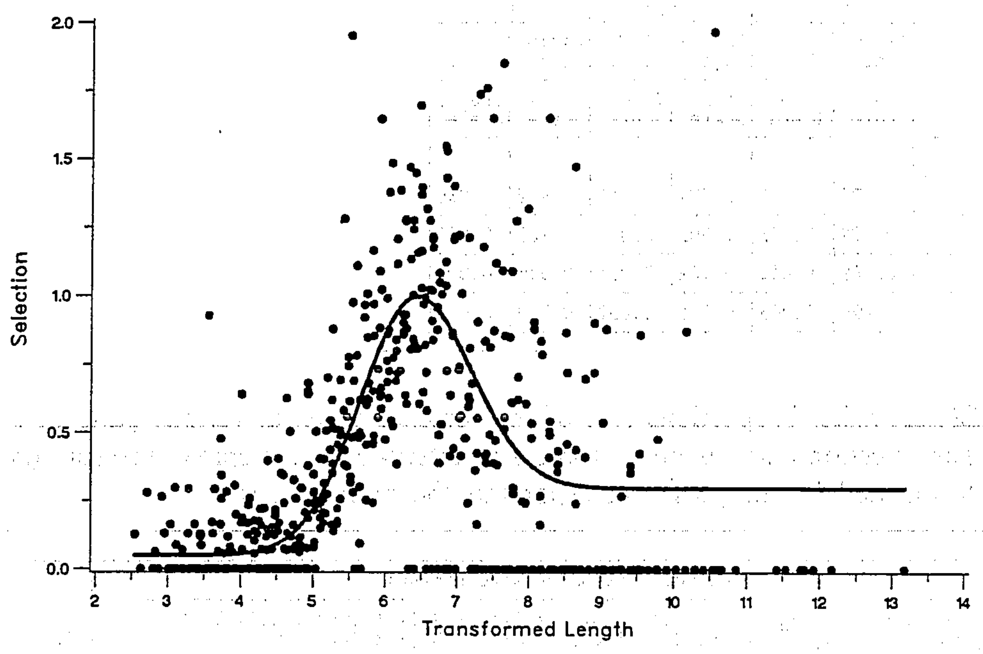
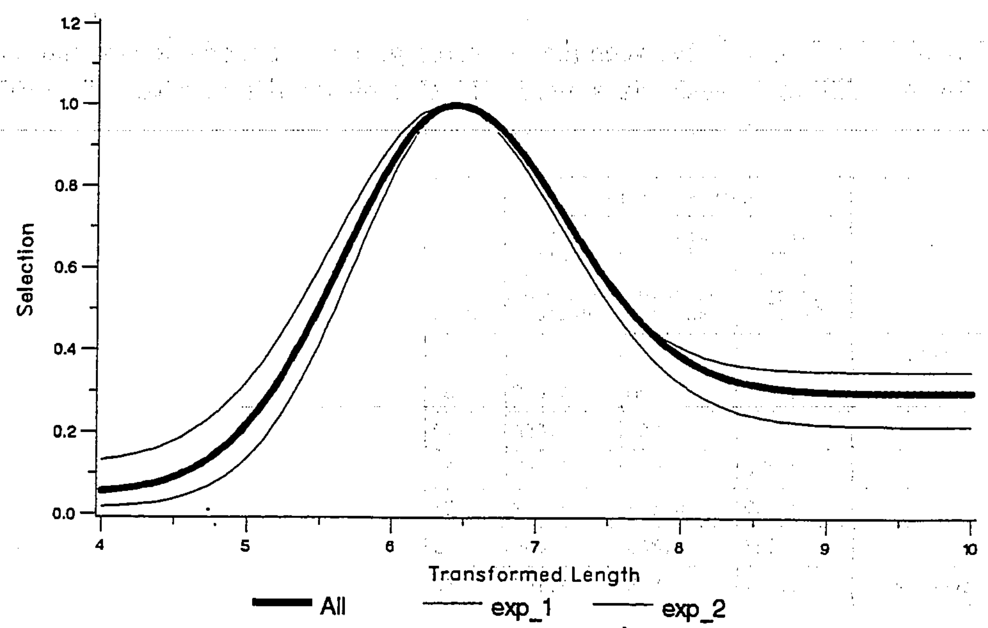


Fig . 3.10 : IFREMER hake. Plots of the selection curve estimated on the basis of all experiments and from the individual experiments.



1.3.4.5 SEAFISH hake

The experiments were conducted with monofilament gill-nets using 5 mesh-sizes ranging from 92 to 143 mm, stretched mesh. The mesh size chosen was relatively large with the smallest mesh-size used being larger than the two smallest mesh-size used by IFREMER. Four experiments were carried out yielding a total catch of 2938 hake. Catches were rather unevenly distributed on experiments with less than 200 hake taken in the first experiment. In the fourth experiment, a small number of hake of a size between 25 and 40 cm were taken across all mesh sizes. These hake were far to small to be gilled in any of the mesh-sizes.

The fit between the observed and predicted catches were reasonable although there are a slight tendency for the model to underestimate catches for the two largest mesh-sizes (Appendix B). The comparison between the selection curve and the selection values estimated for the individual data points (fig. 3.11) show overall a considerable amount of scatter around the selection curve. The modal value was estimated at 6.81, ranging from 6.56 to 7.05 in the individual experiments (table 3.14). The overall spread were found at 1.01 whereas both *C1* and *C2* were estimated at zero. The plot of the selection curves (fig. 3.12) indicate a fair resemblance of the ascending parts of the various selection curves whereas the descending parts differs considerable between experiments

As shown in table 3.15 a very limited amount of information was available to estimate the right most part of the selection curve as only 0.8% of the catches , corresponding to 24 fish, were caught at sizes exceeding ***k+2st***. This may be attributed to the relatively large mesh-sizes used in the experiments.

The analysis of the girth-length relations showed significant differences between experiments (girth was measured at the first tree experiments). The proportionality constants between length and girth was found at 0.36 (gill girth), 0.38 (maximum girth) and at 0.29 (maxillar girth) in the first experiment (Appendix C). The similar proportionality constants were estimated 2 and 6 % below these values, for the second and third experiment, respectively. This should imply that the modal value should be expected found at higher values in experiment 3 compared to experiment 2 (experiment 1 is not considered as the estimated parameters are assumed unreliable due to the low catches in this experiment). However, in the estimations the modal value was in fact estimated higher in experiment 2 compared to experiment 3. Relating girth to mesh perimeter for the modal lengths in each mesh indicate that the girth measured at the gill and the pectoral fin exceeds the mesh perimeter with 22% and 32 % , respectively, whereas the maxillar girth almost approaches the mesh perimeter (table 3.16).

Table 3.14 : SEAFISH hake. Selection parameters estimated from the total catch information and from the individual experiments.

	Experiment									
	All		exp_1		exp_2		exp_3		exp_4	
	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter										
K	6.807	0.038	6.556	0.069	7.052	0.180	6.645	0.069	6.670	0.057
ST	1.006	0.021	0.666	0.040	1.192	0.093	0.811	0.051	0.798	0.041
C1	0.001	0.000	0.000	0.000	0.000	0.000	0.017	0.005	0.014	0.009
C2	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.080	0.083	0.042

Table 3.15: SEAFISH hake. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes												Total
	<-5 St	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	>5 St	
	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Pct.	Nos in Catch
Experiment													
no. 1	0.0	4.8	5.4	6.0	18.0	45.5	17.4	3.0	0.0	0.0	0.0	0.0	167
no. 2	0.2	1.4	5.0	12.4	26.3	39.7	12.4	2.5	0.2	0.0	0.0	0.0	1329
no. 3	0.0	0.6	1.6	7.8	21.9	47.1	15.8	4.0	1.1	0.2	0.0	0.0	631
no. 4	0.0	4.8	5.4	3.3	17.3	41.6	21.5	4.8	0.9	0.5	0.0	0.0	811
All	0.1	2.4	4.4	8.5	22.4	42.1	15.9	3.5	0.6	0.2	0.0	0.0	2938

Table 3.16 : SEAFISH hake. The ratio between the measured girth at the modal length and the mesh perimeter for the different mesh sizes used. 'Nos' indicate the number of girth measurements

	Measurement at			
	Gill Girth	Maxilar Girth	Maximum Girth	
	Average Ratio	Average Ratio	Average Ratio	Nos.
Mesh-size (mm)				
92	1.189	0.938	1.266	20
106	1.229	0.926	1.336	29
116	1.194	0.915	1.460	4
129	1.211	0.915	1.343	2
143	1.414	1.058	1.575	1
Overall average	1.215	0.931	1.324	56

Fig. 3.11 : SEAFISH hake. A comparison between the estimated selection curve and the selections calculated for individual data points (cf. eq. 2.5) .

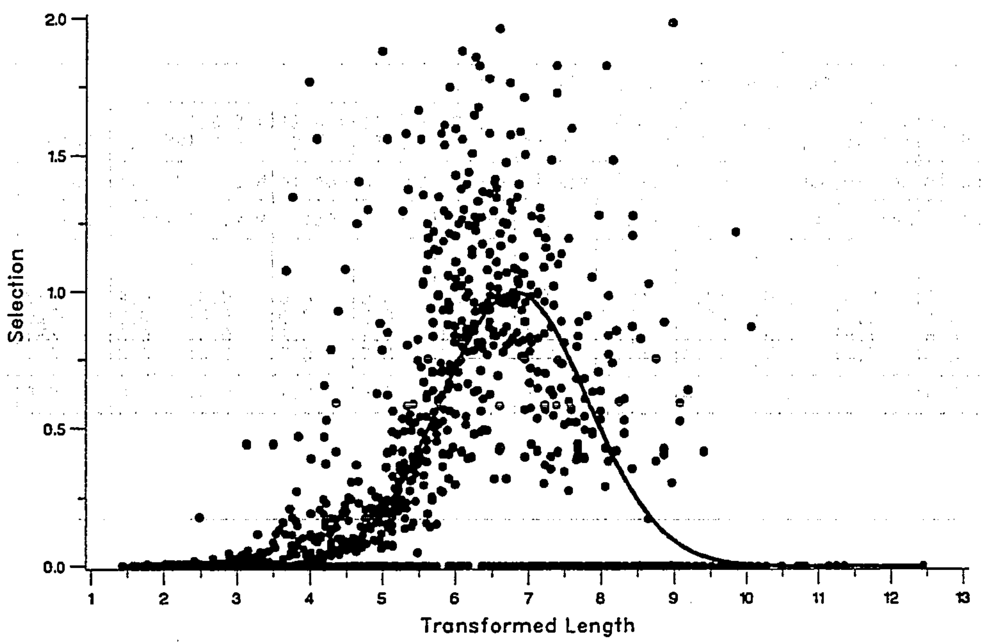
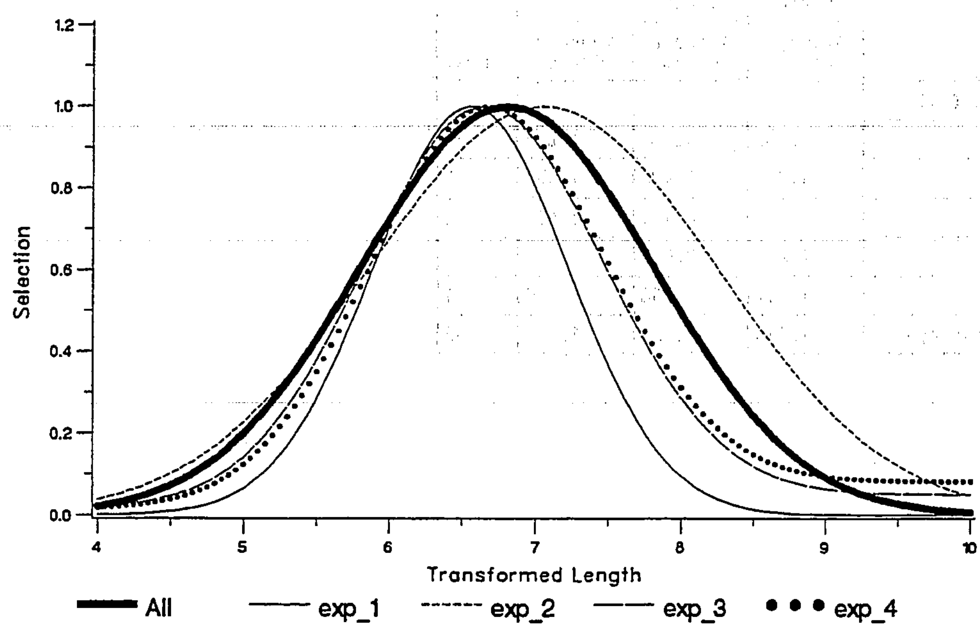


Fig . 3.12 : SEAFISH hake. Plots of the selection curve estimated on the basis of all experiments and from the individual experiments.



1.3.4.6 DIFTA plaice

The fishery were carried out by multifilament trammel nets using six mesh-sizes in the range 98 mm to 151 mm measured as stretch mesh. Three experiments were conducted resulting in a total catch of about seventeen thousand fish. Catches were unevenly distributed between experiments with the catches accounting for 10%, 20% and 70% of the total in experiment 1 to 3, respectively.

Evaluating the fit between the observed and the estimated catches show an unsatisfactory fit for the first experiment, a moderate fit for the second experiment and an god fit for the third experiment (Appendix B). However, when evaluation the fit between the estimated catches and the observations from the analysis of the individual experiments all fits were found to be adequate (Appendix B). This indicate that the unsatisfactory fit for the first experiment when using all data is caused by the fact that the model tries to fit all observed data and that little weight is given to the first experiment were low catches were made.

The correspondence between the estimated selection curve and the selection for the individual cm. groups a moderate level of scatter for both the ascending part and for the descending part of the selection curve until a transformed length of approximately 3.0 (fig.3.13). Scrutinizing the relations for the individual meshes indicate that the scatter increases for plaice sizes above about 35 cm. Plaice above this size were rare in all experiments (Appendix B). Fig 3.13 also show that for sizes around the modal value the selection curve tend to fall below the estimates derived from the individual points. This is not seen when evaluating the selection plots found when analysing the experiment one by one which indicate that it is difficult to fit the tree experiments with a common set of selection parameters.

The parameters estimates are summarized in table 3.17. The parameters found for the analysis using all data differs but little from the parameters found in the third experiment. This is to be expected due to the high proportion of the total catches taken in that experiment. The modal values estimated in the three experiments are almost equal whereas considerable differences are seen between the spreads which ranges from 0.15 to 0.32. *C1* accounting for the non mesh dependent catch below the modal value were found low in all experiments (0.00 to 0.02) and were estimated at zero for the analysis using all data. *C2* were estimated at 0.14 (range 0.03 to 0.16). A comparison of the estimated selection curves show that the estimates derived from experiment 2 and 3 were rather similar whereas experiment 1 deviates with regards to both the ascending and descending part of the selection (fig. 3.14).

Splitting the catches on size groups relative to the modal value show that only about 3% of the catches were taken to the left of ***k+2st*** (table 3.18). However, due to the high numbers caught this never the less corresponds to 480 fish.

Width information were available from the first and third experiments and showed that the width were about 3% larger in experiment 1 as compared to experiment 3 (Appendix C). This should argument a lower modal value in experiment 1. However, the opposite was seen in the estimated values. The ratio between 2*width and mesh perimeter for size groups adjacent to the modal length of the different mesh sizes show average values of 0.833 and 0.917 for measurements made at the location of the ventral spine and made at the maximal with, respectively (table 3.19). Interpreted at face value this ratio suggest that the plaice were two small to be entangled. To some extent this may be caused by the 2*width underestimates the girth. However, it was also observed that the enmeshment often took plaice with the meshes found diagonally across the body of the plaice.

Table 3.17 : DIFTA Plaice. Selection parameters estimated from the total catch information and from the individual experiments.

	Experiment							
	All		exp_1		exp_2		exp_3	
	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter								
K	2.513	0.008	2.533	0.009	2.540	0.007	2.463	0.010
ST	0.314	0.006	0.145	0.006	0.233	0.006	0.321	0.007
C1	0.000	0.001	0.020	0.003	0.019	0.005	0.000	0.000
C2	0.138	0.028	0.385	0.030	0.155	0.016	0.139	0.018

Table 3.18: DIFTA Plaice. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes											
	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 5 St	Total
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
EXP												
no. 1	0.0	0.0	1.0	4.1	36.3	43.2	11.3	2.7	0.9	0.3	0.3	1741
no. 2	0.0	0.0	0.5	9.8	41.2	36.8	8.6	1.9	0.8	0.2	0.2	3270
no. 3	0.0	0.1	3.2	24.1	38.8	24.8	6.5	1.7	0.6	0.2	0.0	12151
All	0.0	0.1	2.4	19.4	39.0	28.9	7.4	1.8	0.7	0.2	0.1	17162

Table 3.19 : DIFTA plaice. The ratio between 2* measured width at the modal length and the mesh perimeter for the different mesh sizes used. 'Nos' indicate the number of girth measurements

	Measurement at		
	Max. Girth	Spine Girth	
	Average Ratio	Average Ratio	Nos
Mesh-size (mm)			
98	0.940	0.862	43
108	0.912	0.831	102
119	0.917	0.830	88
129	0.901	0.817	49
140	0.925	0.820	18
151	0.923	0.844	8
Overall average	0.917	0.833	308

Fig. 3.13 : DIFTA Plaice. A comparison between the estimated selection curve and the selections calculated for individual data points (cf. eq. 2.5) .

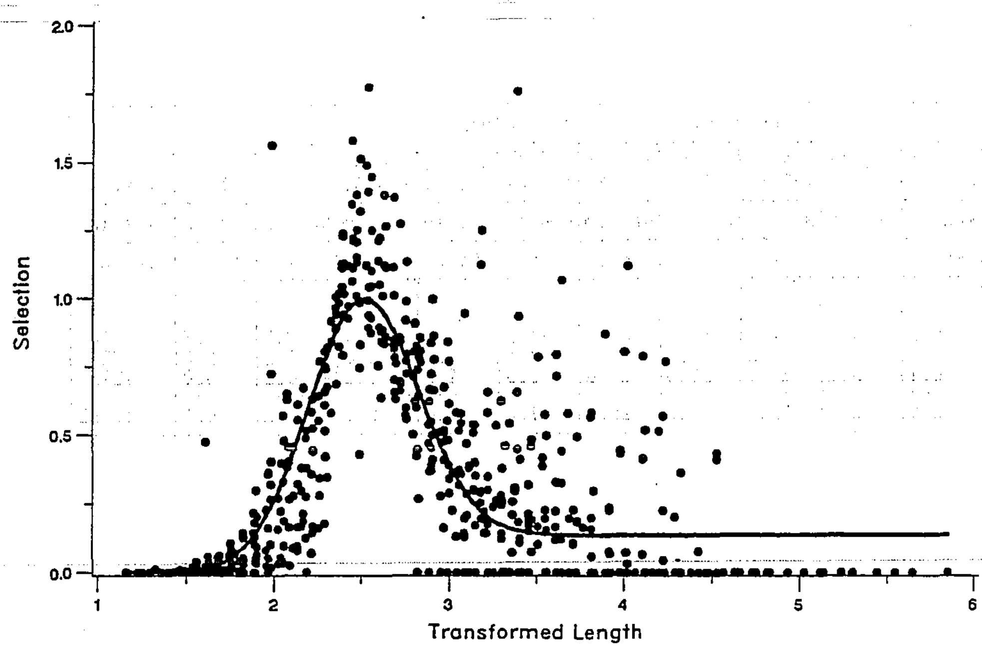
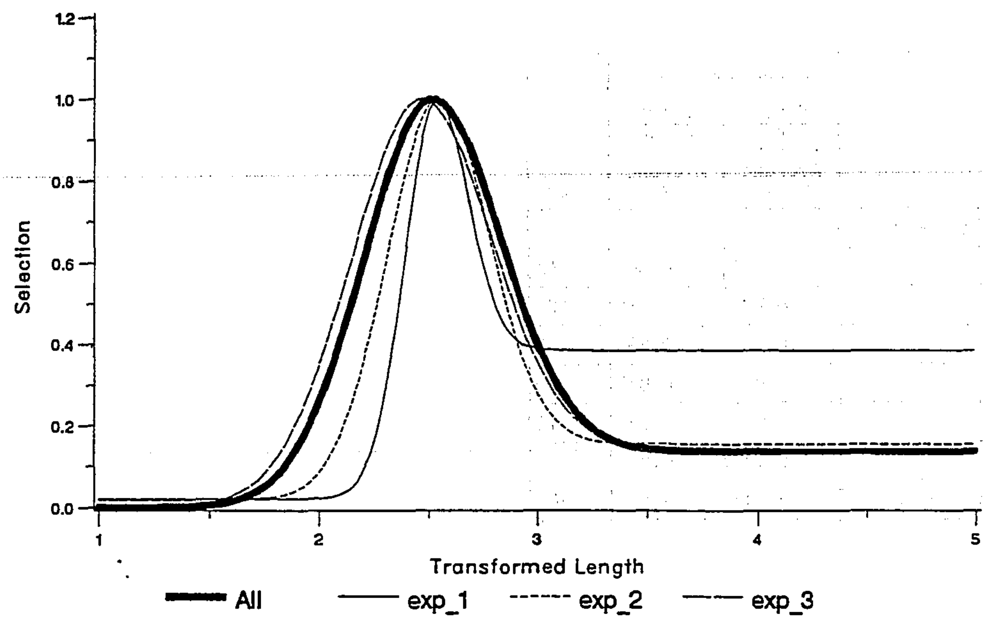


Fig . 3.14 : DIFTA plaice. Plots of the selection curve estimated on the basis of all experiments and from the individual experiments.



1.3.4.7 DIFTA plaice by-catches in fisheries targeting cod and sole

By catch information was available from DIFTA's four cod experiment and from DIFTA sole experiment yielding plaice catches of 1473 and 3405, respectively. Prior to the analysis, the plaice catches in the cod experiments were aggregated over experiments leading to a single length by mesh-size matrix.

For both sets of by catch data the fit between the observed and the predicted catches were found to be acceptable (Appendix B). For the by-catches in the cod-fishery, the correspondence between the selection curve and the selection estimated from the individual data points was found adequate for transformed length below approximately 3 (fig. 3.15). Evaluating the selection plots by mesh-sizes (Appendix B) show the high level of scatter around the selection curve was found for plaice exceeding the length of about 35 cm. Few plaice of this size were taken in the cod experiments. For the by catch in the sole fishery little scatter was seen for both the ascending and the descending leg of the selection curve (fig 3.16).

The estimated selection parameters were estimated at rather similar values (table 3.20) with the largest difference found for the parameter *C2* which ranged from 0.14 to 0.23. The similarity of the two estimated selection curves also appears from fig. 3.17.

About 7 % of the catches in each fishery were taken at fish sizes exceeding ***k+2st*** corresponding to 105 and 235 individuals in the cod and sole fishery, respectively (table 3.21).

Table 3.20 : DIFTA Plaice by-catches. Selection parameters estimated from the total catch information and from the individual experiments.

	Fishery for			
	Cod		Sole	
	Estimate	Std. Err.	Estimate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter				
K	2.532	0.026	2.636	0.017
ST	0.369	0.016	0.355	0.014
C1	0.000	0.000	0.000	0.000
C2	0.227	0.046	0.141	0.027

Table 3.21: DIFTA Plaice by catches. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes										
	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 5 St	Total
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
Bycatch in											
Cod fishery	0.0	1.6	16.6	32.9	32.4	9.4	5.6	1.2	0.2	0.1	1473
Sole fishery	0.0	0.9	11.7	39.4	28.9	12.2	4.8	1.6	0.3	0.2	3405

Fig. 3.15. DIFTA plaice by catches in the cod fishery. A comparison between the estimated selection curve and the selection calculated for individual data points (cf. Eq. 2.5)

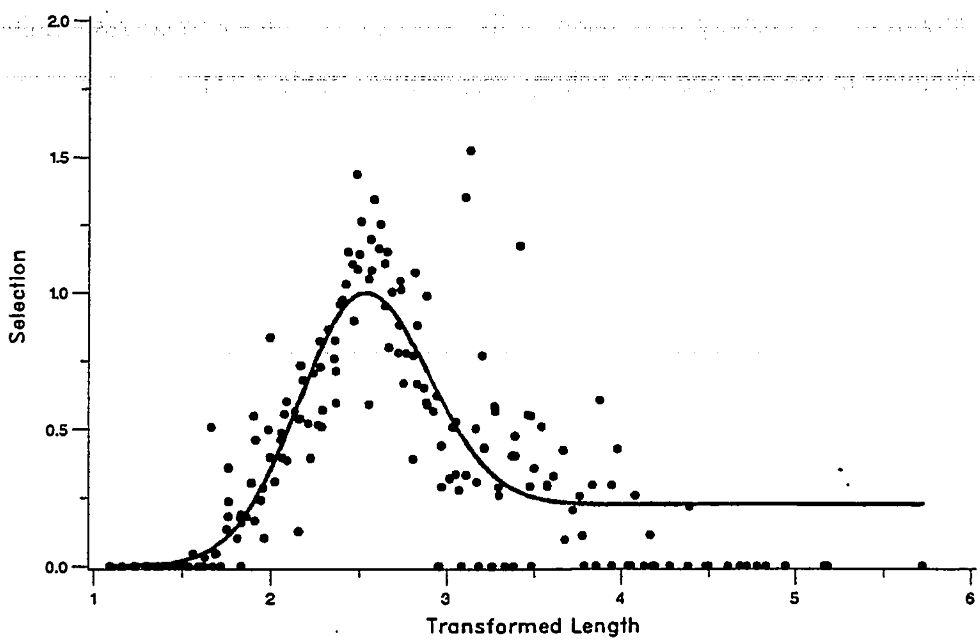


Fig. 3.16. DIFTA plaice by-catches in the sole fishery. A comparison between the estimated selection curve and the selection calculated for individual data points (cf. Eq. 2.5)

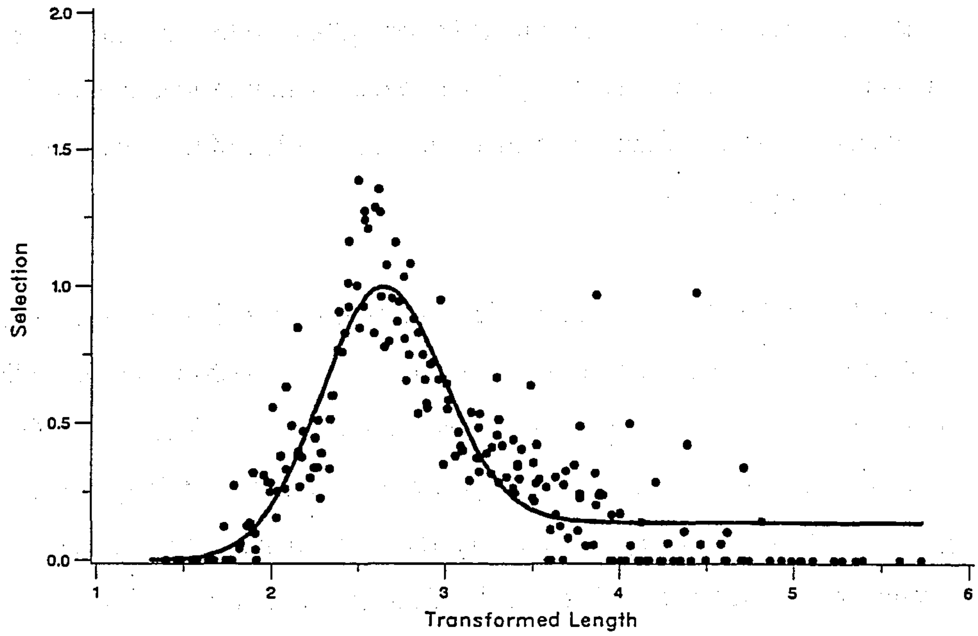
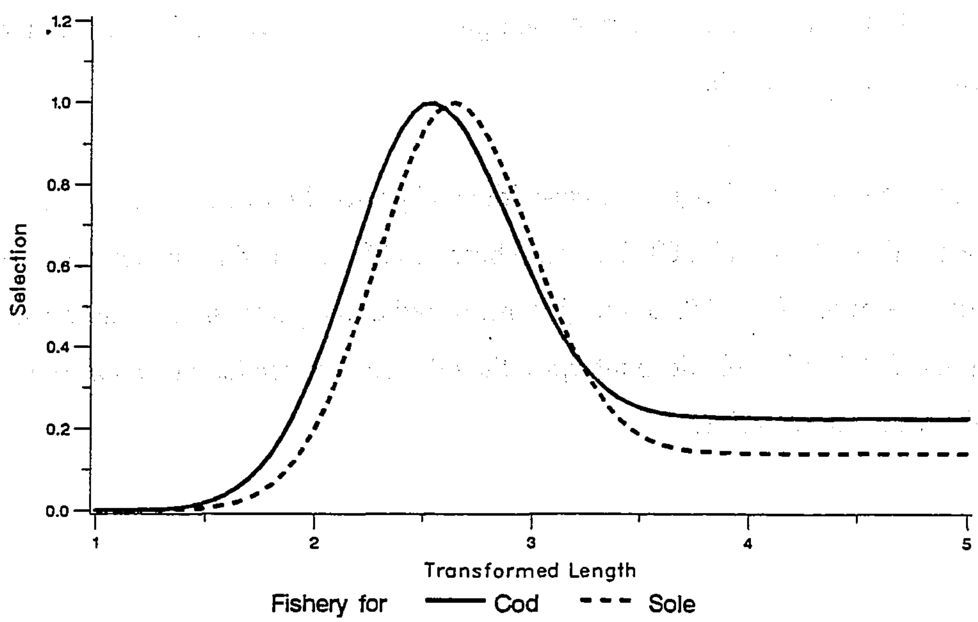


Fig 3.17 : DIFTA plaice by catches. Plots of the selection curve from the by-catches in the cod and sole fisheries.



1.3.4.8 DIFTA sole

Only one experimental fishery was carried out targeting sole this, however, yielding a catch of 10547 hundred individuals. The gear used was a multimonofilament gill-net with seven mesh-sizes ranging between 81 mm and 118 mm, stretched mesh. The size distribution caught in individual mesh-sizes were generally uni-modal but a distinct shoulder appears to the left of the model length in the three largest mesh-sizes (Appendix B).

Adequate fits were found between the observed and predicted catches for the five smallest mesh-sizes whereas somewhat inferior fits were experienced for the two largest mesh-sizes (Appendix B). The fit between the selection curve and the estimated selection for the individual data points show a reasonable fit with a moderate amount of scatter for transformed length below approximately 3.5 (fig 3.18). When evaluating the selection fits by mesh-size it appears that the increased variability is found for sole above ca. 35 cm. Sole of this size were rare in both catches and in the estimated length distribution of the stock (Appendix B).

The estimated selection parameters and the selection curve are shown in table 3.22 and fig 3.18 respectively.

The proportion of the total catch taken in various parts of the selection curve are given in table 3.23 Only about 2 % of the catches were taken to the right of ***k+2st***. However, due to the high catch this correspond to about 230 fish.

The proportionality constant between length and gill-width and pectoral fin width was estimated at 0.19 and 0.26, respectively (Appendix C). The ratio between 2*width and mesh perimeter at the modal length show values of 0.85 and 0.63 for girth measured at the pectoral fin an at the gill cover, respectively (table 3.24). It is difficult to interpret the relation between length and girth for reasons similar to those stated for plaice.

Table 3.22 : DIFTA sole. Selection parameters estimated from the sole experiment.

	Experiment	
	All	
	Estimate	Std. Err.
	Trans. Scale	Trans. Scale
Parameter		
K	3.291	0.013
ST	0.246	0.008
C1	0.044	0.004
C2	0.231	0.038

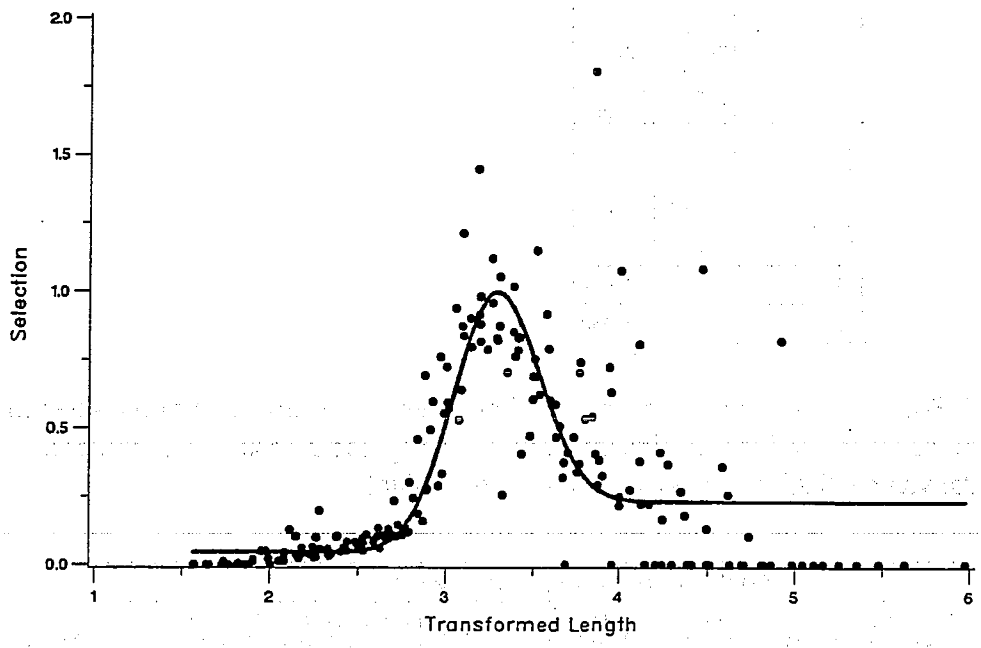
Table 3.23: DIFTA Sole. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes												
	<-5 St	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 5 St	Total
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
EXP													
All	0.4	2.1	4.6	8.1	19.0	37.0	21.0	5.6	1.5	0.5	0.2	0.0	10547

Table 3.24 : DIFTA sole. The ratio between 2* measured width at the modal length and the mesh perimeter for the different mesh sizes used. 'Nos' indicate the number of girth measurements

	Measurement at		
	Max. Girth	Spine Girth	
	Average Ratio	Average Ratio	Nos
Mesh-size (mm)			
98	0.940	0.862	43
108	0.912	0.831	102
119	0.917	0.830	88
129	0.901	0.817	49
140	0.925	0.820	18
151	0.923	0.844	8
Overall average	0.917	0.833	308

Fig. 3.18. Difta Sole. A comparison between the estimated selection curve and the selection calculated for individual data points (cf. Eq. 2.5)



1.3.4.9 DIFTA sole by-catches in fisheries targeting cod and plaice

By-catch information is available from the gill-net experiments after cod and for the trammel-net experiments after plaice. In total 501 and 1701 sole were taken in the cod and plaice fisheries, respectively. The catch data from each fishery were aggregated across experiments prior to analysis.

Considering the low amount of catches taken the fits between the observed and the predicted catches may be described as reasonable for both fisheries (Appendix B). The fit between the selection curve and the selection estimated from the individual data points show a number of selection points at values of zero in the rage between 2 and 4 on the transformed scale (fig 3.19-3.20). Referring to the selection plots by mesh-sizes show that these points stems from the larger mesh-size which caught few sole (Appendix B). These plots also show that the scatter around the right most part of the selection curve is associated with the large soles of which few were taken.

The estimated modal length (*k*)and spread (*st*) were estimated at slightly higher in the fishery after plaice than in the sole fishery (table 3.25). The constants *C1* and *C2* were estimated at low values in both experiments. The two selection curves are compared in fig 3.21.

For both sets of experiments the proportion of the catches taken to the right of ***k+2st*** were low - 3 % and 0.3% of the total catches for the two fisheries (table 3.26). As the numbers caught was low this implies that the right most part of the selection curve is based on few individuals.

Table 3.24 : DIFTA sole by-catches. Selection parameters estimated from the by-catches in the cod and plaice fisheries.

	Fishery for			
	Cod		Plaice	
	Estim-ate	Std. Err.	Estim-ate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter				
K	3.034	0.021	3.181	0.022
ST	0.248	0.015	0.298	0.012
C1	0.023	0.007	0.035	0.004
C2	0.067	0.045	0.010	0.036

Table 3.25: DIFTA Sole by-catches. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes												
	<-5 St	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 5 St	Total
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
Bycatch in													
Cod fishery	0.4	2.0	3.6	6.2	13.2	34.5	32.8	4.0	2.9	0.2	0.2	0.0	551
Plaice fish.	0.8	5.2	8.2	12.1	20.6	37.7	13.8	1.4	0.2	0.1	0.0	0.0	1701

Fig. 3.19. DIFTA sole by-catch in the cod fishery A comparison between the estimated selection curve and the selection calculated for individual data points (cf. Eq. 2.5)

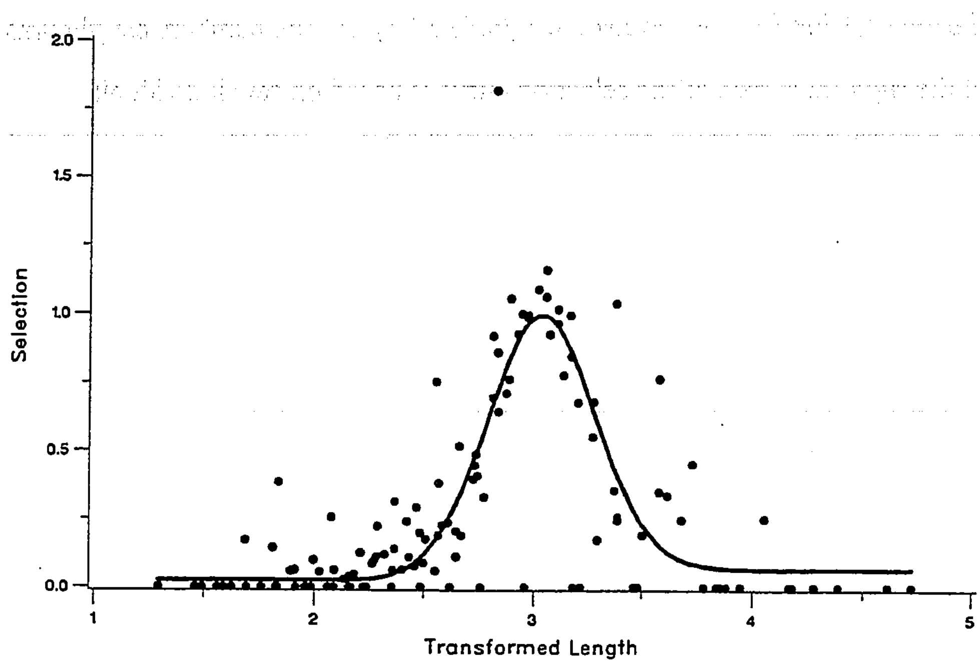


Fig. 3.20. Difta Sole by-catch in the plaice fishery A comparison between the estimated selection curve and the selection calculated for individual data points (cf. Eq. 2.5)

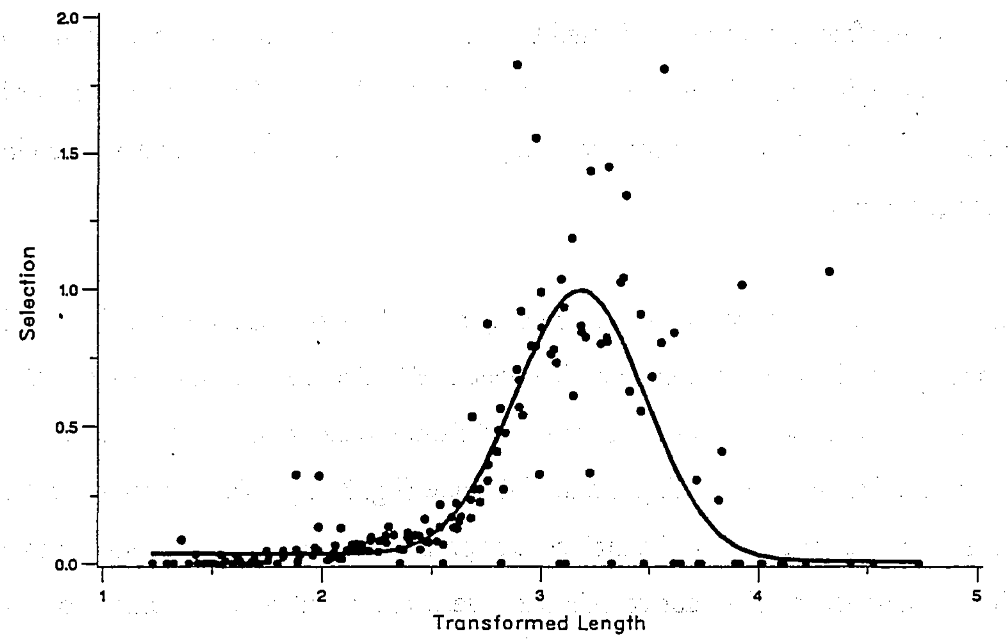
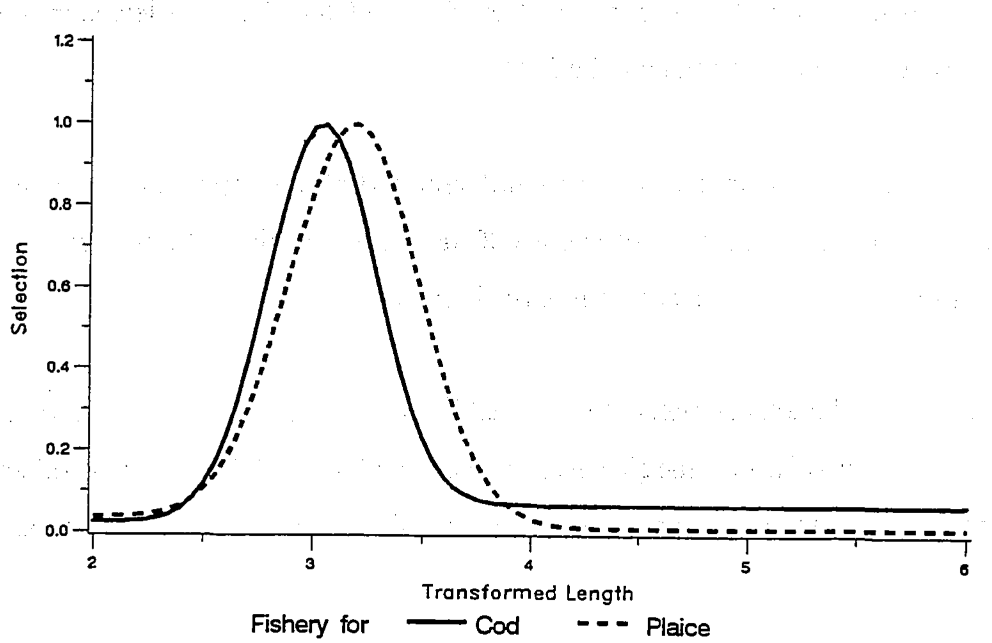


Fig 3.21: DIFTA sole by catches. Plots of the selection curves estimated from the by-catches in the cod and sole fisheries.



1.3.4.10 IFREMER sole (Multifilament nets)

Four experimental fisheries after sole were conducted by IFREMER using multifilament trammel nets using 5 mesh-sizes ranging from 84 mm to 111 mm, stretched length. The total numbers of sole caught amounted to 4769. The catches was unevenly distributed with small catches taken in the second and third experiment.

Except for the third experiment were the numbers caught was low an acceptable fit is found between the estimated and the observed catches (Appendix B). The comparison between the estimated selection curve and the selection values estimated from the individual data points show a considerable scatter for fish sizes exceeding the modal value (fig. 3.22). When comparing the selection plots by mesh sizes it appears that the high scatter points are associated with sole above about 35 cm. The abundance of sole above this size were estimated at low values for all experiments (Appendix B).

The modal value (***k***), the spread (***st***) and the constant relating to the non mesh-size dependent catches below the mode (***C1***) were estimated at rather similar values in all experiments (table 3.25). The constant relating to the non mesh-size dependent catches above the mode (***C2***) showed considerable between experiment differences ranging from 0.41 to 0.83. This is reflected in the comparison of the selection curves presented in fig 3.23.

The distribution of the catches available to estimate the different part of the selection curve show that about 13% of the catches (equivalent of about 600 fish) were available to estimate the selection of the right most part of the selection curve (table 3.26).

The ratio between 2*width and mesh perimeter at the modal length show values of 0.93 and 0.65 for girth measured at the pectoral fin an at the gill cover, respectively (table 3.27). As for the other flatfish it is difficult to interpret the relation between length and girth for reasons similar to those stated for plaice.

Table 3.25 : IFREMER sole, MF-nets. Selection parameters estimated from the total catch information and from the individual experiments.

	Experiment									
	All		exp_1		exp_2		exp_3		exp_4	
	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter										
K	3.263	0.013	3.284	0.022	3.307	0.030	3.186	0.073	3.209	0.019
ST	0.226	0.007	0.210	0.012	0.235	0.022	0.224	0.042	0.223	0.011
C1	0.013	0.002	0.015	0.003	0.020	0.014	0.003	0.008	0.014	0.004
C2	0.523	0.040	0.616	0.076	0.416	0.090	0.834	0.180	0.413	0.049

Table 3.26: IFREMER Sole, MF-nets. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes												
	<-5 St	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 4 St	Total
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
Experiment													
no. 1	0.3	0.9	1.5	4.4	19.1	29.8	23.8	8.8	6.4	2.7	1.4	0.9	2202
no. 2	0.0	0.3	0.8	2.3	16.1	33.2	22.9	12.5	7.5	2.9	0.8	0.8	385
no. 3	0.0	0.3	1.6	3.2	15.7	26.8	19.8	12.5	9.6	4.8	3.2	2.6	313
no. 4	0.6	1.3	1.8	8.7	25.3	22.5	17.1	7.9	5.9	3.8	3.0	2.1	1869
All	0.4	0.9	1.6	5.8	21.1	27.0	20.8	9.0	6.5	3.3	2.1	1.4	4769

Table 3.27 : IFREMER sole , MF-nets. The ratio between 2* measured width at the modal length and the mesh perimeter for the different mesh sizes used. 'Nos' indicate the number of girth measurements.

	Measurement at		
	Gill Girth	Pect. Girth	
	Average Ratio	Average Ratio	Nos
Mesh-size (mm)			
84	0.646	0.914	69
90	0.661	0.937	69
96	0.653	0.939	70
100	0.654	0.939	70
111	0.630	0.925	72
Overall average	0.649	0.931	350

Fig. 3.22. IFREMER sole, MF-nets. A comparison between the estimated selection curve and the selection calculated for individual data points (cf. Eq. 2.5)

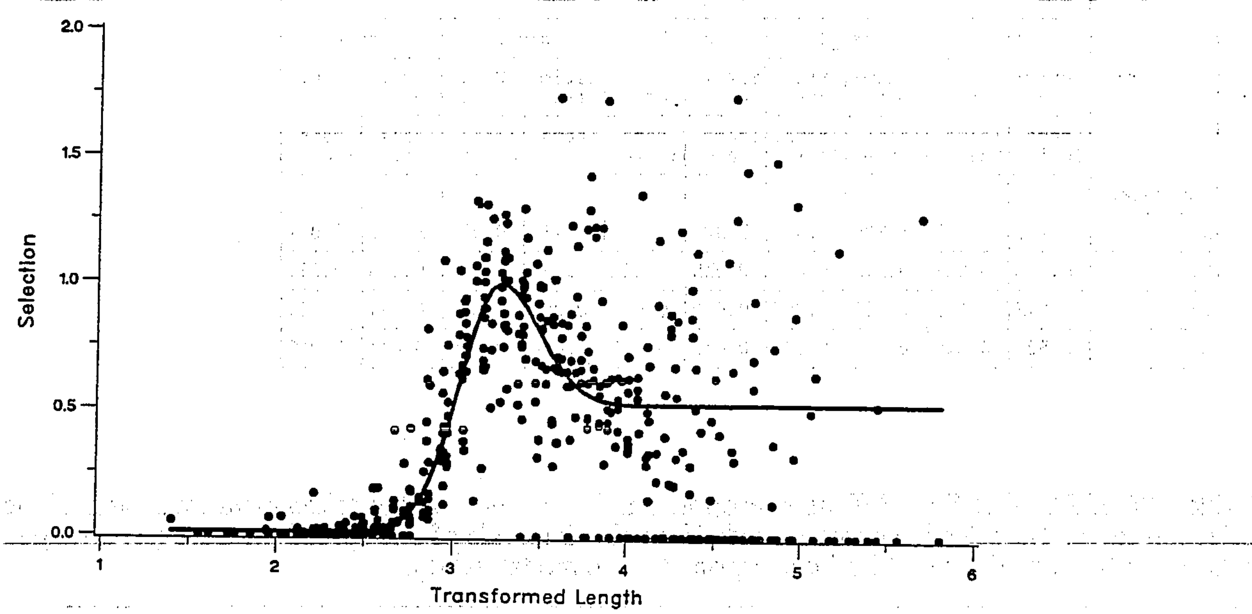
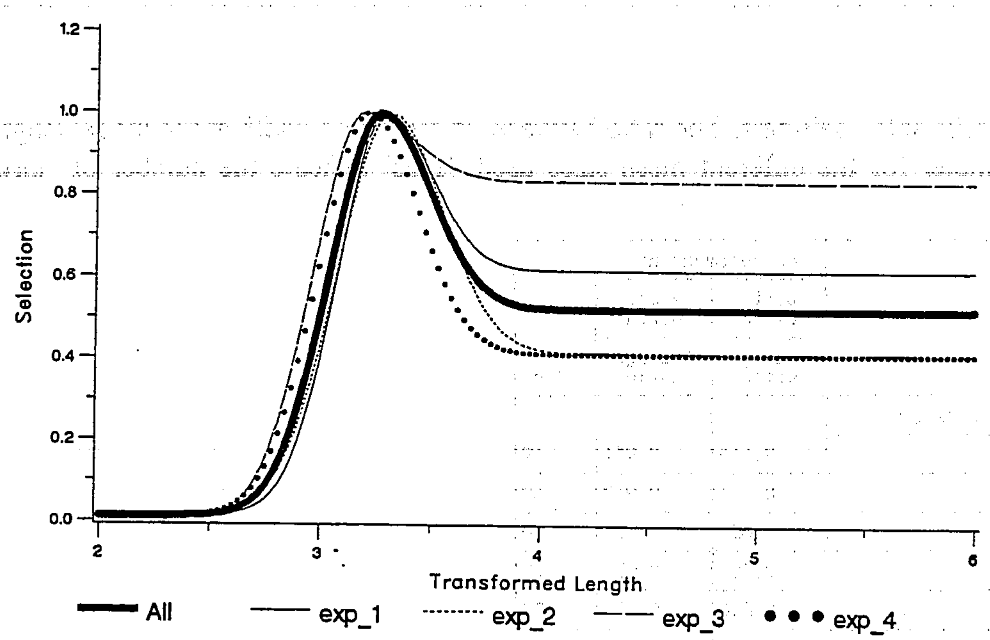


Fig 3.23 : IFREMER sole, MF-nets. Plots of the selection curve from the by-catches on the basis of all experiments and from the individual experiments.



1.3.4.11 IFREMER sole (Multimonofilament nets)

The experiments were carried out at the same time and at the same locations as the experiments using the multifilament nets and used similar mesh sizes. The number caught in the mutimonofilament nets, 3135 soles, was considerable below what was found in the multifilament nets. As the mesh sizes were the same and they encountered the same population one may relate the power of the two net types by comparing the catch rates. Considerable difference were found in the net dimensions of the 5 different multimonofilament nets but after an adjustment to a average net length the fishing power of the multimonofilament nets may be estimated as being only 0.72 times the power of the multifilament nets.

A scrutinization of the multimonofilament catch data revealed that there were considerable differences regarding the fishing power between the various mesh-size sections. An equal fishing power, corresponding to the selection curves being of equal height (cf. fig. 1.1), implies that the mesh-size having the highest selection gradually changes with fish length. As the different mesh sizes encounters the same population this imply that the largest catches within cm-groups should shift gradually from the smallest mesh-size to the largest mesh-size. This pattern is not recognized for the IFREME MM-nets (table 3.28). This is most notable for the 96 mm mesh-size where the numbers caught is lower than what is taken in the two adjacent mesh-sizes. A similar under performance seems to appear for the largest mesh size which generally catches less fish than the 100 mm mesh.

The differences regarding the fishing power of the multimonofile nets is also indicated when comparing the catches from this net material with the catches taken in the same mesh sizes in the multifilament nets. Based on the aggregated catches over the four experiments the ratios between the catches in the multimonofilament and the multifilament nets were found at 0,53 (84 mm mesh size), 0,82 (90 mm mesh size), 0.60 (96 mm mesh size), 1.13 (100 mm mesh size), and 0.74 (111 mm mesh size). This comparison also suggest that the irregularities in the catches in the multimonofile nets may be caused by the fishing power of the 96 mm mesh being substantially below the two adjacent mesh sizes. The comparison moreover indicate that the power of the smallest mesh may well be below the average.

As the assumption of equal power is violated in the multimonofile experiments the estimated selection curves from this fishery can not be considered reliable. However, the results of the analysis may be found in Appendix A and B.

The multimonofile nets are constructed of different materials: the 84, 96 and 110 mm mesh size using 6*1.5 multimono as opposed to 8*1.1 for the 90 and 100 mm mesh size. The researchers conducting the experiments noted that the 6 filament material was stiffer than the 8 filament material. It appears that the 8 filament material performs the best when being compared to the mulfifilament experiments. This indicate that the power differences could be associated with the net material.

Table 3.28 : The aggregated catch of sole taken in IFREMER's four experiments using multimonofile nests given by length and mesh size. Due to the difference in net size the catches has been adjusted to a common net length of 39.64 m.

Experiment All

Mesh size	8.38	8.99	9.56	9.96	11.04	Total	
Net length	39.64	39.64	39.64	39.64	39.64		
	Catch (nos.)	Catch (nos.)	Catch (nos.)	Catch (nos.)	Catch (nos.)	Catch (nos.)	Max. Catch
Length (cm)							
19.5	0	1	0	0	0	1	1
20.5	0	1	1	3	1	6	3
21.5	1	1	0	4	1	7	4
22.5	12	13	4	8	4	41	13
23.5	16	11	4	10	7	47	16
24.5	34	22	9	11	9	85	34
25.5	80	45	8	16	6	154	80
26.5	148	69	15	29	6	267	148
27.5	166	139	34	20	5	363	166
28.5	117	146	44	44	12	363	146
29.5	58	99	59	68	12	295	99
30.5	50	69	67	97	24	307	97
31.5	44	56	46	82	25	253	82
32.5	25	46	38	76	51	236	76
33.5	25	34	33	61	47	200	61
34.5	8	30	30	41	45	155	45
35.5	17	29	20	38	32	136	38
36.5	11	17	14	31	25	98	31
37.5	6	11	9	21	22	69	22
38.5	4	4	7	10	21	45	21
39.5	7	4	3	10	5	30	10
40.5	4	2	6	6	8	25	8
41.5	2	7	3	2	5	19	7
42.5	0	2	3	2	3	10	3
43.5	1	2	1	4	4	12	4
44.5	1	1	1	1	1	5	1
45.5	0	2	0	4	1	7	4
46.5	0	0	0	1	0	1	1
47.5	1	0	0	0	0	1	1
48.5	0	0	0	0	0	0	0
49.5	0	0	0	0	0	0	0
50.5	0	1	0	0	0	1	1
Total	838	867	460	699	378	3242	

1.3.4.12 SEAFISH sole

The experimental fisheries were conducted with multimonofilament trammel nets using 5 mesh-sizes between 97 mm and 128 mm. This imply that the smallest mesh-size used in SEAFISH's experiments were considerably higher than what was used in the sole experiments of the two other participating institutes (the smallest mesh-size was larger than the tree smallest mesh-sizes used by DIFTA and IFREMER). The mesh-sizes are also large when judged in relation to the catches as more than 50% of the catches derived from length groups below the estimated modal length of the smallest mesh-size. A total catch of 1945 sole were taken in four experiments. The catches were rather low in the first and fourth experiment (321 and 177 fish, respectively).

The fit between the observed and predicted catches were of varying quality but generally acceptable for the experiments and mesh-size were a reasonable number of sole were taken (Appendix B). When comparing the selection curve with the estimated selection from individual length groups a fair correspondence was found for the ascending part of the selection (fig. 3.24). However, for length exceeding the modal length a very considerable amount of variability is seen in the selection estimates derived from the individual data points. When scrutinizing the selection plots from the individual mesh sizes (Appendix B) it appears the high variability stems from cm groups from 33 cm and above. Few soles of this size were taken in the catches (Appendix B).

The overall modal value was estimated at 3.11 ranging from 3.03 to 3.18 in individual experiment (table 3.29). The overall spread was found at 0.33 (range 0.26 to 0.36). *C1* and *C2* were both estimated at low values for all experiments. In general , the selection curves estimated from the individual experiments are fund relative similar (fig.3.25).

The use of large mesh sizes in the experiments is reflected when compiling the amount of information available for estimating the right most part of the selection curve (table 3.30). Only 0.7 % of the total catch (equivalent of 14 soles) were taken to the right of ***k+2st.***

Width information available from the third experiment showed that the ratio between 2*width and the mesh perimeter for sole taken at the modal size were found at 0.66 and 0.93 for width measured at the gill and at the pectoral fin, respectively (table 3.31). These values are similar to what was estimated by DIFTA and IFREMER. That 2*width is found smaller than the mesh perimeter may be caused by the enmeshment not taking place with the mesh perpendicular to the length axis of the fish.

Table 3.29 : SEAFISH sole. Selection parameters estimated from the total catch information and from the individual experiments.

	Experiment									
	All		exp_1		exp_2		exp_3		exp_4	
	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter										
K	3.112	0.018	3.088	0.037	3.129	0.033	3.182	0.049	3.031	0.030
ST	0.333	0.010	0.329	0.022	0.343	0.018	0.363	0.024	0.259	0.020
C1	0.006	0.002	0.002	0.009	0.000	0.000	0.009	0.004	0.000	0.000
C2	0.004	0.031	0.000	0.000	0.012	0.060	0.000	0.000	0.066	0.068

Table 3.30: SEAFISH Sole. Proportions (%) of the catches taken in various parts of the selection curve. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

	Catch composition by size classes										
	<-4 St >-5 St	<-3 St >-4 St	<-2 St >-3 St	<-1 St >-2 St	< 0 St >-1 St	< 1 St > 0 St	< 2 St > 1 St	< 3 St > 2 St	< 4 St > 3 St	< 5 St > 4 St	> 5 St	Total
	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in	Nos in
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Catch
Experiment												
no. 1	0.3	0.9	6.9	19.9	45.8	19.6	5.6	0.6	0.3	0.0	0.0	321
no. 2	0.0	0.9	5.6	19.8	51.8	17.2	3.9	0.6	0.1	0.0	0.0	787
no. 3	0.3	2.7	13.6	28.5	40.6	12.3	1.7	0.2	0.2	0.0	0.0	660
no. 4	0.0	1.1	1.7	20.9	44.6	24.3	5.6	1.1	0.6	0.0	0.0	177
All	0.2	1.5	8.2	22.9	46.4	16.6	3.6	0.5	0.2	0.0	0.0	1945

Table 3.31 : SEAFISH sole. The ratio between 2* measured width at the modal length and the mesh perimeter for the different mesh sizes used. 'Nos' indicate the number of girth measurements

	Measurement at		
	Gill Girth	Pect. Girth	
	Average Ratio	Average Ratio	Nos
Mesh-size (mm)			
97	0.661	0.940	22
102	0.681	0.946	18
110	0.658	0.914	7
123	0.581	0.854	4
128	0.699	0.957	1
Overall average	0.662	0.932	52

Fig. 3.24. SEAFISH sole. A comparison between the estimated selection curve and the selection calculated for individual data points (cf. Eq. 2.5)

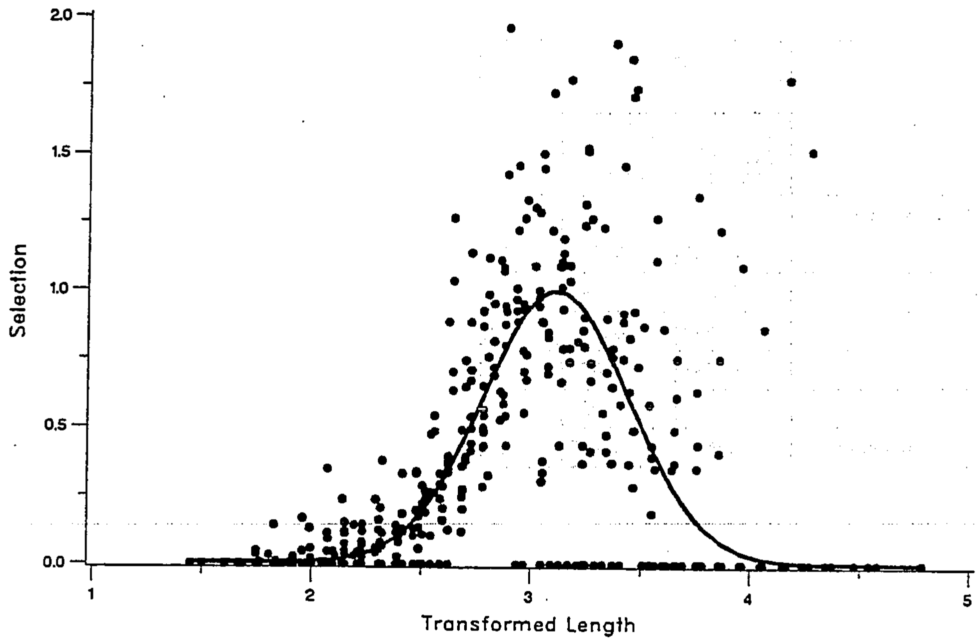
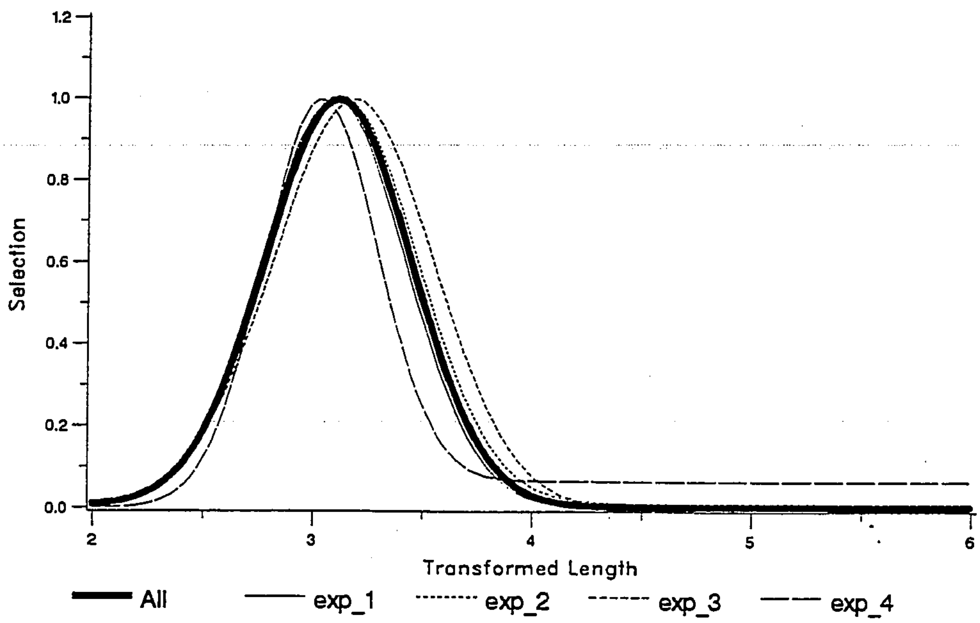


Fig 3.25 : SEAFISH sole. Plots of the selection estimated on the basis of all experiments and from the individual experiments.



1.4 Discussion

1.4.1 Model and estimation

Gill-net selection is usually estimated by indirect procedures. These methods are based on comparison of catch at size information from several mesh-sizes fishing simultaneous. Its is further necessary to assume how the catches in different mesh sizes are related. The present analysis makes three assumptions:

1) The selection curves, i.e. retention as a function length, for different mesh sizes have the same form when normalized with a function of mesh-size. This means that the selection process can be described by the principle of geometrical similarity as formulated by Baranov (1948). The simplest assumption is that gill-net selection only depends of the ratio between length and mesh size.

2) Fishes of the same size are equally available to all the mesh-sizes used and that the catch is proportional to the effort exerted by the different mesh-size.

3) The fishing power of different net sections, i.e. the catch efficiency per net-unit and per time unit should be equal.

The first assumption, the principle of geometrical similarity, can be derived from isometric growth, i.e. when all body proportions grow with the same rate. The isometric growth assumption was checked through a number of fish where length, girth and width was measured. The statistical fit to an allometric growth model, however, while being significant at a 5 % level, was only marginal better than the fit to an isometrical growth model (table 3.2, figugres in Appendix C). This imply that the errors associated with assuming an isometrical growth will be small and hence that the Baranov transformation is justified.

The second assumption, the equal availability of fish of similar size to all nets, was achieved by including the net length in the model assuming a direct proportionality between net length and effort. Also, in all experiments the order of nets of different mesh sizes have been arranged at random to restrict any effects regarding the position of mesh sizes within the net series.

The third assumption, the equal power between nets, is usually made in gill-net selection work but may be questionable in some situations. Hamley (1975) notes that the changes of cotton yarn to nylon yarn and later to monofile could be attributed to an increasing fishing power of these new materials. For gill nets Baranov (1948) assumed that the fishing power depended on the ratio between twine diameter and mesh size. A number of comparative studies using similar mesh sizes of different twine thickens indicate that gill-nets of thinner twines catches better than coarser twine (see Hovgård, 1996b, for a review). Hovgård inferred large power differences from substantial differences in the catch rates from gill-nets of rather similar mesh-sizes and estimated the power differences but had to rely on auxiliary assumptions. In the present study differences in power were found between the two types of trammel nets used for sole by IFREMER and power differences were also inferred between the different mesh sizes of the multimonefile nets. Very little is known on the factors of importance to the fishing power of trammel nets and it is therefore not possible to adjust the catches in the multimonofile experiments to common power standard.

Gill-net selection has been modelled by uni-modal selection curves either being symmetrical (e.g. Holt, 1964) or skew to the right (e.g. McCombie and Fry, 1960, Gulland and Harding, 1961, Reiger and Robson 1966). Bi-modal selection curves have been suggested in several studies (Hamley and Reiger, 1973, Hovgård, 1996 a,b). The present study uses a flexible formulation of an uni-modal selection curve which can take both a symmetrical and a skew form. In contrast to previous approaches the model includes factors to describe catches taken non-selectively, i.e. where the fish size do not relate to the mesh-size. This was introduced to account for catches of fish below the modal size of the smallest mesh which occurred across all mesh sizes. Such catches were seen in several experiments most notably in the experiments for cod. In the first and forth cod experiment conducted by DIFTA it was observed that these small cod was attached to the netting by their teeth. The model formulation used in the final analysis includes two constants *C1* and *C2* to describe non-selective catches below and above the modal length, respectively. This formulation was argued because it was found unreasonable to assume the same probabilities of non-selective catchabilities for sizes of fish which could pass through the mesh and fishes which were hindered in such a passage by their size. From the present data it can not be ascertained that the catches of fish considerable larger than the modal size is taken non-selectively as almost equally good fits could be derived by modelling the selection to the right of the modal length by assuming a continuos declining selectivity (table 3.1, fig 3.1). However, in experiment targeting juvenile cod by using small mesh-sizes (3.3-6.8 cm, stretched mesh) Hovgård (1996b) found no trait of mesh selection in the by-catch of large individuals of American plaice (*Hippoglossoides platessoides*) and hence described these catches by as being caught by constant non-selective rate.

The procedure used to estimate the selection parameters is based on the approach used by Hovgård (1996a). However, the non-linear regression used differed as a square root transformation was applied in the present analysis. This change implied a considerable improvement in the distribution of the residuals.

The observed caches and the catches predicted from the non-linear regression generally corresponded reasonably well. There were however considerable uncertainty on the estimate of the part of the selection curve to the right of the modal value due to relatively few fish taken at sizes above the modal length. The scarcity of these sizes of fish is attributed to a non optimal match between the mesh-sizes chosen and the stock size distribution, i.e. that too large mesh-sizes were used.

1.4.2 The estimated selection curves for the individual species

1.4.2.1 Cod

Gill net selection of cod have been estimated by using uni-modal selection curves by Hylen and Jacobsen (1979) and Clay (1981) and by bi-modal selection curves by Hovgård (1996 a). Hovgård argumented the bi-modal selection by the fact that two peaks were apparent in the catch length frequency distributions and that these two peaks could be associated with cod being gilled and wedged by their maxillae (Hovgård 1988, 1996a). He noted that the identification of the mode associated with the maxillar catching was made possible by the fact that he, in contrast to Hylen and Jacobsen and Clay (*op cit*) used small mesh-sizes which resulted in that a large number of cod were available to estimate the part of the selection curve to the right of the modal value of the gilling catch process.

During DIFTA's forth cod experiment it was observed that the smallest cod were attached to the nets by their teeth, that medium size cod were gilled and that the larger cod were wedged around their maxillae. For this reason attempts were made to describe the selection by a model accounting for the three observed ways of catching, :

$$\text{Selection} = \varphi_{gill} + B * \varphi_{maxilae} + C1 \qquad \text{(Eq.4.1)}$$

where φ_{gill} , $\varphi_{maxilae}$ signifies normal distributions (N(***k1,st1***) and N(***k2,st2***)) describing cod being gilled and enmeshed around their maxillae. The parameter '***B***' indicate the efficiency of maxillar catching relative to gilling and *C1* is used to account for the non-selective catches.

The selection plot derived from this model (fig. 4.1) show a considerable amount of scatter around the selection curve to the right of the first mode and it seems questionable to apply a model using three parameters (***B, k2, st2***) to describe this part of the selection curve. The uncertainty regarding the right portion of the selection curve is also evident when comparing the estimated parameters and the selection curves derived from the analysis of the individual experiments where considerable differences are seen between the four experiments (fig. 4.2 and table 4.1).

Table 4.1 Parameters estimated for DIFTA's cod fisheries by the two modal selection model given in equation 5.1.

	Experiment									
	All		exp_1		exp_2		exp_3		exp_4	
	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.	Estim-ate	Std. Err.
	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale	Trans. Scale
Parameter										
K1	4.324	0.011	4.485	0.016	4.213	0.012	4.234	0.012	4.531	0.018
K2	5.463	0.095	5.609	0.100	5.175	0.044	5.351	0.170	5.698	0.083
ST1	0.278	0.010	0.254	0.016	0.269	0.010	0.268	0.012	0.268	0.017
ST2	0.620	0.099	0.6[illegible]3	0.095	0.119	0.045	0.642	0.202	0.277	0.107
B	0.257	0.021	0.381	0.038	0.121	0.047	0.184	0.024	0.222	0.066
C1	0.069	0.004	0.060	0.006	0.050	0.006	0.052	0.004	0.120	0.015

Fig. 4.1 : The estimated selection curve and the selection values calculated for individual data points when using the model given in eq. 4.1.

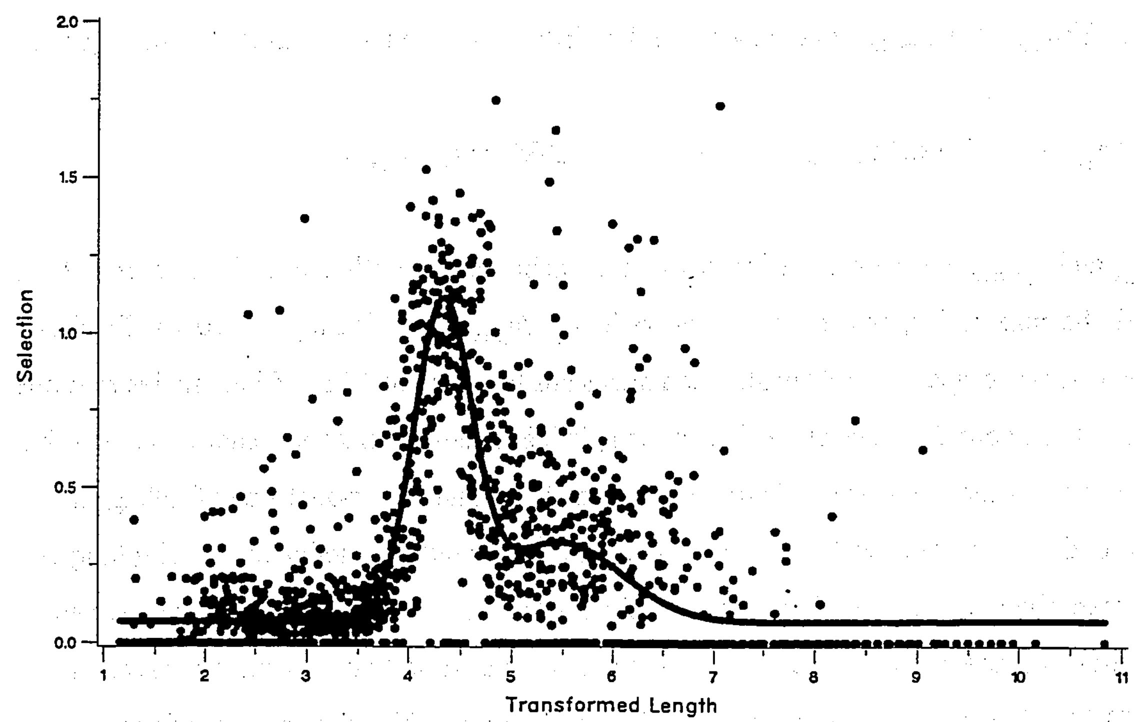
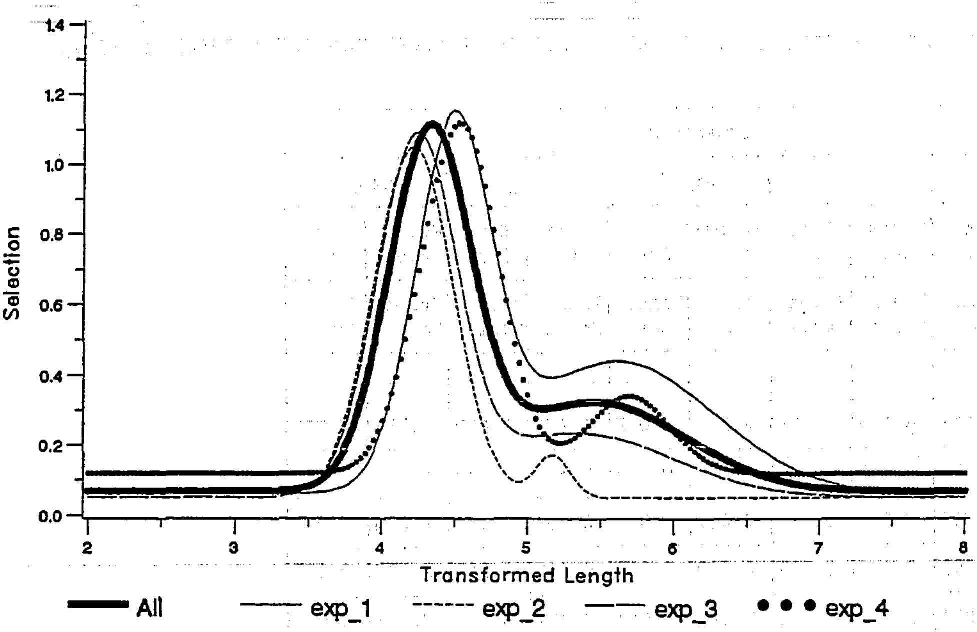


Fig 4.2. Plots of the selection curves estimated by the model given in eq. 4.1 based on all experiments and from analysis of the individual experiments



The bi-modal model is argumented by fish being caught at two positions of the body and one may hence evaluate wether the girth at the two estimated modal lengths matches the mesh perimeter. Assuming that the gilled and the maxillar caught cod in a particular mesh size (MS) have the same girth (i.e. $Girth_{gill} = Girth_{maxilar}$) one may relate the girth at the two modal values by the equation

$$MS*k1*a_{gill} = MS*k2*a_{gmaxilar} \quad => \quad k2/k1 = a_{gill} / a_{gmaxilar}$$

where a_{gill} and $a_{gmaxilar}$ are the proportionality constants between length and girth measured at the gills and the maxillaries, respectively. The ratio $a_{gill} / a_{gmaxilar}$ are found at 1.50 for DIFTA's measurements (in comparison SEAFISH's cod data leads to a ratio of 1.51) which implies that one from geometrical considerations of the fit between girth and mesh perimeters should expect that the modal size of the maxillar cod is to be found at 1.50 times the modal size of gilling .In the work on cod in Greenland waters Hovgård (1996a) estimated the modal values of gilling and maxillar enmeshing at 4.74 and 6.99, respectively, leading to a ratio of 1.48, i.e. at the expected value. However, the analysis of DIFTAS's data leads to a ratio between the estimated modal values of 1.26. The estimated modal value for gilled cod is reasonable as it corresponds to a girth-perimeter ratio of 1.01, i.e. that peak gilling occurs when the girth slightly exceeds the mesh perimeter. The estimated maxillar modal value corresponds to a girth-perimeter ratio as low as 0.85, i.e. that the girth at the estimated modal length is to small to small to allow the fish to be retained by the mesh. This indicate that the modal value of the maxillar catch process is significantly underestimated. This may be related to the lack of the larger fish available. The expected modal value associated with maxillar enmeshment corresponds to a size of cod 7.6 spread measures above the modal size of gilling. Only 4% of the total catch catches was taken above the modal value of gilling plus 5 spread measures

Although it is quite likely that the larger cod are selectively taken by enmeshing around the maxillae as suggested by DIFTAS visual observations and as seen for the cod in Greenland this catch process can not be adequately estimated from the present data. For this reason the bi-modal model was not used in the final analysis.

The estimated selection curves from DIFTA and SEAFISH directed cod fisheries and from the by-catches in DIFTA's plaice and sole fisheries show considerable differences with regard to the level of non-selective catches taken to the right side of the modal value (fig.4.3). As described in section 3 this part of the selection curve is estimated with a considerable uncertainty especially for the SEAFISH data and for the two by-catches. This uncertainty is also evident when comparing the estimates derived from the individual experiments (table 4.2) where the parameter *C2* ranges from 0.07 to 0.28 and from 0 to 0.90 for DIFTA's and SEAFISH data respectively. The modal length (*k*) is estimated at 4.33 for the DIFTA data as opposed to 4.55 for the SEAFISH data but an overlap in modal values is seen when comparing in the estimates derived from the individual experiments. The spread of the selection curve (*st*) is found somewhat higher for the SEAFISH data (range 0.28 to 0.49) than for the DIFTA data (range 0.26 to 0.27). The estimated levels of non-mesh size dependent selection below the modal value (*C1*) is found similar for all four fisheries studied with averages ranging from 0.07 to 0.11.

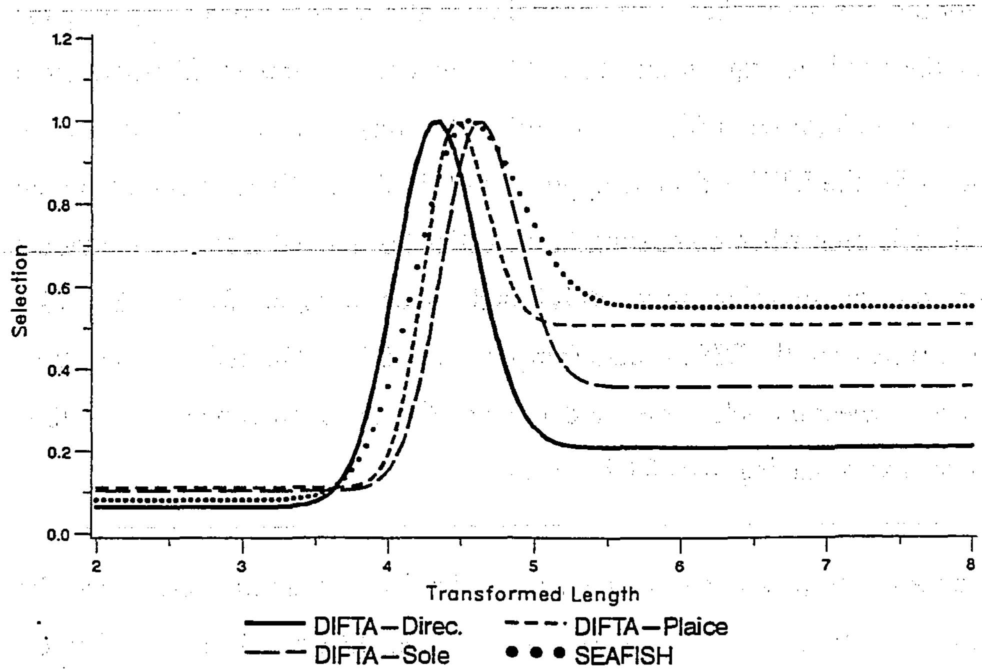
The modal values estimated in the present study agrees whit what have been found previously for cod. Hylen and Jacobsen (1979) estimated the modal value between 4.61 and 4.83 dependent on the net material. Clay (1981) estimated it in the range 4.1-4.6 dependent on the estimation procedure. For cod in Greenland Hovgård (1996a) estimated the modal value for gilled cod at

4.74 and the spread associated with the gilling at 0.33.

Table 4.2 . Estimated selection parameters from the analysis carried out on the cod data.

Institute	Target species	Gear	Experiment	K	St.	C1	C2
DIFTA	Cod	Gill-net	All	4.33	0.28	0.07	0.21
			1	4.50	0.26	0.06	0.28
			2	4.21	0.27	0.05	0.07
			3	4.23	0.27	0.05	0.18
			4	4.52	0.26	0.12	0.16
DIFTA	Plaice	Trammel	All	4.46	0.21	0.11	0.51
DIFTA	Sole	Gill-net	All	4.62	0.26	0.10	0.35
SEAFISH	Cod	Trammel	All	4.55	0.35	0.08	0.55
			1	4.74	0.33	0.01	0.00
			2	4.43	0.28	0.08	0.90
			3	4.89	0.48	0.06	0.14
			4	4.57	0.40	0.10	0.67
			5	4.42	0.29	0.10	0.56
			6	4.84	0.43	0.03	0.01
			7	4.75	0.49	0.07	0.01

Fig 4.3 : The estimated selection curves from the different cod fisheries.



1.4.2.2 Hake

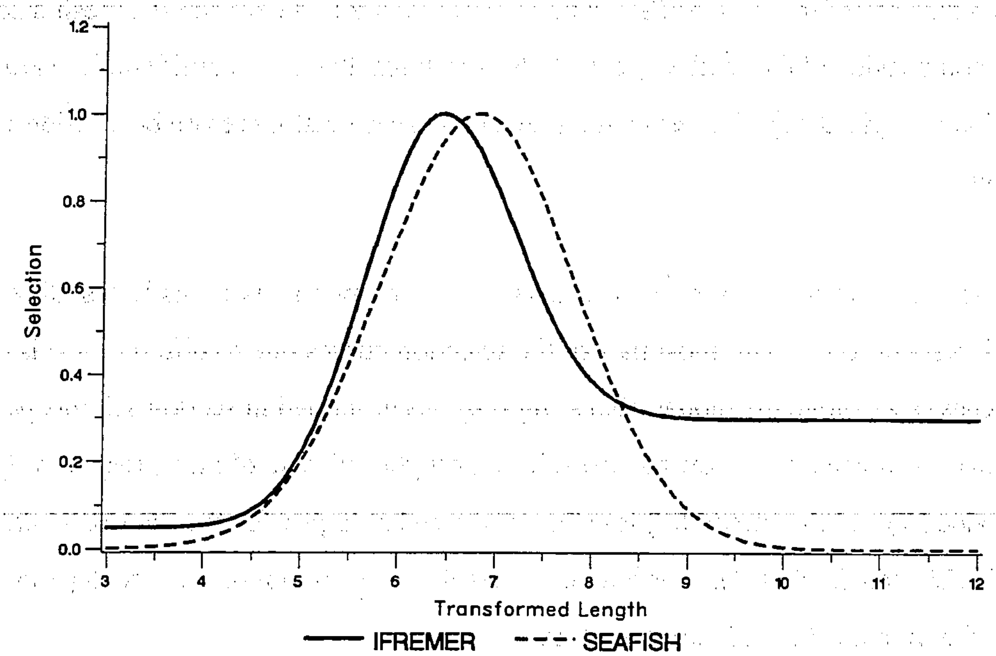
The data available for estimating the selection curves for hake most be considered as of poor quality. For the data provided by IFREMER this is caused by the low number of fish caught (1645 fish). For the catch data provided by SEAFISH a poor match was found between the mesh-sizes used and the size composition of the catches (table 3.15) which resulted in a considerable scatter around the selection plot (fig. 3.11). The estimated selection curves must therefore be considered as being imprecise.

The estimated selection curves based on the data provided by the two institutes differs considerable with respect to the right most part of the selection curves due to different levels of non-selective catches (*C2*) above the modal values (fig.4.4). As described in section 1.3 this part of the selection curve is estimated on a low number of fishes caught - 95 and 24 hake, respectively. Both the modal value (*K*) and the spread (*st*) is estimate somewhat higher for the SEAFISH data than for the IFREMER data (table 4.3). For both data sets the levels of non-mesh size depended selections below the modal value (*C1*) are found low.

Table 4.3 . Estimated selection parameters from the analysis carried out on the hake data

Institute	Target species	Gear	Experiment	K	St.	C1	C2
IFREMER	Hake	Gill-net	All	6.43	0.77	0.05	0.23
			1	6.38	0.81	0.12	0.22
			2	6.44	0.71	0.02	0.35
SEAFISH	Hake	Gill-net	all	6.81	1.01	0.00	0.00
			1	6.56	0.67	0.00	0.00
			2	7.05	1.19	0.00	0.00
			3	6.65	0.81	0.02	0.05
			4	6.67	0.79	0.01	0.08

Fig 4.4. The estimated selection curves from the different hake fisheries.



1.5.2.3 Plaice

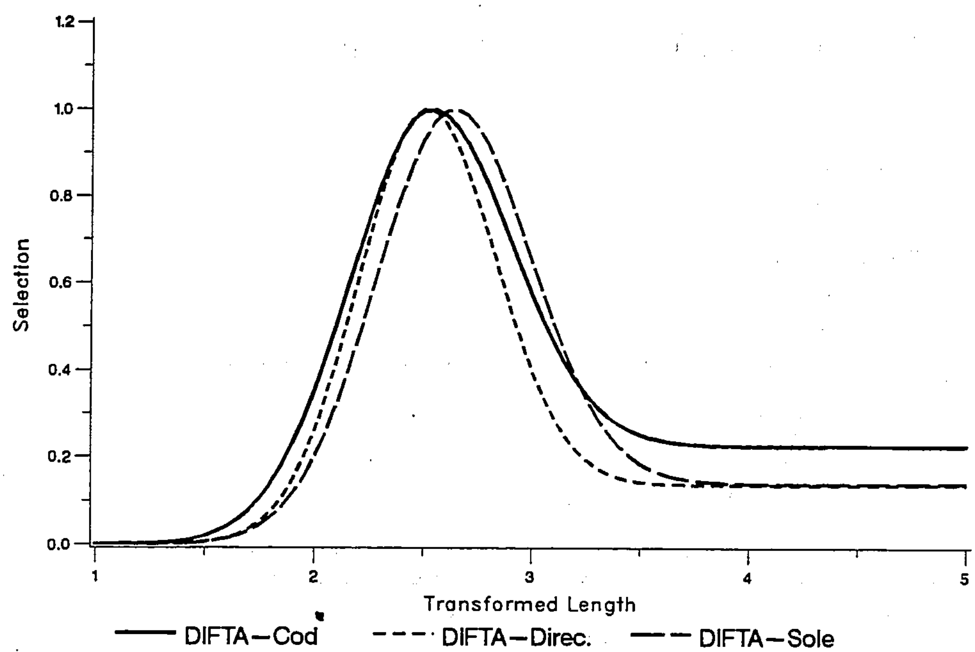
The selection curves for plaice are found similar for the directed fisheries and the by-catches in the cod and sole fisheries (fig. 4.5). Except for the 1st experiment in the directed plaice fishery this similarity is also found in the parameter estimates of the individual experiments (table 4.4). The number of plaice caught was very high in both the directed fisheries and in the by-catch in the sole fishery (17162 and 3405, respectively) and for this reason an reasonable number of plaice were available to estimate the level of non-selective catches (*C2*) above the modal length (480 and 235 plaice, respectively). In all experiments the level of non-selective catches to the left of the modal value were found very low - *C1* ranging from 0 to 0.02.

The aggregated catches for the first and second directed plaice experiments have previously been analysed by applying a range of different estimation procedures (Holst and Moth-Poulsen, 1995). In these analysis the estimated modal value ranged from 2.40 to 2.69. Besides this work no other estimates of gill-net selection of plaice is available in the literature. Compared to other flatfishes the modal value for plaice is found low as the modal value for halibut is found at 3.2 (Olsen and Tjemsland, 1963) for Greenland halibut at 3.4 (Boje and Hovgård, 1995) and for sole at about 3.2 (this report).

Table 4.4 . Estimated selection parameters from the analysis carried out on the plaice data

Institute	Target species	Gear	Experiment	K	St.	C1	C2
DIFTA	Plaice	Trammel	All	2.51	0.31	0.00	0.14
			1	2.53	0.14	0.02	0.39
			2	2.54	0.23	0.02	0.16
			3	2.46	0.32	0.00	0.14
DIFTA	Cod	Gill-net	All	2.53	0.37	0.00	0.23
DIFTA	Sole	Gill-net	All	2.63	0.36	0.00	0.14

Fig 4.5. The estimated selection curves from the different plaice fisheries



1.4.2.4 Sole

Several problems were encountered in the analysis of the sole data sets. For the IFREMER multimono nets the assumption of equal fishing power between nets was not full-filled and the estimated selection curves from this fisheries were therefore considered unreliable. For SEAFISH's sole fisheries the mesh sizes were large in relation to the stock size composition as revealed by the fact that more than 50% of the catch were taken below the modal length of the smallest mesh. Considering the relative low catches in this fishery (1945 fish) this implies that only about 400 fish were available for estimating the selection at or above the modal value and the estimates may therefore be considered imprecise. Also the analysis based on DIFTA's by-catch in the cod fishery should be interpreted with great care as it is based on a catch of only 551 fish.

The estimated selection curves and selection parameters are given in fig 4.6 and table 4.5 respectively. The estimated modal values (*K*) ranges from 3.03 to 3.29 where the lower value stems from the questionable estimate from the by-catch in the cod fishery. The spread (*st*) and the level of non-mesh dependent selection of the fish below the modal value (*C1*) are estimated at about equal levels in all experiments at values of 0.25 and 0.02, respectively. The level associated with of non-selective catches (*C2*) is estimated in ranges from 0.00 to 0.52. However, only the data from DIFTA's directed fishery and for the fishery by IFREMER contain a reasonable numbers of fish relevant for the estimation of *C2*.

Fig 4.6 . The estimated selection curves from the diferents sole fisheries.

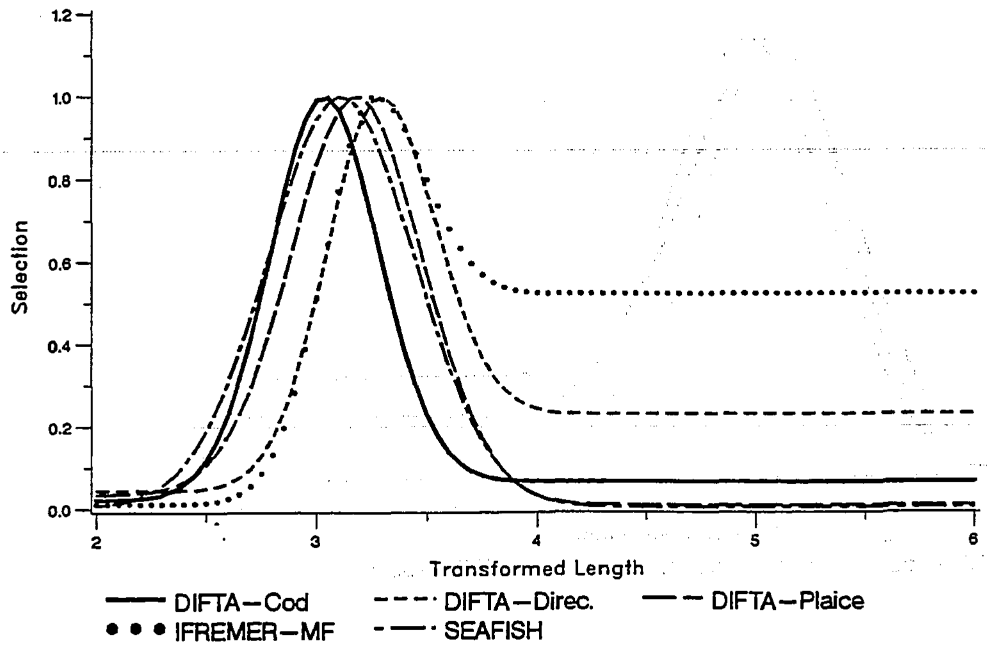


Table 4.5 . Estimated selection parameters from the analysis carried out on the sole data. The estimates from the Multimonofilament experiments conducted by IFREMER is not included as these estimates are not considered reliable.

Institute	Target species	Gear	Experiment	K	St.	C1	C2
DIFTA	Sole	Gillnet	1	3.29	0.25	0.04	0.23
DIFTA	Cod	Gillnet	All	3.03	0.25	0.02	0.07
DIFTA	Plaice	Trammel	All	3.18	0.30	0.04	0.01
IFREMER	Sole	Trammel	All	3.26	0.23	0.01	0.52
			1	3.28	0.21	0.02	0.61
			2	3.31	0.24	0.02	0.42
			3	3.19	0.22	0.00	0.83
			4	3.21	0.22	0.01	0.41
SEAFISH	Sole	Trammel	All	3.11	0.33	0.01	0.00
			1	3.09	0.33	0.02	0.00
			2	3.13	0.34	0.00	0.01
			3	3.18	0.36	0.01	0.00
			4	3.03	0.26	0.00	0.07

1.4.3 The match between the stock size composition and the mesh sizes

Considerable uncertainties have been found with regard to the estimates of the part of the selection curve to the right of the modal value. This was most thoroughly investigated for the cod catches provided by DIFTA (section 5.2.1) where auxiliary observations on how individual fish were caught could argument a bimodal selection curve as previously used on cod by Hovgård (1996a). However, the estimated parameters relating to the maxillar enmeshment were found unrealistic which could be attributed to the very limited amount of catches available for estimating the selection of the maxillar caught cod. The uncertainties were however found for all fisheries studied as revealed by the selection plots and seen when comparing the selection curves estimated from individual experiments which commonly differed considerably for fish sizes above the modal value.

In the result section the scarcity of the larger fish available to estimate the right most part of the selection curve have been expressed by the number of fish taken to the right of the modal value plus 2 spread measures as these sizes constitutes the part of the catch data which mainly influence form of the right most section of the selection curve. In most cases references were also made to the estimated stock size distributions given in Appendix C. The match between the mesh sizes used and the stock size distribution is presented in a more condensed form in table 4.6. Except for DIFTA cod less than 6% of the estimated stock are available for estimating the right most part of the selection curve.

Table 4.6 The proportion of the total estimated stock abundances available to estimate various parts of the selection curves for the experiments covered in the present study. The selection curve is divided into size intervals of one spread measure (*st*) arranged relative to the modal value ('0 st' correspond to the modal value).

Size classes		<-5 St	>-5 St <-4 St	>-4 St <-3 St	>-3 St <-2 St	>-2 St <-1 St	>-1 St < 0 St	> 0 St < 1 St	> 1 St < 2 St	> 2 St < 3 St	> 3 St < 4 St	> 4 St < 5 St	> 5 St
		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Species	Institute												
Cod	DIFTA	32.0	12.2	10.9	8.6	8.0	7.1	6.0	3.6	3.0	2.0	1.9	4.8
Cod	SEAFISH	5.2	16.2	20.2	19.3	14.7	10.0	5.0	3.6	2.5	1.5	0.9	1.0
Hake	IFREMER	0.4	3.7	12.5	19.7	22.1	17.6	11.6	6.7	3.4	1.5	0.5	0.3
Hake	SEAFISH	3.4	58.7	27.1	4.6	2.9	1.9	0.9	0.3	0.1	0.0	0.0	0.0
Hake	IFREMER	0.4	3.7	12.5	19.7	22.1	17.6	11.6	6.7	3.4	1.5	0.5	0.3
Plaice	DIFTA	0.0	0.8	5.6	14.6	25.6	21.3	16.7	8.4	3.5	1.9	0.8	0.8
Sole	DIFTA	5.9	15.7	20.6	19.3	15.0	11.8	6.5	3.2	1.3	0.5	0.2	0.1
Sole-MF	IFREMER	8.2	13.3	21.6	17.7	11.6	9.6	7.1	4.4	2.8	1.7	1.0	1.0
Sole	SEAFISH	0.0	9.0	21.6	29.0	18.9	14.3	4.7	1.8	0.4	0.2	0.1	0.0

At the initial project meeting where the experimental planing was discussed it was noticed that if small mesh-size was included this would possible lead to higher catch numbers (as small fish are generally more abundant than larger ones) and that it would also lead to a better resolution of the part of the selection curve to the right of the modal value. However, at the same time it was felt unreasonable to base the study on mesh sizes significantly below those used commercially as it could be questioned wether parameters derived from small mesh-sizes could be applied to the mesh sizes actually used in the fisheries. For this reason the actual choice of mesh sizes were to be chosen by the institutes conducting the practical fisheries as these institutes had the best knowledge of size structure of the various stocks and the mesh sizes used in the fisheries.

The present study indicate that for future studies more emphasis should be given to optimizing the ranges of mesh-sizes used in relation to the actual stock size distribution. This may require trawl trials using small meshed cod-ends to indicate the abundance of various sizes of fish in the areas where the gill net selection experiments are to be carried out.

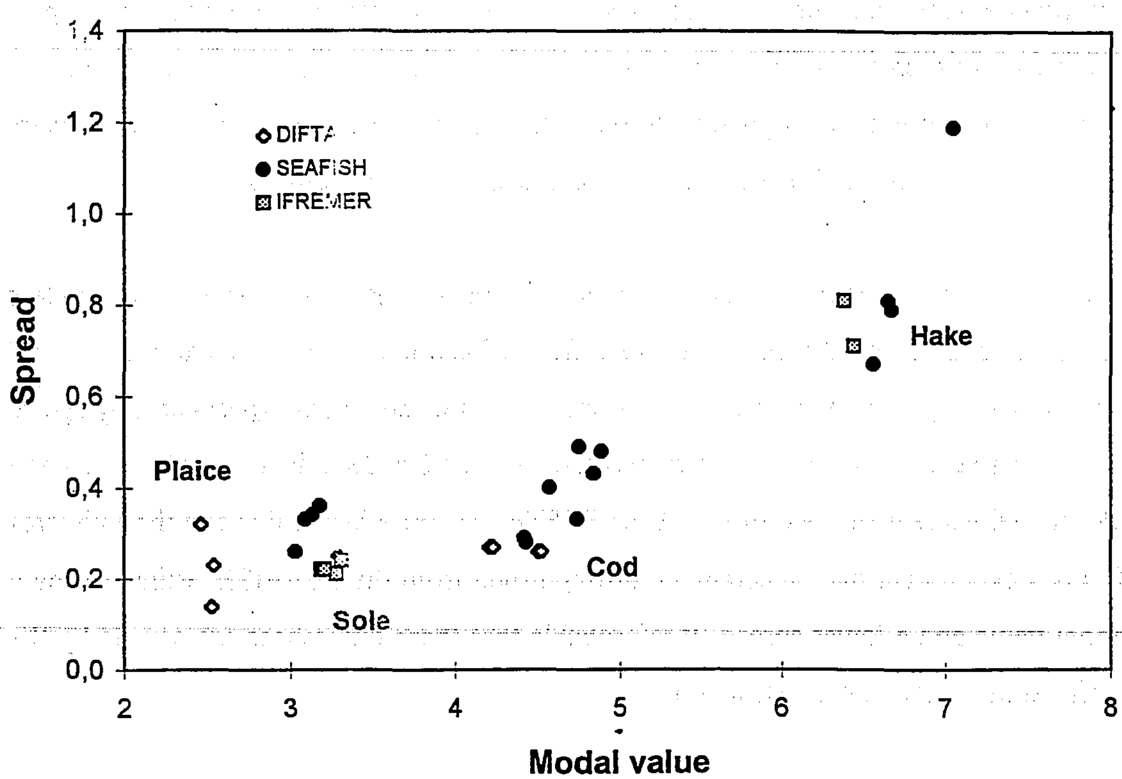
1.4.4 Evaluation of differences between net types.

The fisheries have been conducted with net types and net riggings that is typically used in the commercial fisheries in the different countries. This implies that the nets have differed with respect to a range of factors such as net dimensions, net material, hanging-ratio, net types (gill-net vs. trammel nets). Therefore, it is not possible to relate the differences in the estimated parameters found between the experimental fisheries to particular aspect of the net design.

In most cases, however, systematic differences are found between the estimated parameters derived from the analysis on the data from the different institutes. This is indicated in fig. 4.7 which summarize the spread and modal value estimated for the individual experiments by specie and institute. For sole, for instance, the estimates based on the SEAFISH data show larger spread and smaller modal value than the estimates from DIFTA and IFREMER. For cod the estimates from DIFTA's experiment may generally be distinguished from the SEAFISH estimates by a lower modal value and a lower spread. It is probable that these differences are caused by the physical differences in the net construction.

It is a general held opinion that trammel nets are much less selective than gill-nets which is argumented by differences in the catching processes - i.e. fish are enmeshed in gill nets whereas the catch in the trammels are caused by the fish being held in pockets of inner net pushed through the larger meshes of the outer net. In the present study little difference is seen between gill-nets and trammels with regards to the selection below the modal value. This is reasonable as the lower boundary of the selection is related to the ability of the fish to pass through the net openings. As for the selection above the modal values there are indications of a higher level of selection in the trammels for both cod and sole but an unambiguous inference is impeded by the uncertainties in the estimation of the right most part of the selection curve. For plaice, where large catches was available from the directed fisheries using trammel nets as well as from the by catch in the sole gill net fishery, little differences is seen between the estimated parameters obtained from gill-net and trammel net (table 4.4).

Fig 4.7. The estimated modal values and spreads from the individual experiments in the fisheries for cod, hake, plaice and sole. The estimates derived from the by-catch data is not included.



1.4.5 Future research

Gill nets have traditionally been used in most European fisheries and have been increasing in importance in several European fisheries in the most resent years. From a management point of view gill net posses the virtue of being highly selective which implies that mesh size regulations may be expected to be efficient in the regulation of the fisheries. However, surprisingly few studies have been carried out on the mesh size selection of gill nets towards the commercial important marine fishes found in European waters. For these reasons more research effort may well be directed to estimate the mesh size selection of gill nets. More research should also be considered regarding the importance of the design parameters of gill nets and trammel nets where little is known both with regard to selection and to fishing power.

2. Evaluation of effects of mesh size changes in North Sea gill net fisheries

2.1 Introduction

The present section contains an evaluation of the effects of mesh size changes for North Sea gill net fisheries on yield and biomass of cod, plaice and sole using the above analyses of gill net selectivity and the selectivity model developed .

The effect of mesh size changes is evaluated for the Danish North Sea gill net fishery, which the most important one in that area.

Total landings and the value of the Danish North Sea gill net fishery landings for 1987-1995 are shown in Table 2.1.1 and Figure 2.1.1. It appears that both the weight and the value of the landings have been increasing since 1990. In 1995 the landings were about 21000 tonnes with a corresponding value of 293 millions DKK.

The evaluation compares equilibrium yield and spawning stock biomass for a baseline characterized by using the present mesh size where scenarios with mesh size is changed. The equilibrium situations occurs after about 5-10 years such that the comparisons should be considered as medium term changes.

2.2 Material and methods

2.2.1 Identification of gill net fisheries

The Danish gill net fisheries have been analysed and described for the period 1987-1993. The analyses are based on a comprehensive database describing the Danish North Sea fishery by each individual trip. The database is established by a cooperation of the Danish Ministry of Fishery and DIFRES. Data stem from four main sources: 1. Sales slip for landings providing catch data by vessel trip, marked size category and species. 2. A vessel register containing vessel characteristics. 3. Log books including spatial distribution of catches, effort and gear information. 4. Biological data providing data for age length keys and species composition in industrial landings. These four databases were combined. The combined database used in the present analyses contains the following information by each vessel trip:

Vessel size category
Gear and mesh size
Year, month and date of the landing
Landing category (human consumption or industrial fishery)
Landings by weight and value by species
Days absent by ICES statistical rectangle

Only vessels greater than 10 GT are included in the database. The landings corresponding to these vessels constituted the main part of total landings.

Cluster analysis was used for classification of landings into groups homogeneous with respect to the species compositions in terms of weight. Only the relative distributions were considered.

Hierarchical cluster analysis was applied. The basic idea in hierarchical cluster analysis is that each observation (the relative catch composition) forms a cluster by itself. The two closest clusters are merged to form a new cluster that replaces the two older clusters. Merging of the two closest is repeated until only one cluster is left.

The SAS centroid CLUSTER procedure (Anon., 1989) was used for the calculations.

In the calculations it has been assumed that the distance between two clusters is defined as the squared Euclidian distance between their centroids or means. The methods used has been described in detail by Lewy et Vinther (1994) and Anon. (1989).

2.2.2 Evaluation of effects of mesh size changes

The Danish gill net fleet, which is the most important one in the North Sea, has been selected for the evaluation of effects of mesh size changes in North sea gill net fisheries. The evaluation of these effects has been carried out by comparing long term yield of a baseline situation, where no future change in mesh size is assumed, and scenarios with specified mesh changes. The comparisons of baseline and the scenarios have been conducted as follows:

1. The comparisons have included the species cod, plaice and sole, which are the most important species in the Danish North sea gill net fishery.

2. A multispecies VPA has been run in order to estimate stock size and fishing mortality for the 10 species included. This VPA corresponds to the keyrun of ICES Multispecies Working Group in 1993 described by Anon. (1994), which gives the input to the model and assumptions made. The terminal year of this analysis is 1991. Stock number at the start of 1992 and fishing mortalities for 1991 estimated and used for predictions are shown in the Tables 2.2.1 and 2.2.2.

3. In order to estimate partial fishing mortality for the Danish gill net fisheries for cod, plaice and sole the catch in numbers by fishery, quarter and age have been calculated for 1991 using the cluster analysis described above for defining the fisheries. As the by-catches of other species than the target species was negligible only the target species in the three fisheries have been considered. Catch in numbers by fishery, quarter and age for the Danish gill net fisheries in 1991 are given in Table 2.2.3.

4. Partial fishing mortality by target species, quarter and age for the Danish gill net fisheries has been calculated as the proportion of the Danish gill net catch in numbers to total international catches multiplied with total international fishing mortality.

5. The evaluation of the effects of mesh size changes in the three gill net fisheries on

cod, plaice and sole has been carried out in the following way:

For the baseline situation fishing mortality has been assumed to be unchanged in the predictions such that the rate of exploitation and the exploitation pattern as estimated for 1991 have been assumed to constant for both the Danish fisheries and the rest of the fleets.

Scenarios defined by specified mesh size changes in the three fisheries considered have been defined. For each scenario and target species fishing mortality at age has been changed according to the change in selectivity caused by change of mesh size. This change of fishing mortality utilizes the gill net selectivity models developed in section 1, the parameters estimated for the target species considered and the mean length at age shown in Table 2.2.3.

The change in fishing mortality for a specified scenario is simply calculated as

$$F_{scenario,age} = F_{baseline,age} * S(l_{age}, \text{mesh size}_{scenario}) / S(l_{age}, \text{mesh size}_{baseline})$$

where

$F_{baseline,age}$	indicates fishing mortality at age in the baseline situation
$F_{scenario,age}$	indicates fishing mortality at age in the scenario
S()	indicates the estimated selection model
l_{age}	indicates mean length at age
$\text{mesh size}_{scenario}$	indicates mesh size for the scenario defined

For the baseline situation and for each of the scenarios predictions of yield and biomass have been made for each of the target species. The predictions are equilibrium predictions carried out for a range of year where the stock has reached the state of equilibrium. For each of the scenarios and target species equilibrium biomass and yield for the Danish fleet and the rest of the fleets have been compared to the equilibrium of the baseline situation.

The so-called 4M model developed and described by AIR-project (1994) has been used to make the predictions. In this prediction model the gill net selectivity model developed has been implemented enabling evaluation of the effect of mesh size changes in gill net fisheries.

In principle the model is a standard Thompson and Bell prediction model (Thompson and Bell, 1934). However, it is a fleet based model where species interaction is included. For the species plaice and sole the predictions do not include species interactions effects as these species are not prey or predators with respect to the species included in the multispecies model. For cod species interactions have been included as cod both is a prey species eaten by predators as for instance whiting and large cod (the cod is a cannibal) and is also a predator itself.

6. The following scenarios have been considered:

Mesh size applied by the Danish North Sea gill net fleet in baseline and scenarios for cod, plaice and sole

	Baseline	Suggested EU minimum	Low	High
Cod	170 mm	120 mm	145 mm	190 mm
Plaice	150 mm	100 mm	125 mm	160 mm
Sole	108 mm	100 mm	104 mm	120 mm

The mesh sizes given for the baseline are based on the gear survey carried out in phase 1 of the project and represent the average mesh size found.

2.3 Results

2.3.1 Identification of gill net fisheries

The analyses of the Danish North sea gill net fisheries showed that five North Sea gill net fisheries could be identified. These were:

Cod fishery
Plaice fishery
Sole fishery
Turbot fishery
Hake fishery

The species distribution by fishery and the development of landings, effort and CPUE are given in Tables 2.1.2 and 2.1.3 and Fig. 2.1.2

Figure 2.1.2 shows that the landings of cod in the gill net fishery in general decreased since 1988; that the plaice fishery has increased since 1990 while the remaining three fisheries have been rather stable. The effort decreased for the cod and plaice fisheries while no changes have taken place for the other fisheries. CPUE decreased for the cod fishery and increased for the sole fishery.

2.3.2 Evaluation of effects of mesh size changes

Fishing mortality rate at age for baseline and the scenarios for the target species of the three gill net fisheries considered are given in Table 2.2.5 while predicted yield and spawning stock biomass are given in Table 2.2.6. It should be stressed that the results assume that all other factors, except for mesh size changes in the Danish gill net fishery, affecting future yield and stock size remains unchanged. This means, for instance, that the effort of all fishing fleets, the spatial distribution of effort relative to the stock and the selectivity of other gears used remains unchanged in the prediction period.

Cod

The yield of the Danish gill net fleet increases when the mesh size decreases, especially the yield will more than double if the mesh size is reduced to 145 mm. The gain of the Danish gill net fishery corresponds to minor reduction of the yield of other fleets. The reason for that can be explained by the trade-off of growth and exploitation pattern on cod. Table 2.2.4 shows that the cod catches mainly consist of the 2- and 3-group (51%). Furthermore, Table 2.2.5 shows that fishing mortality for these two age groups decreases for the suggested EU minimum scenario while they increase for the "Low" scenario.

With respect to the Spawning stock biomass only relative small changes takes place. The biggest change is a decrease of about 16% in the "Low" scenario.

Plaice

For the Danish gill netters the long term yield relative to the baseline is reduced for the suggested EU minimum, it increases for the "Low" scenario and it decreases again for the "High" scenario. The reason for the increase found in the "Low" scenario is the combined effect of increasing fishing mortality for the 4- and 5-group and decreasing mortalities on age groups 6 to 8. (Age group 4 to 8 are the important age groups, see Table 2.2.4). The reduction in yield in the two other scenarios is due to that fishing mortality for most of the age-groups 4 to 8 is reduced compared to baseline.

Spawning stock biomass is only marginally affected by the change in the Danish plaice fishery as this only make up a minor part of the total fishery (about 16 per cent in 1991).

Sole

Although the exploitation patterns are changing for the three scenarios (Table 2.2.5) it is remarkable that the long term yield is almost unchanged. This is due to that fishing mortality for some age groups goes up and some down in such a way that total yield remains constant.

2.4 Discussion

The results of the present analysis show relative little impact of changes in the mesh-sizes used in the Danish gill net fisheries with respect to the overall yield and spawning stock biomass in the North Sea. This is to some extent to be expected due to the magnitude of this fishery in relation to size of the overall international fishery. This is most evident for the sole fishery where the Danish gill net fishery is insignificant relative to the important beam trawl fishery.

For cod it was found that a considerable increase in yield in the gill-net fishery should be expected if the mesh-sizes were reduced. A natural question is therefore why the present fishery is carried out with the use of large mesh-sizes. As far as can be inferred from talks with the Danish commercial fishermen this is caused by the fact that the gill net fishery for cod is specifically targeting concentrations of large cod found in non-trawlable areas especially around wrecks. For the practical fisheries it may not be economical feasible to use small mesh-size to target the more abundant recruiting cod which is probably mush more efficiently harvested by the use of trawls. Similar considerations may be raised regarding the flat-fishes where the fishing grounds to some extend is divided among the different fleet categories.

In general, the present choice of mesh-sizes use in the fisheries (the baseline in the analysis) must be expected to have been optimized in relation to the concrete fisheries taken the species mixture, the market prices and alternative uses of the vessel into account. As a consequence, the suggested mesh size changes used in the alternative scenarios may not be realistic seen from a practical and an economical point of view.

Many sources of errors may affect the predicted effect of mesh size changes on catch and biomass. Important factors are:

- estimated baseline mesh size

- estimated selection parameters
- the selection model
- baseline fishing mortality at age for the Danish gill net fleet and the "other" fleet

Except for the selection parameters the uncertainty on these factors has not been treated in the present report. An overall sensitivity analysis requires that the uncertainties of the factors mentioned is described and quantified. Several sensitivity methods exist for instance the method described by Prager and MacCall (1988) and the FAST method of Cukier *et* al. (1978). Monte Carlo simulation is another possibility.

As a pragmatic alternative to such comprehensive methods an immediate impression of the variability of the selection ogives can be obtained by considering the variation of the estimated selection ogives for each of the selectivity experiments carried out. Such variations are shown in the Figures 3.3, 3.8 and 3.14 for DIFTA/cod, SEAFISH/cod and DIFTA/plaice respectively. The Figures indicate that the precision of the right most part of the selection curve is low. This is mainly caused by the fact that experiments were carried out with the commercial used mesh-sizes targeting relative large individuals.

As a consequence the estimated changes of fishing mortality for the larger fish are relatively poorly determined. However, for the predictions the uncertainties regarding the selection of fish above the sizes actual targeted is of limited importance as these large fish contributes little to the total yield in the present North Sea fishery.

3. Finalization of tasks

All tasks allocated to the institute under the work programme have been completed and all work foreseen under the contract has been terminated.

31 October 1996

Peter Lewy

Project Manager

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Table 2.1.1 Total landings by weight and value of the Danish North Sea gill net fishery 1987-1995

Year	Landings in 1000 tonnes	Landings in million DKK
1987	14	202
1988	16	218
1989	13	213
1990	12	222
1991	17	292
1992	18	296
1993	19	272
1994	22	326
1995	21	293

ıble 2.1.2 Classification of individual trip landings according to species composition (% of total landings weight) ing cluster analysis for the Danish North Sea gill net vessels larger than 10 GT in the period 1987-93.

uster ishery)	No. of trips	Monk	Hake	Other	Haddock	Ling	Pollack	Saithe	turbot	Plaice	Sole	Cod	Total landings weight (tonnes)
ner	1,247	-	-	-	-	-	-	-	-	-	-	-	4,224
d	18,818	0.3	1.1	2.0	1.2	1.0	2.1	1.0	0.7	3.4	0.6	86.7	65,211
ce	2,161	0.3	68.0	3.0	2.2	0.5	2.8	0.6	0.4	3.6	1.0	17.6	4,601
aice	8,662	0.2	0.7	5.1	0.1	0.2	0.2	0.1	1.8	75.3	6.8	9.5	19,887
le	4,105	0.1	0.8	6.0	0.0	0.0	0.0	0.0	1.0	10.7	74.8	6.5	3,399
rbot	2,210	3.5	0.5	5.3	0.1	0.3	0.1	0.3	66.8	8.2	1.5	13.5	5,084

Table 2.1.3 Key figures of the Danish North Sea gill net fisheries 1987-93.

Fishery	Year	No of trips	Effort (days Absent)	Trip duration (days)	Total landings weight (tonnes)	CPUE (kg/day)	CPUE, target species	% of target sp in landings
Cod	87	1,989	7,954	4.0	10,369	1,304	1,181	87
	88	2,347	8,884	3.8	12,427	1,399	1,262	88
	89	2,479	8,132	3.3	10,002	1,230	1,105	89
	90	2,706	7,725	2.9	8,250	1,068	951	88
	91	2,734	7,751	2.8	7,354	949	800	85
	92	3,125	8,939	2.9	7,773	870	734	85
	93	3,438	10,554	3.1	9,035	856	724	85
Hake	87	121	294	2.4	348	1,184	597	54
	88	124	335	2.7	352	1,051	559	61
	89	221	560	2.5	484	866	539	64
	90	244	545	2.2	316	582	409	75
	91	402	1,049	2.6	877	837	511	63
	92	529	1,293	2.4	1,068	826	625	73
	93	520	1,672	3.2	1,153	690	465	70
Plaice	87	812	2,456	3.0	1,803	734	626	84
	88	590	1,612	2.7	1,314	816	627	75
	89	447	1,129	2.5	1,005	891	642	67
	90	627	1,377	2.2	1,132	822	597	72
	91	1,805	4,618	2.6	4,484	971	743	75
	92	2,391	5,960	2.5	5,532	928	710	75
	93	1,990	4,853	2.4	4,614	951	736	75
Sole	87	112	504	4.5	141	280	149	55
	88	314	796	2.5	258	325	207	64
	89	539	1,624	3.0	560	345	220	67
	90	396	1,237	3.1	681	551	409	72
	91	664	1,590	2.4	680	428	340	82
	92	924	1,484	1.6	357	241	176	78
	93	1,156	2,689	2.3	720	268	196	77
Turbot	87	279	1,821	6.5	863	474	309	64
	88	330	2,135	6.5	826	387	237	61
	89	239	1,555	6.5	506	326	199	62
	90	364	1,963	5.4	698	356	244	72
	91	376	1,876	5.0	832	444	287	66
	92	375	1,587	4.2	681	430	286	69
	93	247	1,432	5.8	673	470	343	72

Table 2.2.1 Stock numbers ('000) at age in 1992

Species: Cod

Age	Quarter 1	Quarter 2	Quarter 3	Quarter 4
0			805250	478790
1	433786	359402	297645	249000
2	60393	47224	30955	19103
3	12582	9307	6323	4618
4	9839	7525	5362	4069
5	1418	1035	746	588
6	837	562	431	345
7	524	357	254	199

Species: Plaice

Age	Quarter 1	Quarter 2	Quarter 3	Quarter 4
0			683944	667057
1	800332	780539	761200	742235
2	550568	535875	517869	486191
3	342122	319508	289861	253268
4	183969	166829	142335	116653
5	136329	115297	94561	79318
6	76781	63323	53067	45801
7	80228	66747	58238	51642
8	17856	15260	13446	12407
9	8933	7752	6978	6458
10	6752	6044	5517	5064

Species: Sole

Age	Quarter 1	Quarter 2	Quarter 3	Quarter 4
0			149391	145703
1	423074	412628	402440	391725
2	33267	32369	31347	29024
3	97586	87701	79803	68297
4	36581	31633	27964	23978
5	92026	79476	67724	59500
6	7179	6344	5481	4880
7	8044	7144	6284	5757
8	2063	1842	1597	1463
9	1065	933	814	742
10	1284	1178	1044	947

Table 2.2.2 Total international fishing mortality rate in 1991

Age	Cod	Plaice	Sole
1	0.179	0.003	0.005
2	1.006	0.109	0.135
3	1.009	0.325	0.415
4	1.002	0.539	0.457
5	0.865	0.627	0.483
6	0.819	0.586	0.394
7	0.885	0.492	0.419
8	-	0.382	0.387
9	-	0.334	0.355
10	-	0.272	0.279

Table 2.2.3 Catch in numbers, mean weight and mean length at age by fishery, quarter and age of the target species cod, plaice and sole in the Danish North Sea gill net fishery 1991.

Cod
numbers in 1000' mean weight in kg mean length in mm

Cod fishery	quarter											
	1			2			3			4		
age	number	mean weight	mean length	number	mean weight	mean length	number	mean weight	mean length	number	mean weight	mean length
1				0	0.583	380.0	5	0.832	423.7	82	0.823	413.7
2	61	0.953	441.7	110	1.362	492.3	92	1.922	567.1	406	2.610	609.7
3	366	2.705	623.8	216	2.965	629.6	159	3.400	684.8	226	3.764	709.9
4	226	4.346	752.0	108	4.528	764.0	63	5.604	793.4	64	5.440	789.6
5	98	6.200	834.0	67	5.256	814.6	14	8.426	899.8	34	7.758	875.4
6	122	7.520	895.6	26	7.780	890.9	11	10.444	989.7	25	9.133	916.3
7	31	9.797	982.0	6	10.541	1015	2	12.635	1035			
8	9	11.085	1043	6	10.519	1020	2	12.318	1085	3	12.473	1010
9										3	15.799	1010
10										3	16.968	1220
11				2	15.576	1190						
12							0	1.107	500.0	3	13.700	1200
Total	914	4.338	718.6	541	3.665	673.9	349	3.926	693.4	849	3.538	658.1

Plaice
numbers in 1000' mean weight in kg mean length in mm

Plaice fishery	quarter											
	1			2			3			4		
age	number	mean weight	mean length	number	mean weight	mean length	number	mean weight	mean length	number	mean weight	mean length
2				11	0.187	260.0	8	0.272	297.5	57	0.261	284.9
3	161	0.209	276.9	211	0.288	301.7	239	0.255	291.9	130	0.306	303.0
4	628	0.314	314.7	985	0.277	298.5	797	0.323	312.9	147	0.330	313.7
5	1513	0.393	338.6	1232	0.336	321.6	655	0.426	343.2	69	0.403	336.9
6	2043	0.446	349.7	1249	0.422	344.9	748	0.574	378.1	74	0.482	355.4
7	604	0.630	384.9	192	0.578	386.7	228	0.649	391.1	17	0.528	369.4
8	322	0.761	414.5	112	0.749	423.9	73	0.797	422.1	3	0.778	415.9
9	260	0.718	411.3	68	0.840	432.2	59	0.906	439.4	2	0.907	435.9
10	99	0.858	438.2	52	0.979	450.8	38	0.939	454.7	1	1.204	462.6
11	25	0.995	461.3	18	1.029	466.4	8	1.040	461.3	1	0.786	422.4
12	38	0.890	458.3	4	1.191	496.7	6	1.113	478.3	0	1.468	505.0
13	6	1.226	480.0	4	1.385	518.3	6	1.116	476.7	0	0.916	451.7
14							2	1.286	465.0			
15	13	0.947	472.5	1	0.648	440.0				0	1.586	560.0
16	6	0.981	475.0	1	1.182	465.0	2	1.274	515.0	0	1.272	480.0
19							2	1.866	540.0			
Total	5718	0.475	354.3	4142	0.389	332.3	2871	0.472	350.0	501	0.363	320.4

Table 2.2.3 cont.

Sole
numbers in 1000' mean weight in kg mean length in mm

Sole fishery	quarter											
	1			2			3			4		
age	number	mean weight	mean length	number	mean weight	mean length	number	mean weight	mean length	number	mean weight	mean length
2	5	0.222	297.5	10	0.222	297.5	0	0.222	297.5	0	0.222	297.5
3	109	0.217	286.6	276	0.209	283.0	0	0.221	288.6	3	0.239	292.8
4	228	0.294	314.4	989	0.295	313.6	1	0.295	316.3	5	0.339	326.4
5	78	0.371	341.8	429	0.361	338.6	0	0.401	350.9	1	0.432	351.4
6	42	0.465	368.7	303	0.465	368.4	0	0.467	374.5	0	0.482	369.6
7	46	0.507	376.4	348	0.507	376.4	0	0.582	385.0	0	0.582	385.0
8	3	0.717	425.0	25	0.717	425.0	0	0.851	420.0	0	0.851	420.0
9	10	0.595	410.0	74	0.595	410.0	0	1.090	455.0	0	1.090	455.0
10	3	0.700	425.0	25	0.700	425.0						
11	3	0.527	385.0	25	0.527	385.0						
12	3	0.699	445.0	25	0.699	445.0						
Total	532	0.336	326.7	2530	0.369	336.6	1	0.280	310.0	9	0.327	320.6

Table 2.2.4 Annually proportion by age and target species of total yield of the Danish North Sea gill net fishery 1991 in the baseline situation

Age	Cod	Plaice	Sole
0	0.7	0	0.0
1	14.3	0	0.0
2	29.8	0.3	0.3
3	21.4	3.3	7.4
4	13.2	13.2	32.4
5	14.4	22.4	16.5
6	3.9	32.5	14.4
7	2.2	11.1	17.9
8	0.0	17.2	11.1
Total	100.0	100.0	100.0

Table 2.2.5 Fishing mortality rate for the Danish North Sea gill net fleet for and the remaining part of the North Sea fleets

Cod in the North Sea

	Danish gill net fleet in the North Sea				Other fleets
	Baseline	Suggested EU minimum	Low	High	
Mesh size	170 mm	120 mm	145 mm	190 mm	-
Age					
1	0.001	0.001	0.001	0.001	0.179
2	0.032	0.144	0.229	0.024	0.974
3	0.071	0.054	0.220	0.022	0.938
4	0.214	0.060	0.061	0.199	0.788
5	0.168	0.117	0.117	0.473	0.697
6	0.215	0.212	0.212	0.489	0.604
7	0.233	0.233	0.233	0.236	0.652

Plaice in the North Sea

	Danish gill net fleet in the North Sea				Other fleets
	Baseline	Suggested EU minimum	Low	High	Baseline
Mesh size	150 mm	100 mm	125 mm	160 mm	-
Age					
1	0.000	0.000	0.000	0.000	0.003
2	0.000	0.001	0.001	0.000	0.109
3	0.003	0.007	0.0 11	0.001	0.323
4	0.010	0.012	0.031	0.005	0.528
5	0.027	0.007	0.039	0.016	0.600
6	0.029	0.005	0.021	0.021	0.557
7	0.027	0.004	0.008	0.027	0.464
8	0.026	0.005	0.006	0.035	0.356
9	0.030	0 .006	0.007	0.042	0.304
10	0.011	0.005	0.005	0.020	0.261

Table 2.2.5 cont.

Sole in the North Sea

	Danish gill net fleet in the North Sea				Other fleets
	Baseline	Suggested EU minimum	Low	High	Baseline
Mesh size	108 mm	100 mm	104 mm	120 mm	-
Age					
1	0.000	0.000	0.000	0.000	0.005
2	0.000	0.000	0.000	0.000	0.135
3	0.004	0.012	0.006	0.002	0.411
4	0.005	0.012	0.008	0.001	0.453
5	0.030	0.037	0.037	0.007	0.453
6	0.026	0.013	0.020	0.017	0.368
7	0.085	0.038	0.059	0.084	0.334
8	0.009	0.008	0.008	0.024	0.378
9	0.032	0.025	0.027	0.092	0.323
10	0.017	0.014	0.014	0.049	0.262

Table 2.2.6 Relative scenario changes in equilibrium yield and spawning stock biomass (SSB) compared to baseline

Cod in the North sea

	Baseline	Sugg. EU min.	Low	High
Mesh size	170 mm	120 mm	145 mm	190 mm
Yield :				
Danish gill net	100	135	221	99
Other fleets	100	96	90	100
SSB	100	100	84	96

Plaice in the North sea

	Baseline	Sugg. EU min.	Low	High
Mesh size	150 mm	100 mm	125 mm	160 mm
Yield :				
Danish gill net	100	56	134	83
Other fleets	100	101	98	101
SSB	100	102	99	101

Sole in the North sea

	Baseline	Sugg. EU min.	Low	High
Mesh size	108 mm	100 mm	104 mm	120 mm
Yield .				
Danish gill net	100	99	98	96
Other fleets	100	100	100	101
SSB	100	100	100	102

Figure 2.1.1 Landings by weight and value of the Danish North Sea gill net fishery

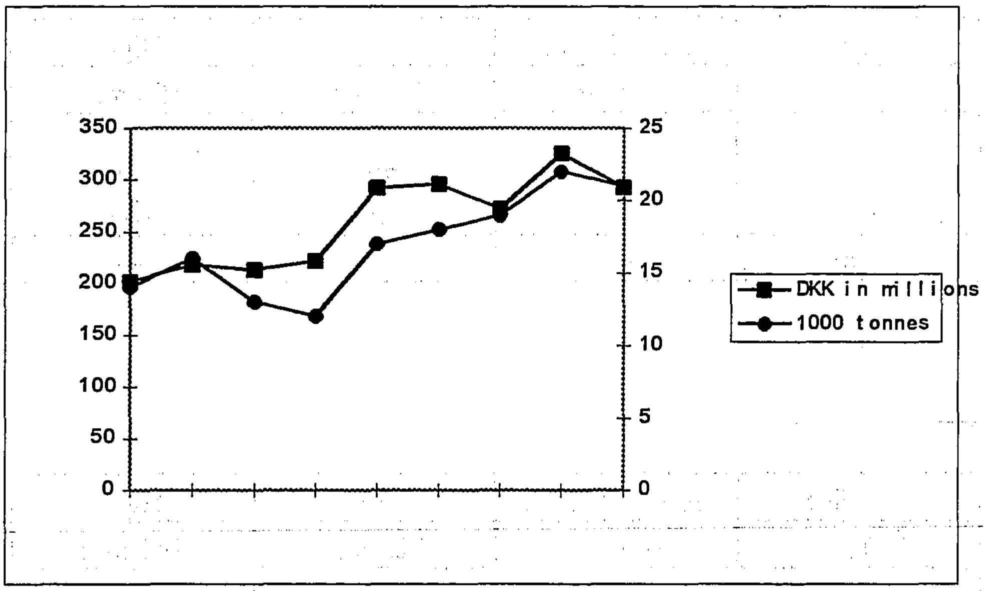
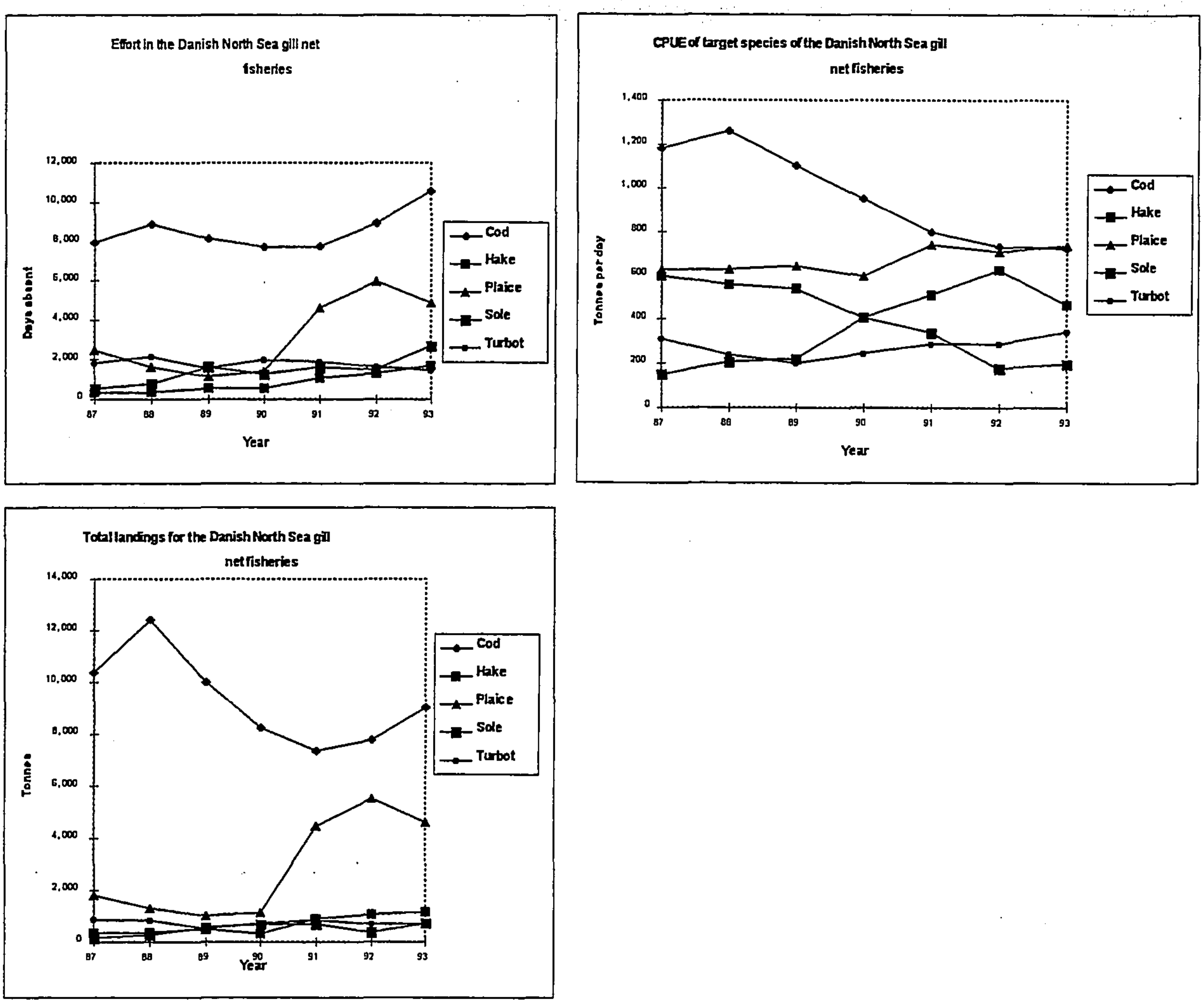


Figure 2.1.2 Effort, Total landings and CPUE for the Danish North Sea gill net fisheries



Appendix A

Results from the non-linear regression analysis

Appendix A

Model output Difta Cod, experiment all

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	7236.4766939	1809.1191735
Residual	1436	712.5233061	0.4961861
Uncorrected Total	1440	7949.0000000	
(Corrected Total)	1439	4178.5989890	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	4.331379043	0.00902430470	4.3136765028	4.3490815826
ST	0.281570874	0.00712458019	0.2675949315	0.2955468168
C1	0.065482203	0.00377384952	0.0580792259	0.0728851803
C2	0.210480481	0.01269286572	0.1855815034	0.2353794590

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.51853243	-0.014000986	-0.252459933
ST	0.51853243	1	-0.011142595	-0.112656675
C1	-0.014000986	-0.011142595	1	0.0588029302
C2	-0.252459933	-0.112656675	0.0588029302	1

Appendix A

Model output : Difta Cod, Bycatch in metier=Plaice

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	1365.6035680	341.4008920
Residual	428	122.3964320	0.2859730
Uncorrected Total	432	1488.0000000	
(Corrected Total)	431	796.8508658	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	4.462272850	0.03551612887	4.3924640631	4.5320816378
ST	0.211248233	0.02345458275	0.1651470379	0.2573494277
C1	0.111589971	0.01106353961	0.0898440124	0.1333359304
C2	0.508368412	0.09262201325	0.3263150564	0.6904217670

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.8051366917	-0.229303689	-0.365449634
ST	0.8051366917	1	-0.019599105	-0.221821614
C1	-0.229303689	-0.019599105	1	0.231789155
C2	-0.365449634	-0.221821614	0.231789155	1

Appendix A

Model output Difta cod, Bycatch in metier=sole

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	703.39554137	175.84888534
Residual	402	84.60445863	0.21045885
Uncorrected Total	406	788.00000000	
(Corrected Total)	405	480.64315470	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	4.624280826	0.02444445411	4.5762251837	4.6723364674
ST	0.259122021	0.01990707260	0.2199864712	0.2982575708
C1	0.103639754	0.01248694281	0.0790915252	0.1281879828
C2	0.357701154	0.04814812578	0.2630461828	0.4523561243

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.6231799752	-0.002376711	-0.3740956
ST	0.6231799752	1	-0.120240819	-0.192125912
C1	-0.002376711	-0.120240819	1	0.1090327173
C2	-0.3740956	-0.192125912	0.1090327173	1

Appendix A

Model output SEAFISH Cod, experiment all

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	2866.7806108	716.6951527
Residual	1576	357.2193892	0.2266620
Uncorrected Total	1580	3224.0000000	
(Corrected Total)	1579	1887.3907669	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	4.547857467	0.02455411693	4.4996944542	4.5960204801
ST	0.353822241	0.01515670239	0.3240922993	0.3835521818
C1	0.081948447	0.00599593986	0.0701873838	0.0937095109
C2	0.551457847	0.04101786287	0.4710011210	0.6319145733

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.8245195054	-0.370781846	-0.334083716
ST	0.8245195054	1	-0.288986506	-0.241627669
C1	-0.370781846	-0.288986506	1	0.1549736985
C2	-0.334083716	-0.241627669	0.1549736985	1

Appendix A

Model output Ifremer Hake, experiment all

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	1513.9627987	378.4906997
Residual	671	180.0372013	0.2683118
Uncorrected Total	675	1694.0000000	
(Corrected Total)	674	908.0344570	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	6.428569801	0.04887666172	6.3325986413	6.5245409615
ST	0.771216916	0.03630565543	0.6999293988	0.8425044335
C1	0.049210709	0.00989286363	0.0297857000	0.0686357183
C2	0.298863709	0.04457833896	0.2113324672	0.3863949512

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.6924048155	-0.14348721	-0.458285313
ST	0.6924048155	1	-0.378148274	-0.384015885
C1	-0.14348721	-0.378148274	1	0.126536232
C2	-0.458285313	-0.384015885	0.126536232	1

Appendix A

Model output Seafish Hake, experiment all

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	2523.2741614	630.8185403
Residual	1251	414.7258386	0.3315155
Uncorrected Total	1255	2938.0000000	
(Corrected Total)	1254	1560.7201986	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	6.807165692	0.03825409770	6.7321151371	6.8822162478
ST	1.005812739	0.02133537768	0.9639549499	1.0476705276
C1	0.001285848	0.00039699830	0.0005069784	0.0020647170
C2	0.000000000	0.00000000000	0.0000000000	0.0000000000

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.6323919998	-0.015264412	.
ST	0.6323919998	1	0.2533171666	.
C1	-0.015264412	0.2533171666	1	.
C2	.	.	.	.

Appendix A

Model output : Difta Plaice, experiment all model

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	16557.756633	4139.439158
Residual	716	604.243367	0.843915
Uncorrected Total	720	17162.000000	
(Corrected Total)	719	11525.043542	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	2.513313279	0.00826582614	2.4970848601	2.5295416982
ST	0.314150025	0.00591730064	0.3025325007	0.3257675489
C1	0.000000109	0.00087479096	-0.0017173813	0.0017175988
C2	0.137646466	0.02760114702	0.0834567243	0.1918362070

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.6968811835	-0.294198933	-0.461784382
ST	0.6968811835	1	-0.437578344	-0.532412507
C1	-0.294198933	-0.437578344	1	0.7852159522
C2	-0.461784382	-0.532412507	0.7852159522	1

Appendix A

Model output Difta Plaice, Bycatch in Metier=Cod

Non-Linear Least Squares Summary Statistics — Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	1418.4012893	354.6003223
Residual	182	54.5987107	0.2999929
Uncorrected Total	186	1473.0000000	
(Corrected Total)	185	652.3178391	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	2.531964102	0.02638476656	2.4799041671	2.5840240371
ST	0.369126415	0.01558803744	0.3383695688	0.3998832618
C1	0.000000000	0.00000000000	0.0000000000	0.0000000000
C2	0.226681005	0.04631873408	0.1352892436	0.3180727660

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.6492178136	.	-0.631890022
ST	0.6492178136	1	.	-0.421709947
C1	.	.	.	.
C2	-0.631890022	-0.421709947	.	1

Appendix A

Model output Difta Plaice, Bycatch in metier=Sole

Non-Linear Least Squares Summary Statistics Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	3288.9436434	822.2359108
Residual	220	116.0563566	0.5275289
Uncorrected Total	224	3405.0000000	
(Corrected Total)	223	1614.8931880	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	2.635653266	0.01748665377	2.6011900518	2.6701164800
ST	0.355133863	0.01371029514	0.3281132081	0.3821545179
C1	0.000000000	0.00000000000	0.0000000000	0.0000000000
C2	0.140609762	0.02667120995	0.0880453530	0.1931741707

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.5004538832	.	-0.445020958
ST	0.5004538832	1	.	-0.483048738
C1	.	.	.	.
C2	-0.445020958	-0.483048738	.	1

Appendix A

Model output Difta Sole, experiment all

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	10355.728766	2588.932191
Residual	185	191.271234	1.033899
Uncorrected Total	189	10547.000000	
(Corrected Total)	188	5740.768017	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	3.290779745	0.01309768689	3.2649394250	3.3166200643
ST	0.246277980	0.00846909115	0.2295693792	0.2629865809
C1	0.044443973	0.00381462099	0.0369181386	0.0519698079
C2	0.230905317	0.03829319764	0.1553569795	0.3064536541

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.7660006785	-0.240697986	-0.4570156
ST	0.7660006785	1	-0.275611359	-0.387753761
C1	-0.240697986	-0.275611359	1	0.1435150781
C2	-0.4570156	-0.387753761	0.1435150781	1

Appendix A

Model output Difta Sole, Bycatch in Metier=Cod

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	509.70239730	127.42559933
Residual	122	41.29760270	0.33850494
Uncorrected Total	126	551.00000000	
(Corrected Total)	125	298.81289560	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	3.034331866	0.02064463660	2.9934634229	3.0752003086
ST	0.247791453	0.01512343848	0.2178528592	0.2777300460
C1	0.023388061	0.00687337376	0.0097814240	0.0369946986
C2	0.067003373	0.04542959861	-0.0229297654	0.1569365108

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.5397964658	-0.032367571	-0.442005142
ST	0.5397964658	1	-0.18381613	-0.413480695
C1	-0.032367571	-0.18381613	1	0.0719315293
C2	-0.442005142	-0.413480695	0.0719315293	1

Appendix A

Model output : Difta Sole, Bycatch in metier=Plaice

Non-Linear Least Squares Summary Statistics Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	1637.1976783	409.2994196
Residual	188	63.8023217	0.3393741
Uncorrected Total	192	1701.0000000	
(Corrected Total)	191	977.3372515	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	3.180834926	0.02246543488	3.1365177041	3.2251521476
ST	0.297989326	0.01233979881	0.2736467921	0.3223318591
C1	0.035178443	0.00376350096	0.0277542423	0.0426026446
C2	0.009511045	0.03638682681	-0.0622686949	0.0812907849

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.8016044336	-0.310567911	-0.324256892
ST	0.8016044336	1	-0.251156817	-0.30485523
C1	-0.310567911	-0.251156817	1	0.1048827726
C2	-0.324256892	-0.30485523	0.1048827726	1

Appendix A

Model oututput : IFRMER Sole-MF, experiment all

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	4568.9051976	1142.2262994
Residual	526	200.0948024	0.3804084
Uncorrected Total	530	4769.0000000	
(Corrected Total)	529	2566.2113762	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	3.263464784	0.01328435684	3.2373674660	3.2895621017
ST	0.225739793	0.00740308766	0.2111963164	0.2402832694
C1	0.012539245	0.00218531667	0.0082461578	0.0168323324
C2	0.523370236	0.04014613999	0.4445025432	0.6022379289

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.8190602386	-0.199595765	-0.30629508
ST	0.8190602386	1	-0.188938517	-0.229451783
C1	-0.199595765	-0.188938517	1	0.0706937347
C2	-0.30629508	-0.229451783	0.0706937347	1

Appendix A

Model output IFRMER Sole-MM, experiment all

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	2947.5608307	736.8902077
Residual	501	187.4391693	0.3741301
Uncorrected Total	505	3135.0000000	
(Corrected Total)	504	1551.5106387	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	3.254300140	0.01562562273	3.2235998410	3.2850004383
ST	0.244206572	0.01097477793	0.2226439781	0.2657691663
C1	0.051335169	0.00811238571	0.0353964336	0.0672739042
C2	0.397765757	0.03998743210	0.3192008173	0.4763306967

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.7150479564	-0.174662487	-0.276244267
ST	0.7150479564	1	-0.305453899	-0.220935933
C1	-0.174662487	-0.305453899	1	0.0723825003
C2	-0.276244267	-0.220935933	0.0723825003	1

Appendix A

Model output Seafish Sole, experiment all

Non-Linear Least Squares Summary Statistics   Dependent Variable SQANT

Source	DF	Sum of Squares	Mean Square
Regression	4	1809.5365580	452.3841395
Residual	481	135.4634420	0.2816288
Uncorrected Total	485	1945.0000000	
(Corrected Total)	484	1108.7201128	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K	3.111611143	0.01809164790	3.0760621686	3.1471601170
ST	0.332898426	0.00976121804	0.3137182338	0.3520786187
C1	0.005747745	0.00242730424	0.0009782413	0.0105172481
C2	0.003768789	0.03066049465	-0.0564771951	0.0640147732

Asymptotic Correlation Matrix

Corr	K	ST	C1	C2
K	1	0.9817579899	-0.203405562	-0.536696911
ST	0.9817579899	1	-0.204468186	-0.377167646
C1	-0.203405562	-0.204468186	1	0.130346693
C2	-0.536696911	-0.377167646	0.130346693	1

Appendix B

Graphical display of the regression results.

Two types of graphical sheets are provided.

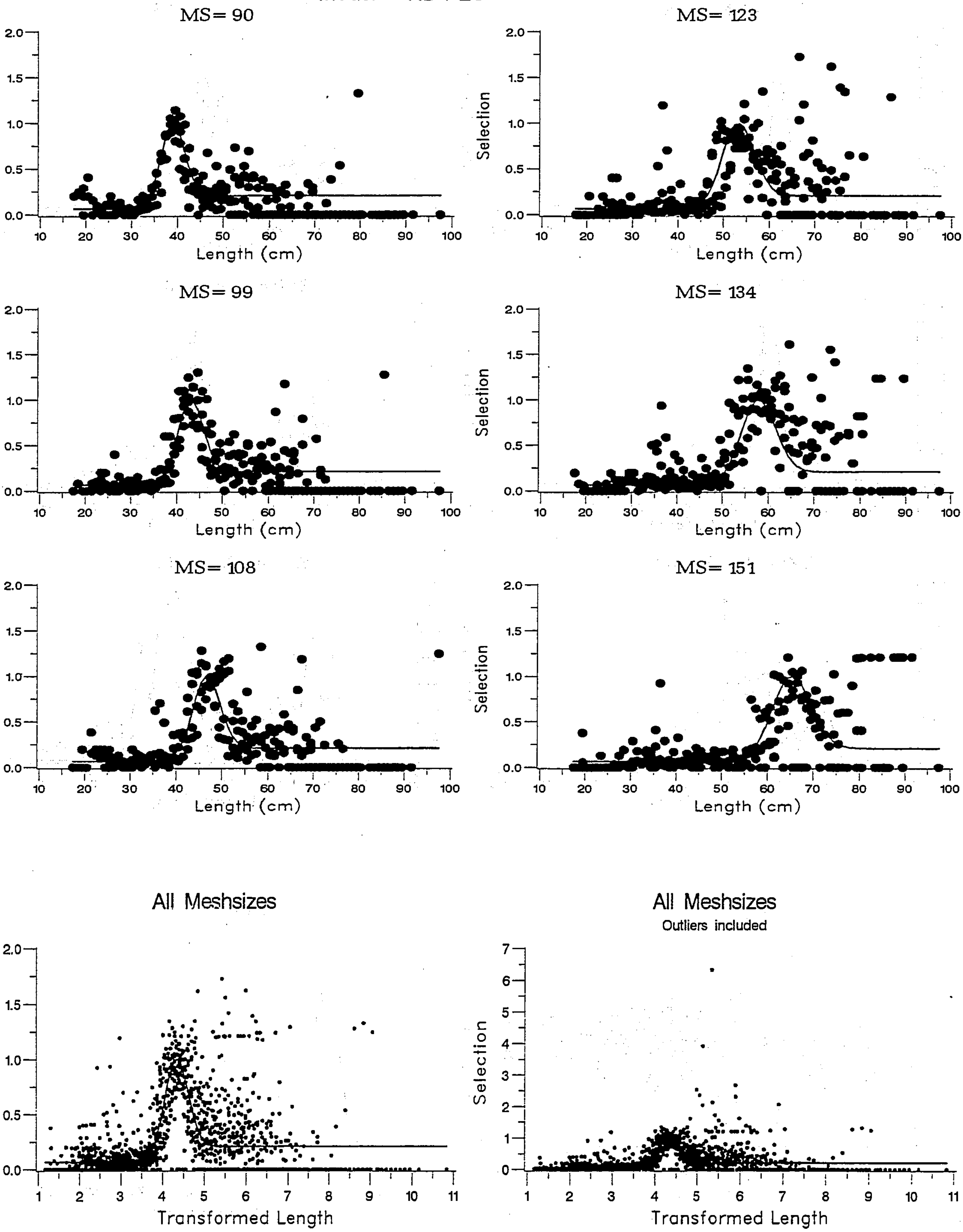
Catch and stock features are given on pages labelled 'Estimated catch and stock'. The observed catch are shown by dots and the estimated catch by a line.

Selection features are given on pages labelled 'Estimated selection'. The calculated selection for individual points is shown as dots and the estimated selection curve by a line.

Difta Cod Experiment all

Estimated Selection

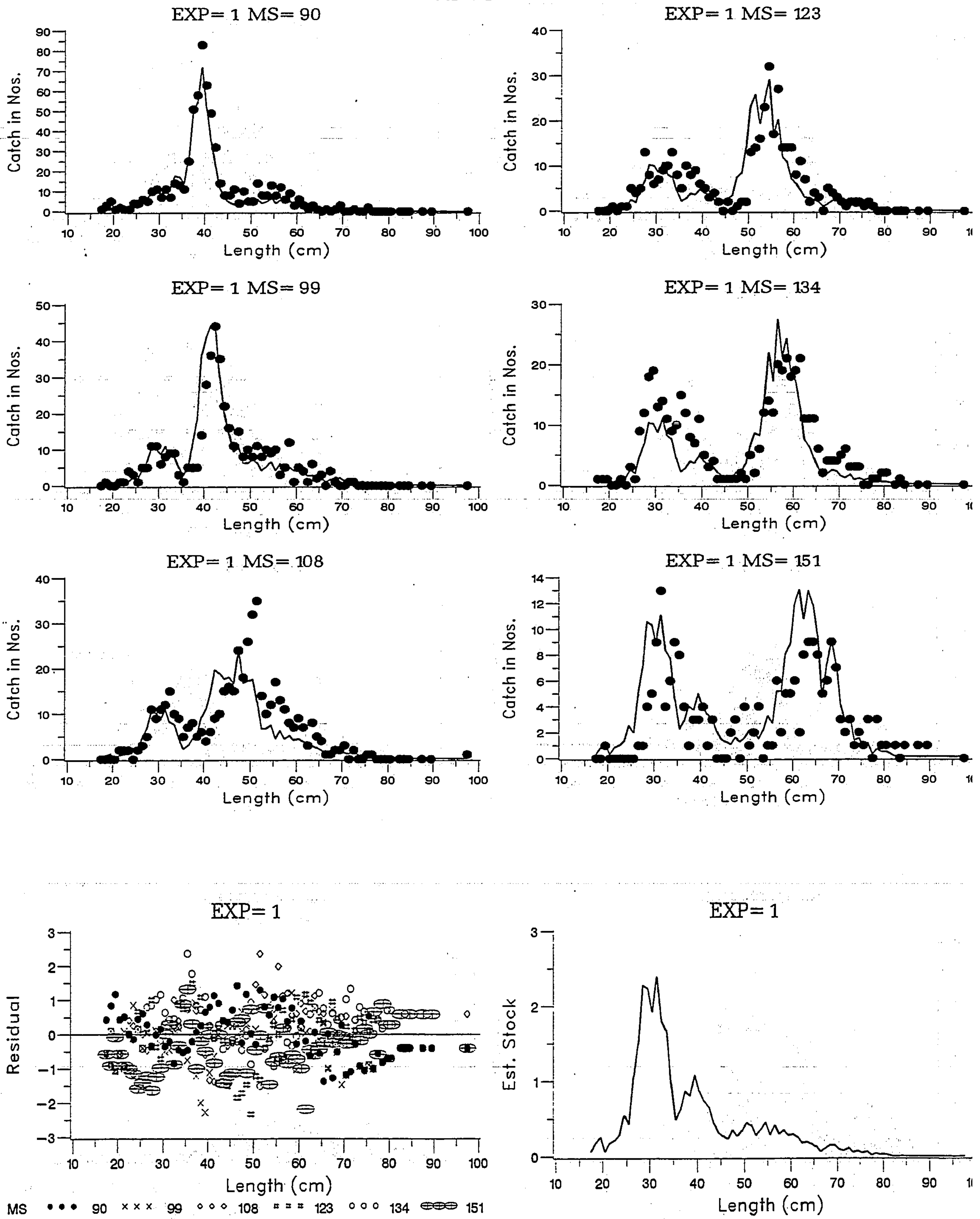
Model= ND+2C



Difta Cod Experiment all

Estimated Catch and Stock

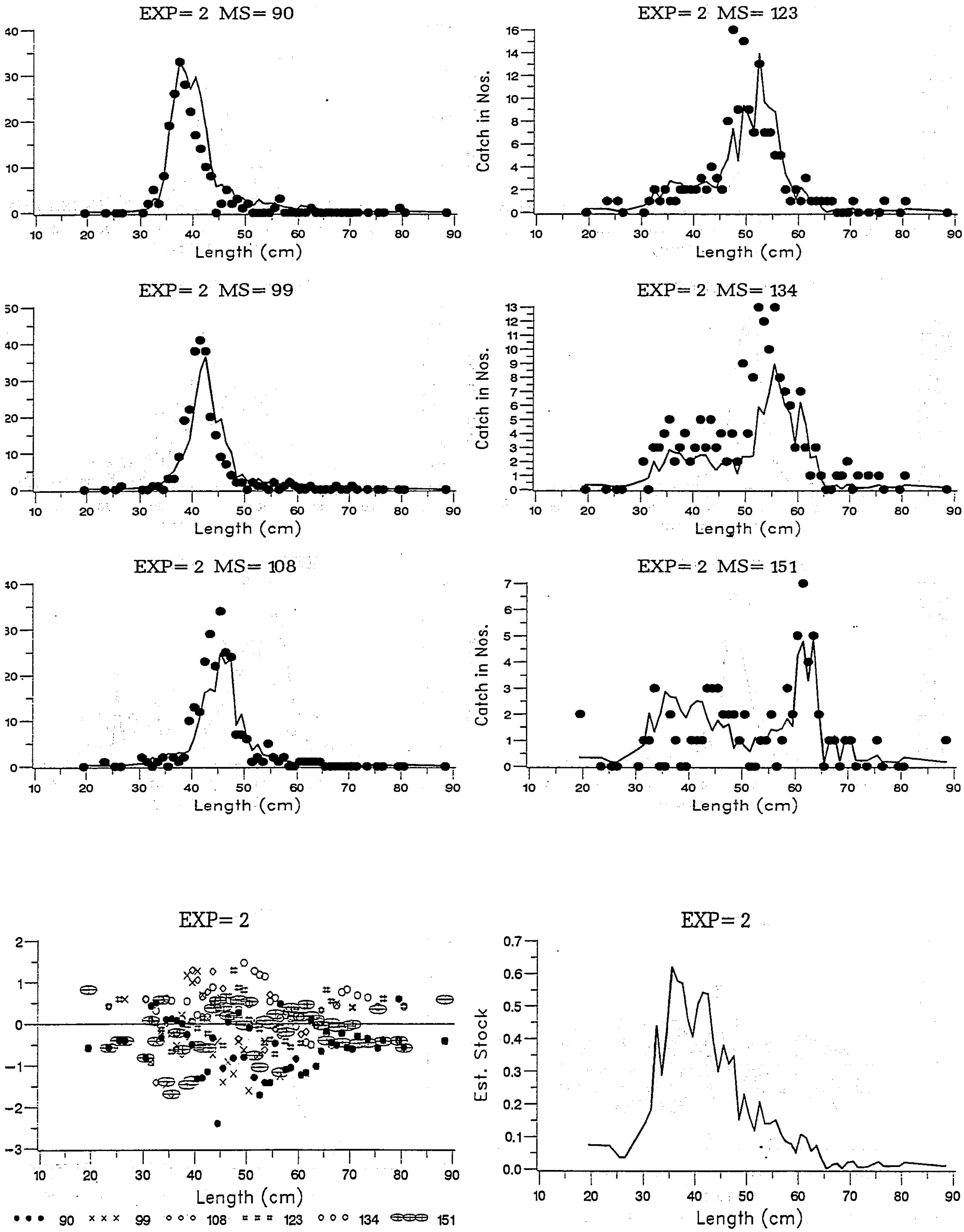
Model= ND+ 2C



Difta Cod Experiment all

Estimated Catch and Stock

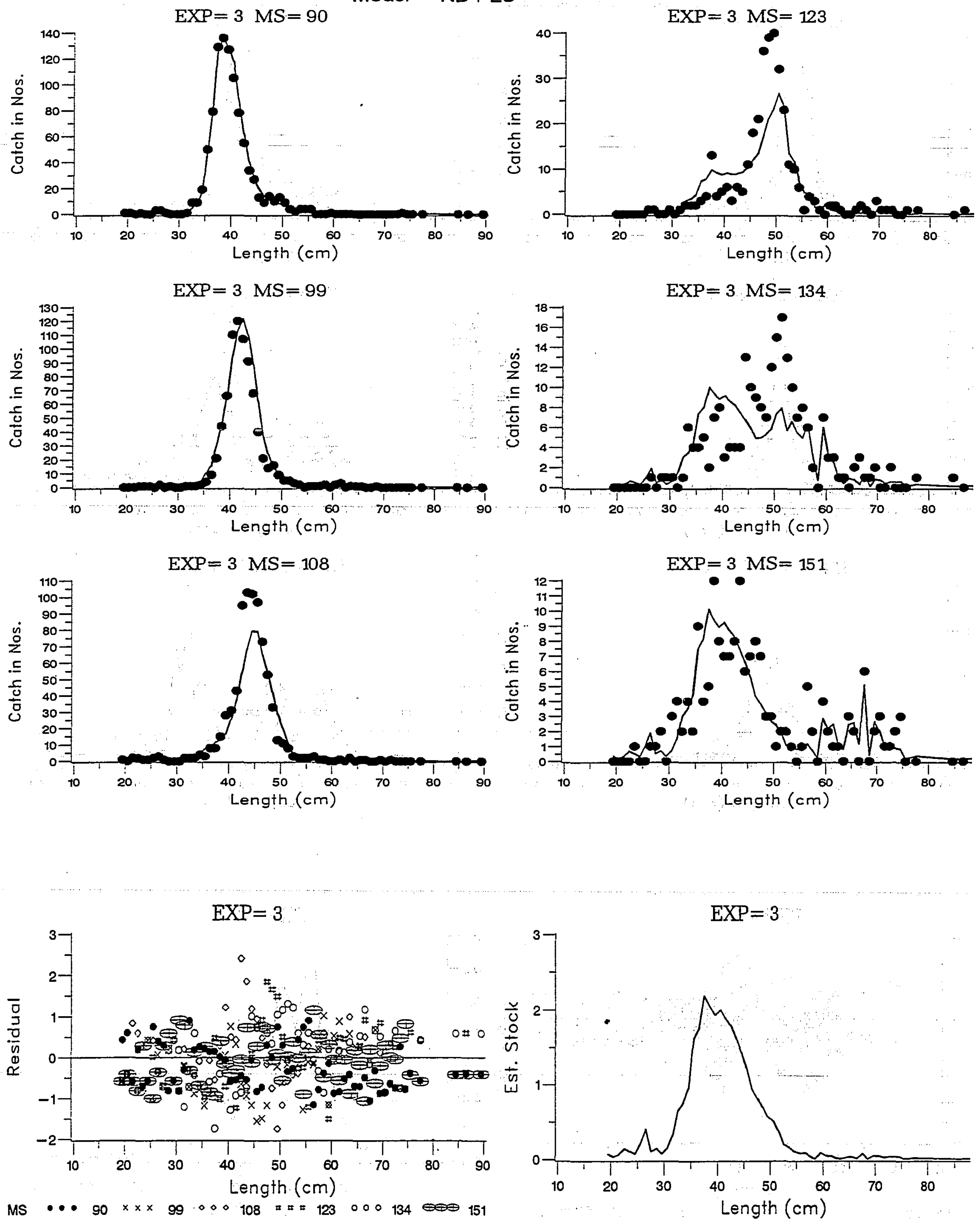
Model= ND+2C



Difta Cod Experiment all

Estimated Catch and Stock

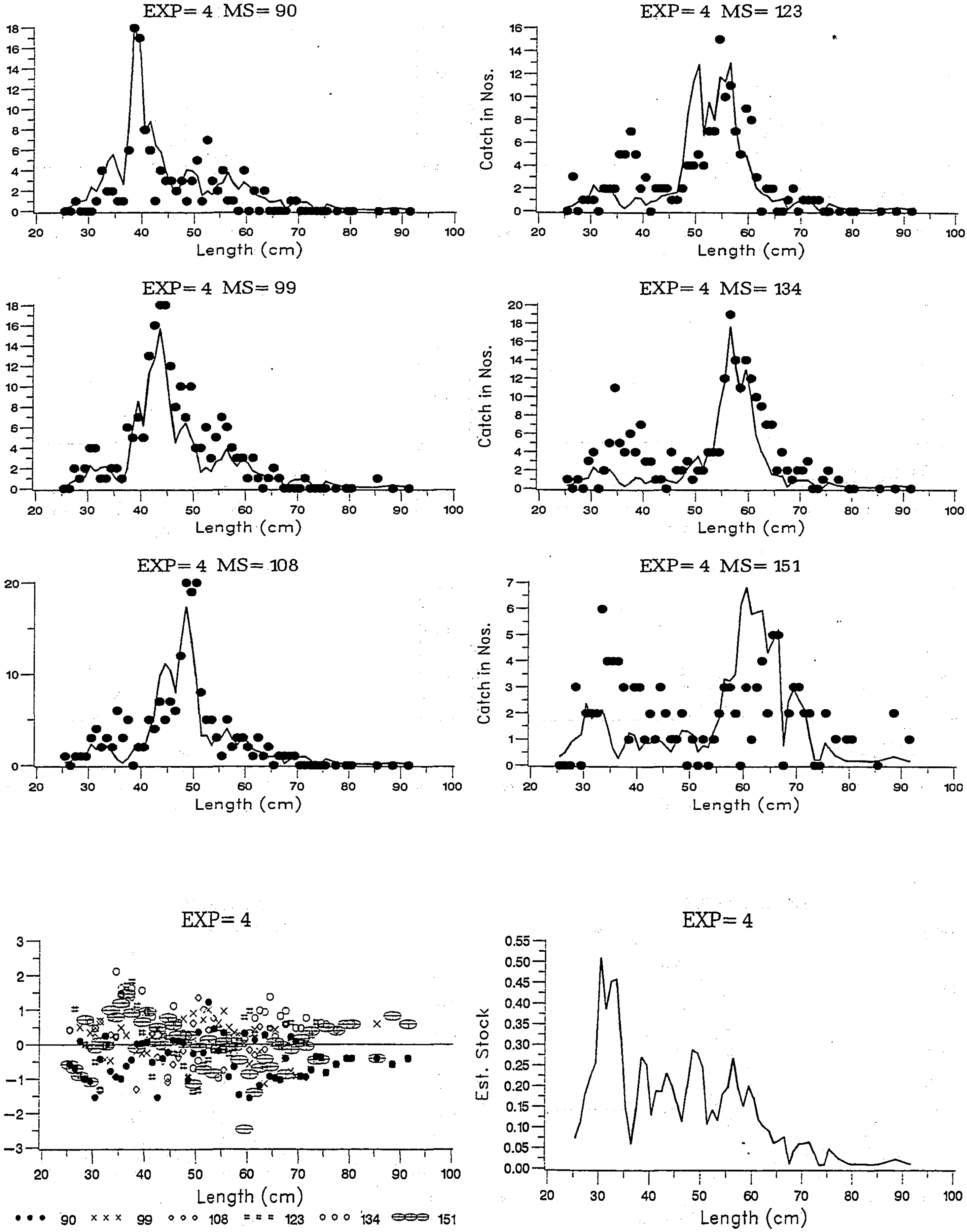
Model= ND+2C



Difta Cod Experiment all

Estimated Catch and Stock

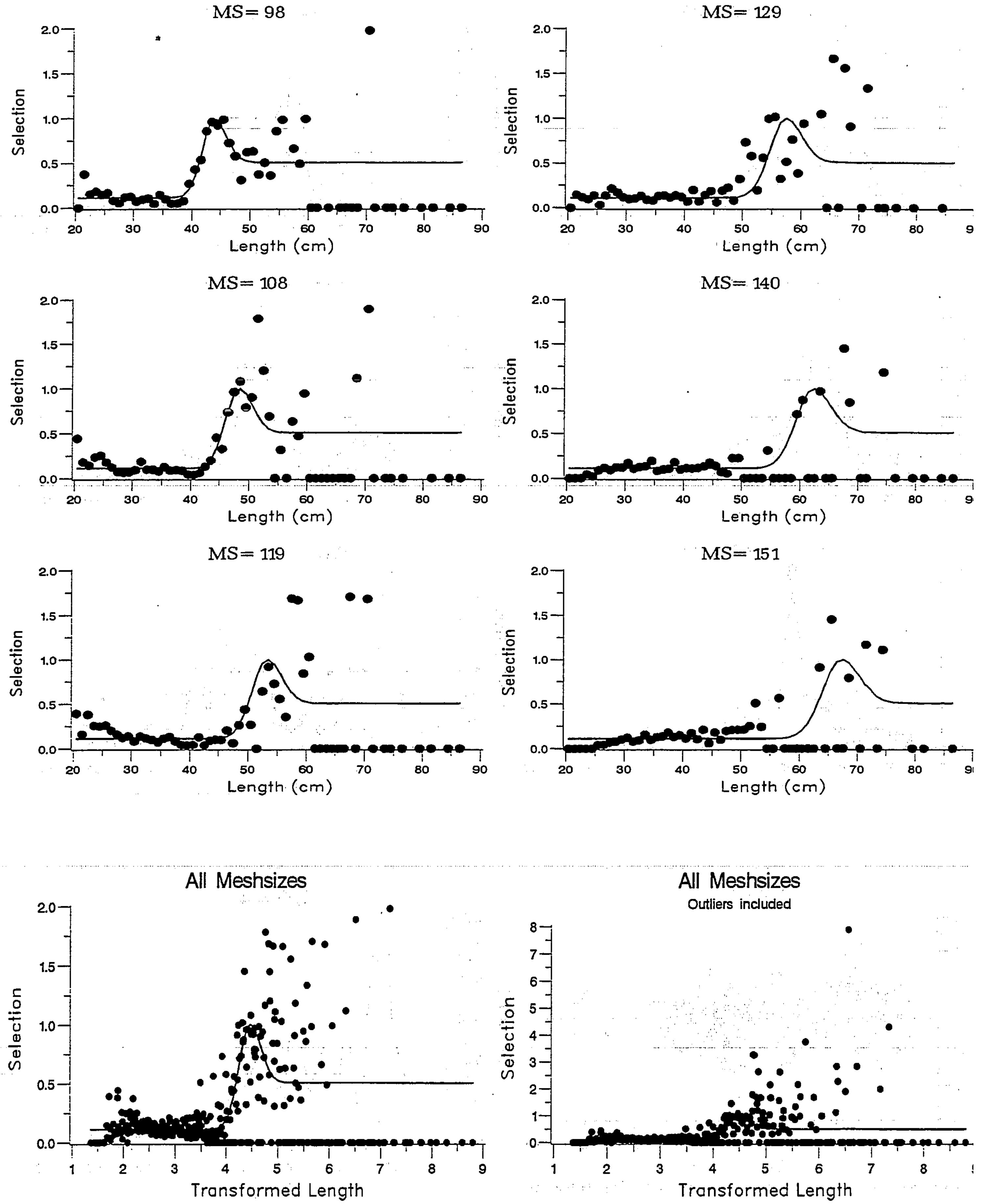
Model= ND+ 2C



Difta Cod, Bycatch in Metier = Plaice

Estimated Selection

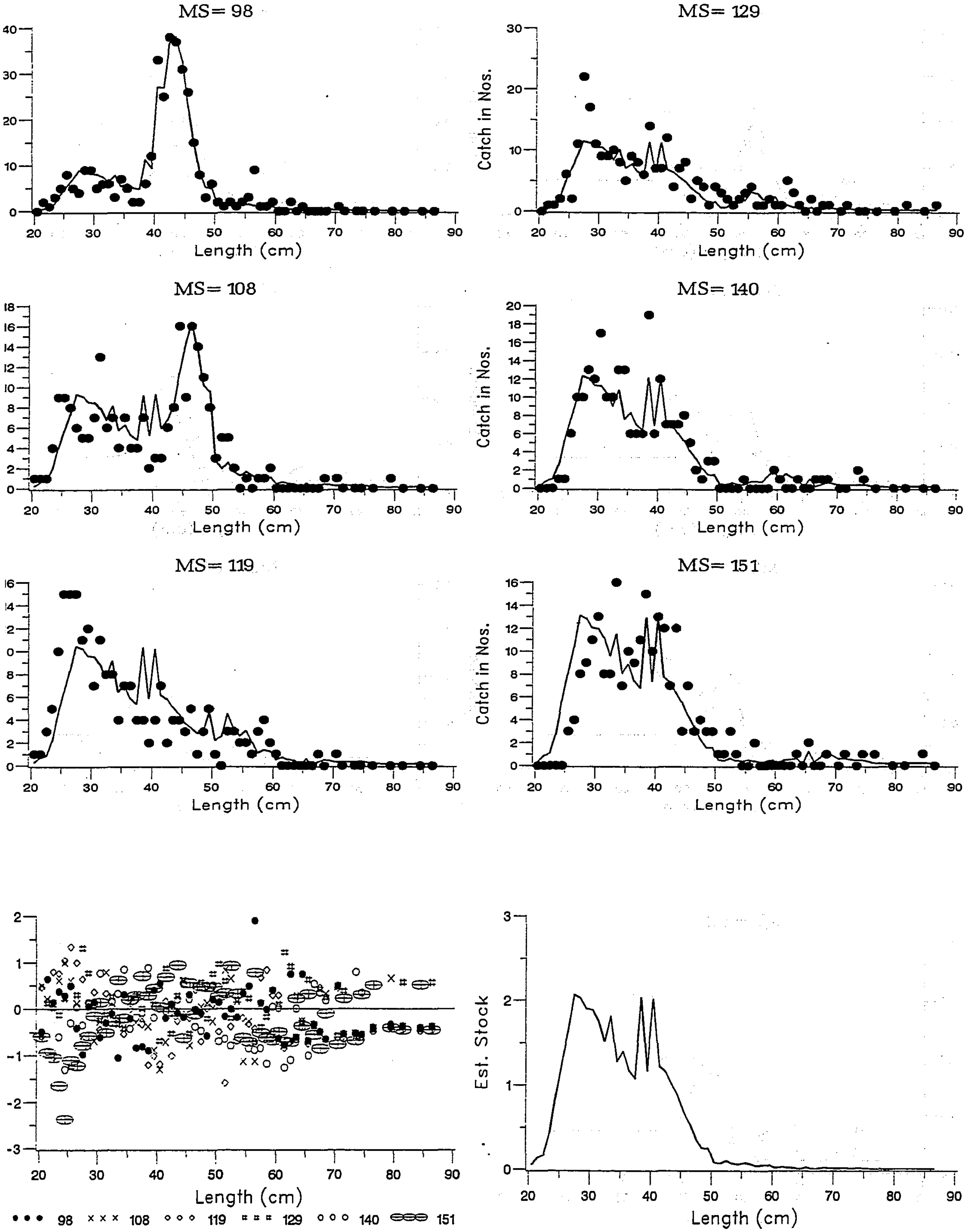
Model= 2ND+2C



Difta Cod, Bycatch in Metier = Plaice

Estimated Catch and Stock

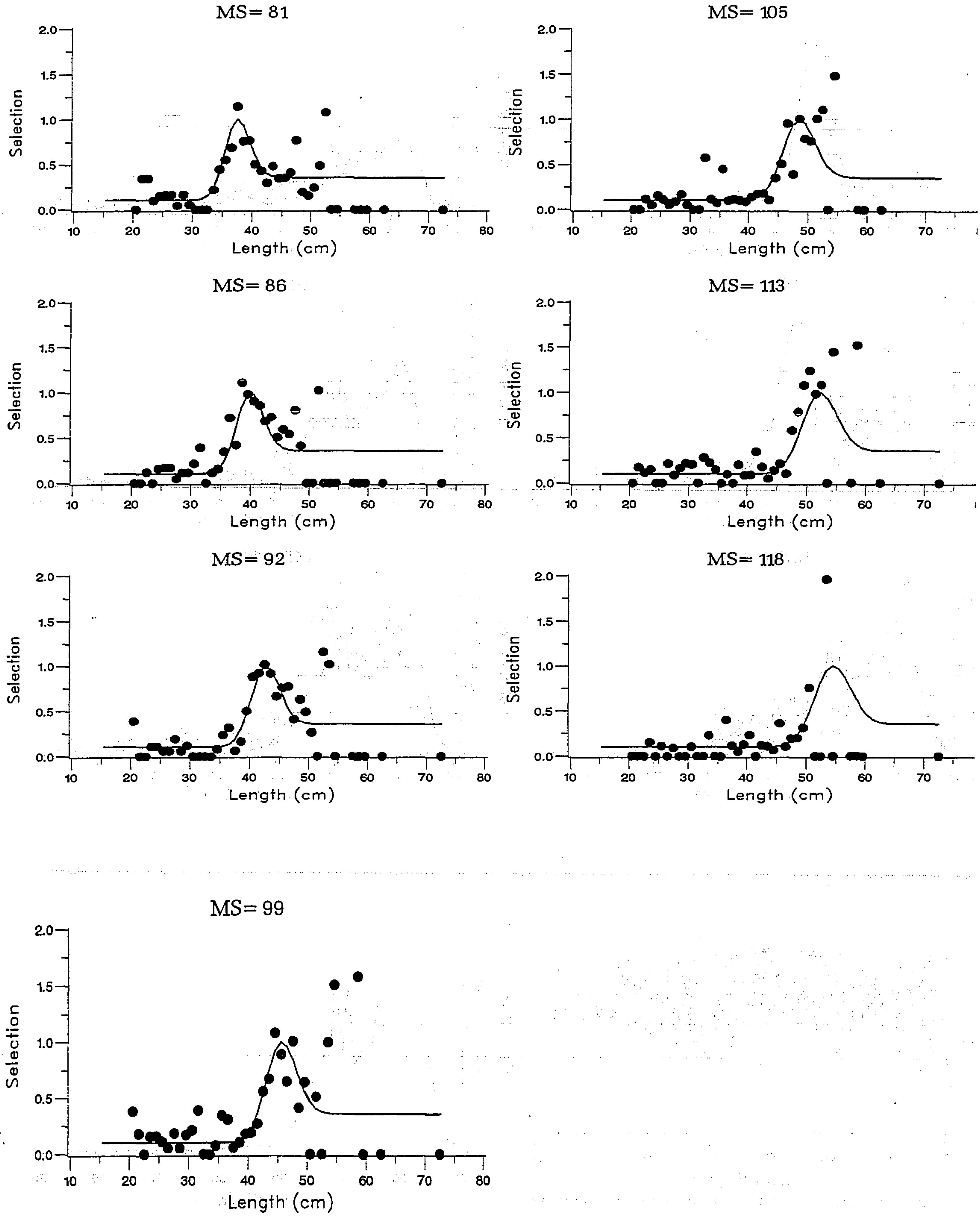
Model= 2ND+2C



Difta cod, Bycatch in Metier= sole

Estimated selection

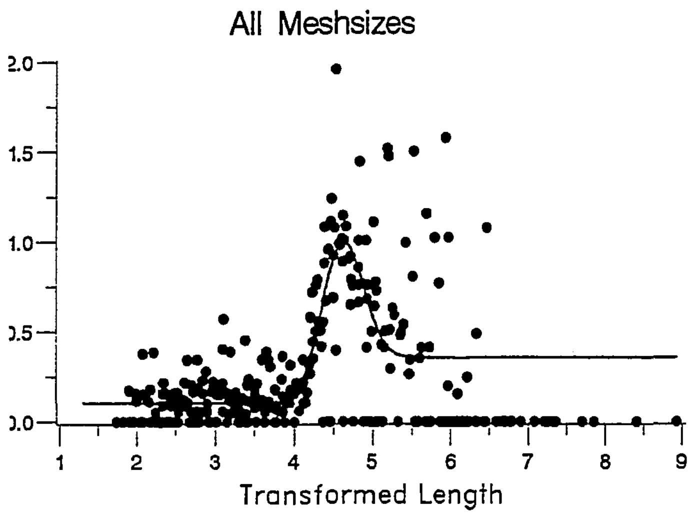
Model= ND+ 2C

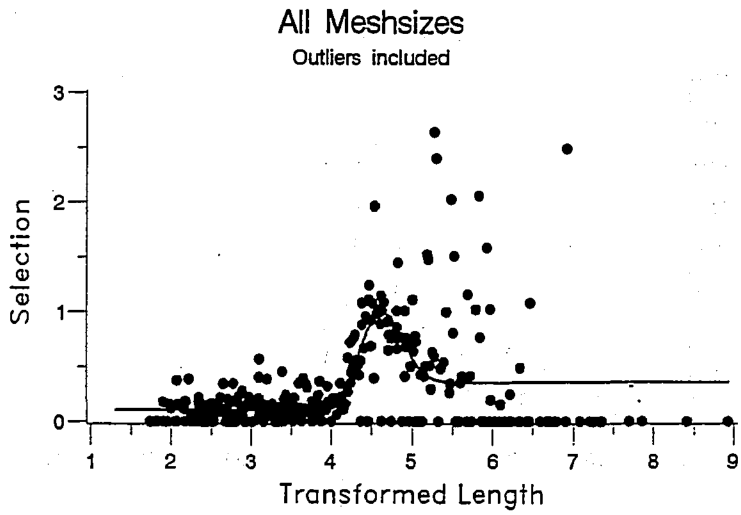


Difta cod, Bycatch in Metier= sole

Estimated selection

Model= ND+ 2C

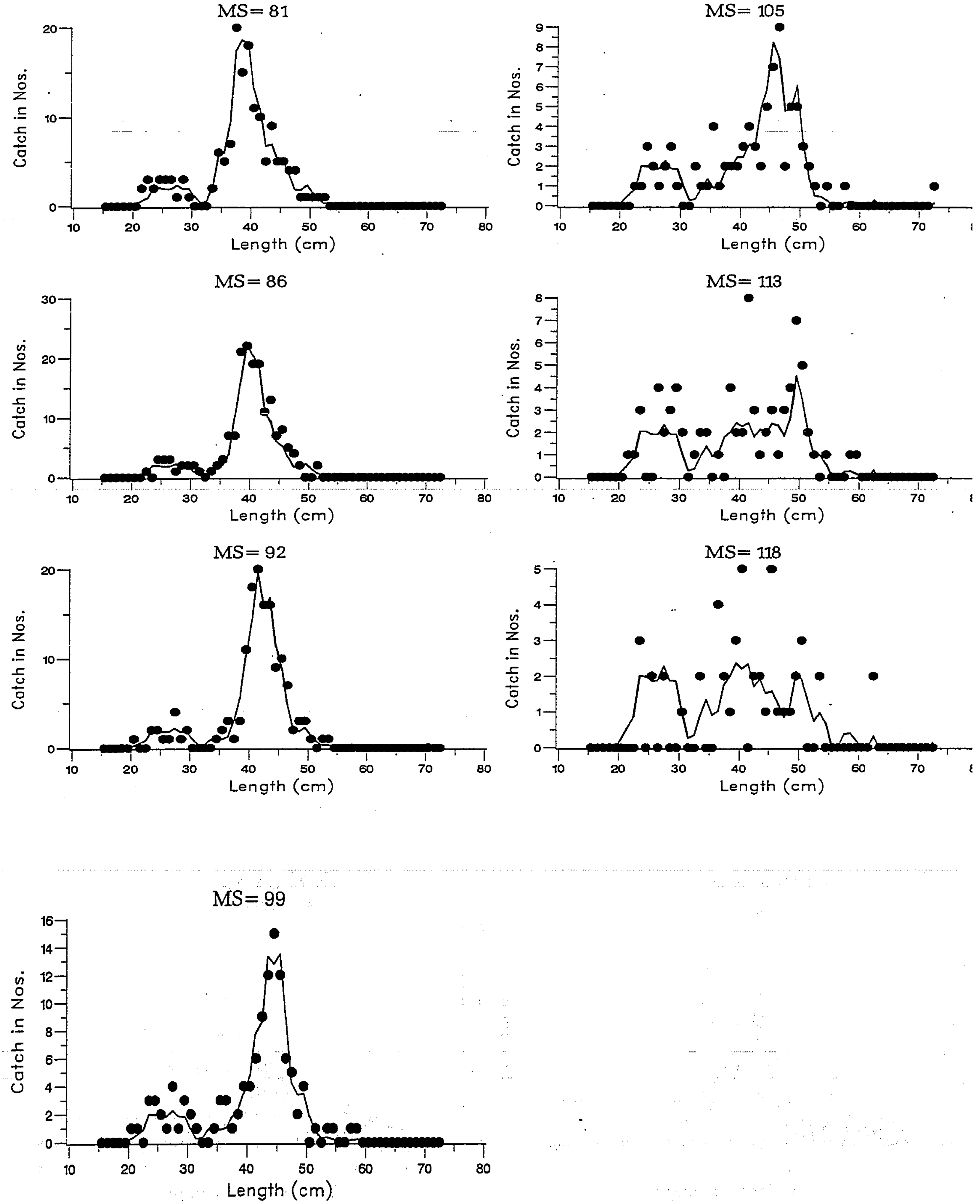




Difta cod, Bycatch in Metier= sole

Estimated Catch and Stock

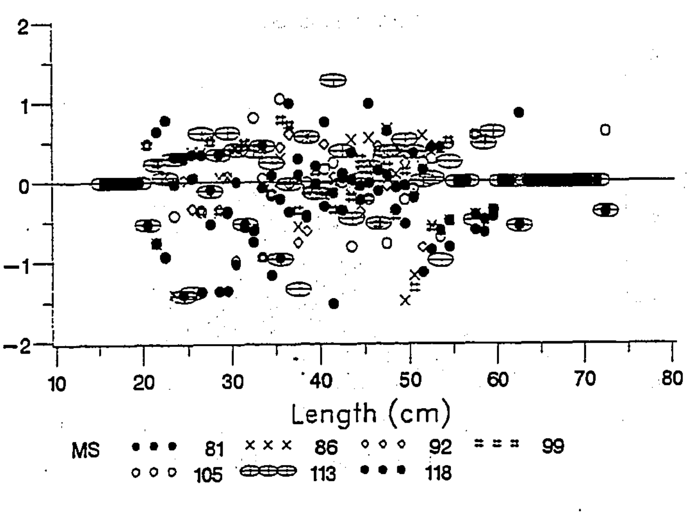
Model= ND+ 2C

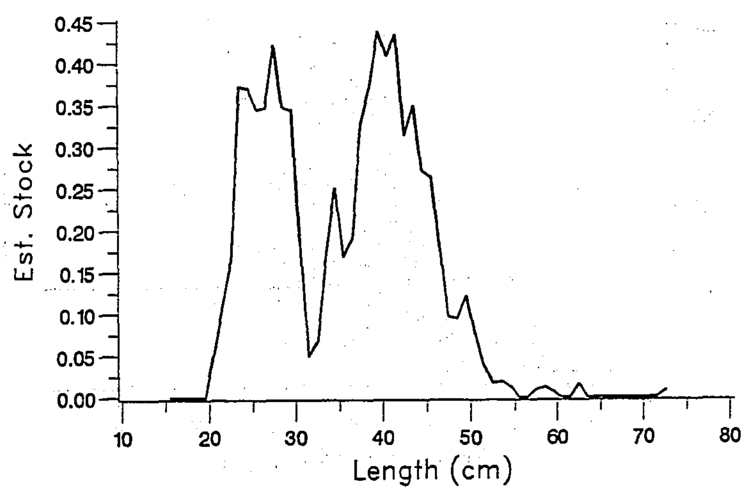


Difta cod, Bycatch in Metier= sole

Estimated Catch and Stock

Model= ND+ 2C

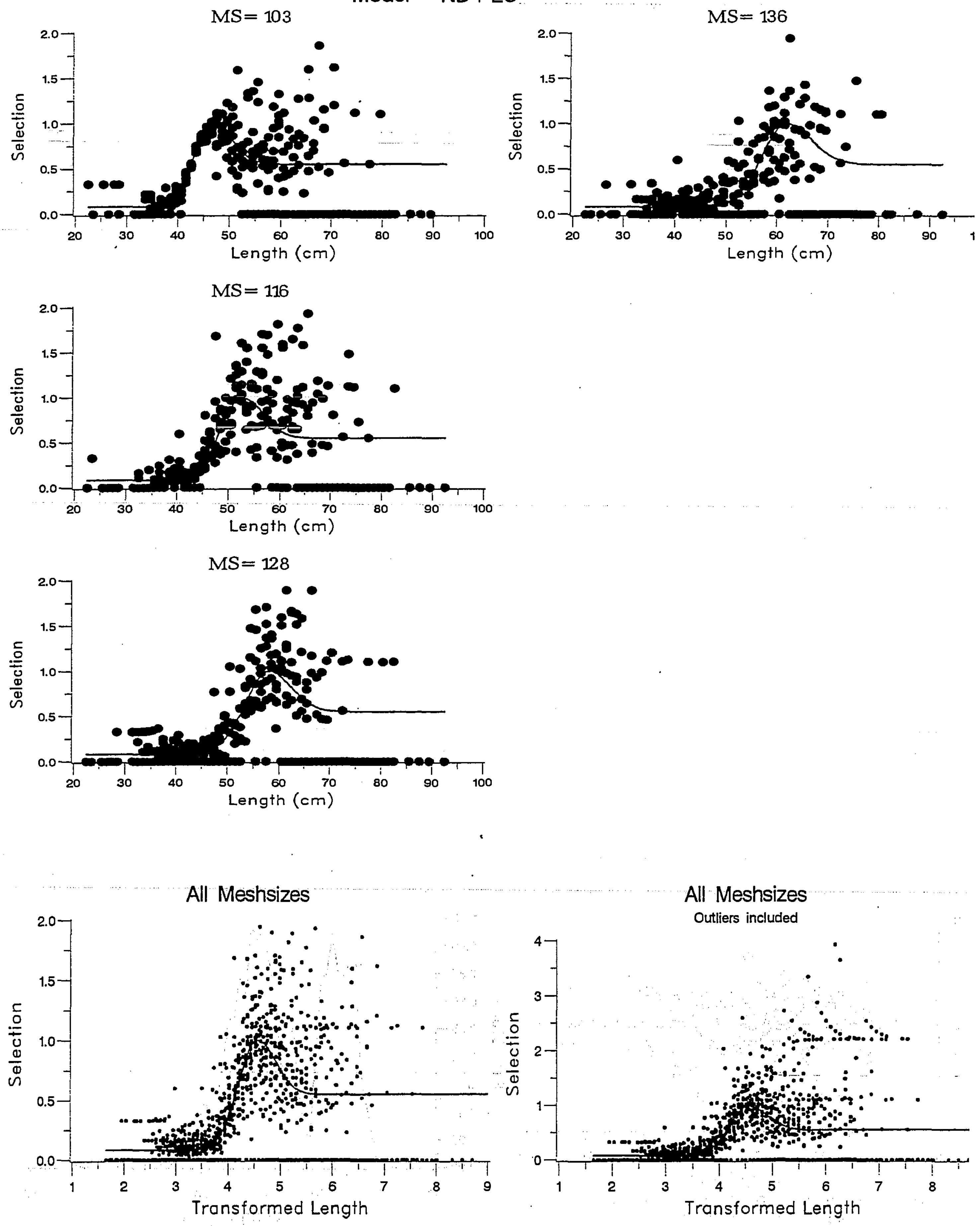




SEAFISH Cod Experiment all

Estimated Selection

Model= ND+2C

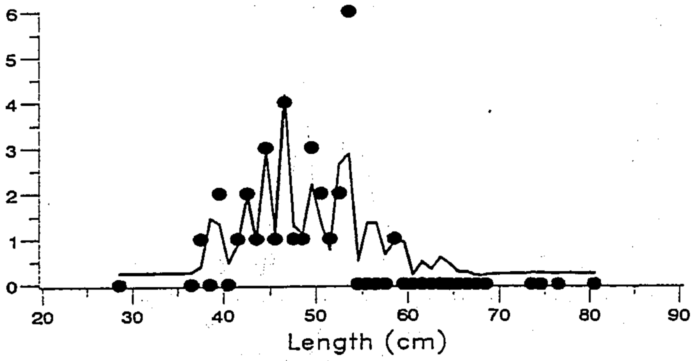


SEAFISH Cod Experiment all

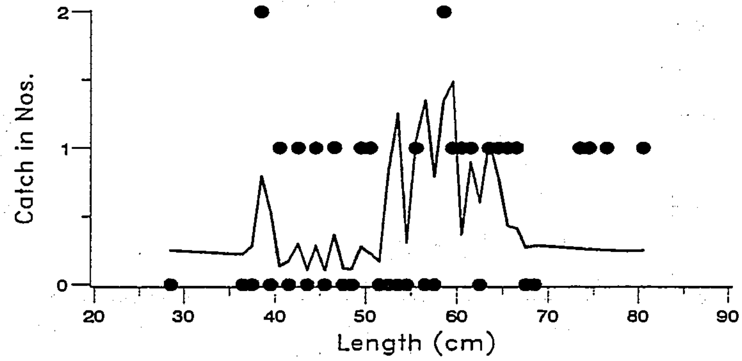
Estimated Catch and Stock

Model = ND+ 2C

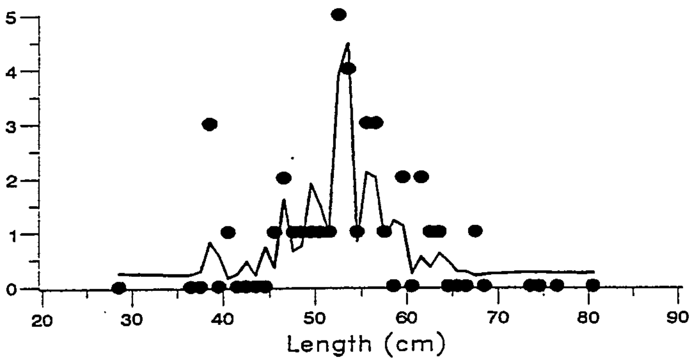
EXP= 1 MS= 103



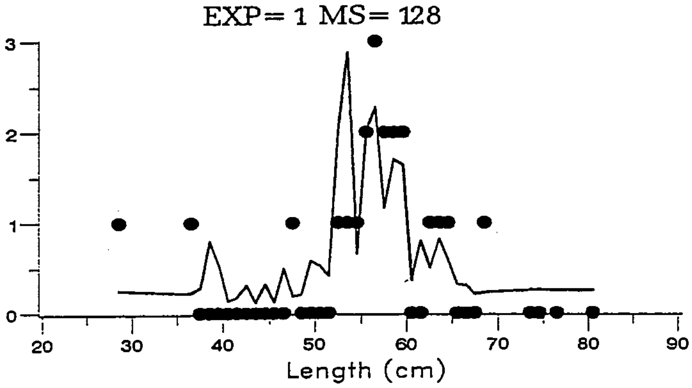
EXP= 1 MS= 136



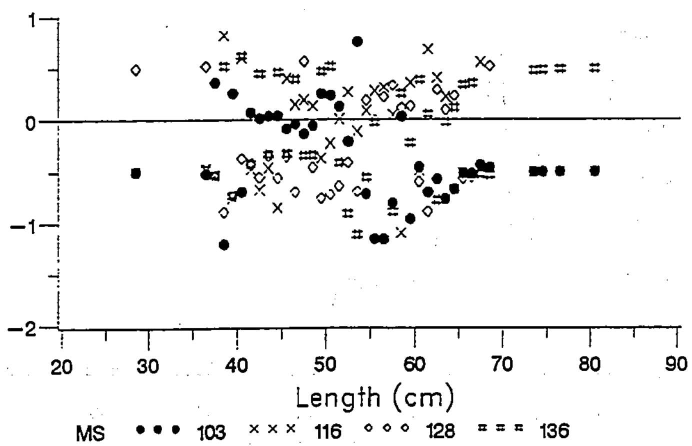
EXP= 1 MS= 116



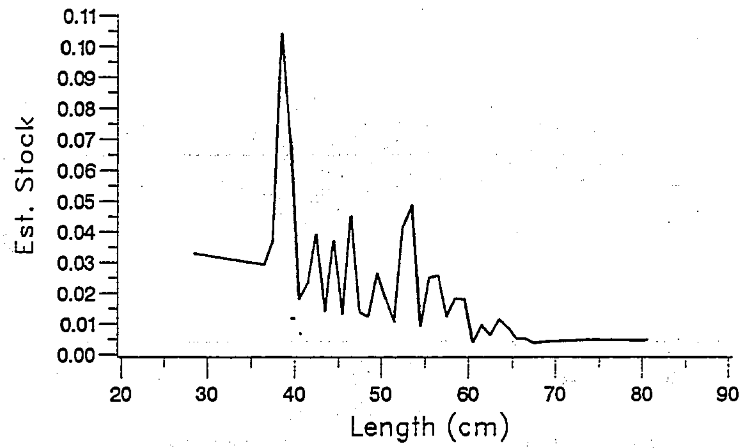
EXP= 1 MS= 128



EXP= 1



EXP= 1

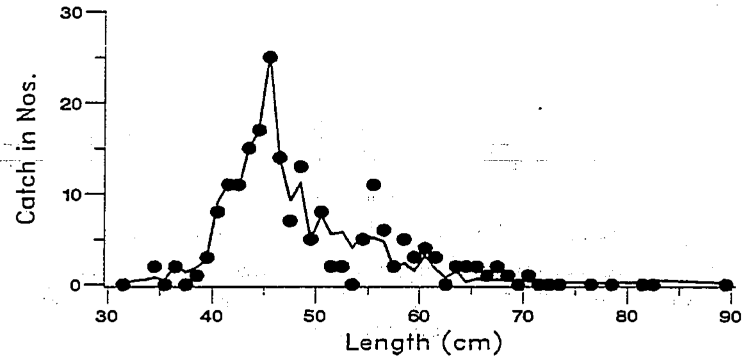


SEAFISH Cod Experiment all

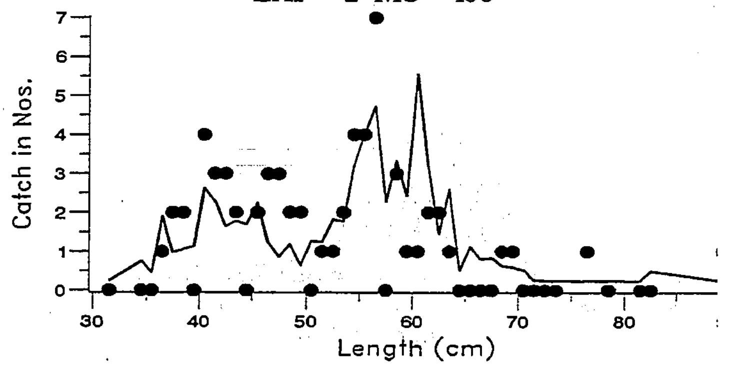
Estimated Catch and Stock

Model = ND+2C

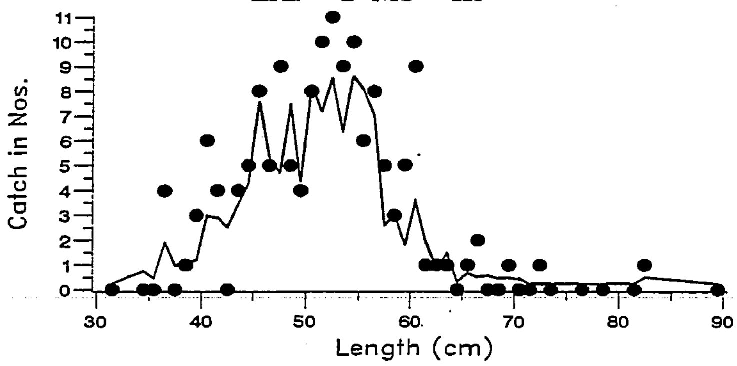
EXP= 2 MS= 103



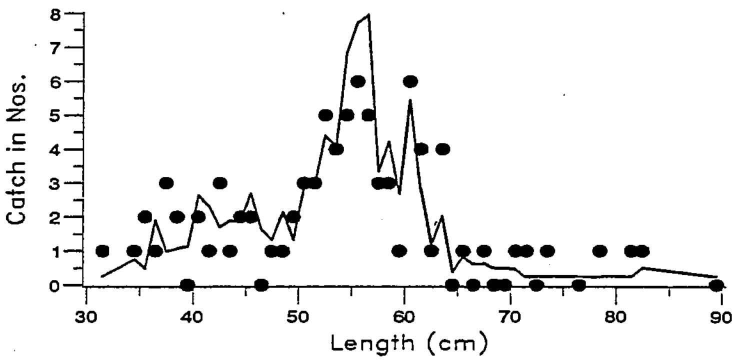
EXP= 2 MS= 136



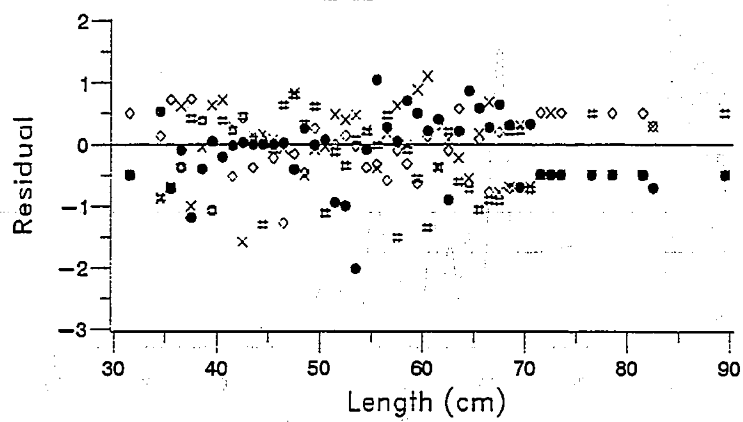
EXP= 2 MS= 116



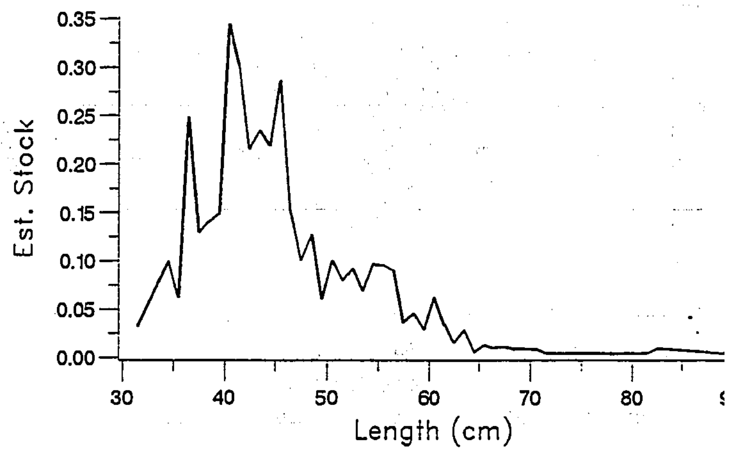
EXP= 2 MS= 128



EXP= 2



EXP= 2

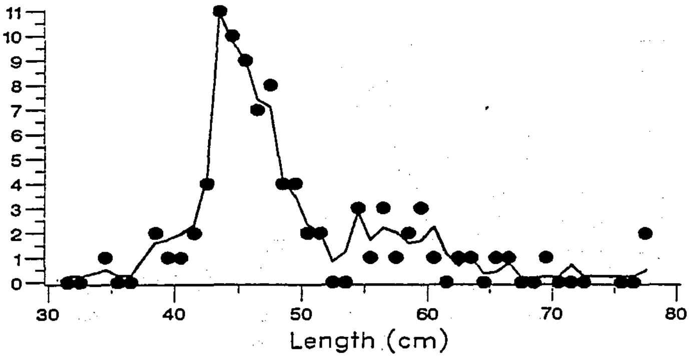


SEAFISH Cod Experiment all

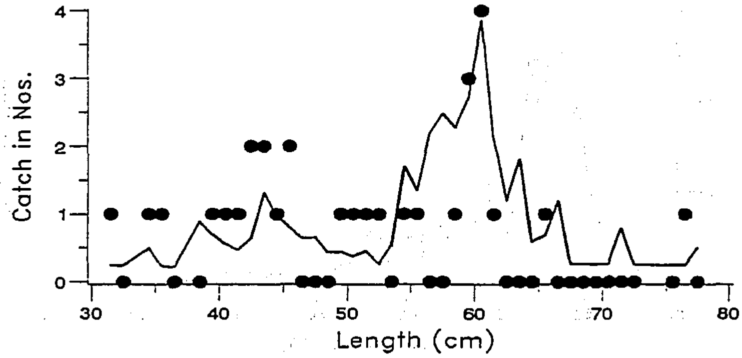
Estimated Catch and Stock

Model = ND+ 2C

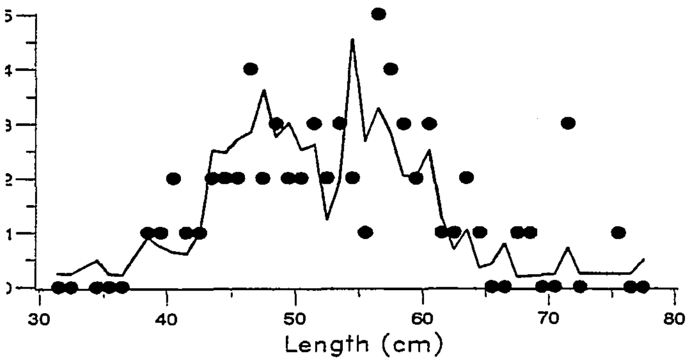
EXP= 3 MS= 103



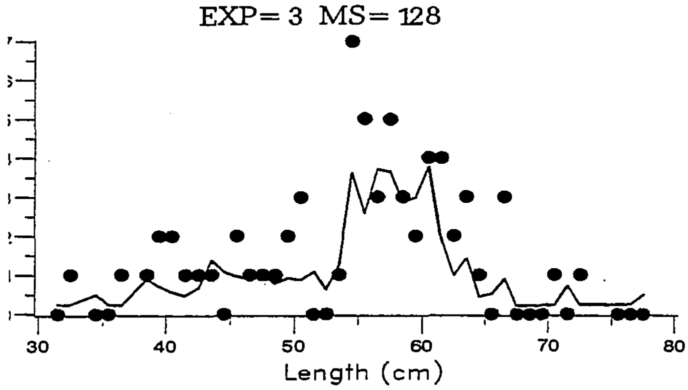
EXP= 3 MS= 136



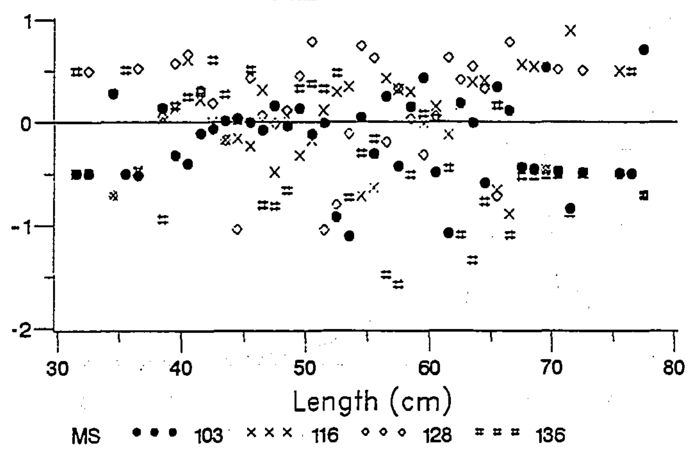
EXP= 3 MS= 116



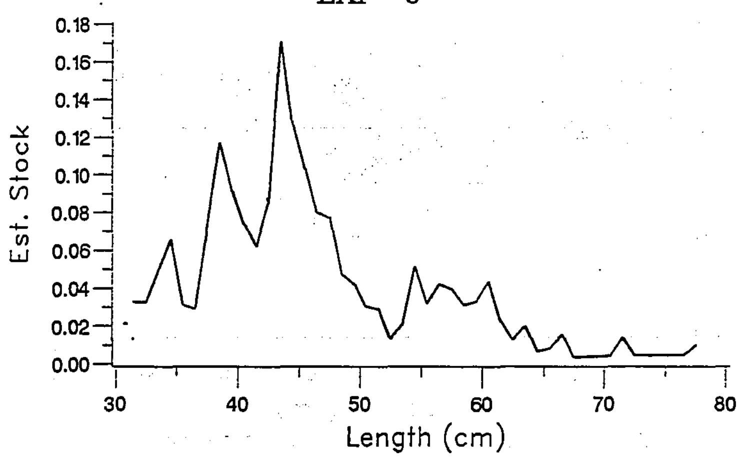
EXP= 3 MS= 128



EXP= 3



EXP= 3

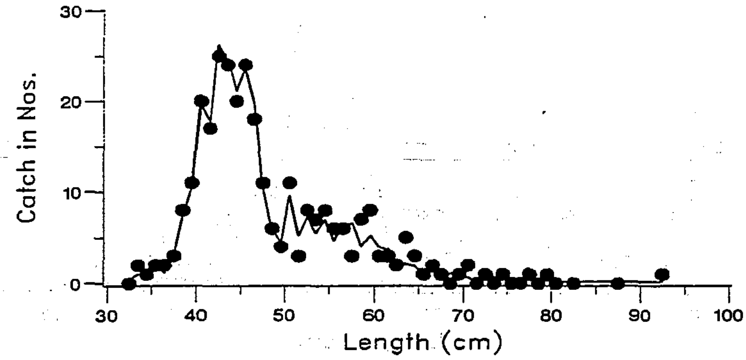


SEAFISH Cod Experiment all

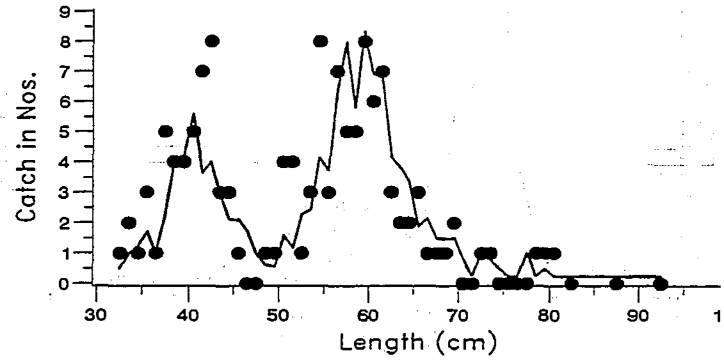
Estimated Catch and Stock

Model = ND+ 2C

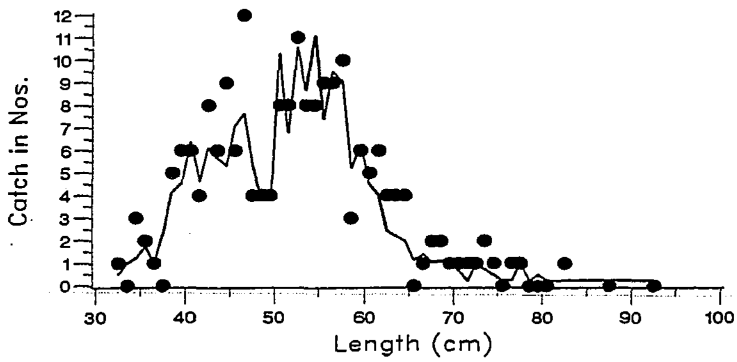
EXP= 4 MS= 103



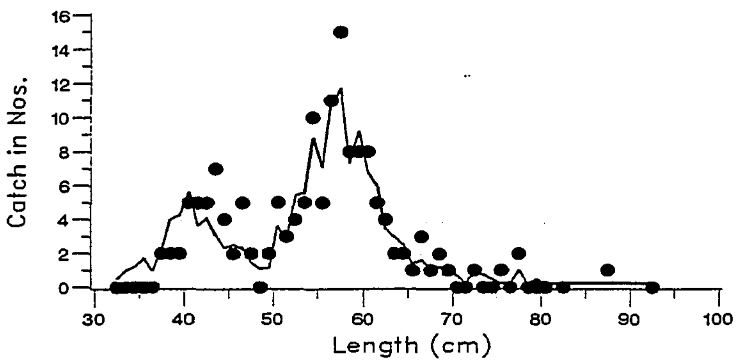
EXP= 4 MS= 136



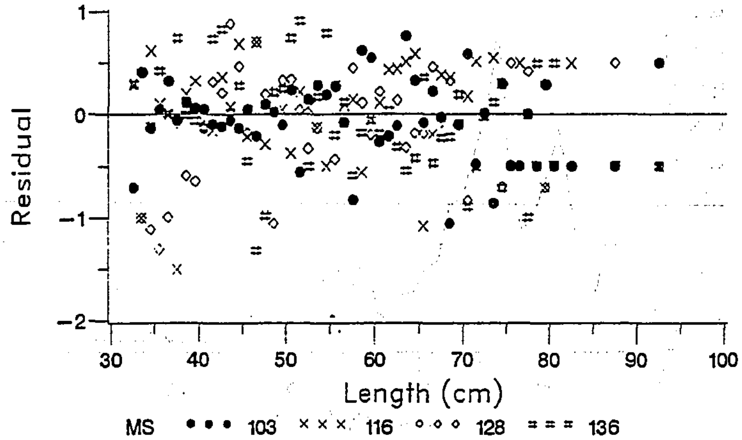
EXP= 4 MS= 116



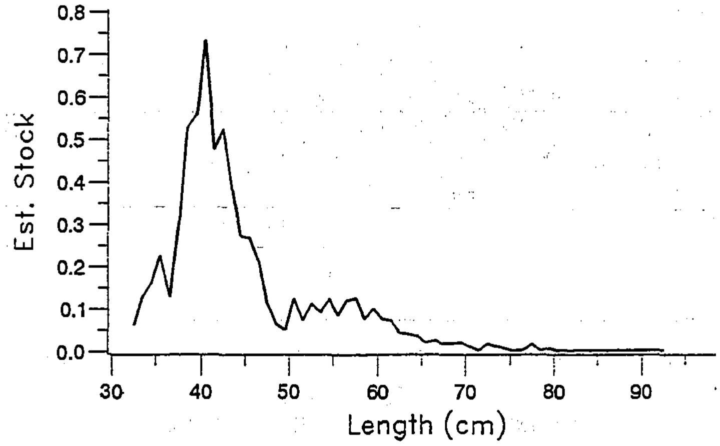
EXP= 4 MS= 128



EXP= 4



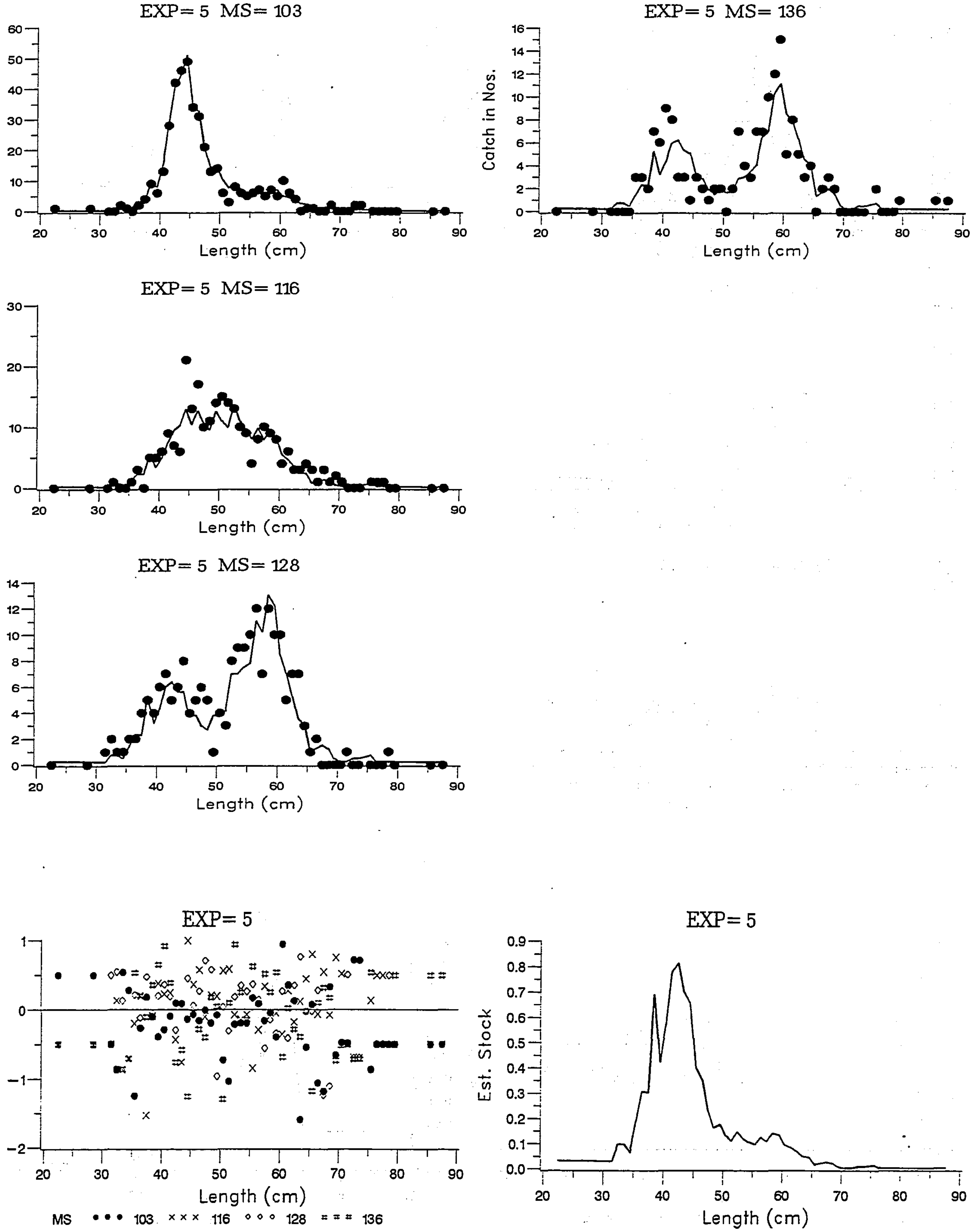
EXP= 4



SEAFISH Cod Experiment all

Estimated Catch and Stock

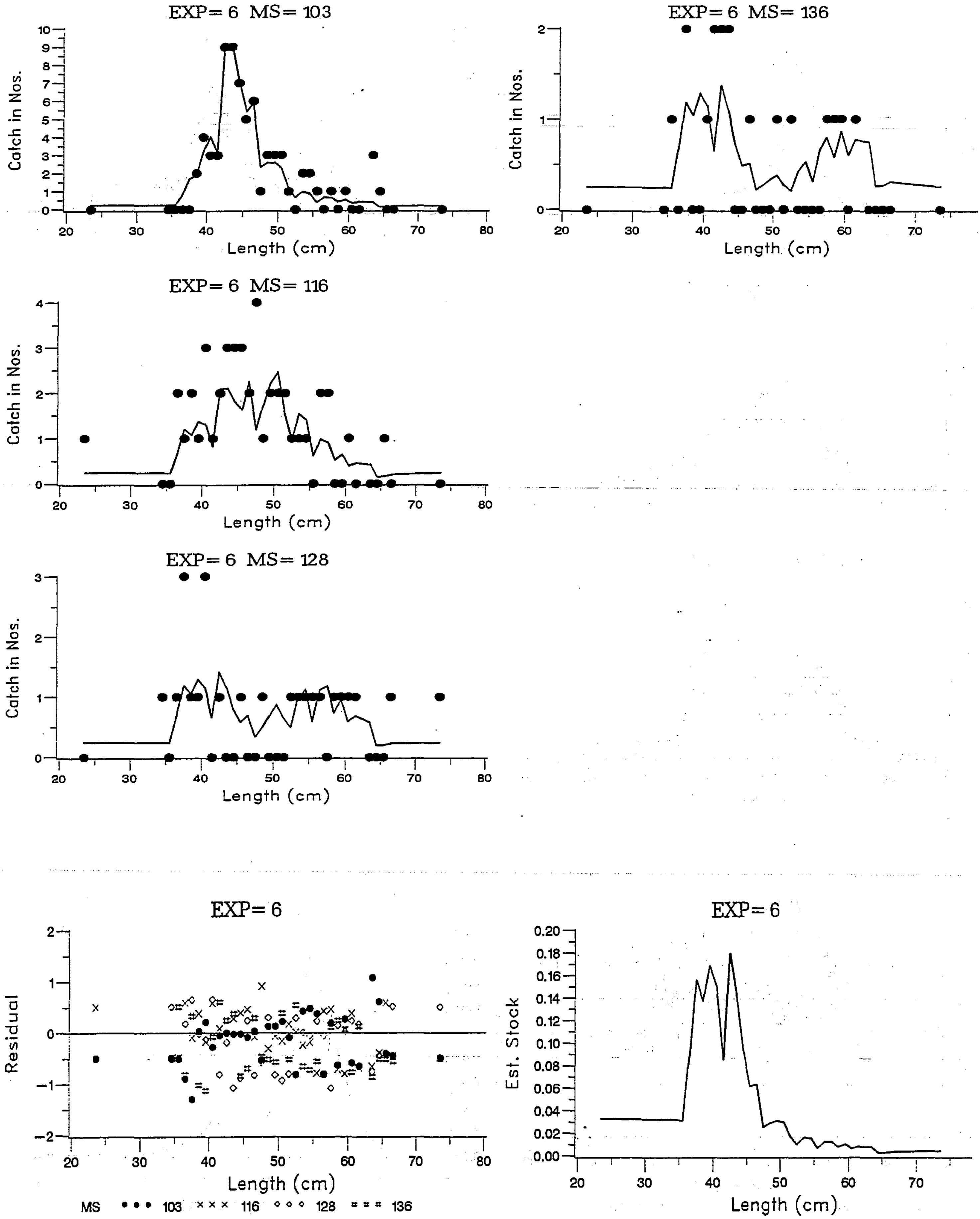
Model = ND+ 2C



SEAFISH Cod Experiment all

Estimated Catch and Stock

Model = ND+2C

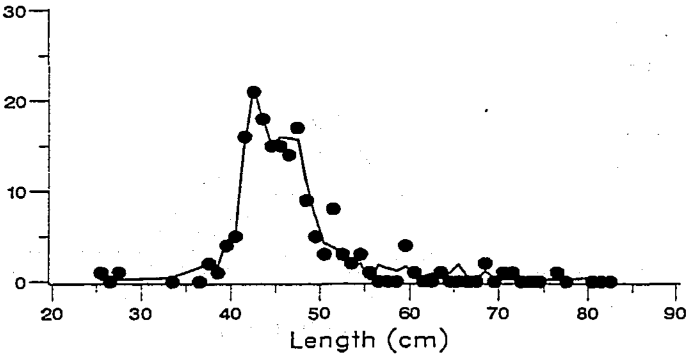


SEAFISH Cod Experiment all

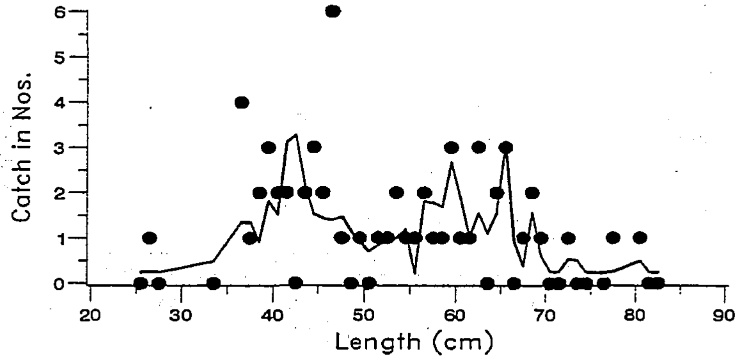
Estimated Catch and Stock

Model = ND+ 2C

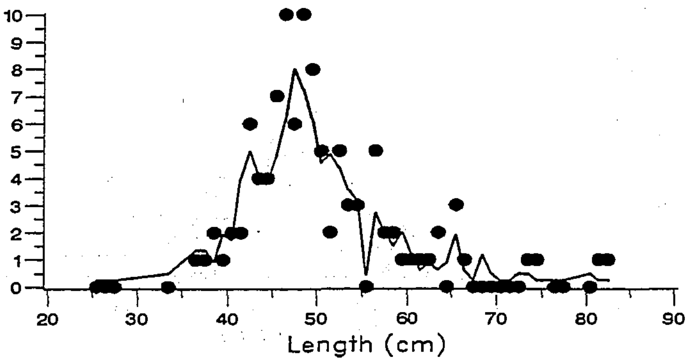
EXP= 7 MS= 103



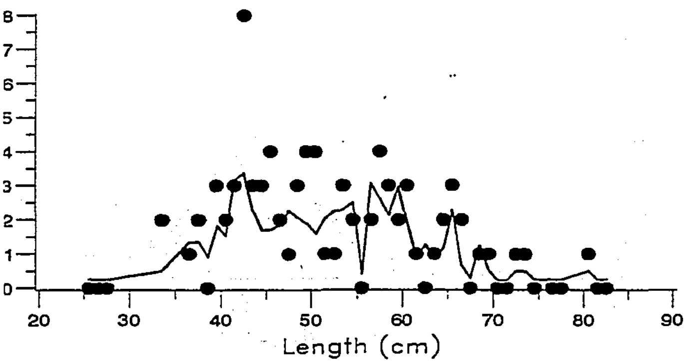
EXP= 7 MS= 136



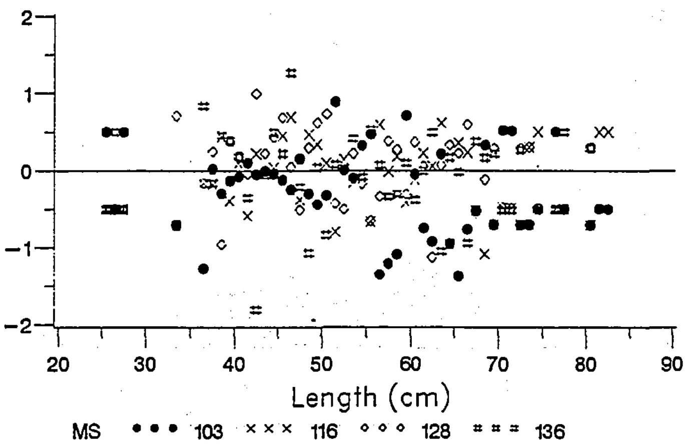
EXP= 7 MS= 116



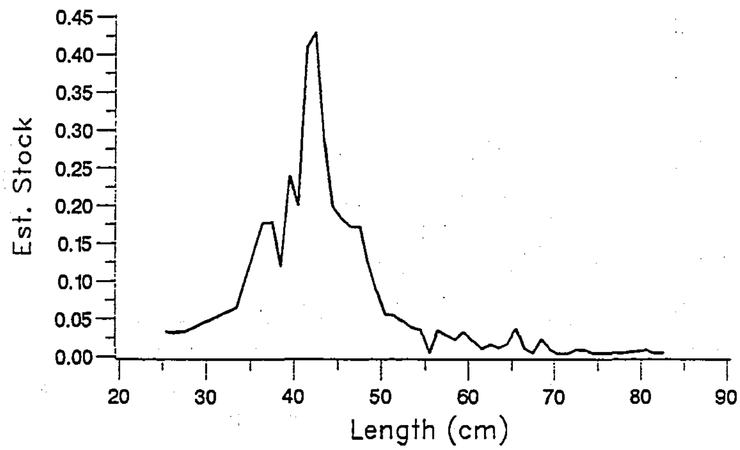
EXP= 7 MS= 128



EXP= 7



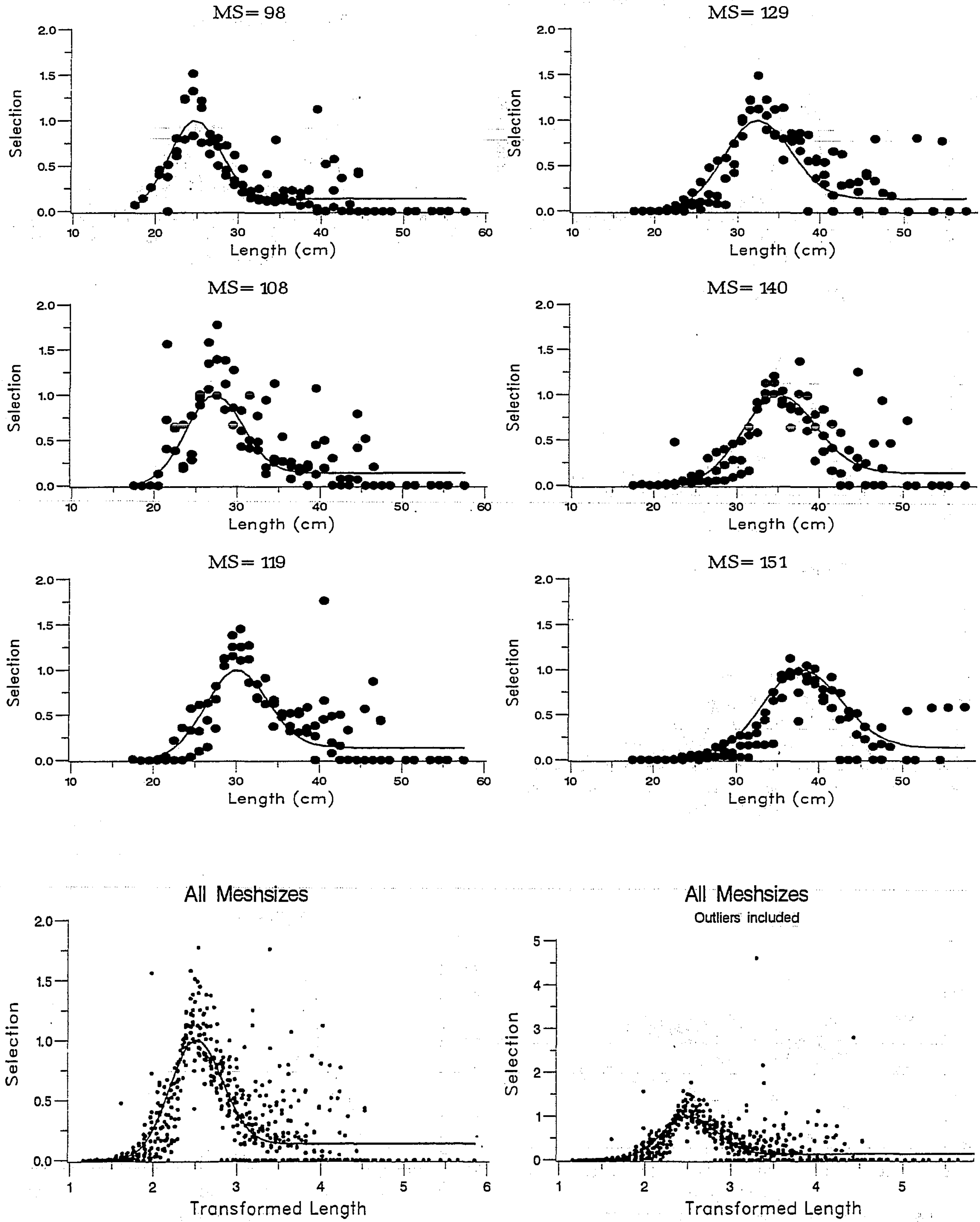
EXP= 7



Difta Plaice Experiment: all

Estimated Selection

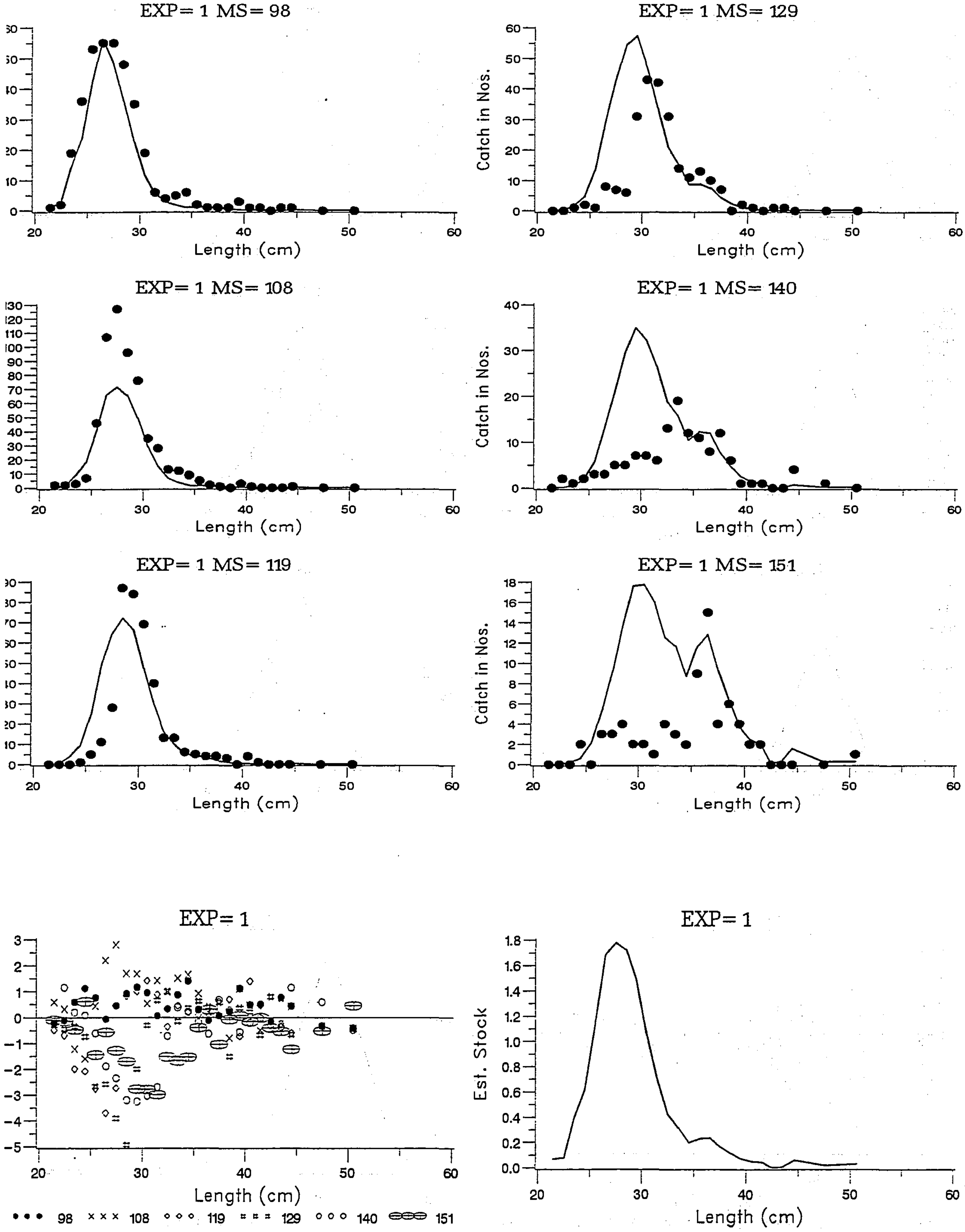
Model= ND+2C



Difta Plaice Experiment: all

Estimated Catch and Stock

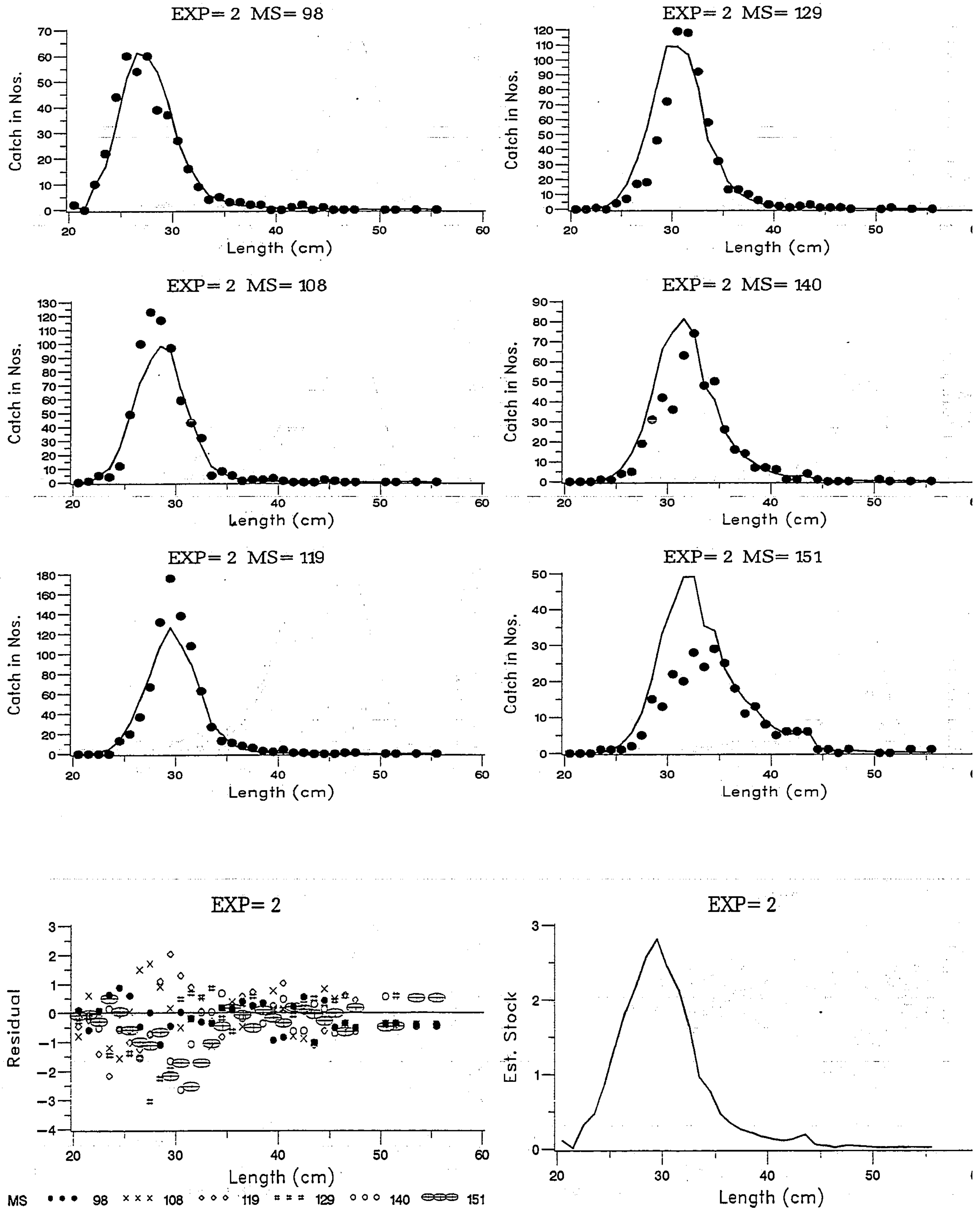
Model= ND+ 2C



Difta Plaice Experiment: all

Estimated Catch and Stock

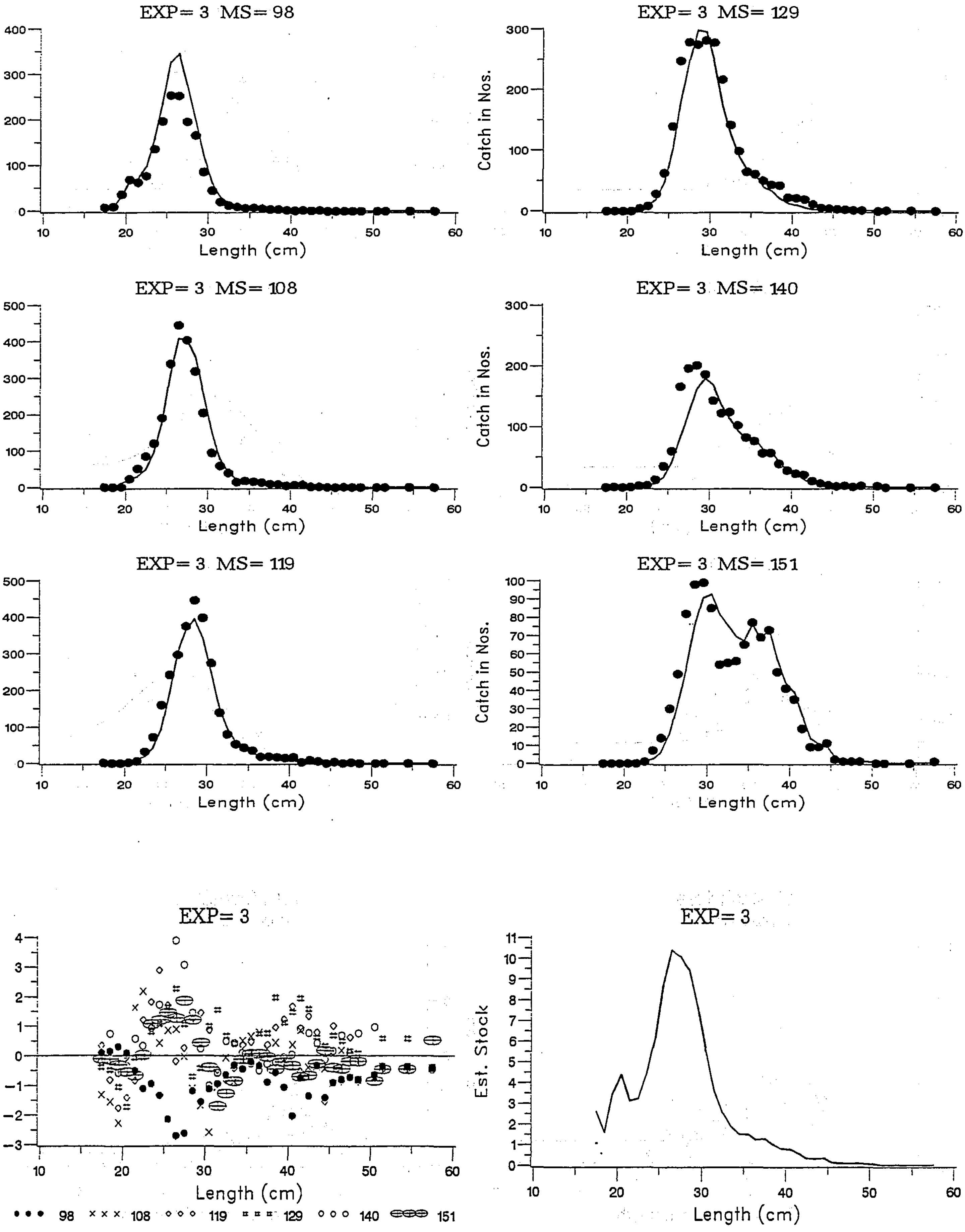
Model= ND+2C



Difta Plaice Experiment: all

Estimated Catch and Stock

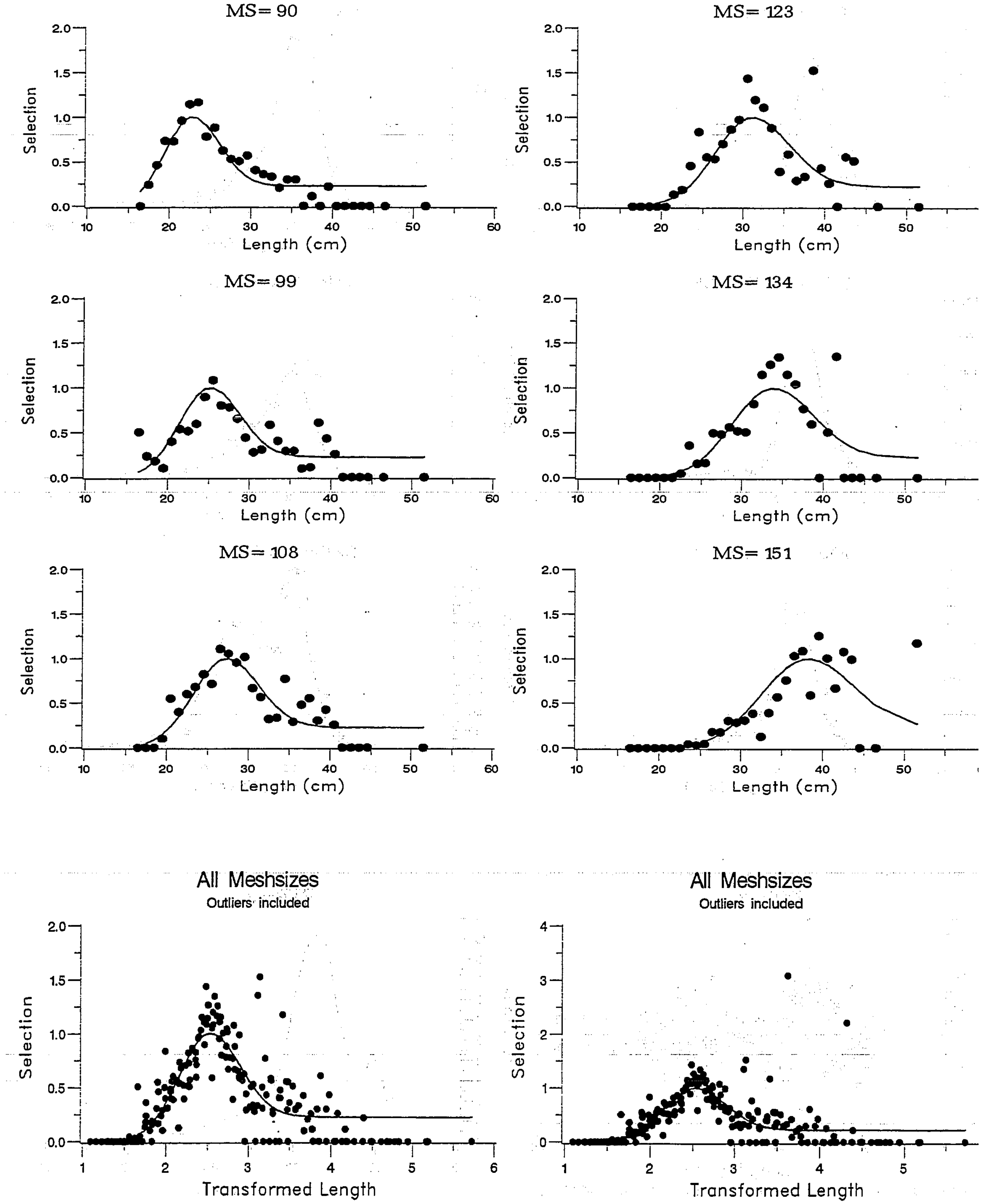
Model= ND+2C



Difta Plaice, Bycatch in Metier= Cod

Estimated Selection

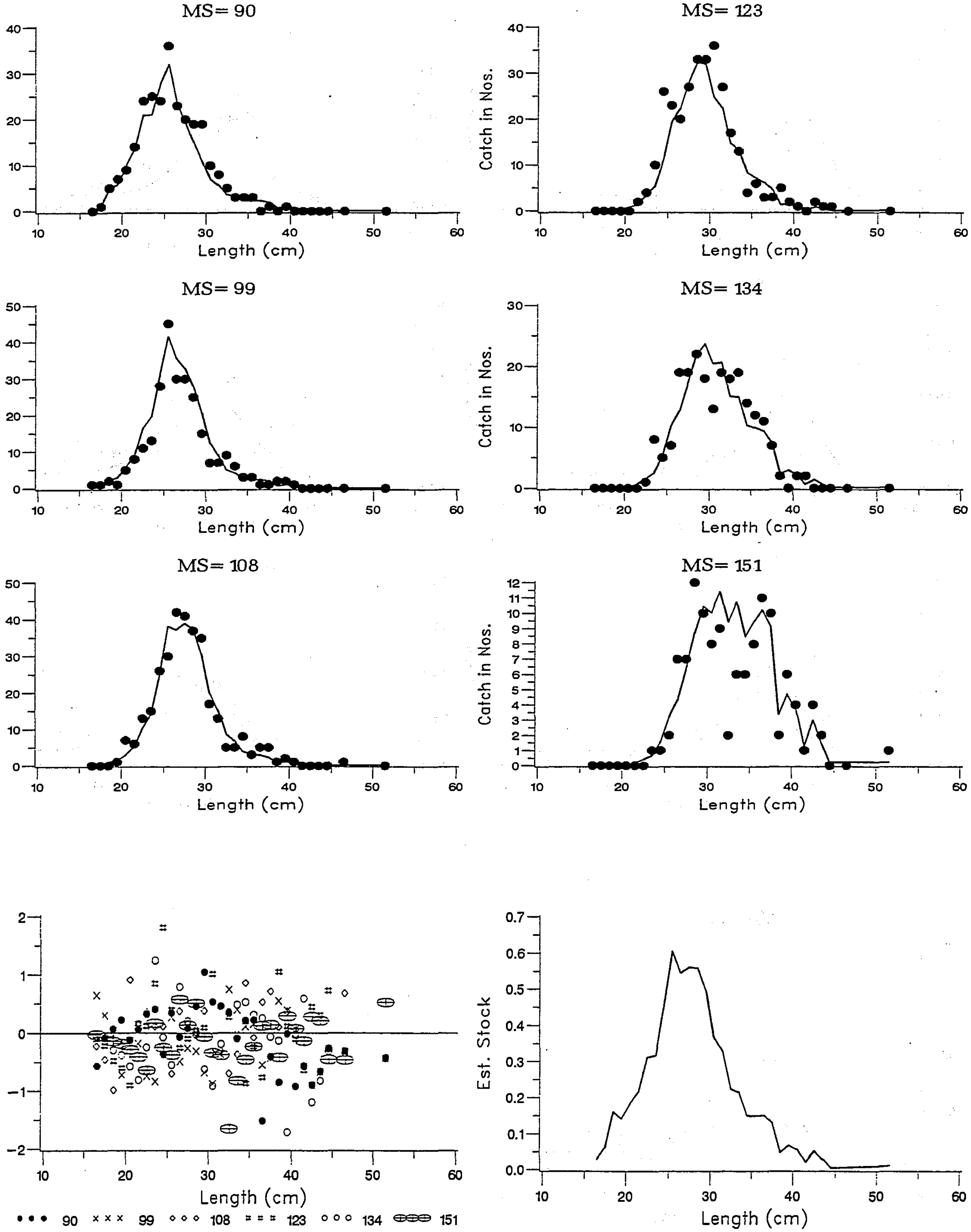
Model= 2ND+2C



Difta Plaice, Bycatch in Metier= Cod

Estimated Catch and Stock

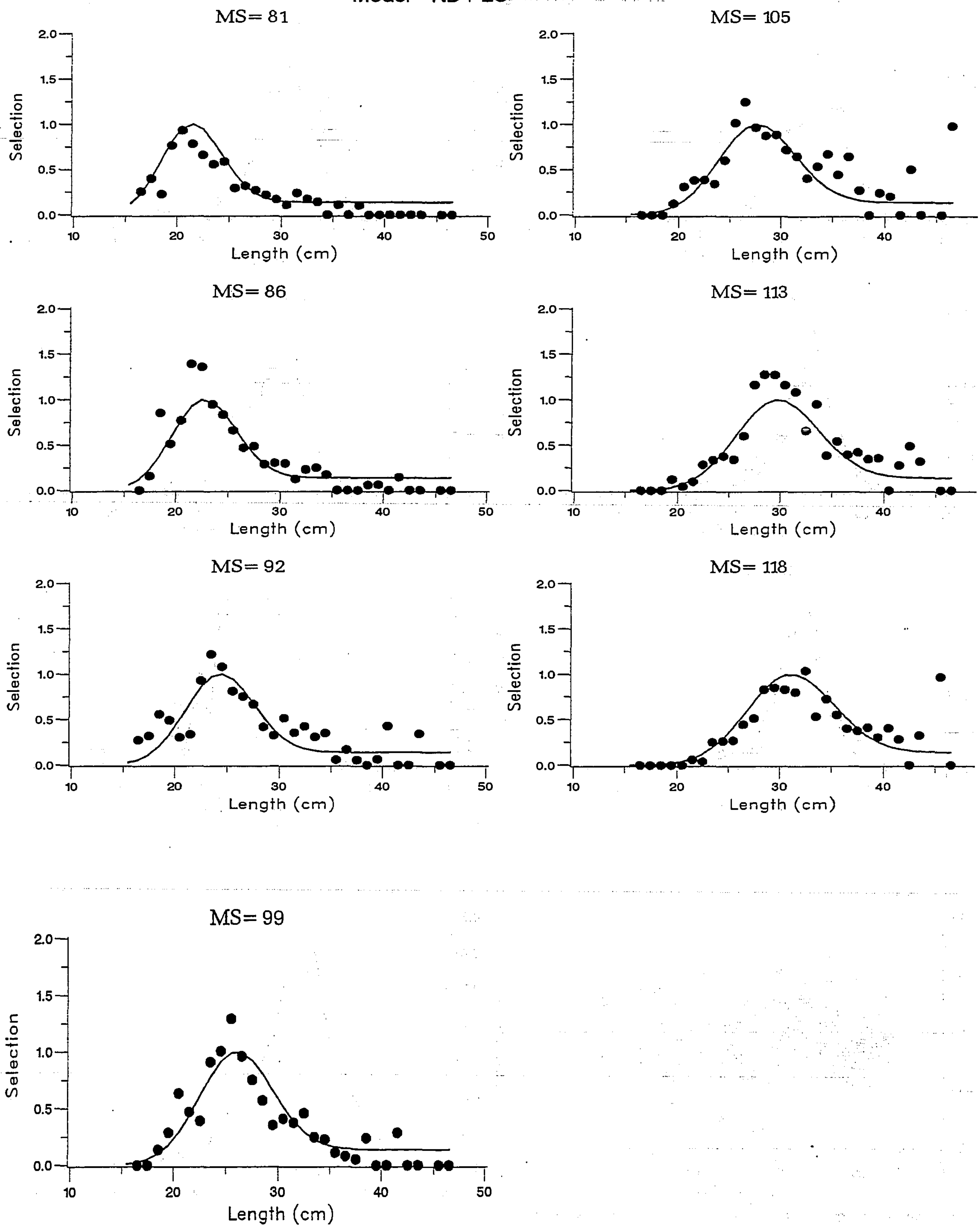
Model= 2ND+ 2C



Difta Plaice, Bycatch in Metier= Sole

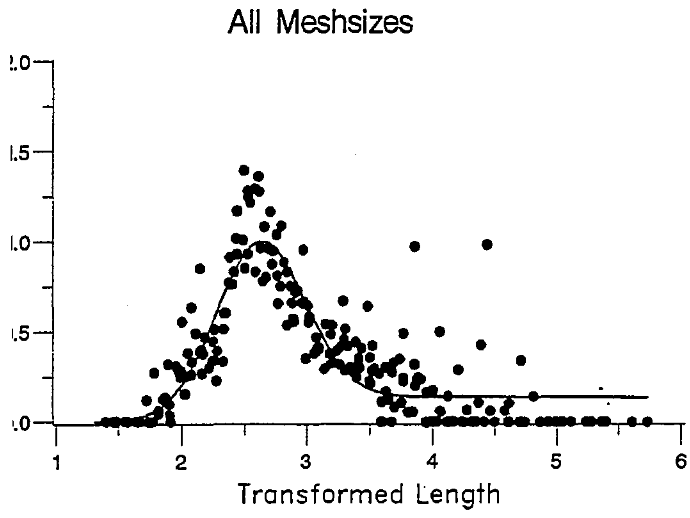
Estimated selection

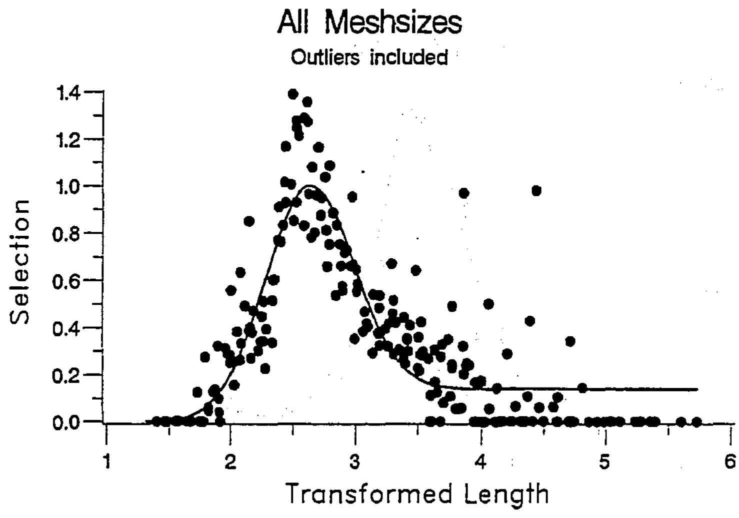
Model= ND+ 2C



Difta Plaice, Bycatch in Metier= Sole

Estimated selection
Model= ND+ 2C

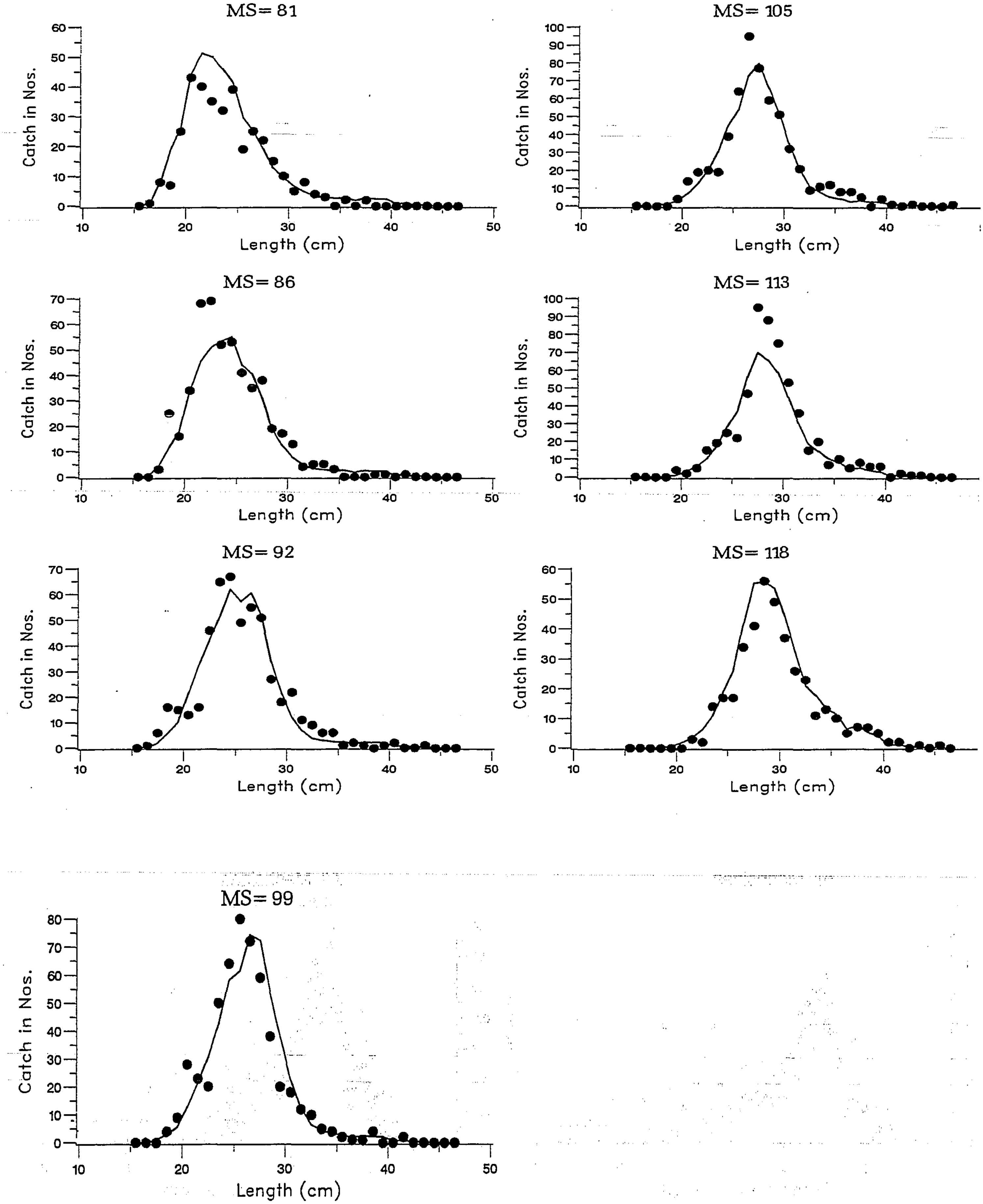




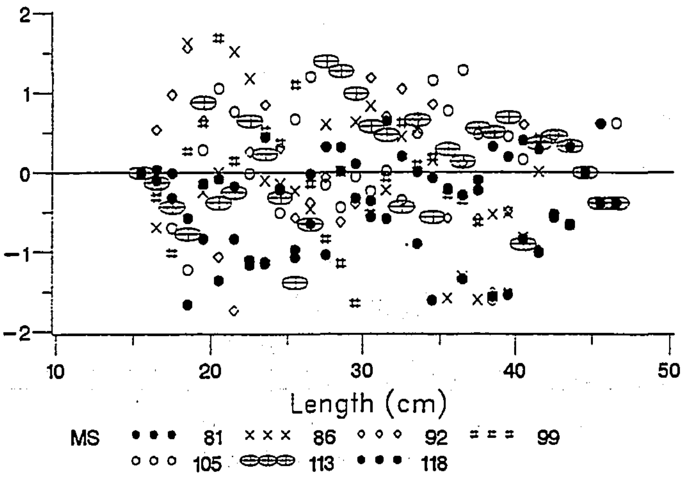
Difta Plaice, Bycatch in Metier= Sole

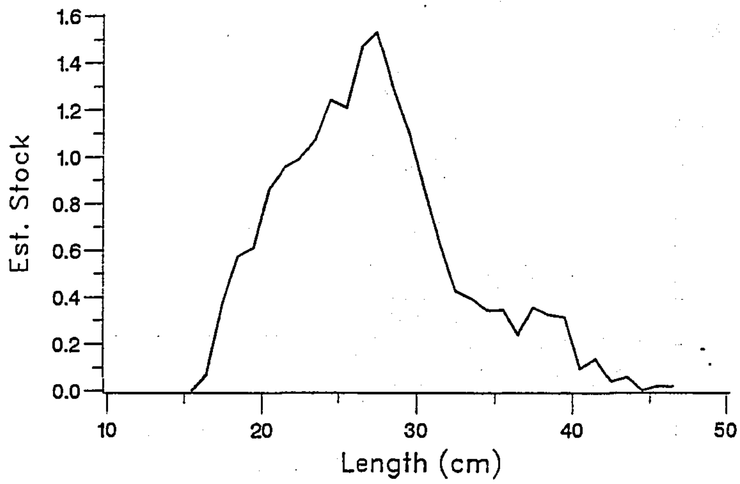
Estimated Catch and Stock

Model= ND+ 2C



Difta Plaice, Bycatch in Metier= Sole
Estimated Catch and Stock
Model= ND+ 2C

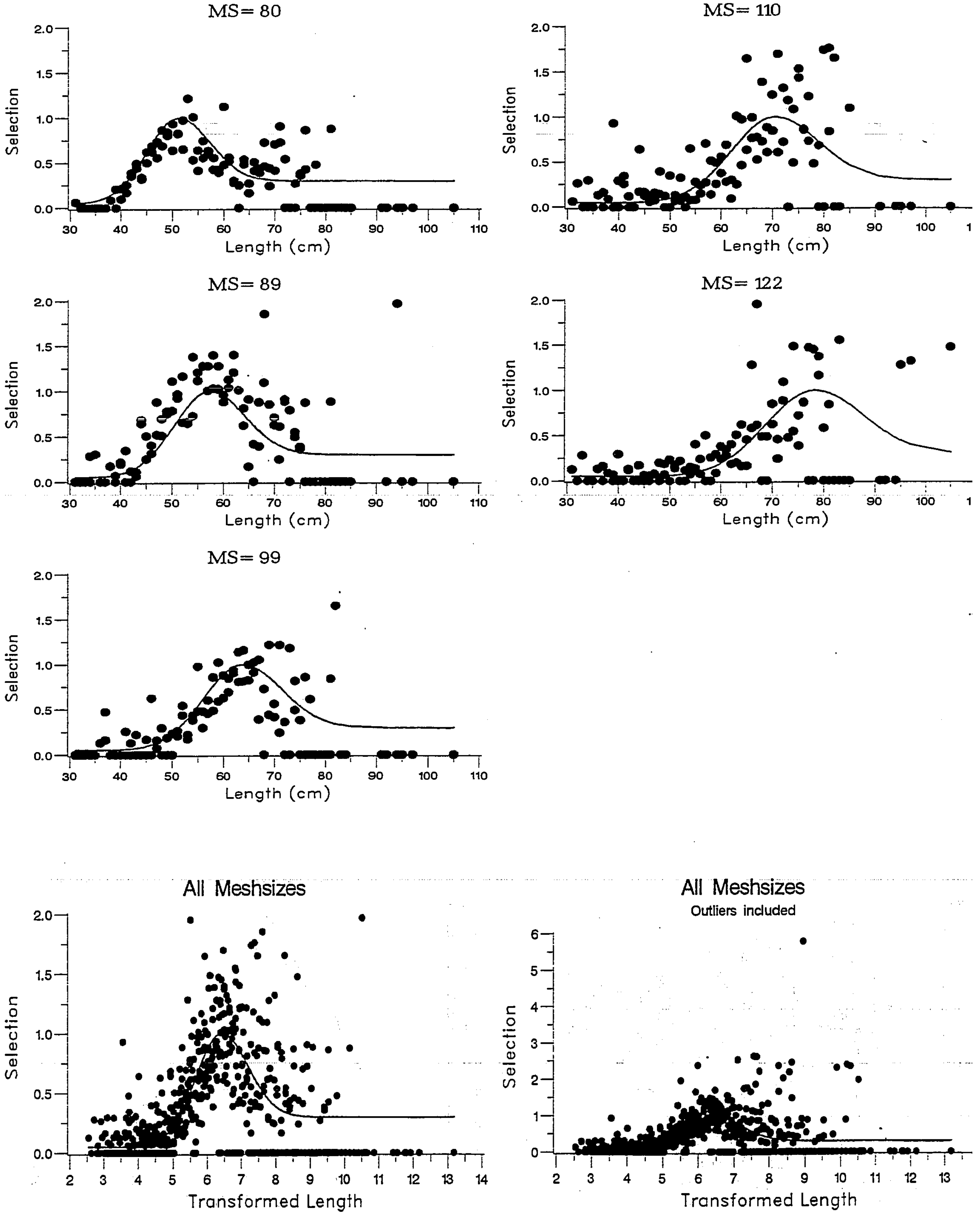




Ifremer Hake Experiment all

Estimated Selection

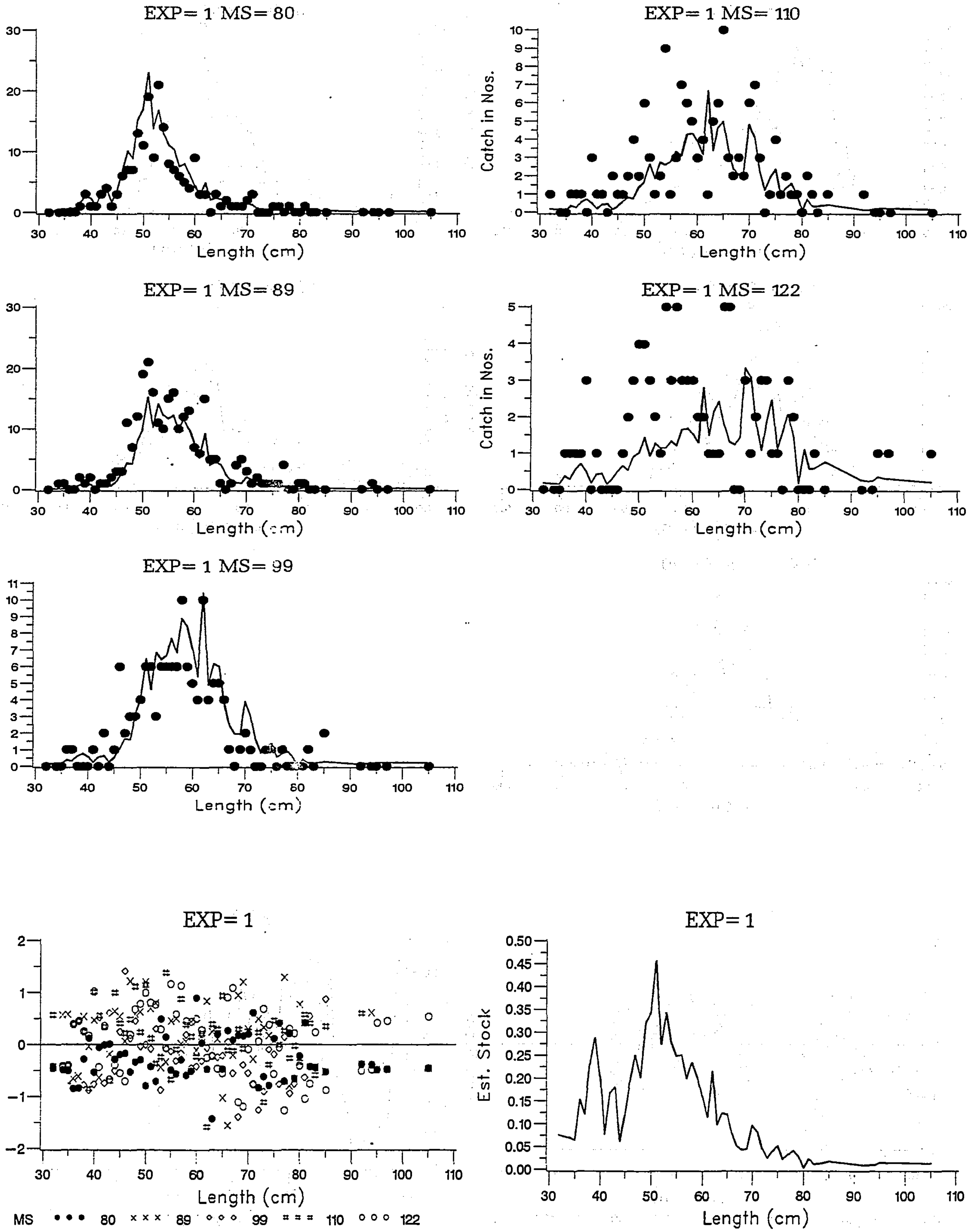
Model = ND+2C



Ifremer Hake Experiment all

Estimated Catch and Stock

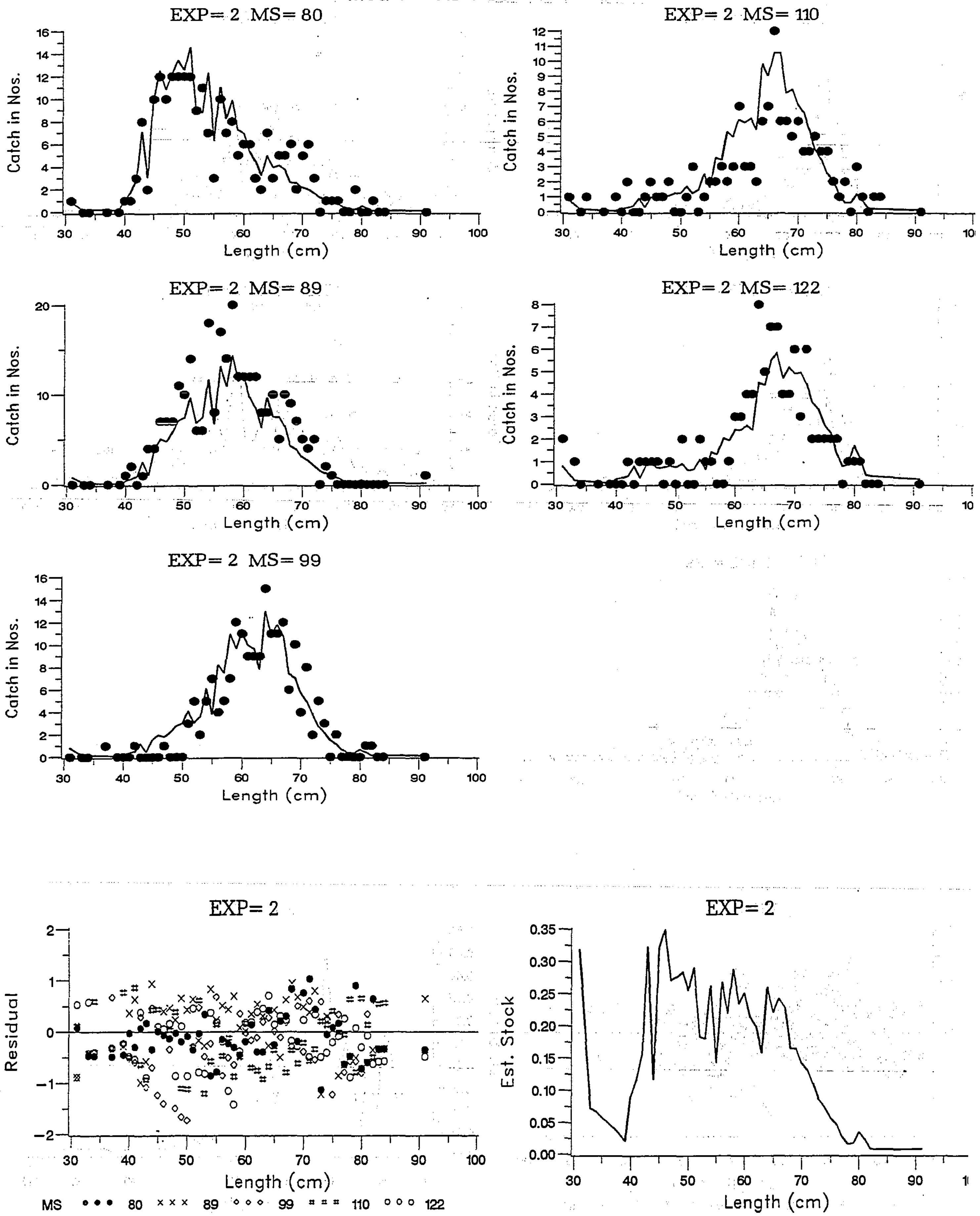
Model = ND+2C



Ifremer Hake Experiment all

Estimated Catch and Stock

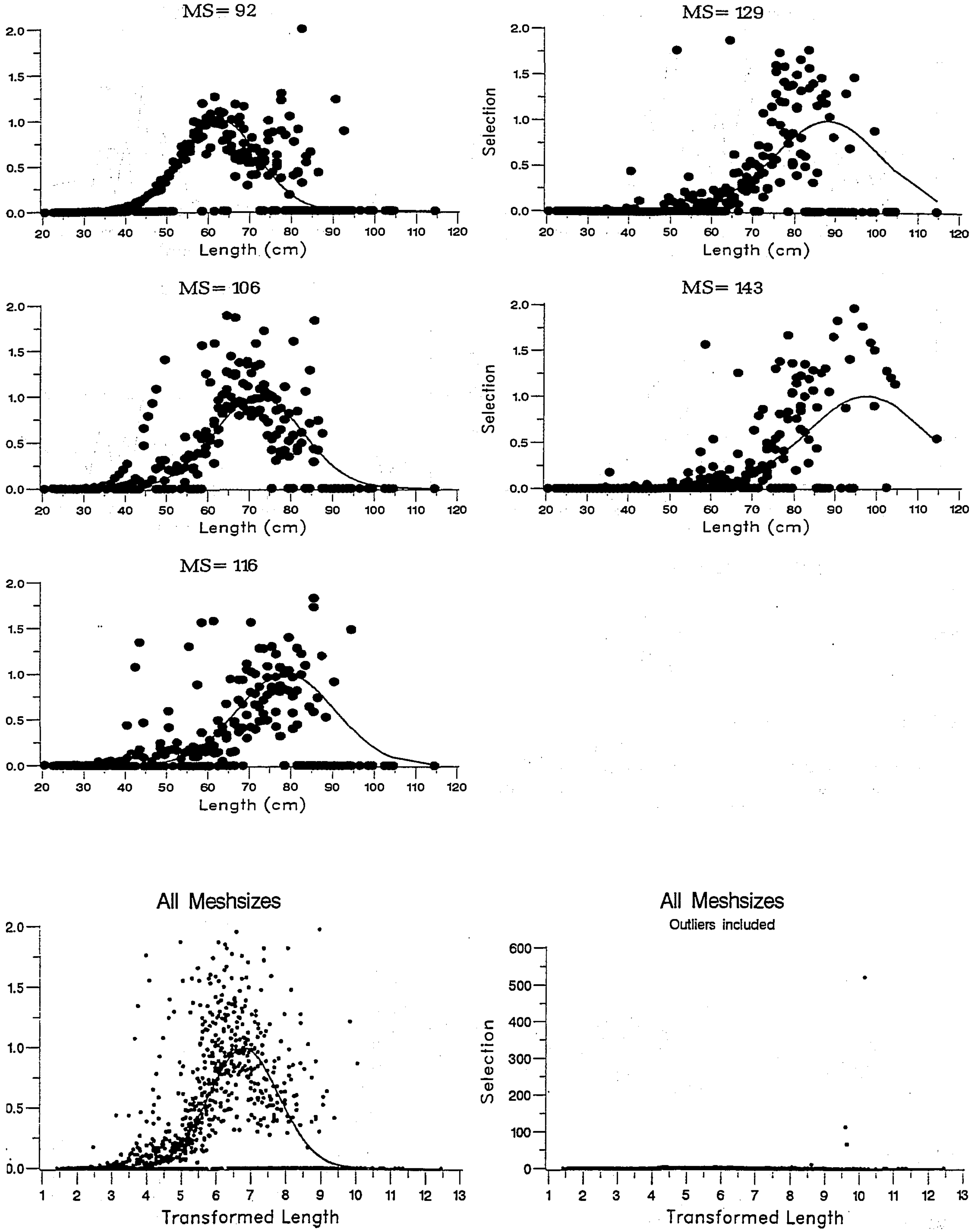
Model = ND+2C



Seafish Hake Experiment all

Estimated Selection

Model= ND+2C

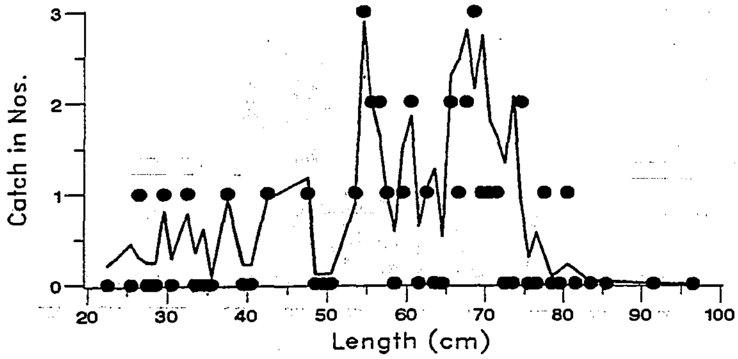


Seafish Hake Experiment all

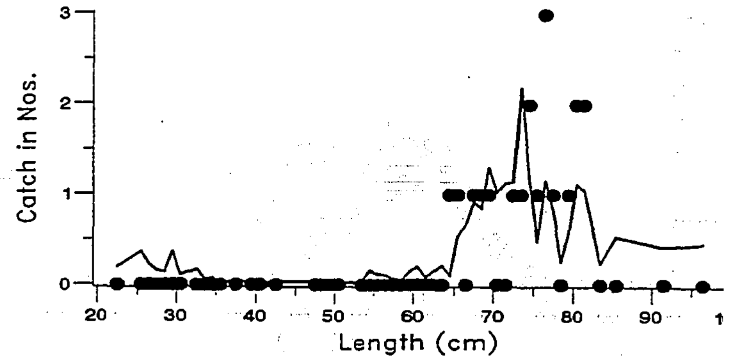
Estimated Catch and Stock

Model= ND+2C

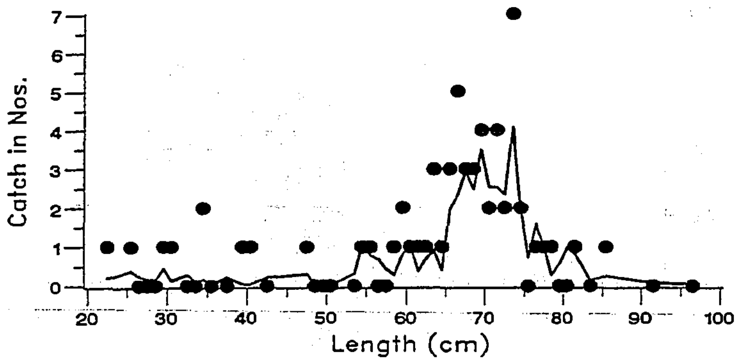
EXP= 1 MS= 92



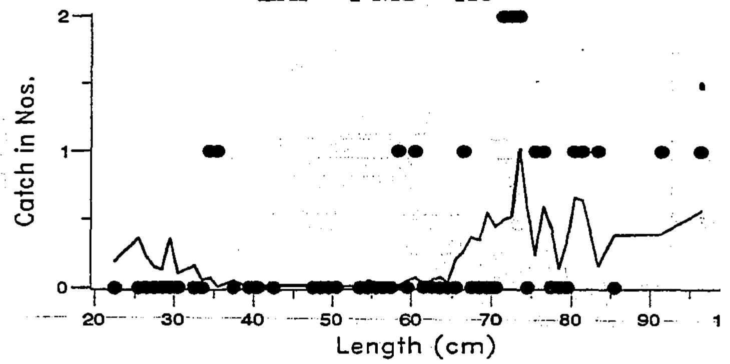
EXP= 1 MS= 129



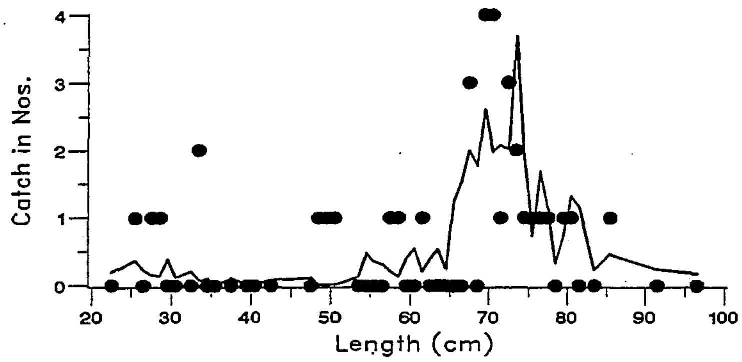
EXP= 1 MS= 106



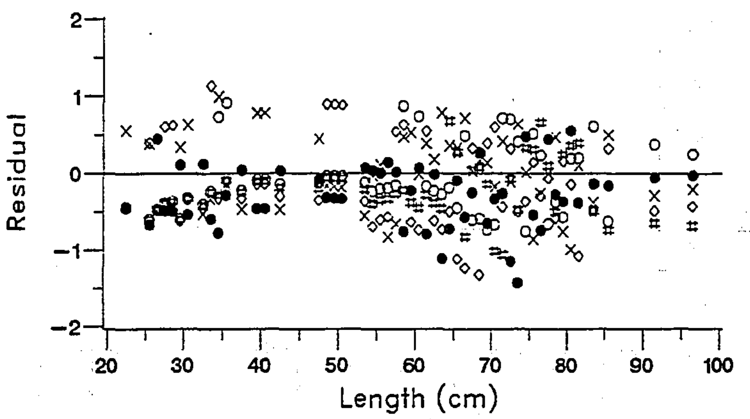
EXP= 1 MS= 143



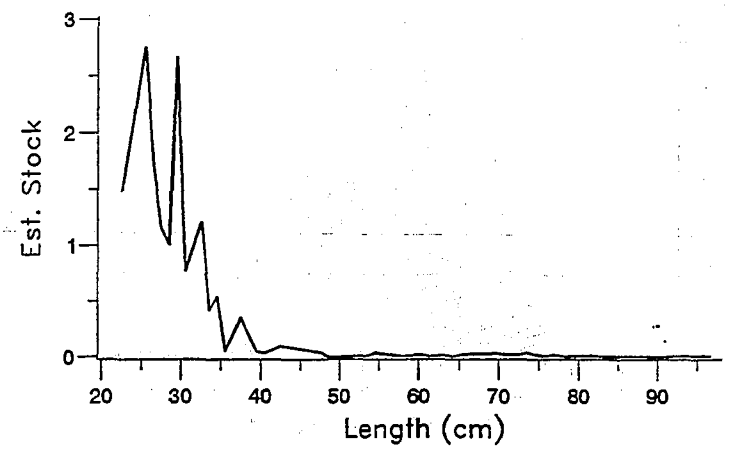
EXP= 1 MS= 116



EXP= 1



EXP= 1

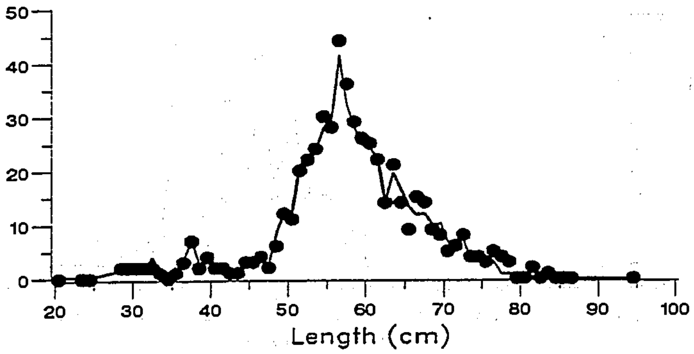


Seafish Hake Experiment all

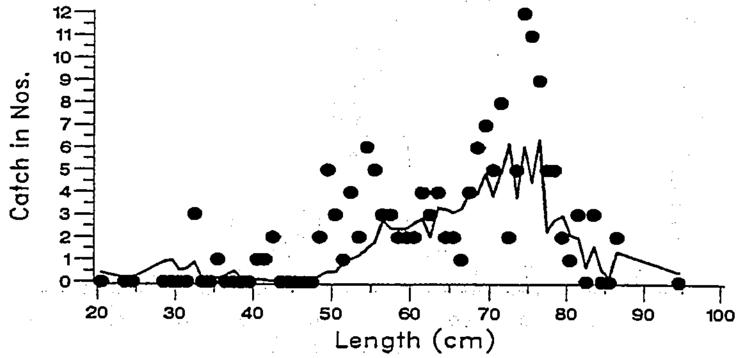
Estimated Catch and Stock

Model= ND+2C

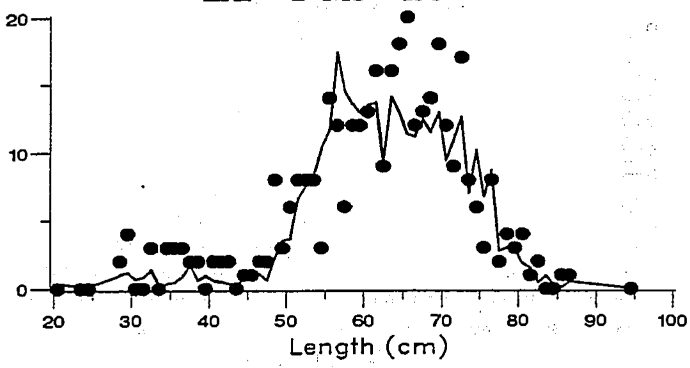
EXP= 2 MS= 92



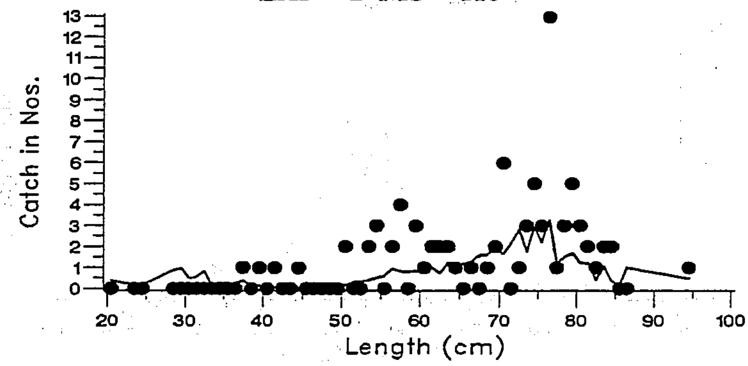
EXP= 2 MS= 129



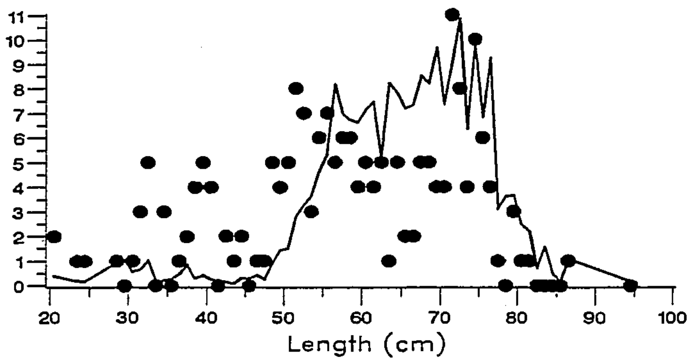
EXP= 2 MS= 106



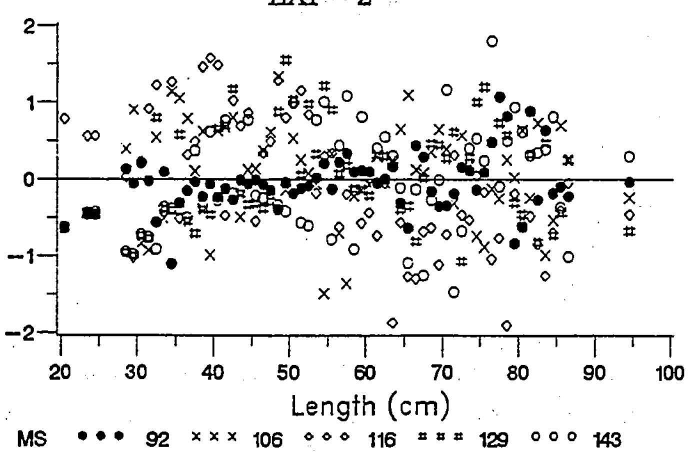
EXP= 2 MS= 143



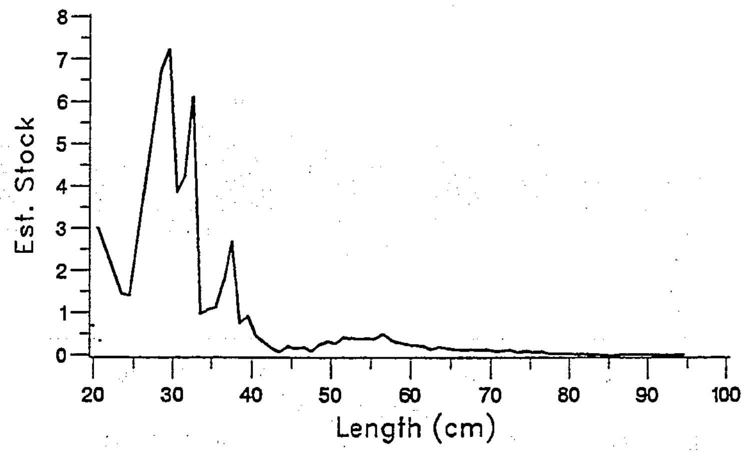
EXP= 2 MS= 116



EXP= 2



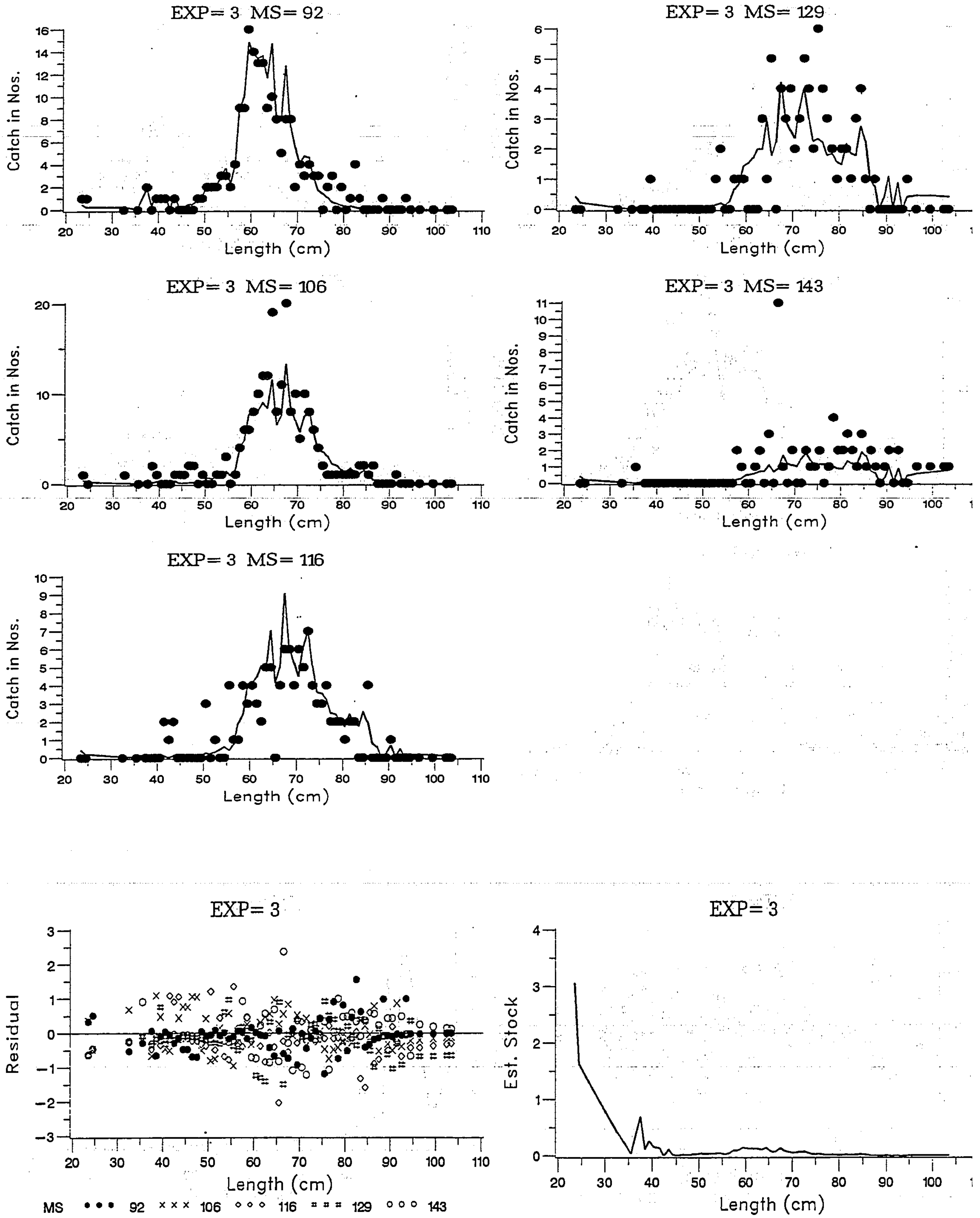
EXP= 2



Seafish Hake Experiment all

Estimated Catch and Stock

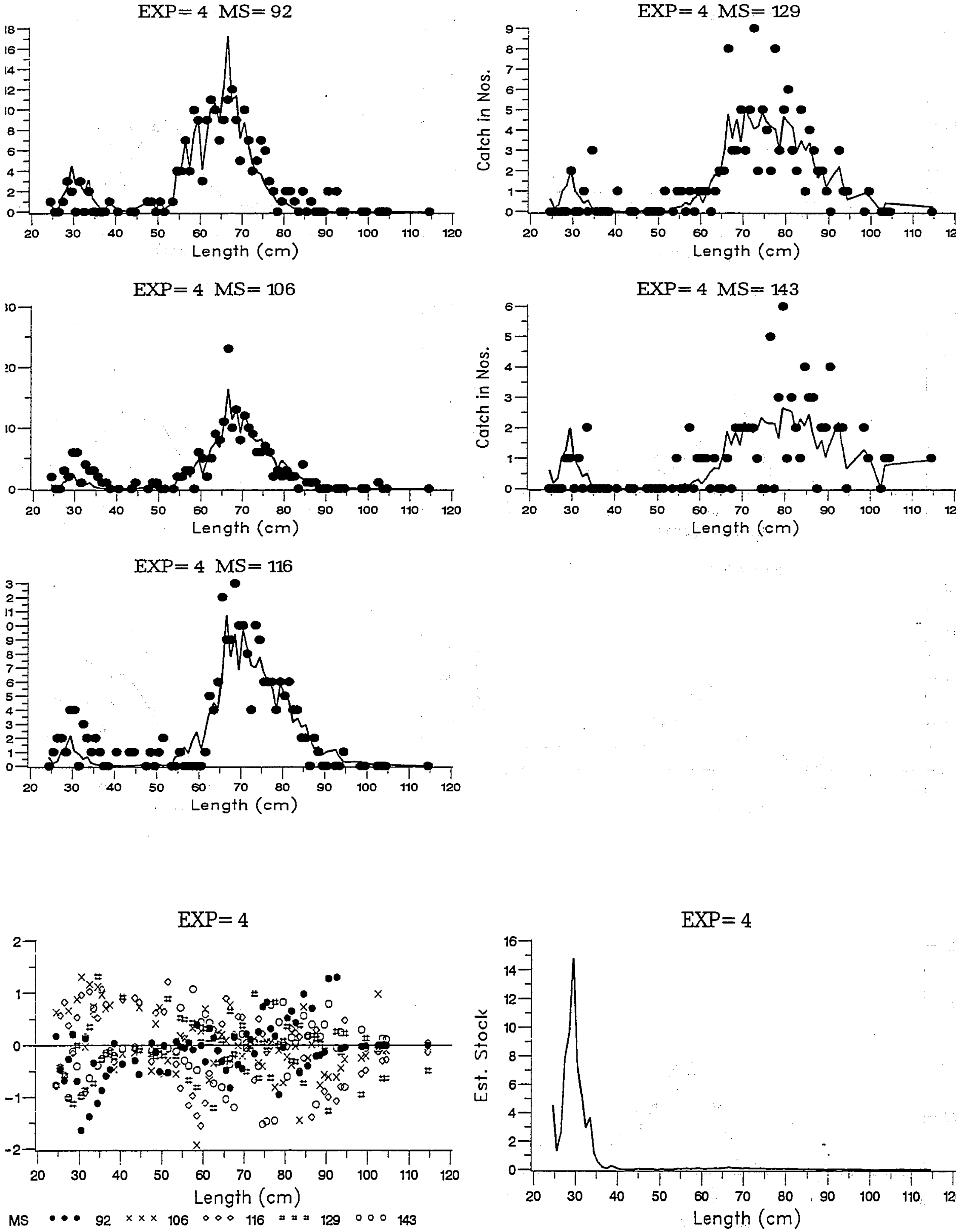
Model= ND+2C



Seafish Hake Experiment all

Estimated Catch and Stock

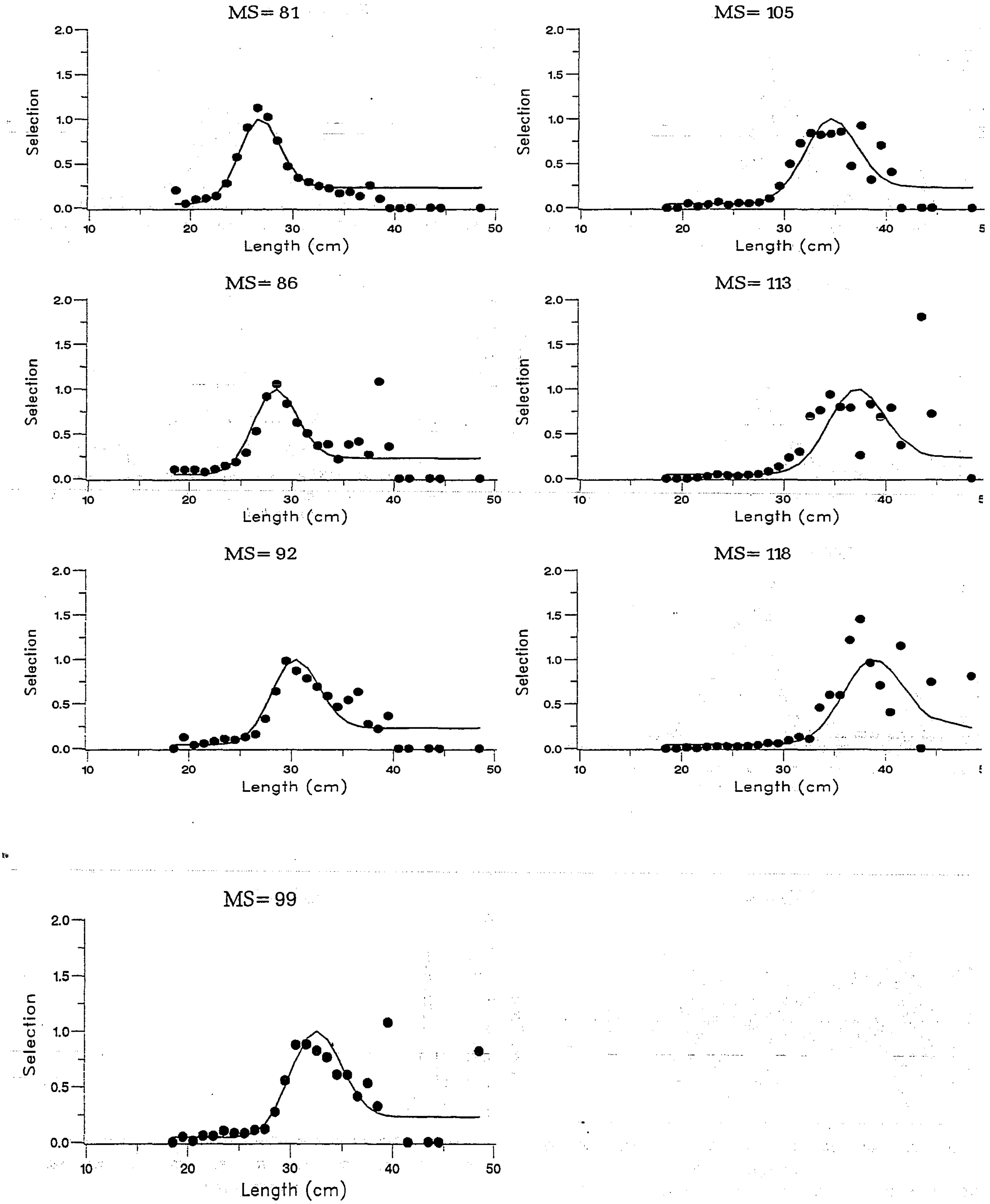
Model= ND+2C



Difta Sole Experiment: all

Estimated selection

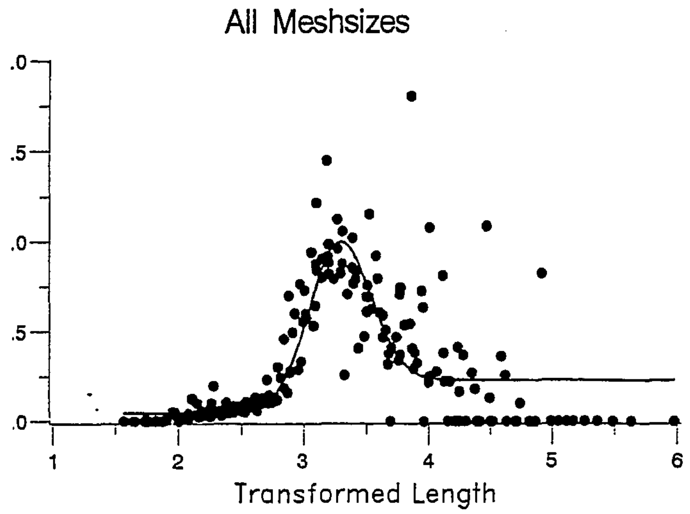
Model= ND+ 2C

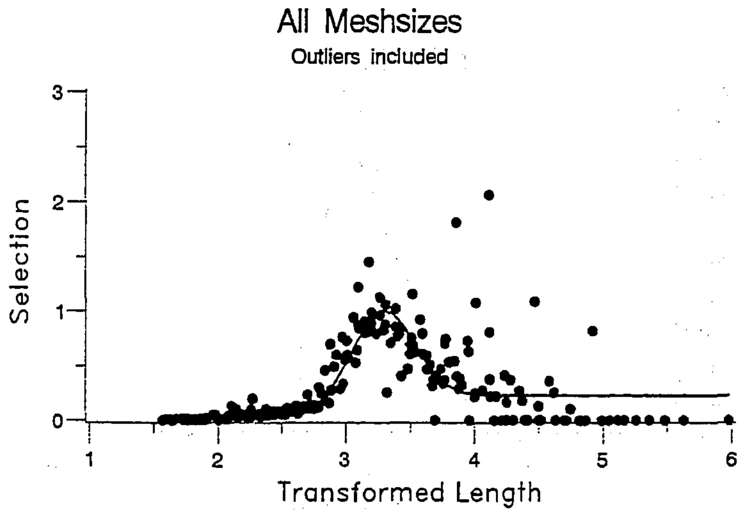


Difta Sole Experiment: all

Estimated selection

Model= ND+ 2C

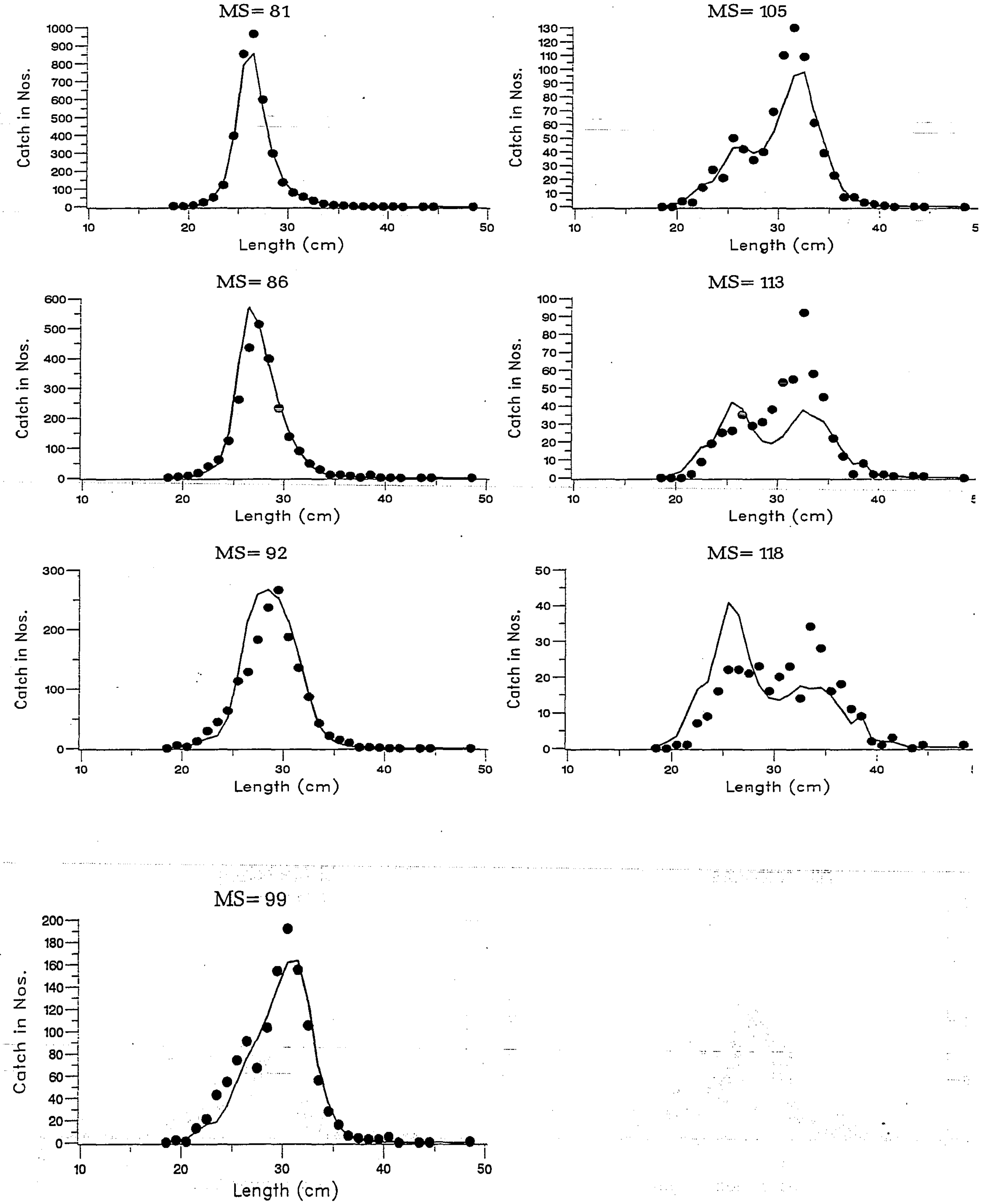




Difta Sole Experiment all

Estimated Catch and Stock

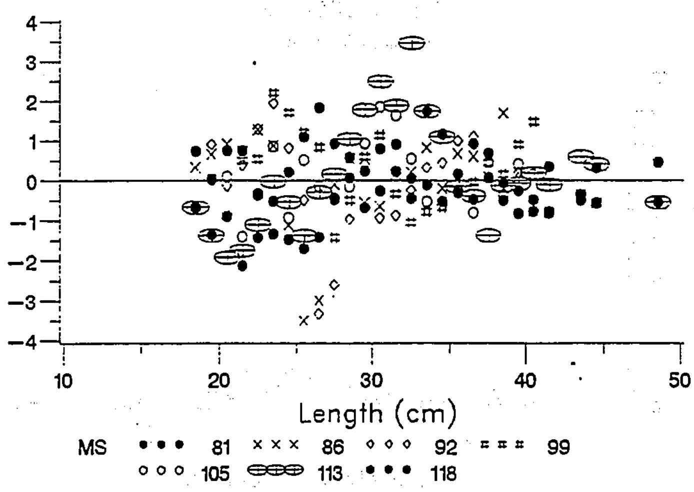
Model= ND+ 2C

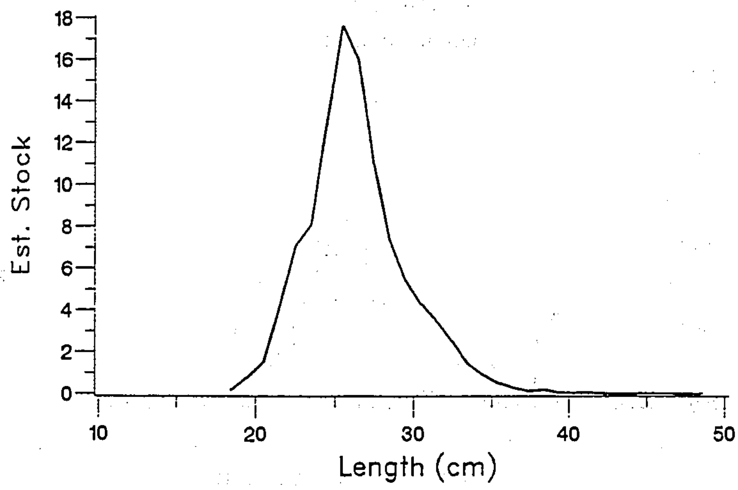


Difta Sole Experiment all

Estimated Catch and Stock

Model= ND+ 2C

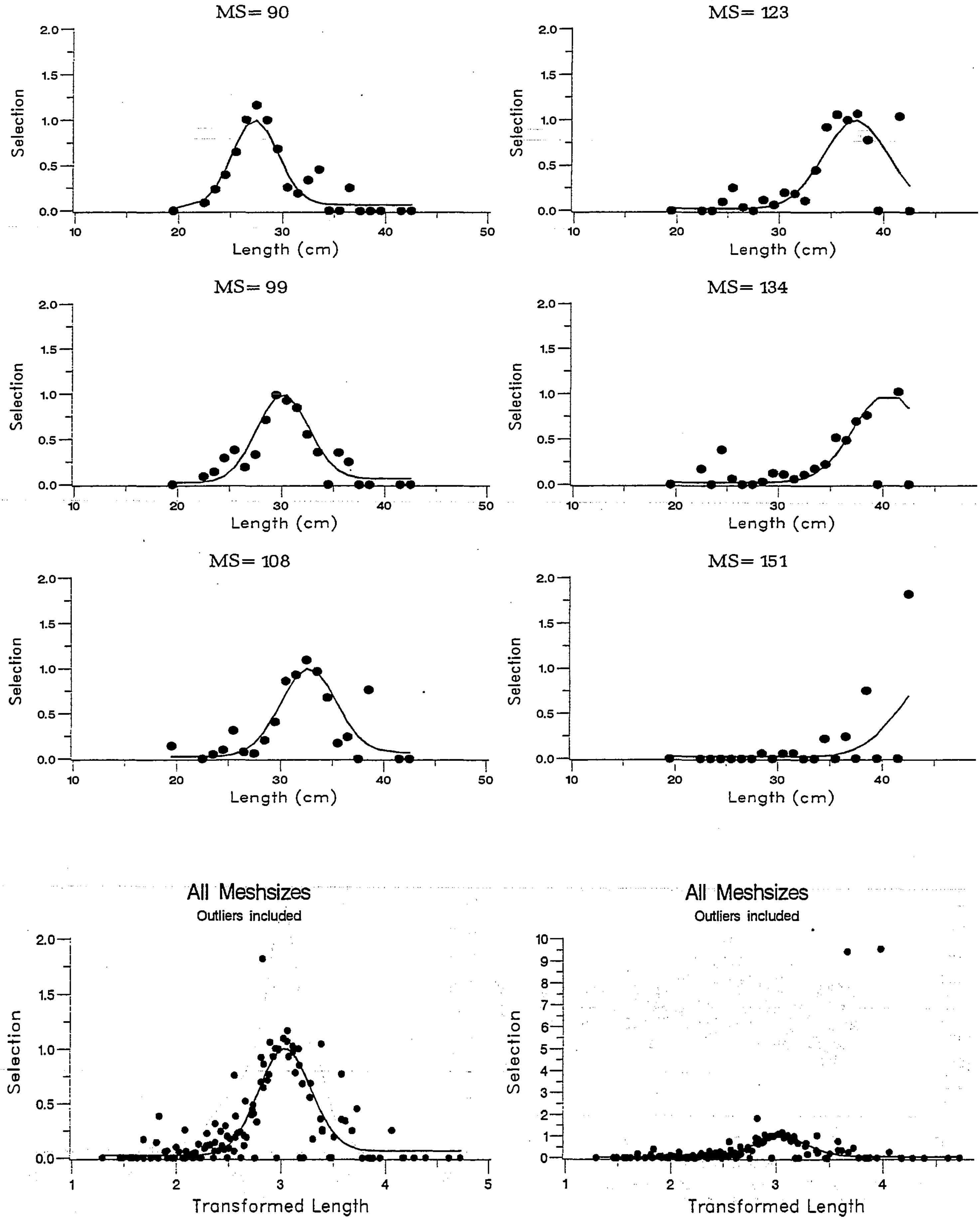




Difta Sole, Bycatch in Metier= Cod

Estimated Selection

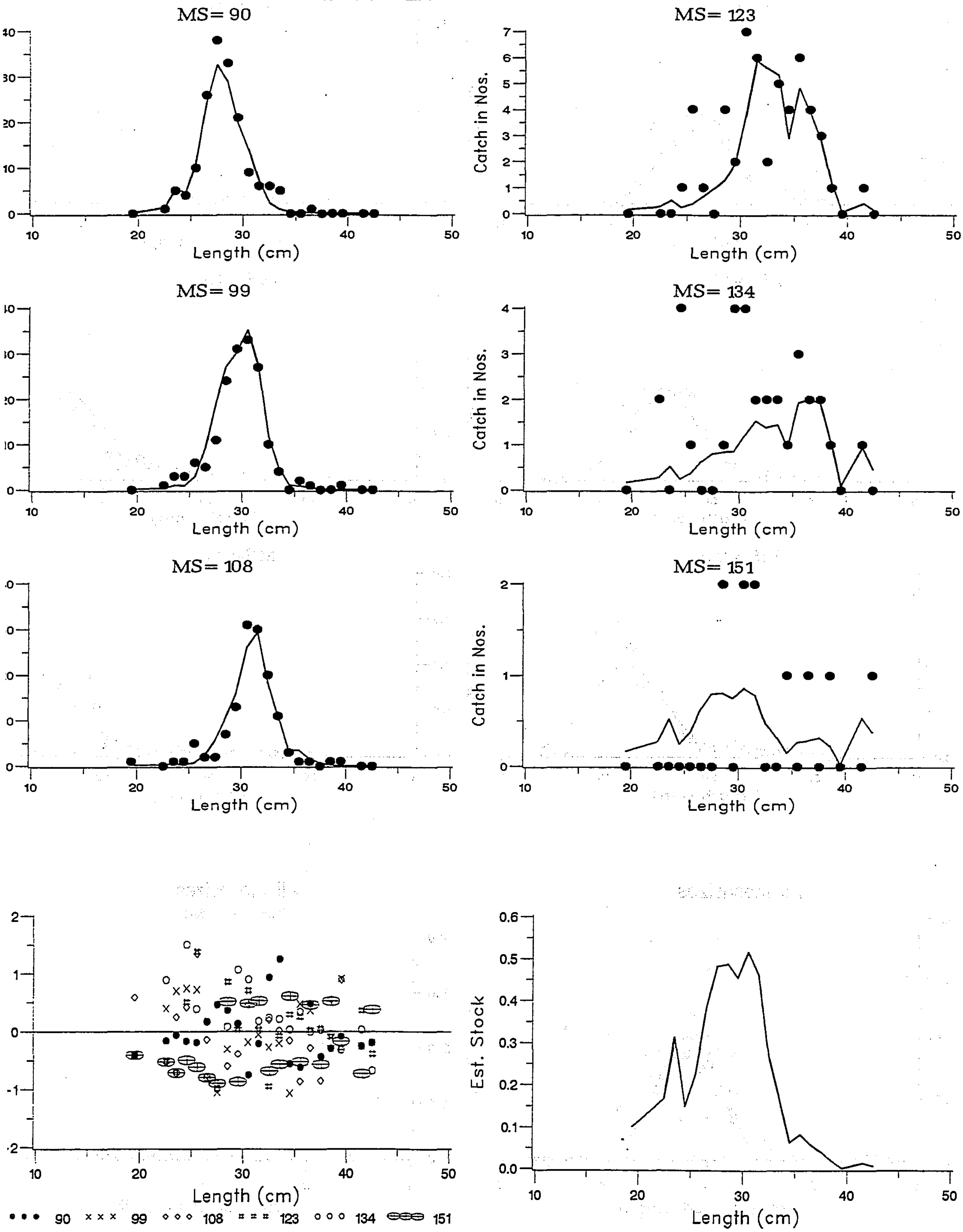
Model= 2ND+ 2C



Difta Sole, Bycatch in Metier= Cod

Estimated Catch and Stock

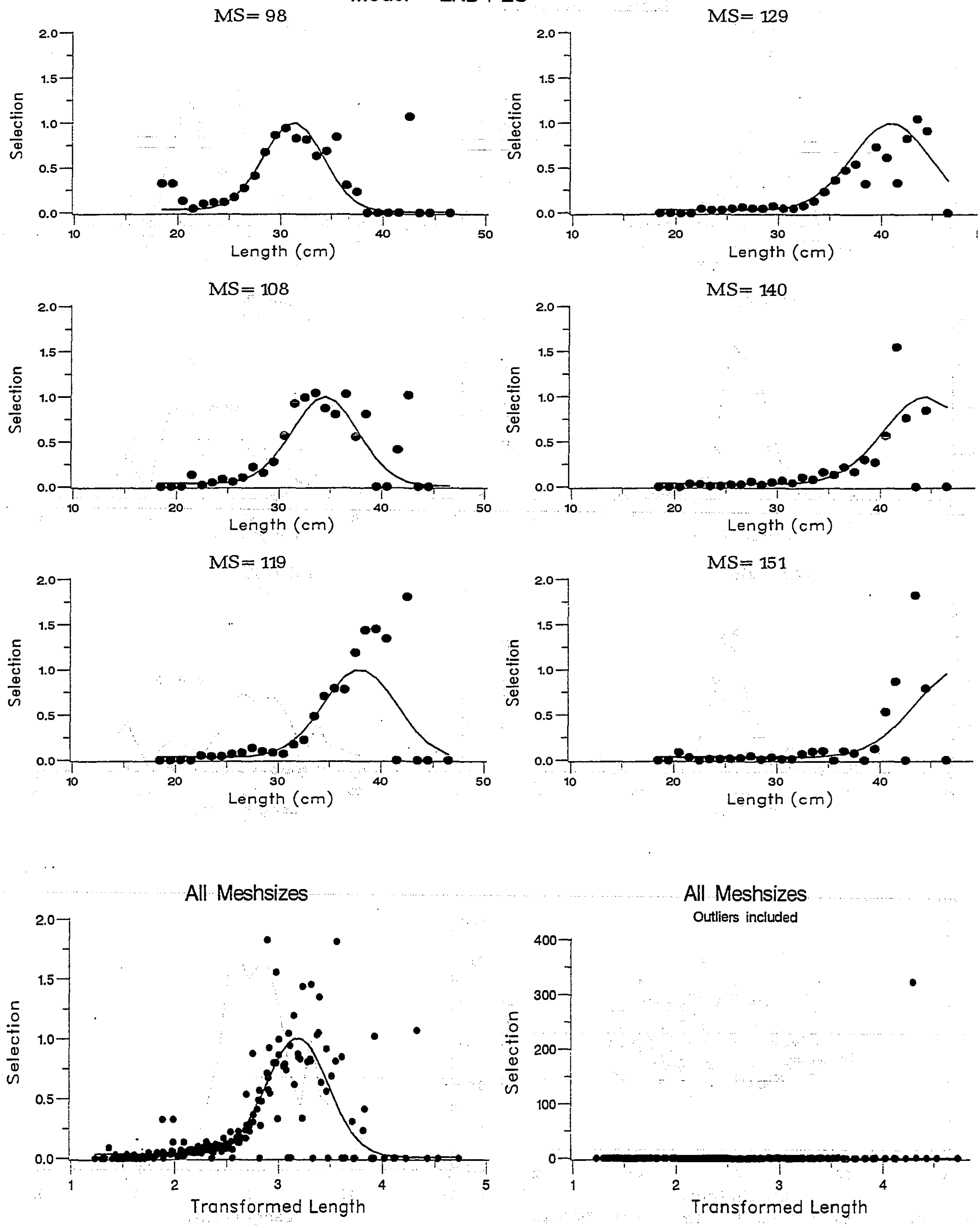
Model= 2ND+ 2C



Difta Sole, Bycatch in Metier = Plaice

Estimated Selection

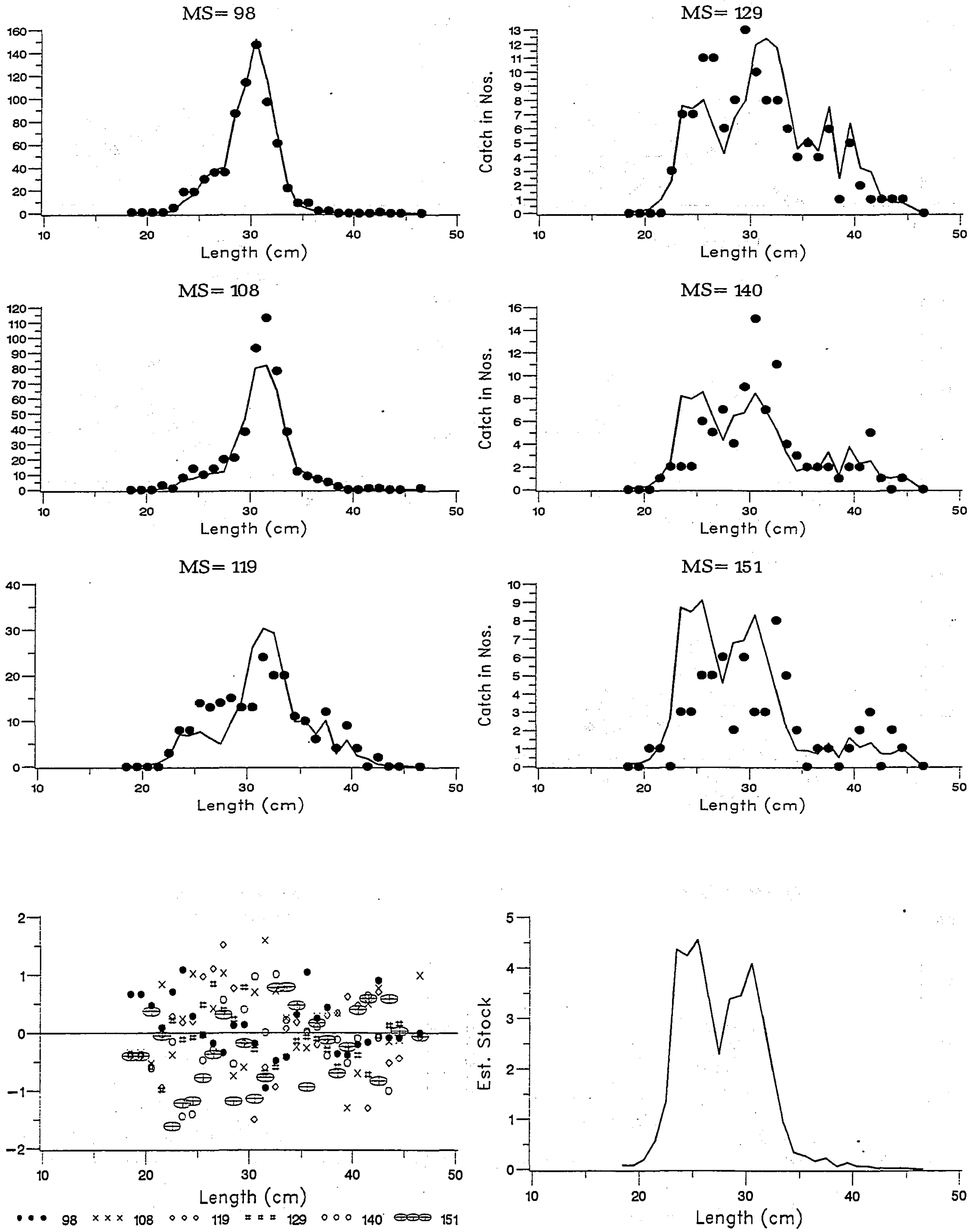
Model= 2ND+2C



Difta Sole, Bycatch in Metier = Plaice

Estimated Catch and Stock

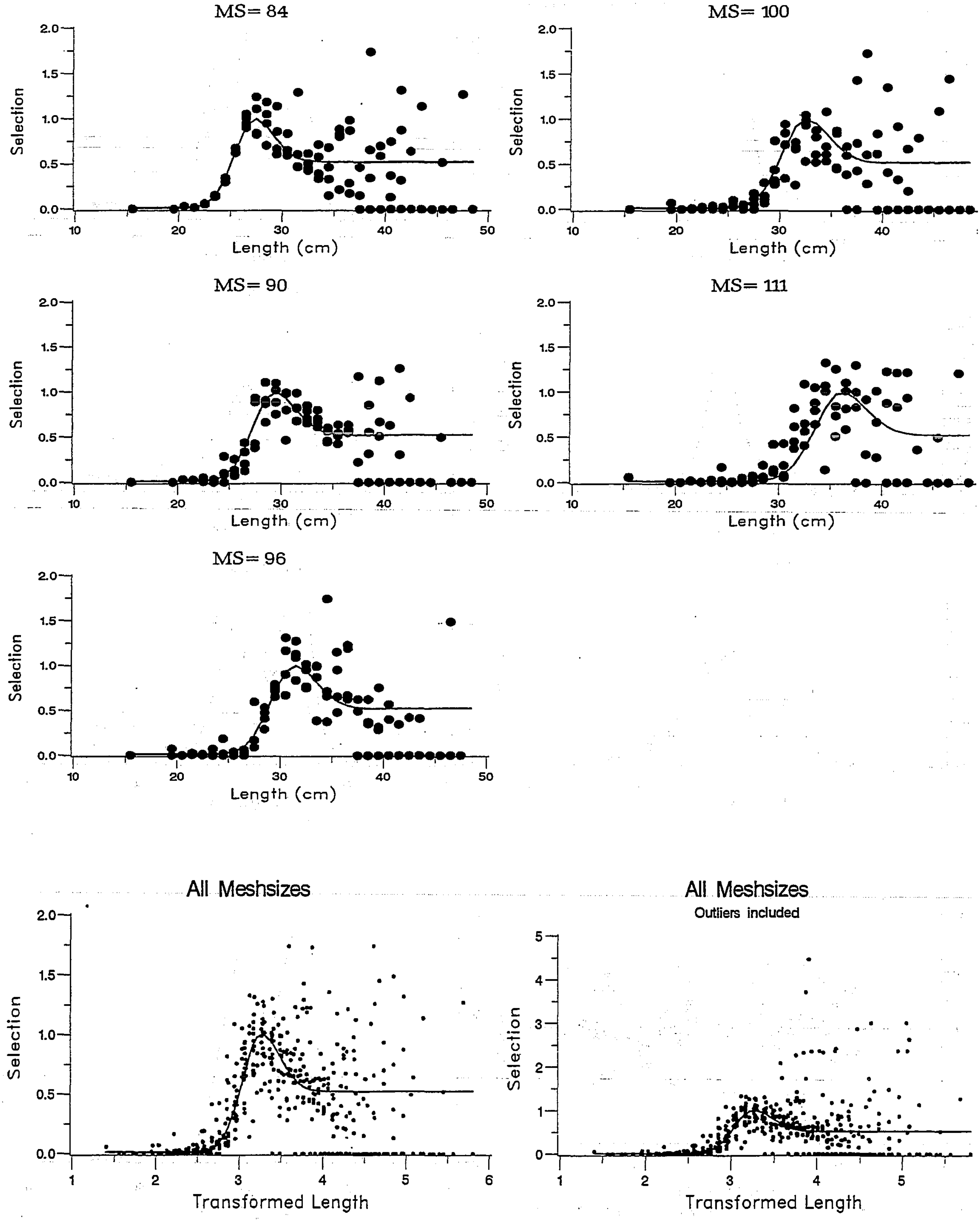
Model= 2ND+2C



IFRMER Sole–MF Experiment: all

Estimated selection

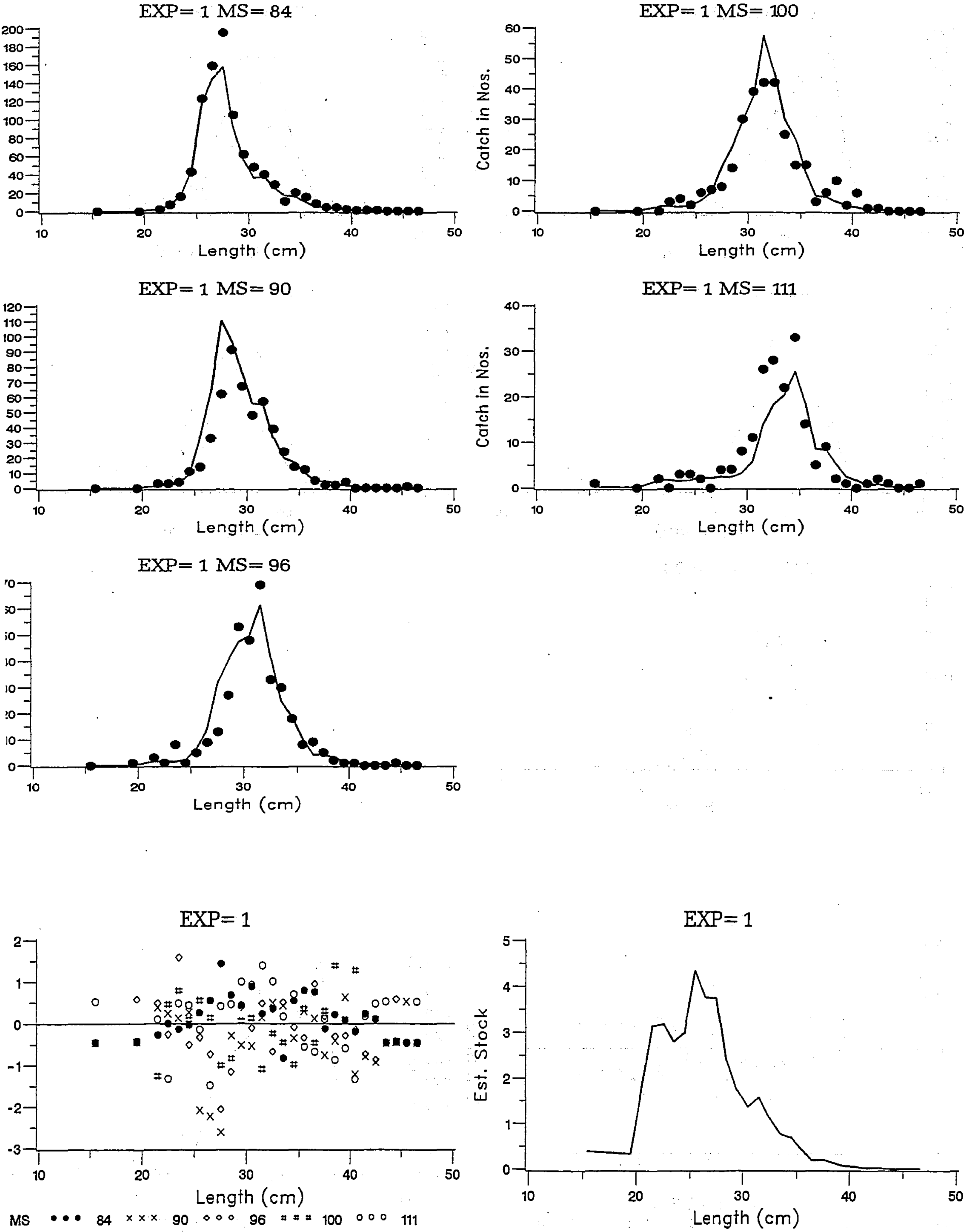
Model = ND+ 2C



IFRMER Sole–MF Experiment all

Estimated Catch and Stock

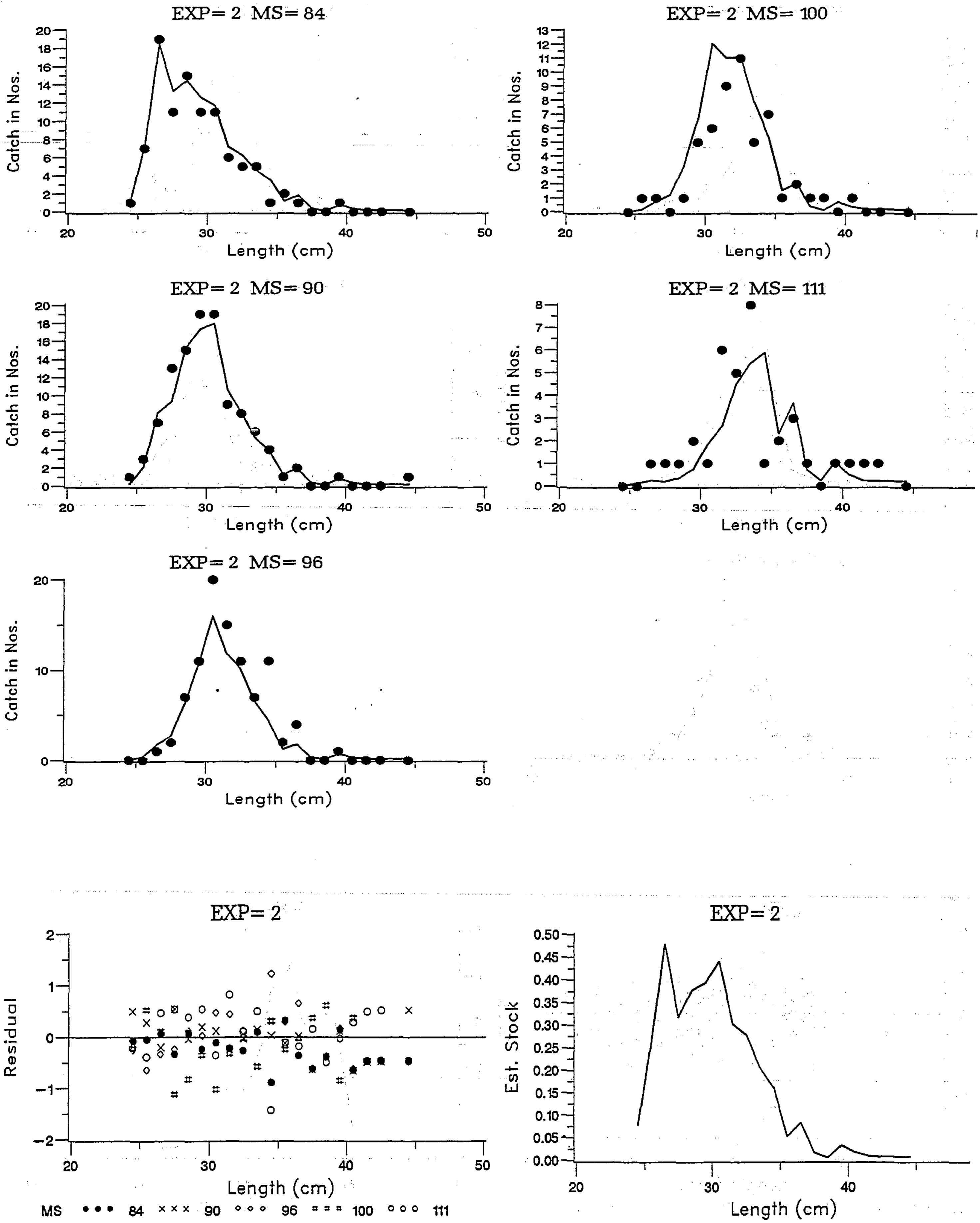
Model = ND+ 2C



IFRMER Sole–MF Experiment all

Estimated Catch and Stock

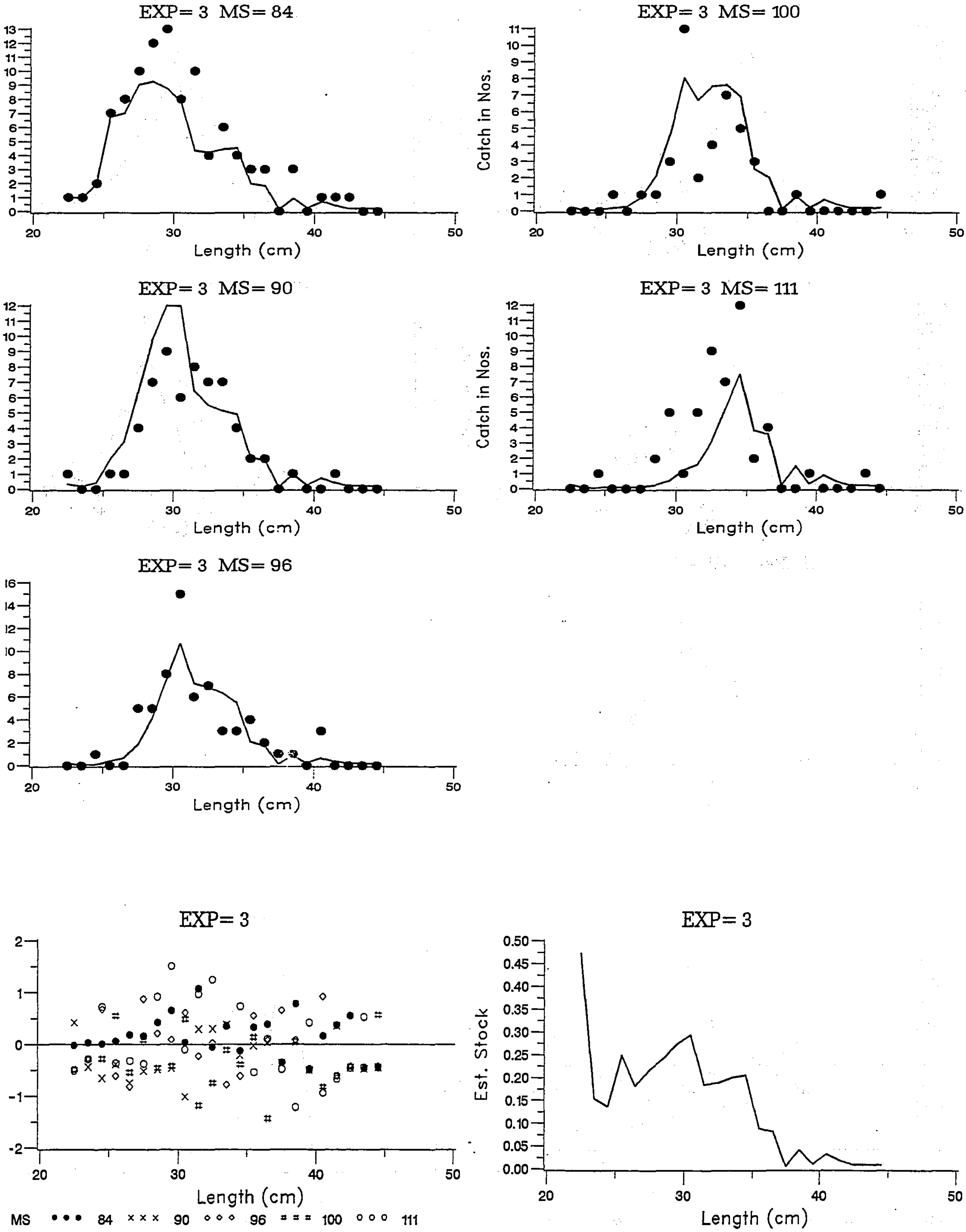
Model = ND+2C



IFRMER Sole–MF Experiment all

Estimated Catch and Stock

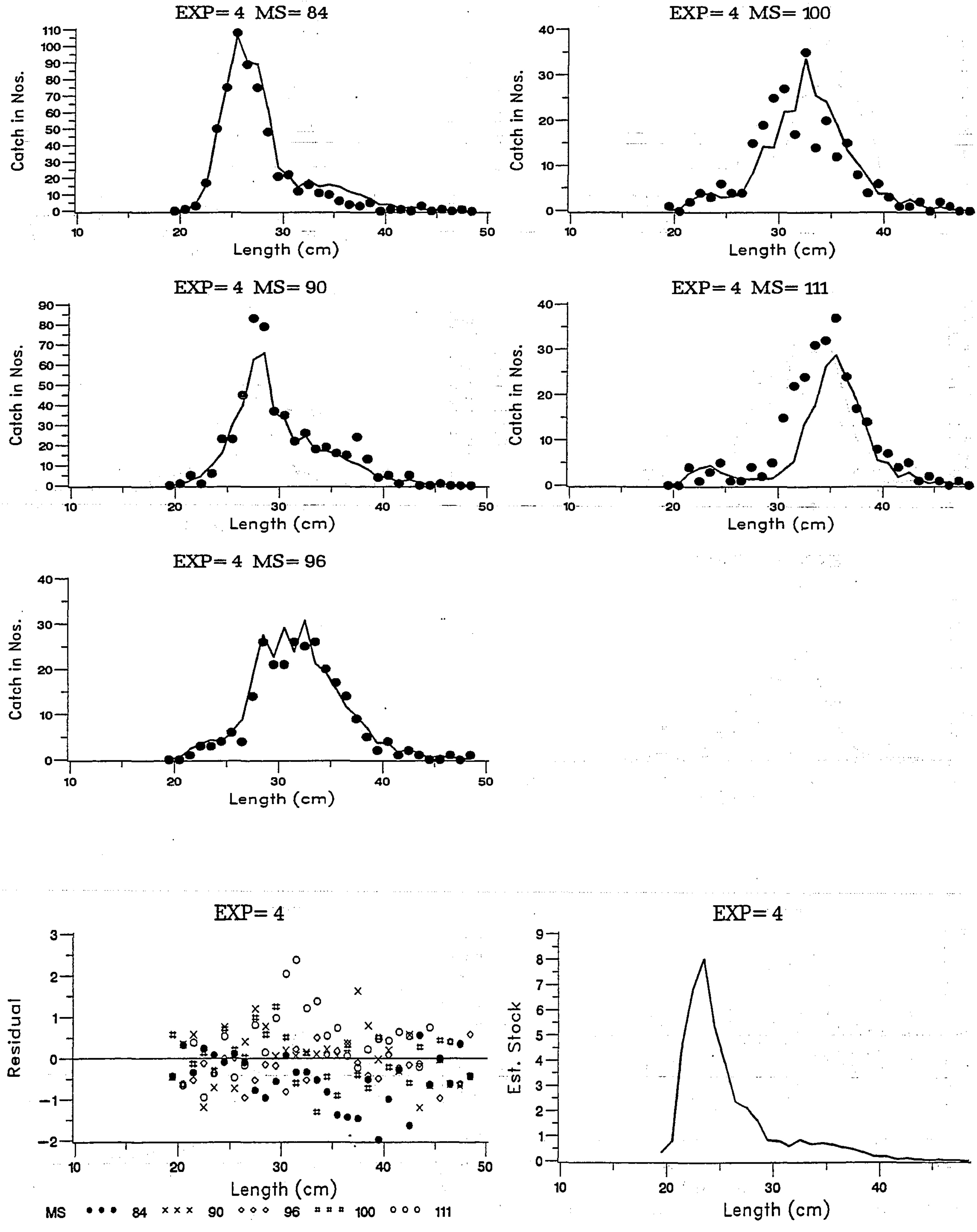
Model = ND+2C



IFRMER Sole–MF Experiment all

Estimated Catch and Stock

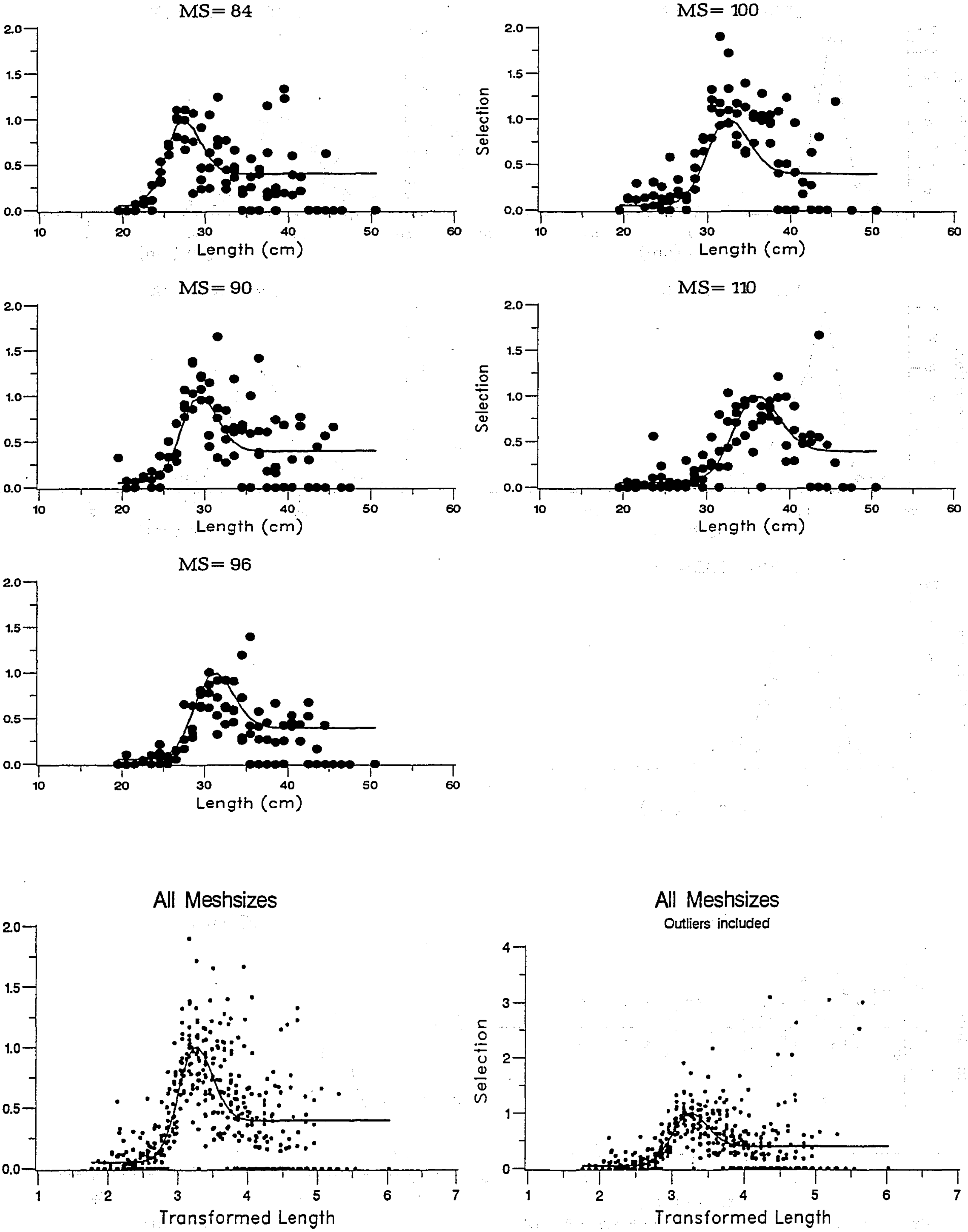
Model = ND+2C



IFRMER Sole–MM Experiment: all

Estimated selection

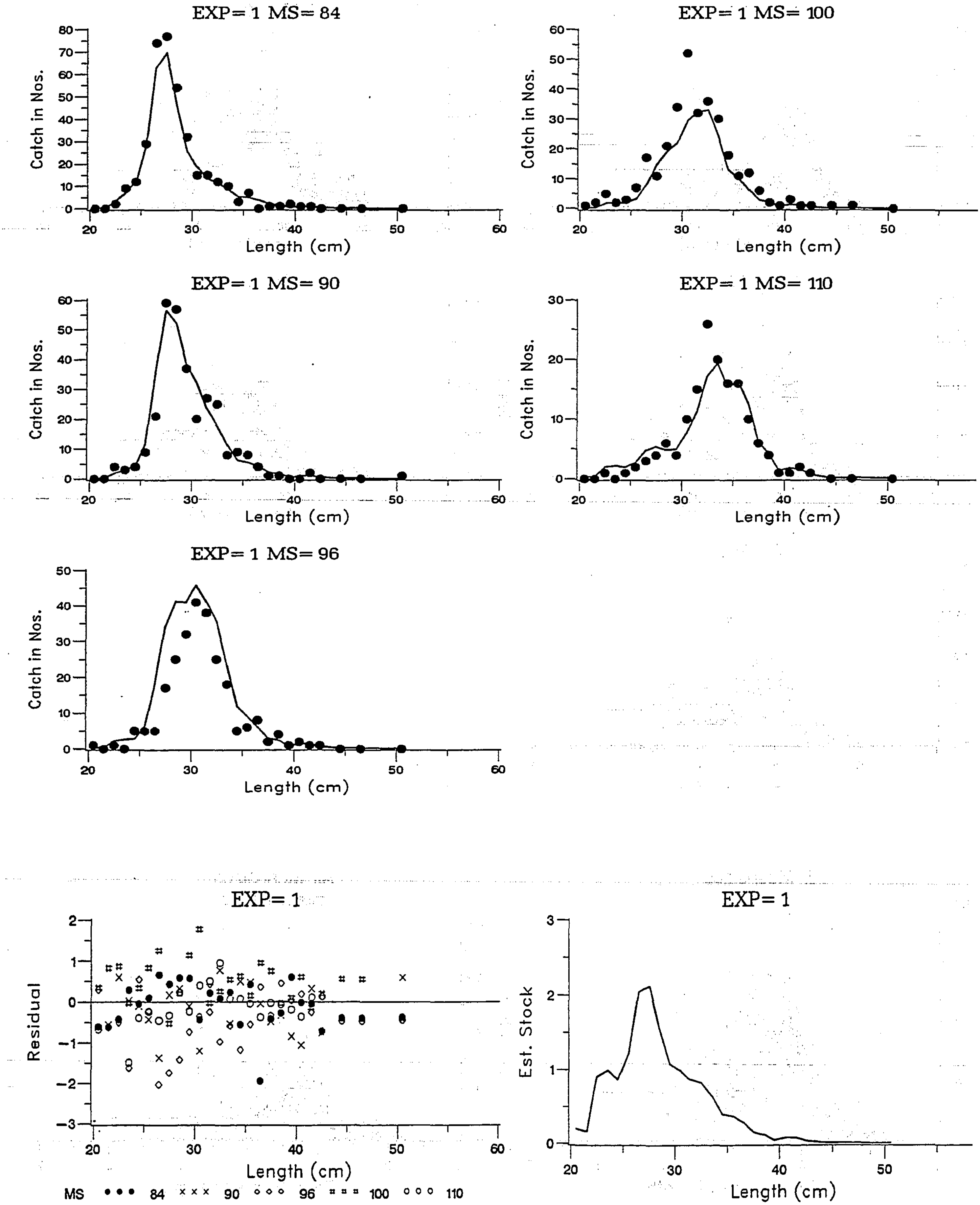
Model = ND+2C



IFRMER Sole—MM Experiment all

Estimated Catch and Stock

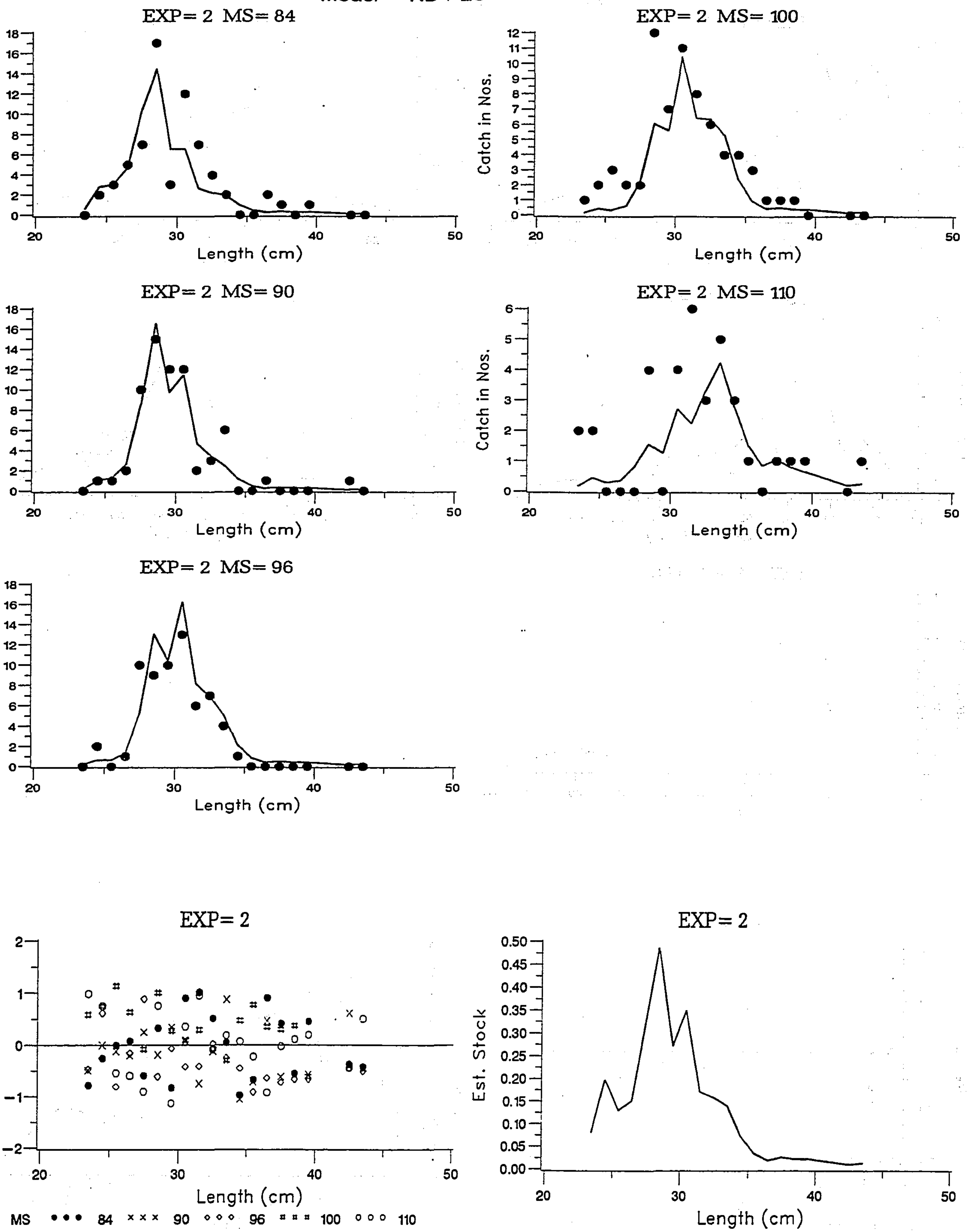
Model = ND+2C



IFRMER Sole—MM Experiment all

Estimated Catch and Stock

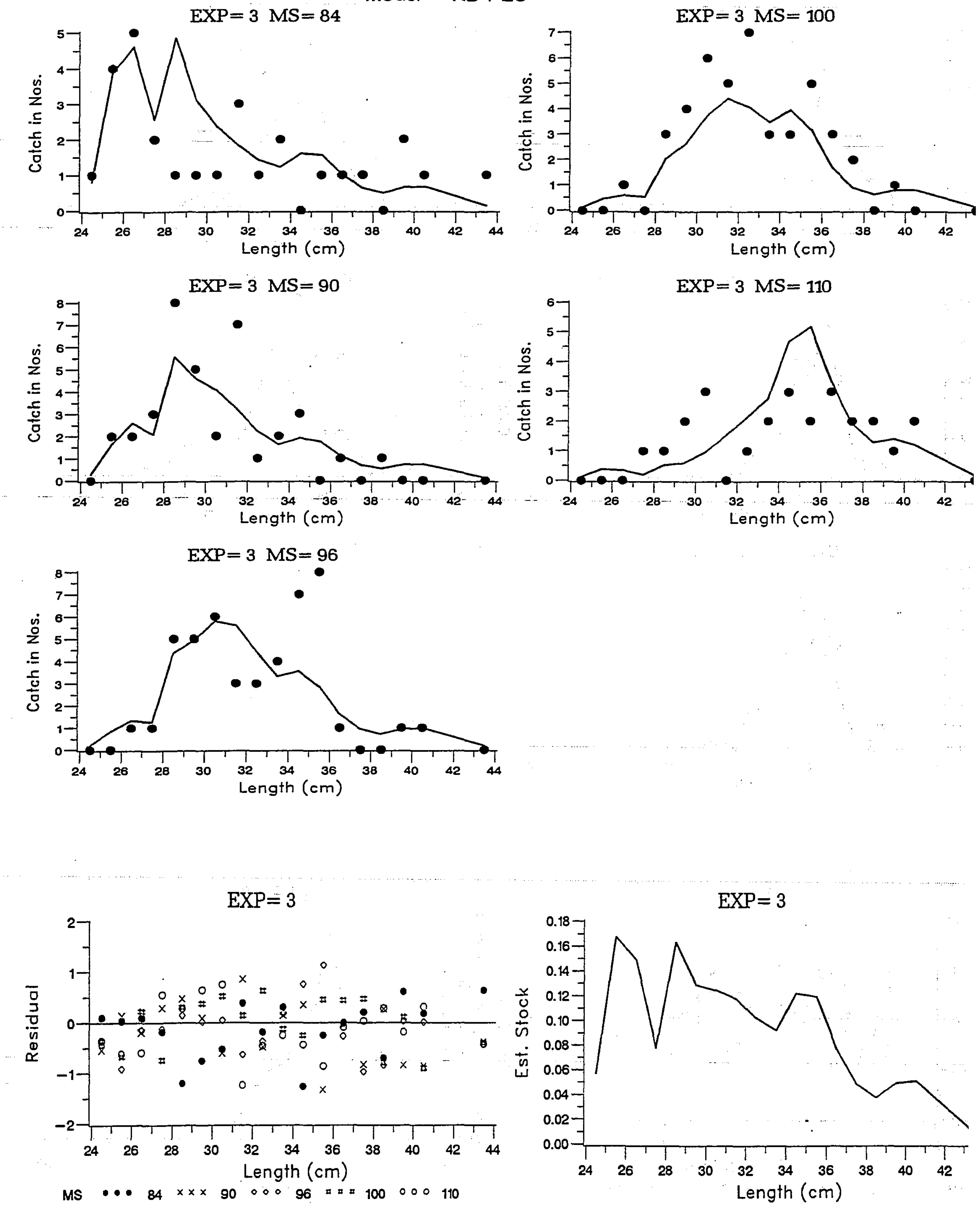
Model = ND+2C



IFRMER Sole–MM Experiment all

Estimated Catch and Stock

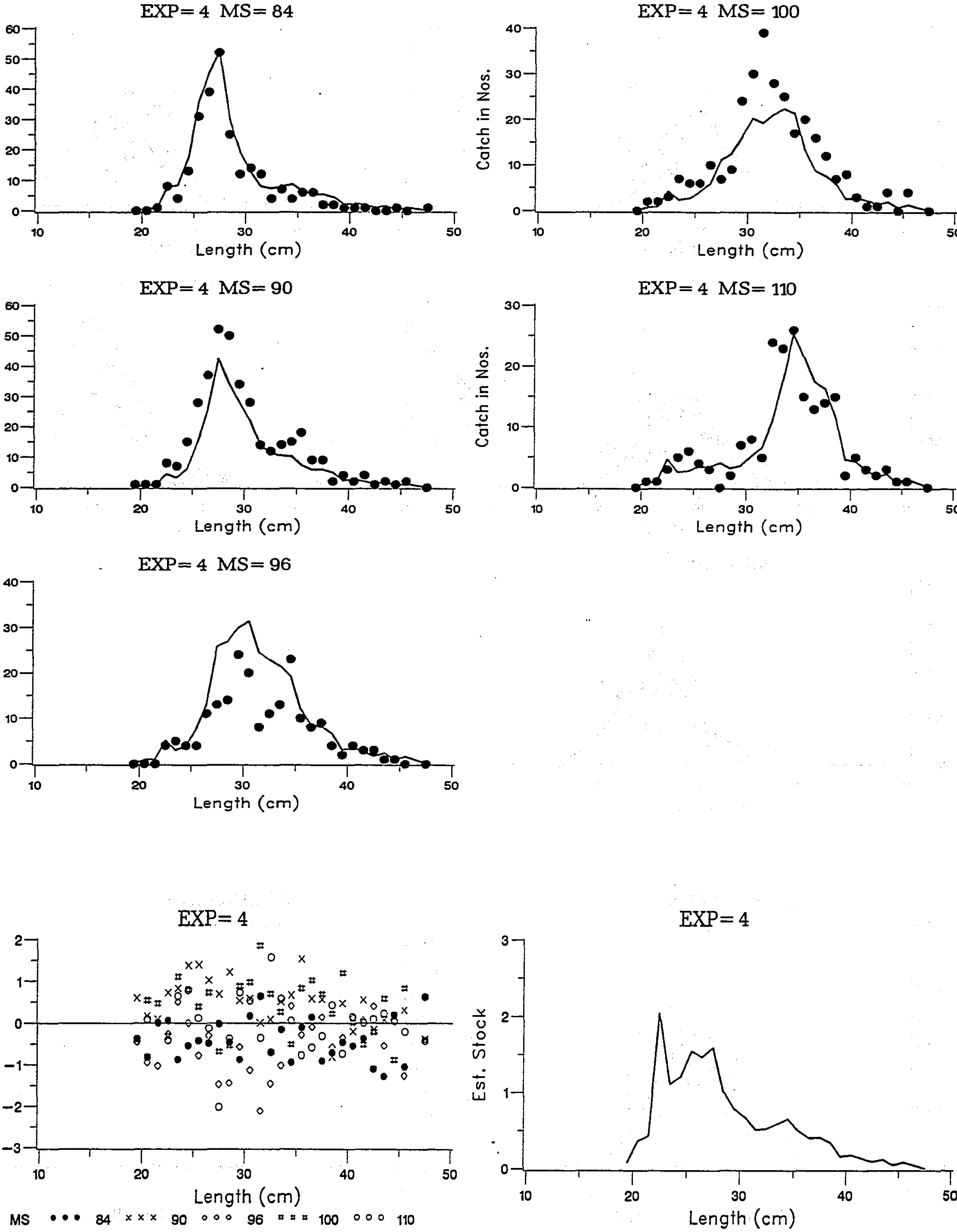
Model =ND+2C



IFRMER Sole—MM Experiment all

Estimated Catch and Stock

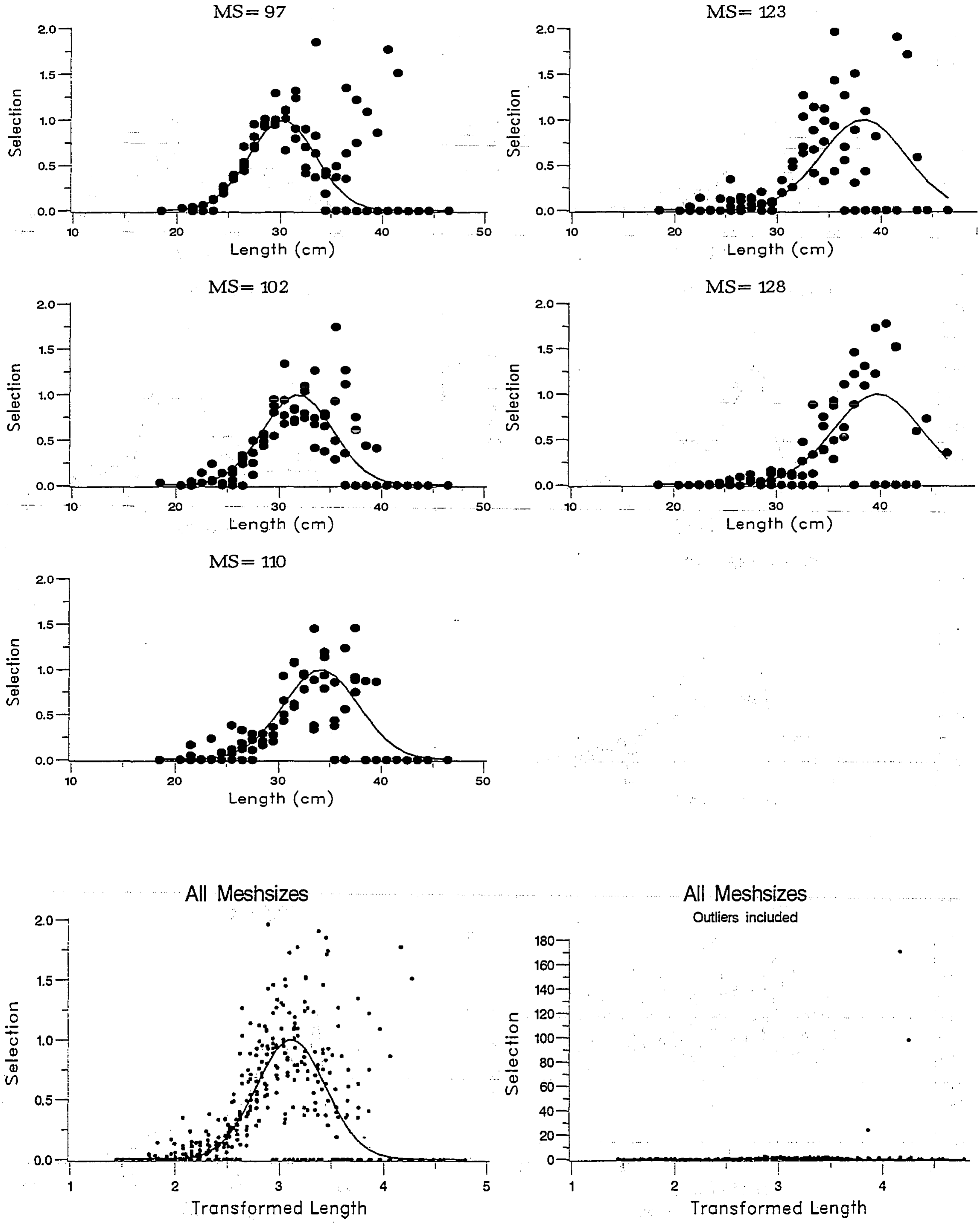
Model = ND+2C



Seafish Sole Experiment all

Estimated Selection

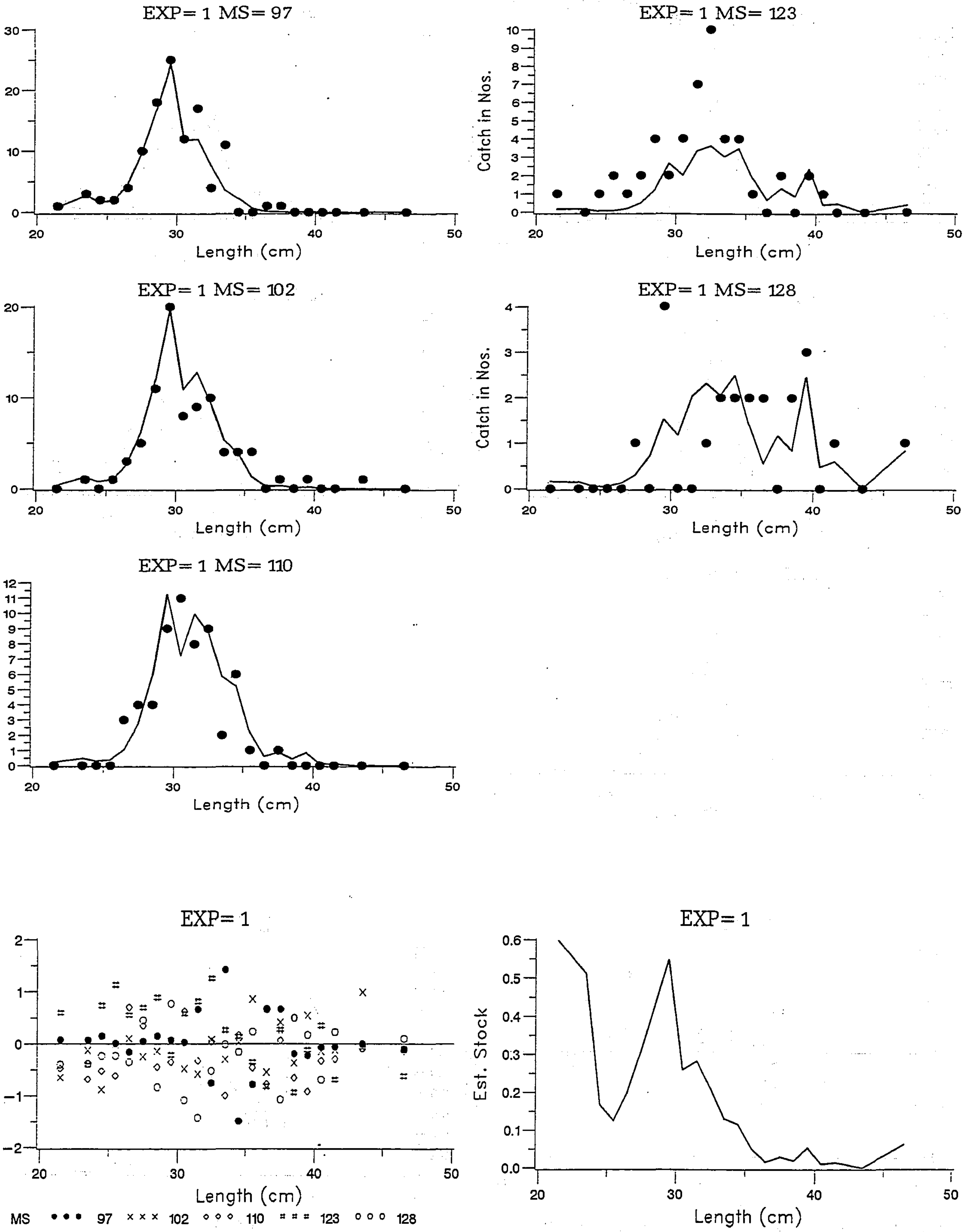
Model = ND+2C



Seafish Sole Experiment all

Estimated Catch and Stock

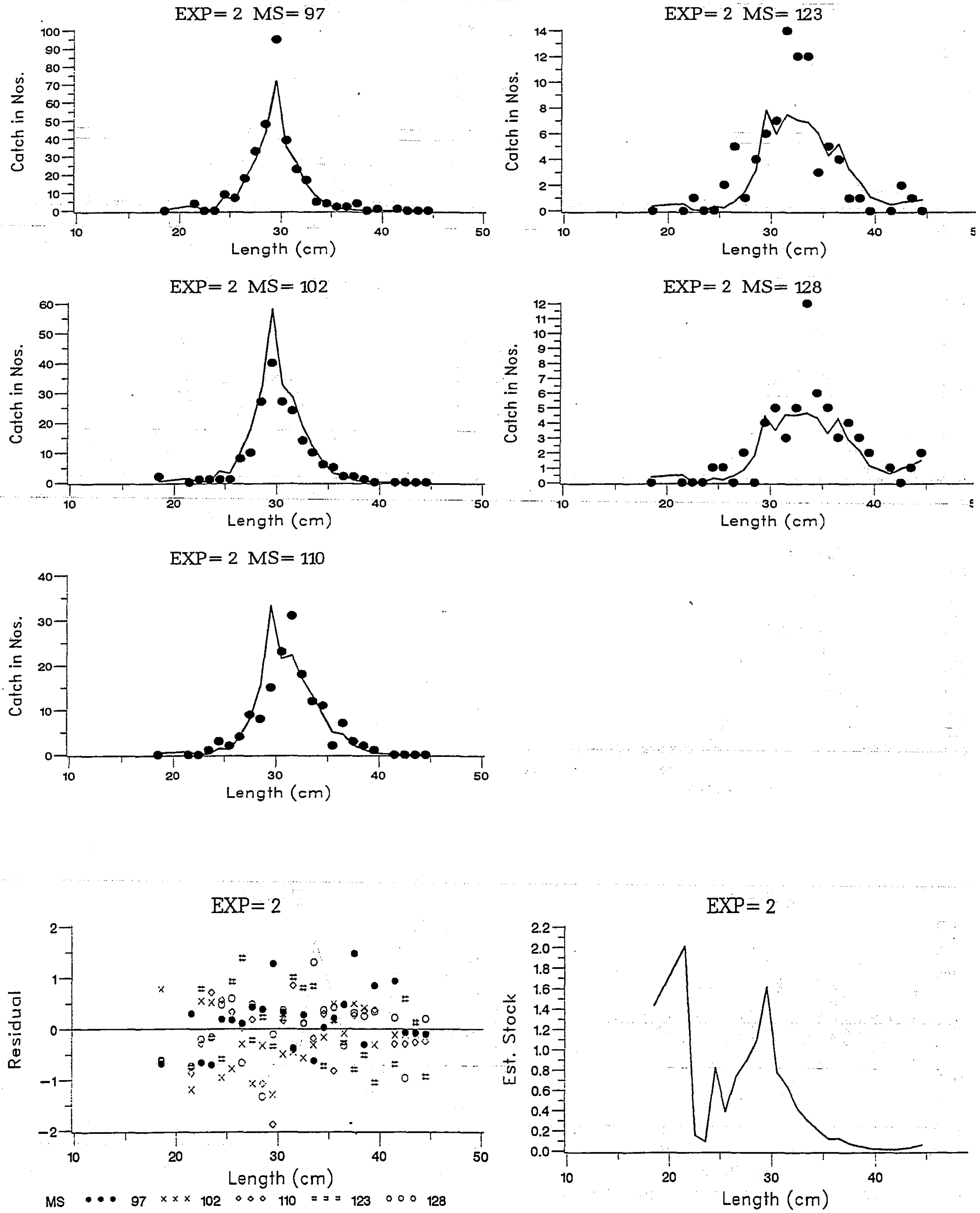
Model = ND+2C



Seafish Sole Experiment all

Estimated Catch and Stock

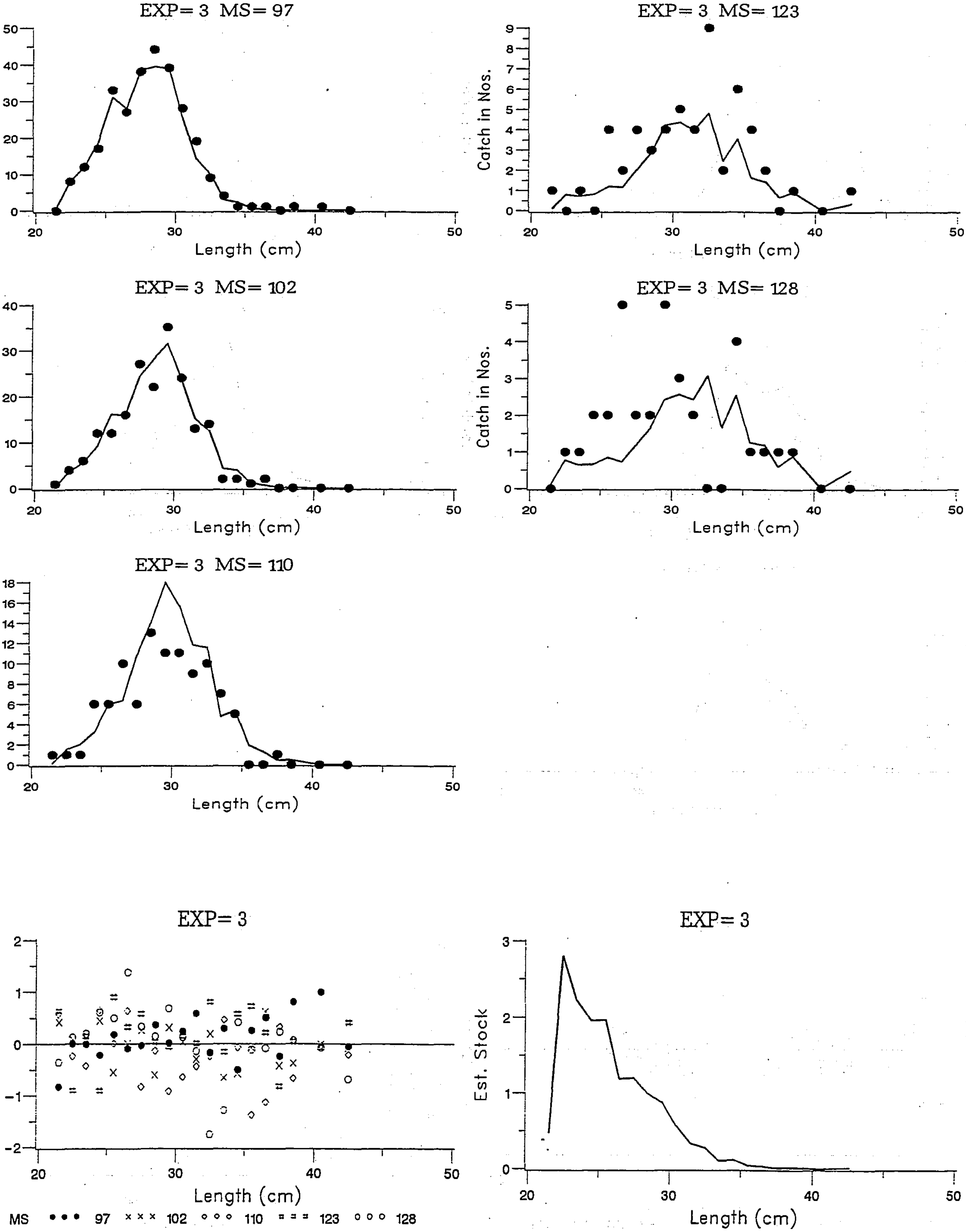
Model = ND+2C



Seafish Sole Experiment all

Estimated Catch and Stock

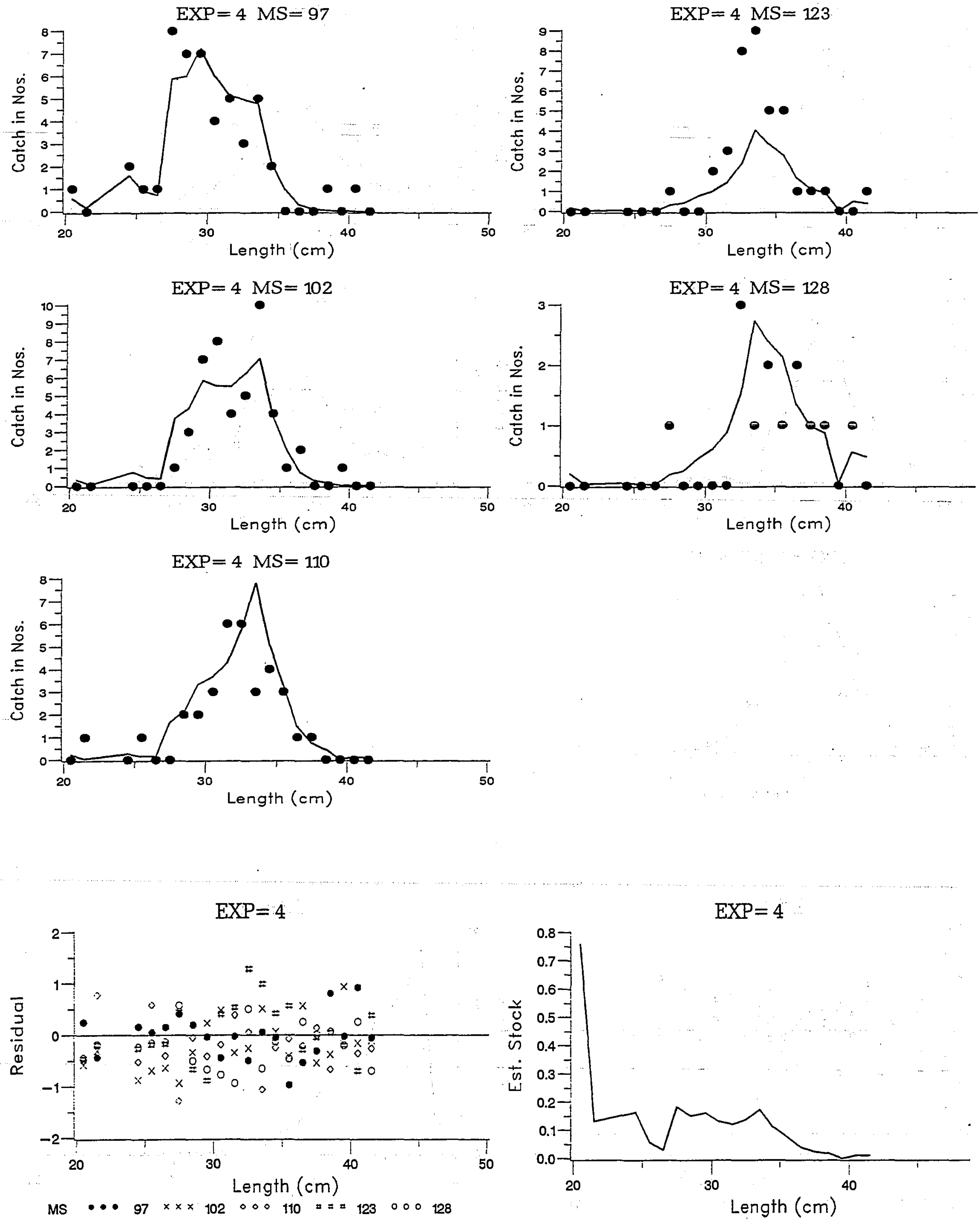
Model = ND+2C



Seafish Sole Experiment all

Estimated Catch and Stock

Model = ND+2C



Appendix C

Analysis of the relation between length and girth/width.

Analysis are provided for isometrical and allometrical growth. On the graphs the fit of the Allometrical growth model is indicated by full lines whereas the fit of the isometrical growth model is indicated by the broken line.

Appendix C

DIFTA Cod. Isometric growth model.

Final ANOVA Model log(Girth/length)= Intercept + Mesure

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	3	gill max maxil
EXP	2	1 2

Number of observations in data set = 1560

General Linear Models Procedure

Dependent Variable: LOGA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	60.92422424	30.46211212	6226.91	0.0001
Error	1557	7.61686227	0.00489201		
Corrected Total	1559	68.54108650			

R-Square	C.V.	Root MSE	LOGA Mean
0.888872	-7.888539	0.0699429	-0.8866397

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MEASURE	2	60.92422424	30.46211212	6226.91	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEASURE	2	60.92422424	30.46211212	6226.91	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.165646750 B	-380.04	0.0001	0.00306720
MEASURE	gill	0.404464153 B	93.24	0.0001	0.00433768
	max	0.432556882 B	99.72	0.0001	0.00433768
	maxil	0.000000000 B	.	.	.

Appendix C

DIFTA Cod. Allometric growth model.

Final reggression Model: Log (Girth)= Int. + Measure +b* log (lgd)

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	3	gill max maxil
EXP	2	1 2

Number of observations in data set = 1560

General Linear Models Procedure

Dependent Variable: LOGGIRTH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	116.79962266	38.93320755	8527.60	0.0001
Error	1556	7.10400325	0.00456555		
Corrected Total	1559	123.90362591			

R-Square	C.V.	Root MSE	LOGGIRTH Mean
0.942665	2.338351	0.0675689	2.8895957

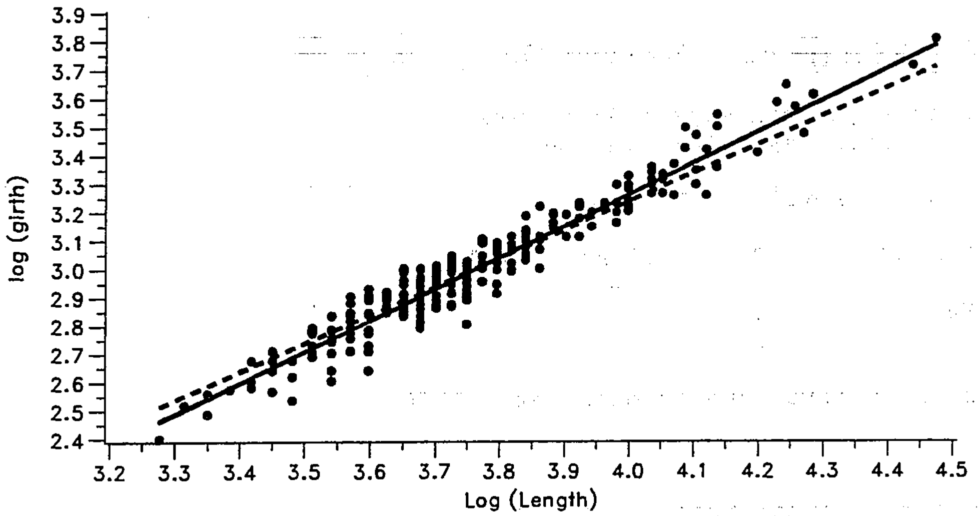
Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLGD	1	55.87539843	55.87539843	12238.47	0.0001
MEASURE	2	60.92422424	30.46211212	6672.16	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLGD	1	55.87539843	55.87539843	12238.47	0.0001
MEASURE	2	60.92422424	30.46211212	6672.16	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.565762548 B	-41.35	0.0001	0.03786754
LOGLGD		1.105956263	110.63	0.0001	0.00999711
MEASURE	gill	0.404464153 B	96.52	0.0001	0.00419044
	max	0.432556882 B	103.22	0.0001	0.00419044
	maxil	0.000000000 B	.	.	.

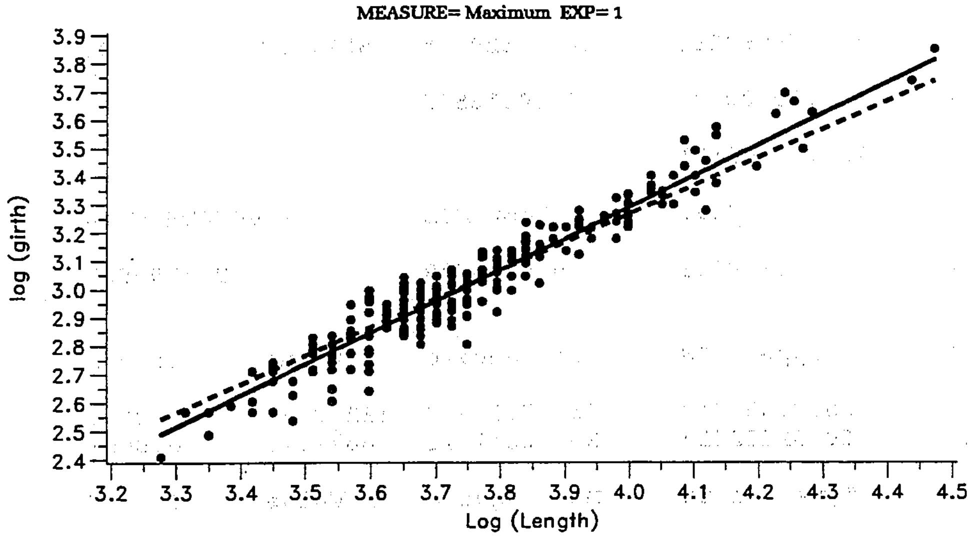
Girth length relation for DIFTA Cod

MEASURE= Gill EXP= 1



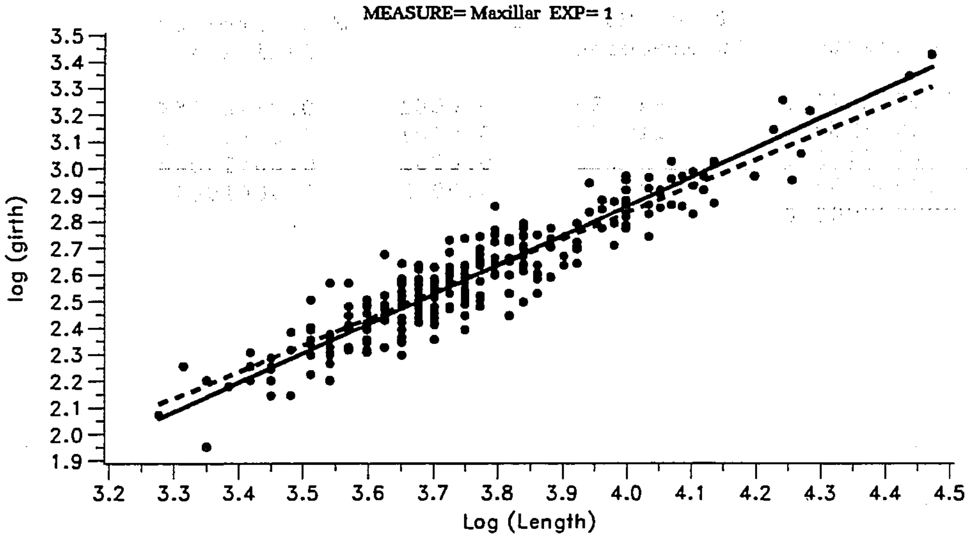
Girth length relation for DIFTA Cod

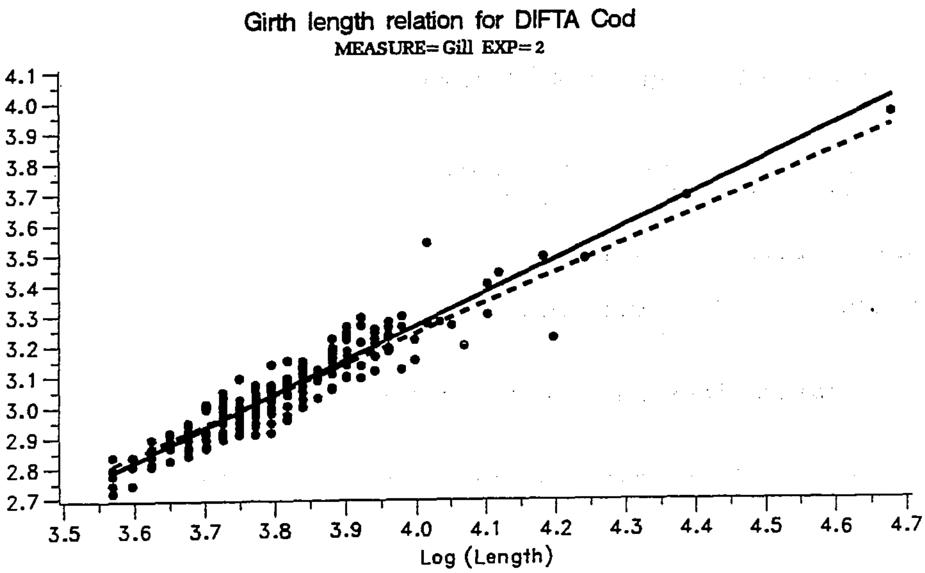
MEASURE= Maximum EXP= 1

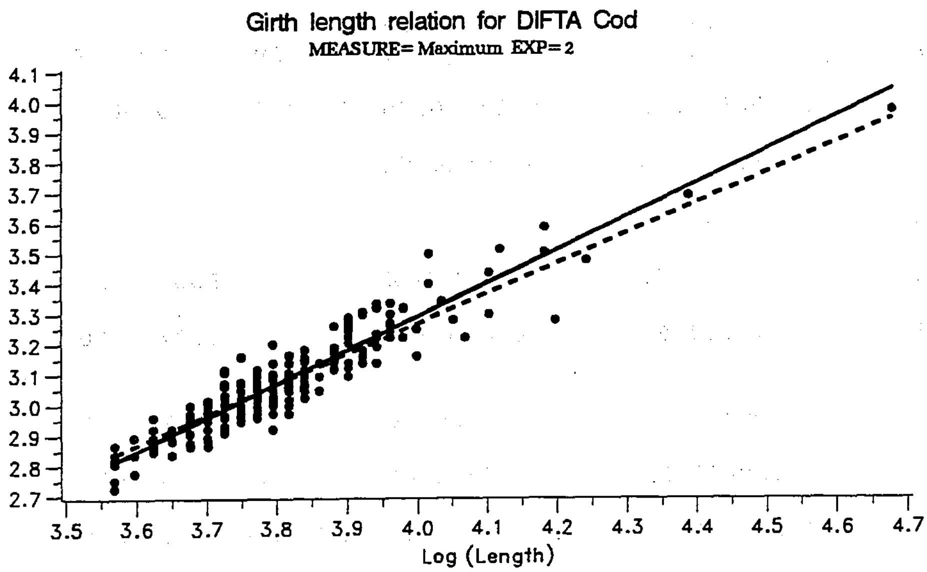


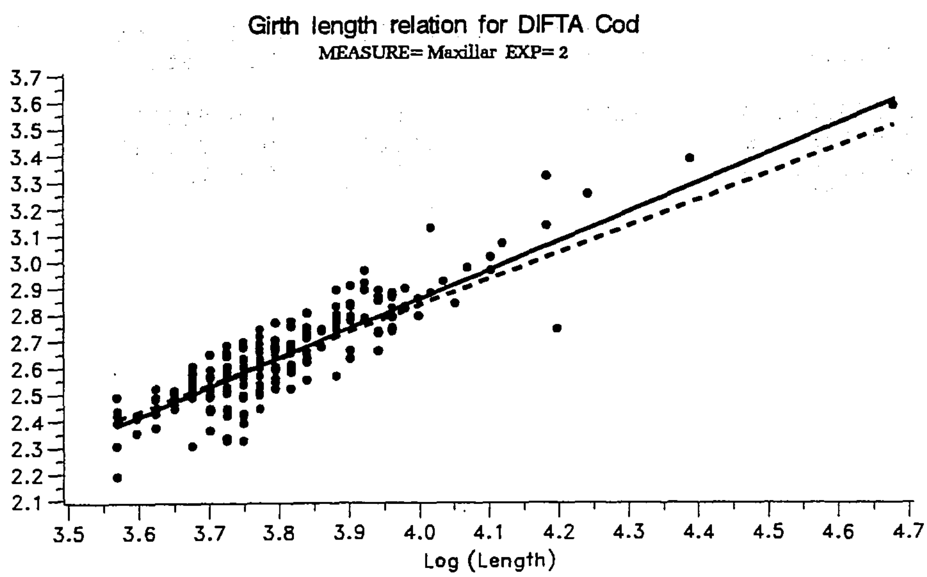
Girth length relation for DIFTA Cod

MEASURE= Maxillar EXP= 1




Girth length relation for DIFTA Cod
MEASURE= Gill EXP= 2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
3.5 3.6 3.7 3.8 3.9 4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7
Log (Length)


Girth length relation for DIFTA Cod
MEASURE= Maximum EXP= 2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
3.5 3.6 3.7 3.8 3.9 4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7
Log (Length)


Girth length relation for DIFTA Cod
MEASURE= Maxillar EXP= 2
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
3.5 3.6 3.7 3.8 3.9 4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7
Log (Length)

Appendix C

SEAFISH Cod. Isometric growth model

Final ANOVA Model log(Girth/length)= Intercept + Mesure

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	3	gill max maxil

Number of observations in data set = 498

NOTE: Due to missing values, only 497 observations can be used in this analysis.

General Linear Models Procedure

Dependent Variable: LOGA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	18.50653612	9.25326806	2102.73	0.0001
Error	494	2.17389989	0.00440061		
Corrected Total	496	20.68043601			

R-Square	C.V.	Root MSE	LOGA Mean
0.894881	-7.623198	0.0663371	-0.8702000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MEASURE	2	18.50653612	9.25326806	2102.73	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEASURE	2	18.50653612	9.25326806	2102.73	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.142683561 B	-221.93	0.0001	0.00514876
MEASURE	gill	0.410154983 B	56.33	0.0001	0.00728144
	max	0.408112691 B	55.96	0.0001	0.00729246
	maxil	0.000000000 B	.	.	.

Appendix C

Seafish cod. Allometric growth model

Final reggression Model: Log (Girth)= Int. + Measure +b* log (lgd)

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	3	gill max maxil

Number of observations in data set = 498

NOTE: Due to missing values, only 497 observations can be used in this analysis.

General Linear Models Procedure

Dependent Variable: LOGGIRTH

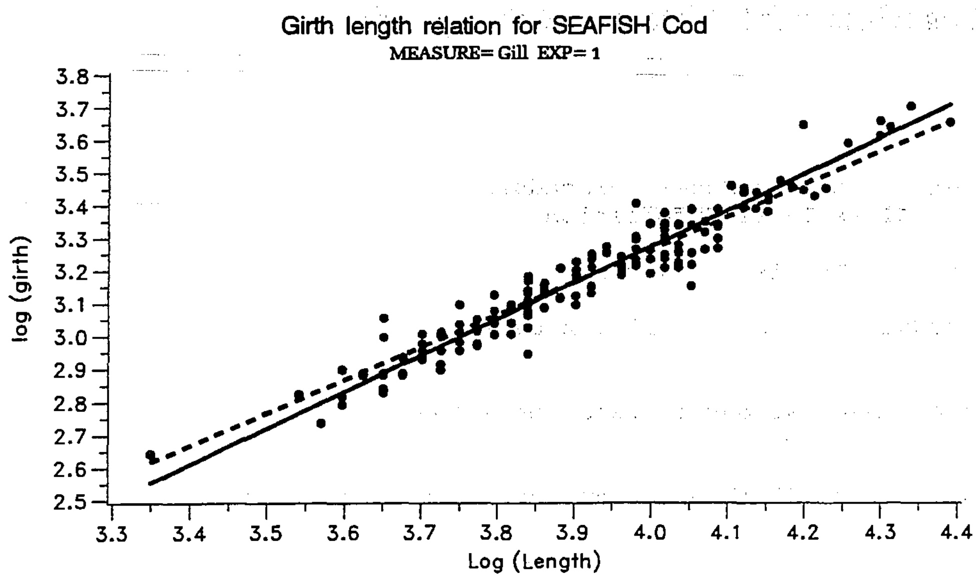
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	38.01785654	12.67261885	3159.86	0.0001
Error	493	1.97717822	0.00401050		
Corrected Total	496	39.99503475			

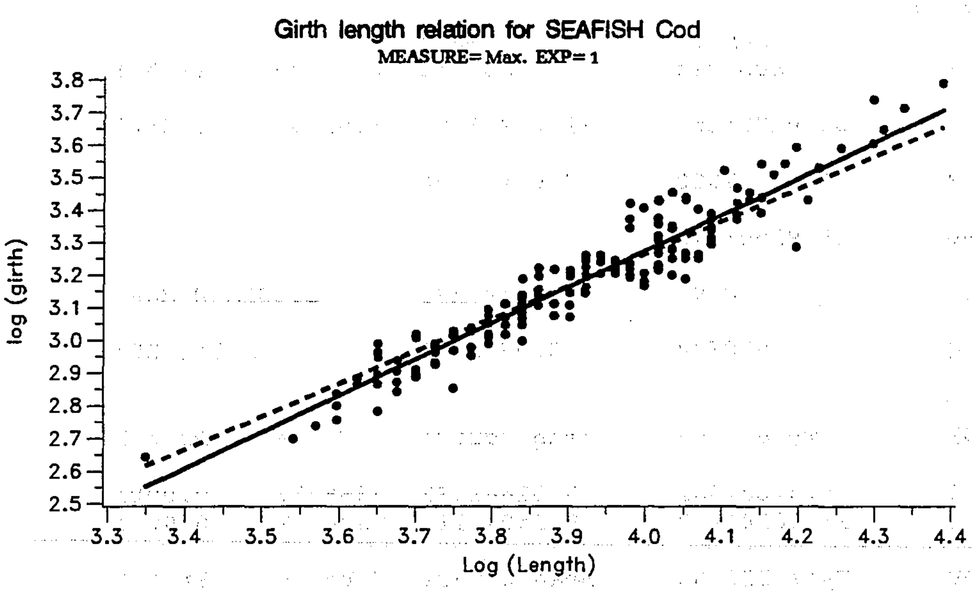
R-Square	C.V.	Root MSE	LOGGIRTH Mean
0.950564	2.078638	0.0633285	3.0466355

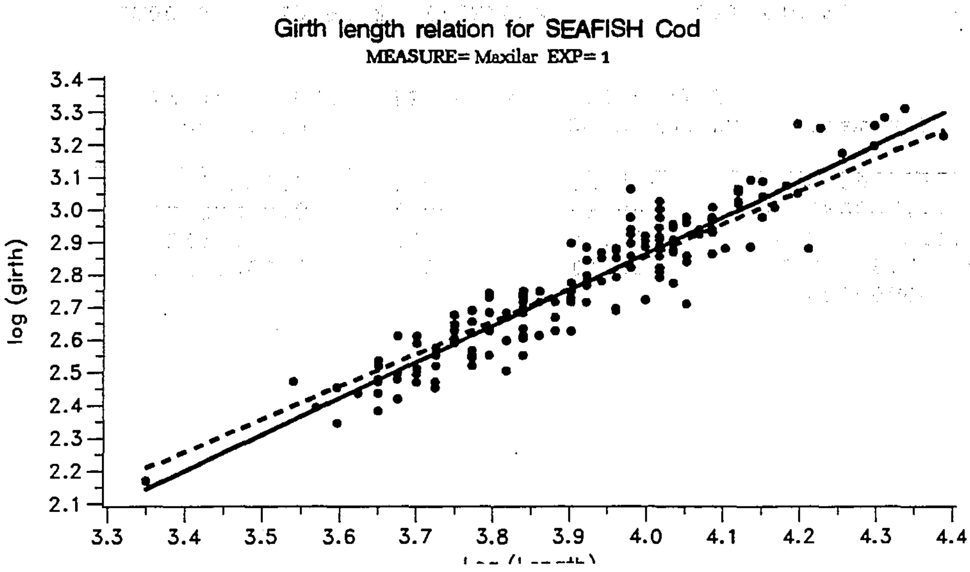
Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLGD	1	19.51641432	19.51641432	4866.33	0.0001
MEASURE	2	18.50144222	9.25072111	2306.62	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLGD	1	19.46590862	19.46590862	4853.73	0.0001
MEASURE	2	18.50144222	9.25072111	2306.62	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.580406579 B	-25.21	0.0001	0.06269193
LOGLGD		1.111763839	69.67	0.0001	0.01595786
MEASURE	gill	0.410154983 B	59.00	0.0001	0.00695121
	max	0.407999575 B	58.61	0.0001	0.00696175
	maxil	0.000000000 B	.	.	.


Girth length relation for SEAFISH Cod
MEASURE= Gill EXP= 1
log (girth)
Log (Length)


Girth length relation for SEAFISH Cod
MEASURE= Max. EXP= 1
log (girth)
Log (Length)


Girth length relation for SEAFISH Cod
MEASURE= Maxilar EXP= 1
log (girth)

Appendix C

IFREMER Hake. Isometric growth model

Final ANOVA Model log(Girth/length)= Intercept + Mesure

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	3	gill maxil pect

Number of observations in data set = 1821

General Linear Models Procedure

Dependent Variable: LOGA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	17.69353884	8.84676942	1417.84	0.0001
Error	1818	11.34358965	0.00623960		
Corrected Total	1820	29.03712849			

R-Square	C.V.	Root MSE	LOGA Mean
0.609342	-6.956968	0.0789911	-1.1354246

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MEASURE	2	17.69353884	8.84676942	1417.84	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEASURE	2	17.69353884	8.84676942	1417.84	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.065379840 B	-332.29	0.0001	0.00320615
MEASURE	gill	-0.000688656 B	-0.15	0.8793	0.00453418
	maxil	-0.209445694 B	-46.19	0.0001	0.00453418
	pect	0.000000000 B	.	.	.

Appendix C

IFREMER Hake. Allometric growth model

Final reggression Model: Log (Girth)= Int. + Measure +b* log (lgd)

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	3	gill maxil pect

Number of observations in data set = 1821

General Linear Models Procedure

Dependent Variable: LOGGIRTH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	61.36377896	20.45459299	3311.26	0.0001
Error	1817	11.22411586	0.00617728		
Corrected Total	1820	72.58789482			

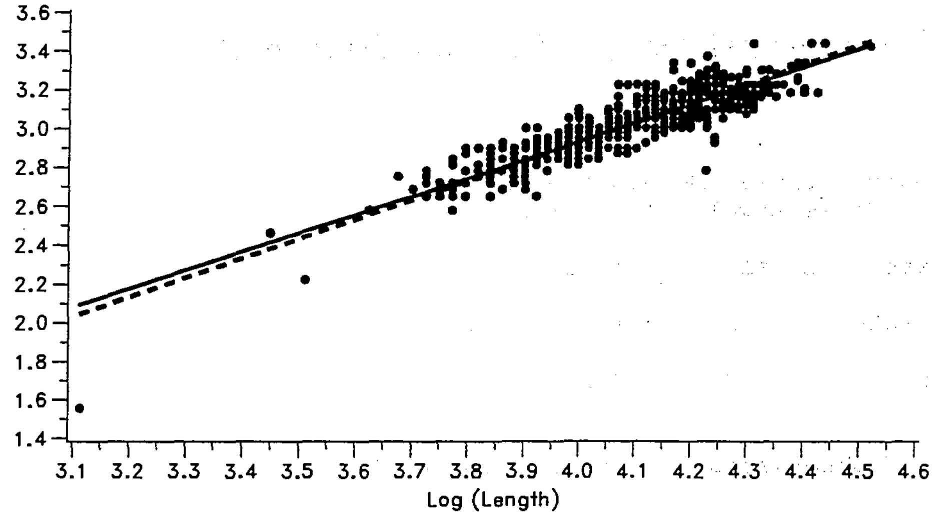
R-Square	C.V.	Root MSE	LOGGIRTH Mean
0.845372	2.662274	0.0785957	2.9522008

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLGD	1	43.67024012	43.67024012	7069.49	0.0001
MEASURE	2	17.69353884	8.84676942	1432.15	0.0001

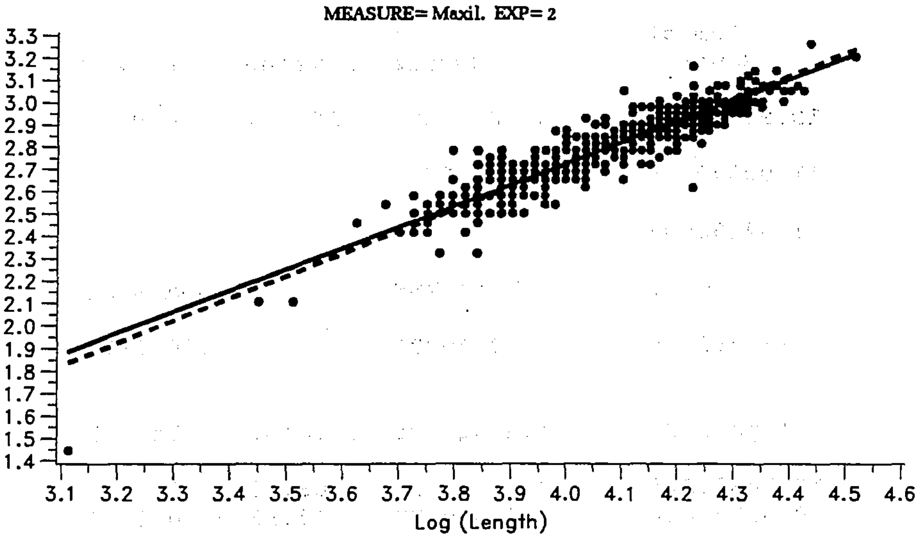
Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLGD	1	43.67024012	43.67024012	7069.49	0.0001
MEASURE	2	17.69353884	8.84676942	1432.15	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-.8622035748 B	-18.62	0.0001	0.04630929
LOGLGD		0.9502947934	84.08	0.0001	0.01130223
MEASURE	gill	-.0006886563 B	-0.15	0.8787	0.00451148
	maxil	-.2094456939 B	-46.43	0.0001	0.00451148
	pect	0.0000000000 B	.	.	.

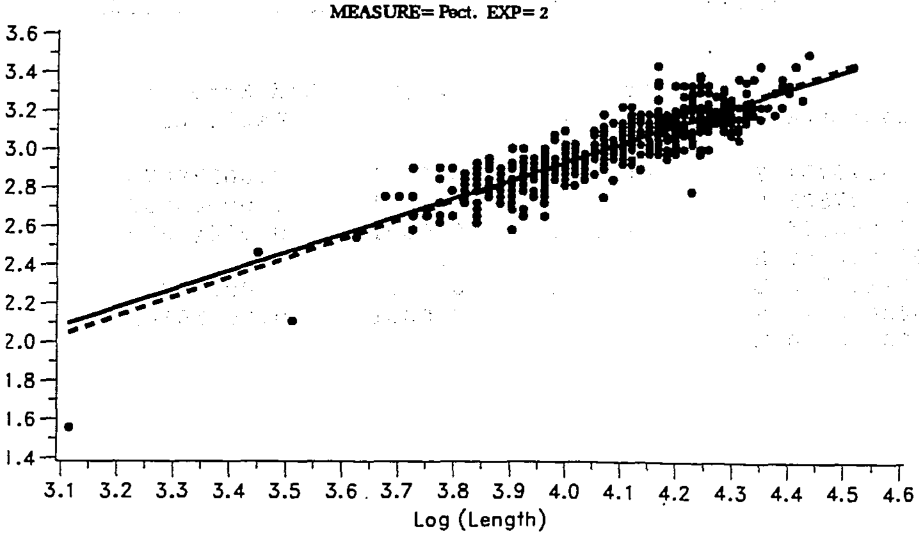
Girth length relation for IFREMER Hake
MEASURE= Gill EXP= 2



Girth length relation for IFREMER Hake
MEASURE= Maxil. EXP= 2



Girth length relation for IFREMER Hake
MEASURE= Pect. EXP= 2



Appendix C

SEAFISH Hake. Isometric growth model

Final ANOVA Model log(Girth/length)= Intercept + Mesure + Experiment

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	3	gill max pect
EXP	3	1 2 3

Number of observations in data set = 1260

General Linear Models Procedure

Dependent Variable: LOGA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	19.95514110	4.98878527	564.57	0.0001
Error	1255	11.08979588	0.00883649		
Corrected Total	1259	31.04493697			

R-Square	C.V.	Root MSE	LOGA Mean
0.642782	-8.491118	0.0940026	-1.1070699

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MEASURE	2	19.14335245	9.57167623	1083.20	0.0001
EXP	2	0.81178864	0.40589432	45.93	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEASURE	2	19.14335245	9.57167623	1083.20	0.0001
EXP	2	0.81178864	0.40589432	45.93	0.0001

Parameter		Estimate		T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.023376751	B	-176.73	0.0001	0.00579075
MEASURE	gill	-0.061987823	B	-9.56	0.0001	0.00648680
	max	-0.286898675	B	-44.23	0.0001	0.00648680
	pect	0.000000000	B	.	.	.
EXP	1	0.061112508	B	9.03	0.0001	0.00676799
	2	0.043620418	B	7.05	0.0001	0.00618609
	3	0.000000000	B	.	.	.

Appendix C

SEAFISH Hake. Allometric growth model

Final reggression Model: Log (Girth)= Int. + Mea. +Exp. + $(b+b_{exp})$* log (lgd)

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	3	gill max pect
EXP	3	1 2 3

Number of observations in data set = 1260

Dependent Variable: LOGGIRTH

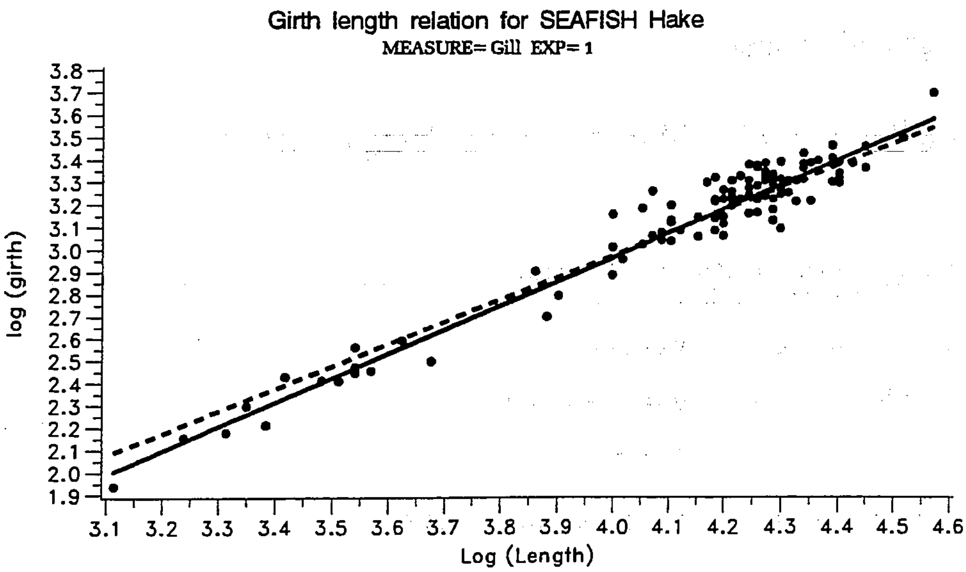
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	173.06243502	24.72320500	3362.50	0.0001
Error	1252	9.20549252	0.00735263		
Corrected Total	1259	182.26792754			

R-Square	C.V.	Root MSE	LOGGIRTH Mean
0.949495	2.906452	0.0857475	2.9502454

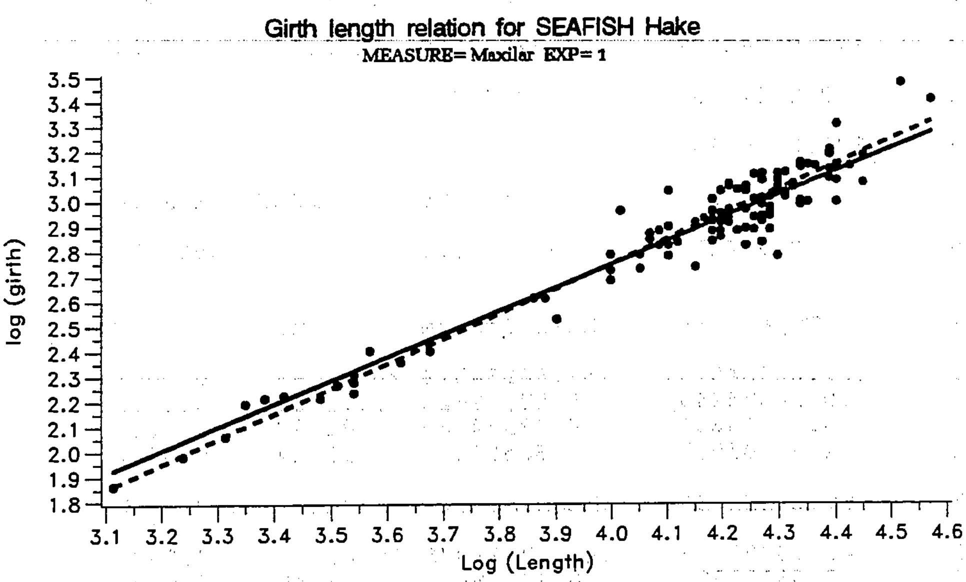
Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLGD	1	151.88934519	151.88934519	20657.83	0.0001
MEASURE	2	19.14335245	9.57167623	1301.80	0.0001
EXP	2	0.65868652	0.32934326	44.79	0.0001
LOGLGD*MEASURE	2	1.37105087	0.68552543	93.24	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLGD	1	146.03891075	146.03891075	19862.13	0.0001
MEASURE	2	0.68233823	0.34116911	46.40	0.0001
EXP	2	0.65868652	0.32934326	44.79	0.0001
LOGLGD*MEASURE	2	1.37105087	0.68552543	93.24	0.0001

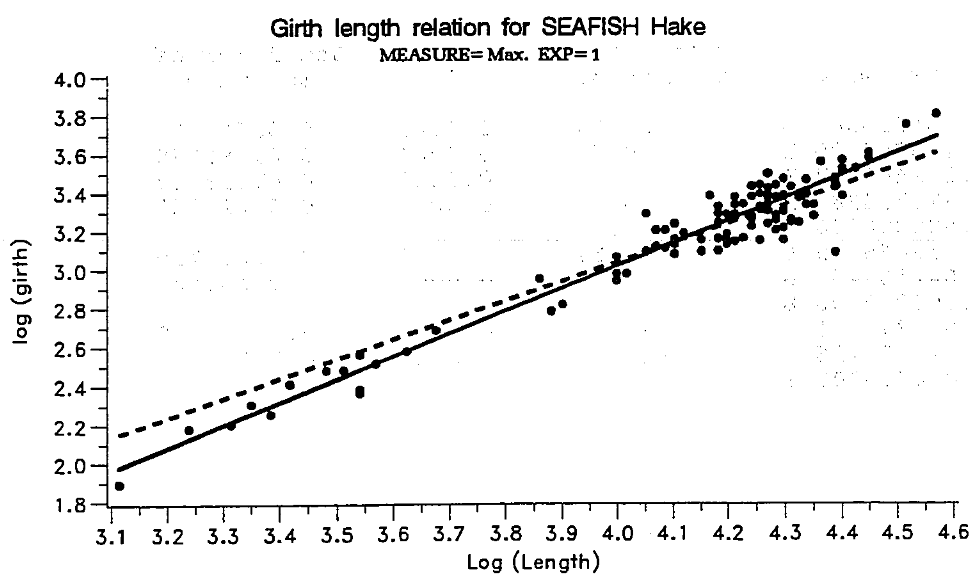
Parameter		Estimate		T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.734990945	B	-32.94	0.0001	0.05267429
LOGLGD		1.175990720	B	90.75	0.0001	0.01295879
MEASURE	gill	0.312403417	B	4.21	0.0001	0.07428765
	max	0.713794288	B	9.61	0.0001	0.07428765
	pect	0.000000000	B	.	.	.
EXP	1	0.053466119	B	8.57	0.0001	0.00624110
	2	0.042559469	B	7.54	0.0001	0.00564427
	3	0.000000000	B	.	.	.
LOGLGD*MEASURE	gill	-0.092275611	B	-5.06	0.0001	0.01825139
	max	-0.246639196	B	-13.51	0.0001	0.01825139
	pect	0.000000000	B	.	.	.



Girth length relation for SEAFISH Hake
MEASURE= Gill EXP= 1
log (girth)
Log (Length)

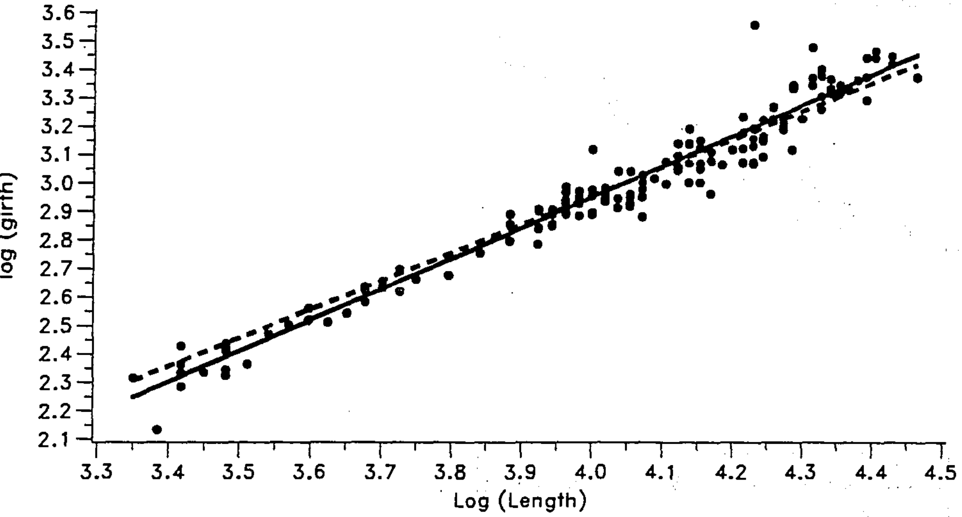


Girth length relation for SEAFISH Hake
MEASURE= Maxilar EXP= 1
log (girth)
Log (Length)

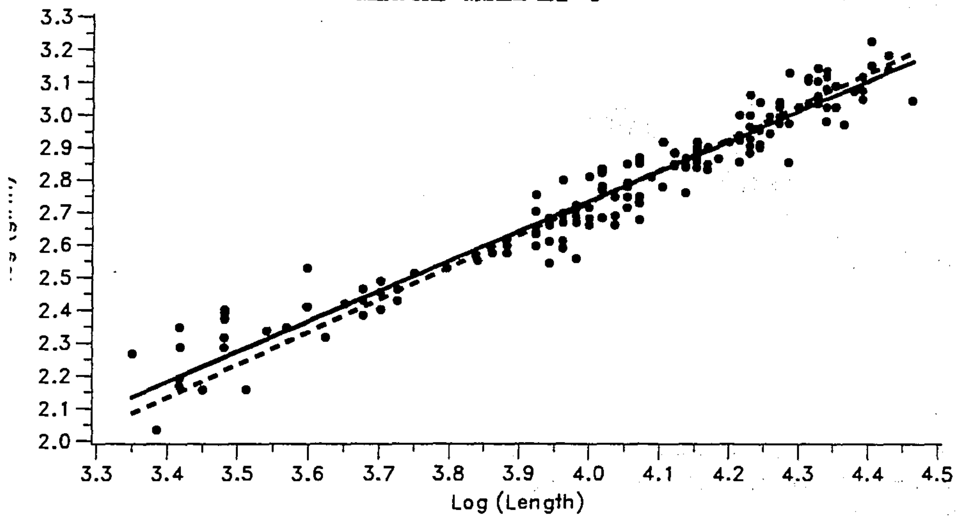


Girth length relation for SEAFISH Hake
MEASURE= Max. EXP= 1
log (girth)
Log (Length)

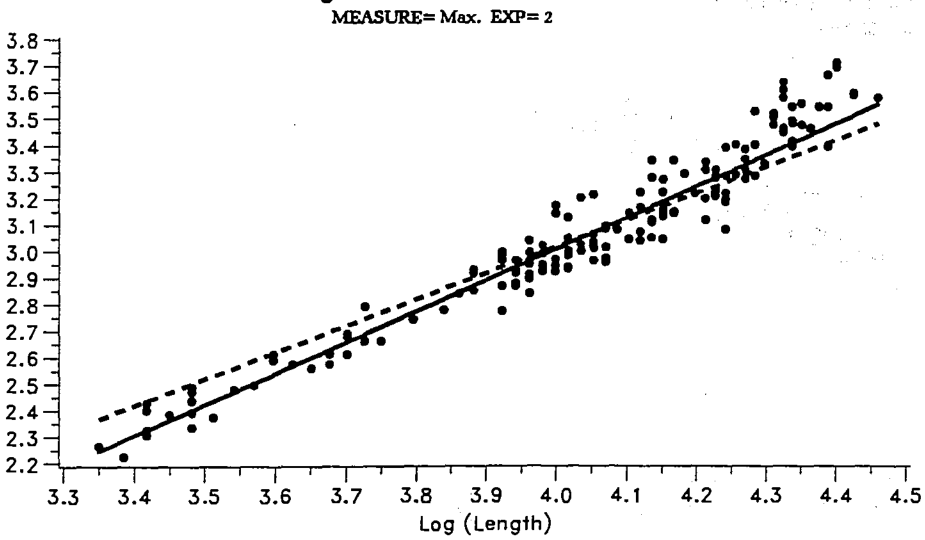
Girth length relation for SEAFISH Hake
MEASURE= Gill EXP= 2

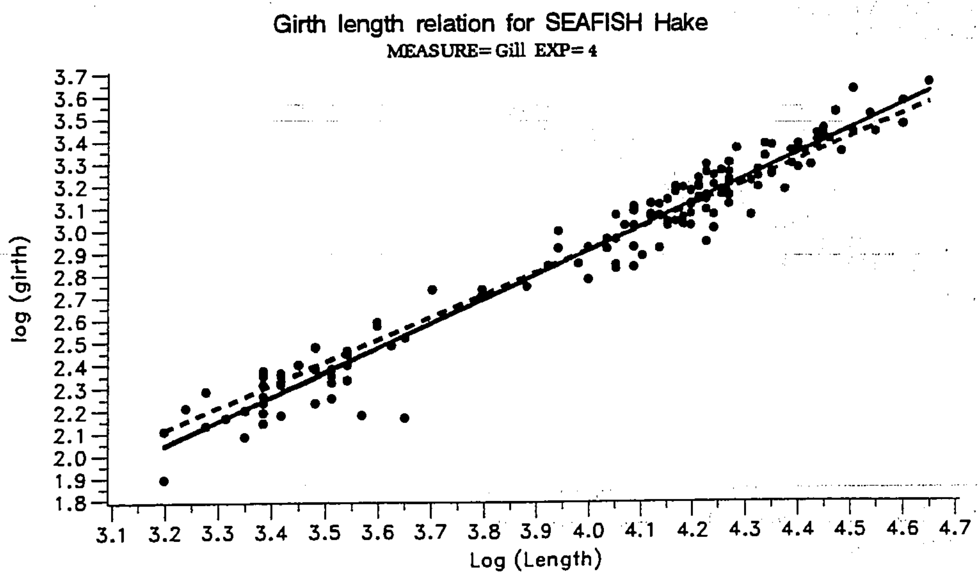


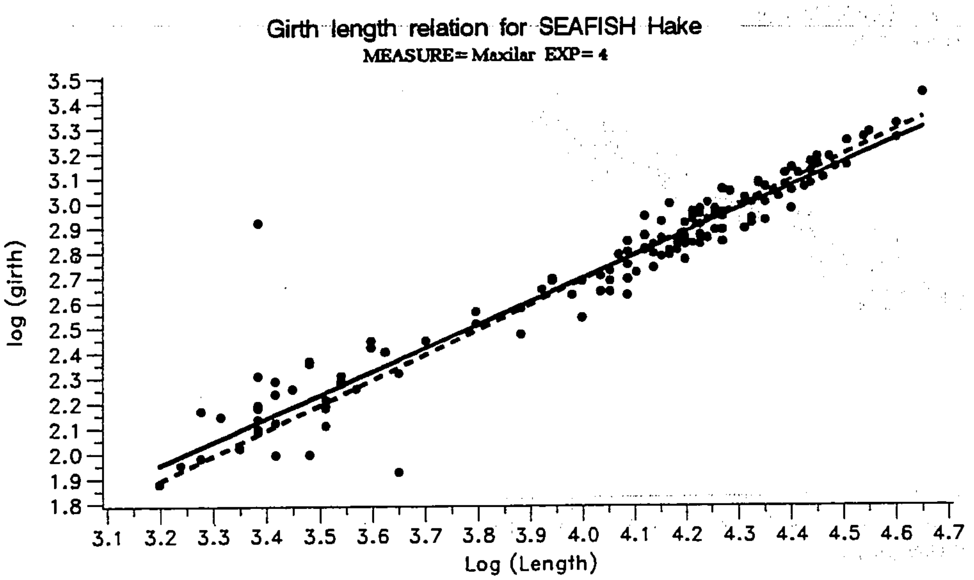
Girth length relation for SEAFISH Hake
MEASURE= Maxilar EXP= 2

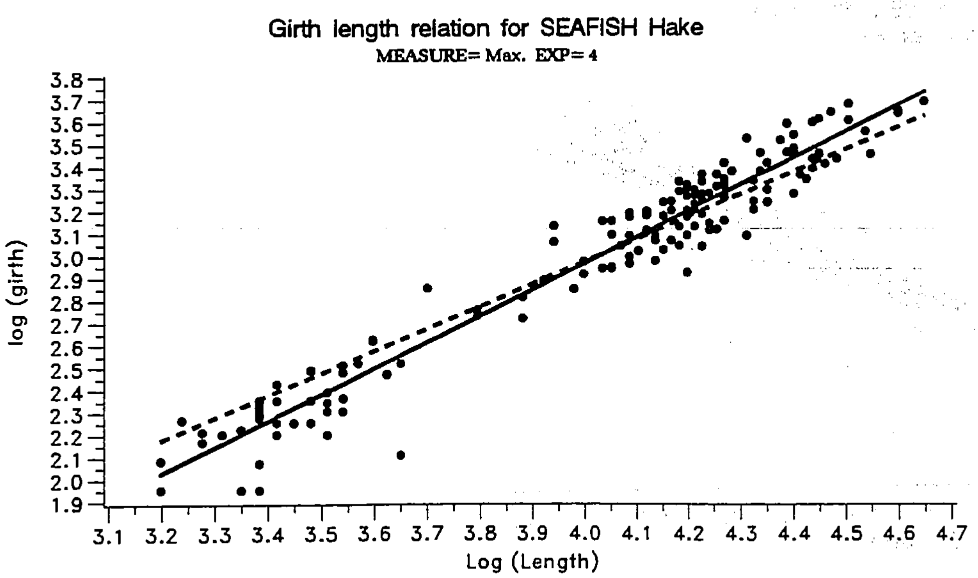


Girth length relation for SEAFISH Hake
MEASURE= Max. EXP= 2




Girth length relation for SEAFISH Hake
MEASURE= Gill EXP= 4
log (girth)
Log (Length)
3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7
1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5 3.6 3.7


Girth length relation for SEAFISH Hake
MEASURE= Maxilar EXP= 4
log (girth)
Log (Length)
3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7
1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5


Girth length relation for SEAFISH Hake
MEASURE= Max. EXP= 4
log (girth)
Log (Length)
3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7
1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8

Appendix C

DIFTA Plaice. Isometric growth model

Final ANOVA Model log(Girth/length)= Intercept + Mesure + Experiment

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	2	max spin
EXP	2	1 3

Number of observations in data set = 874

General Linear Models Procedure

Dependent Variable: LOGA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2.29104172	1.14552086	502.27	0.0001
Error	871	1.98646799	0.00228068		
Corrected Total	873	4.27750971			

R-Square	C.V.	Root MSE	LOGA Mean
0.535602	-4.519748	0.0477564	-1.0566167

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MEASURE	1	2.07390562	2.07390562	909.34	0.0001
EXP	1	0.21713610	0.21713610	95.21	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEASURE	1	2.07390562	2.07390562	909.34	0.0001
EXP	1	0.21713610	0.21713610	95.21	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.123384334 B	-382.12	0.0001	0.00293990
MEASURE	max	0.097424632 B	30.16	0.0001	0.00323077
	spin	0.000000000 B	.	.	.
EXP	1	0.031815225 B	9.76	0.0001	0.00326062
	3	0.000000000 B	.	.	.

Appendix C

DIFTA Plaice. Allometric growth model

Final reggression Model: Log (Girth)= Int. + Mea. +Exp. + b* log (lgd)

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	2	max spin
EXP	2	1 3

Number of observations in data set = 874

General Linear Models Procedure

Dependent Variable: LOGGIRTH

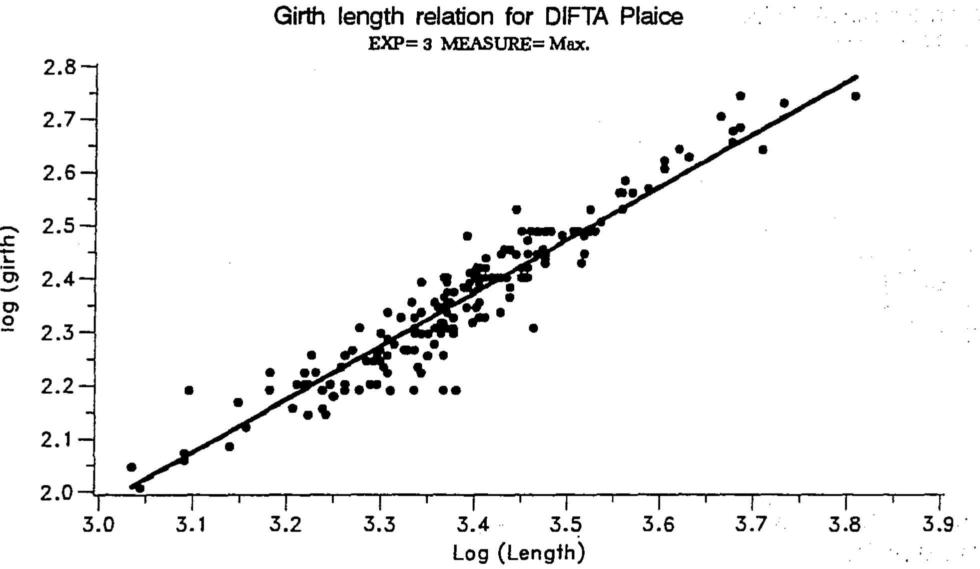
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	14.83478523	4.94492841	2169.98	0.0001
Error	870	1.98254729	0.00227879		
Corrected Total	873	16.81733252			

R-Square	C.V.	Root MSE	LOGGIRTH Mean
0.882113	2.057777	0.0477367	2.3198180

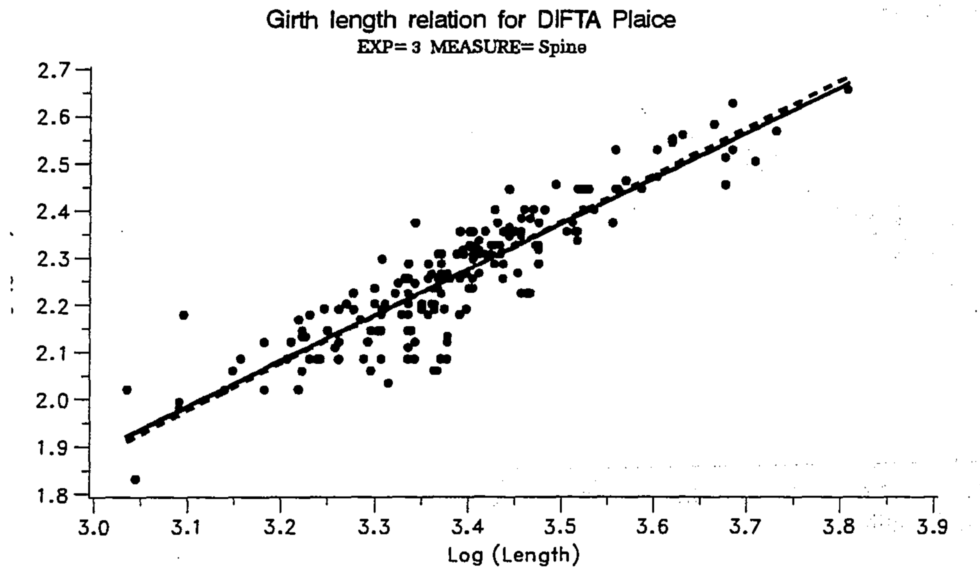
Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLGD	1	12.54914543	12.54914543	5506.93	0.0001
MEASURE	1	2.07390562	2.07390562	910.09	0.0001
EXP	1	0.21173418	0.21173418	92.92	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLGD	1	12.72102798	12.72102798	5582.36	0.0001
MEASURE	1	2.07390562	2.07390562	910.09	0.0001
EXP	1	0.21173418	0.21173418	92.92	0.0001

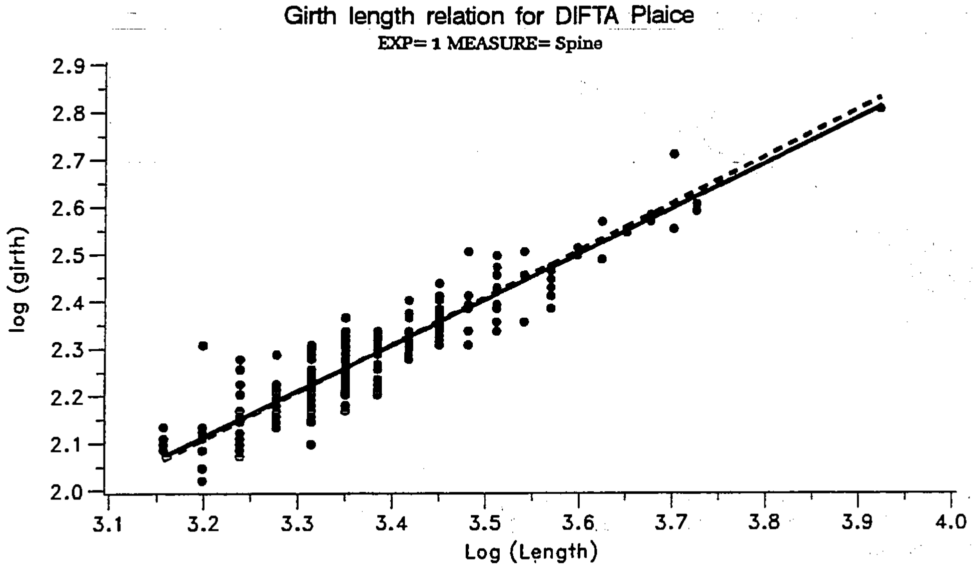
Parameter		Estimate		T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.064952943	B	-23.85	0.0001	0.04464363
LOGLGD		0.982747087		74.72	0.0001	0.01315324
MEASURE	max	0.097424632	B	30.17	0.0001	0.00322943
	spin	0.000000000	B	.	.	.
EXP	1	0.031501474	B	9.64	0.0001	0.00326804
	3	0.000000000	B	.	.	.



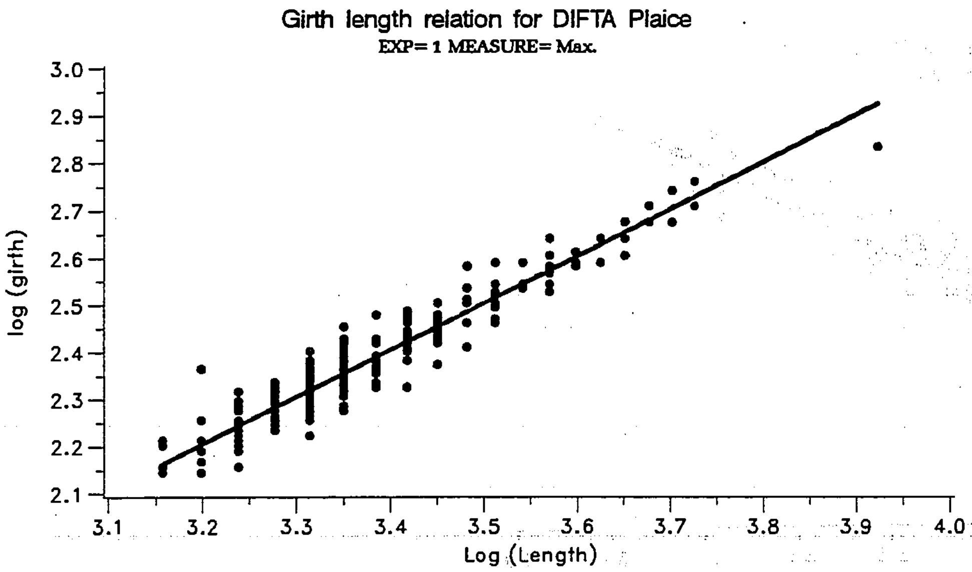
Girth length relation for DIFTA Plaice
EXP= 3 MEASURE= Max.
log (girth)
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
Log (Length)



Girth length relation for DIFTA Plaice
EXP= 3 MEASURE= Spine
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
Log (Length)



Girth length relation for DIFTA Plaice
EXP= 1 MEASURE= Spine
log (girth)
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4.0
Log (Length)



Girth length relation for DIFTA Plaice
EXP= 1 MEASURE= Max.
log (girth)
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4.0
Log (Length)

Appendix C

DIFTA Sole. Isometric growth model

Final ANOVA Model log(Girth/length)= Intercept + Mesure

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	2	gill pect

Number of observations in data set = 510

Final ANOVA, Model a=log(Girth/length)for DIFTA Sole 356

General Linear Models Procedure

Dependent Variable: LOGA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	10.41097461	10.41097461	2564.26	0.0001
Error	508	2.06249815	0.00406004		
Corrected Total	509	12.47347275			

R-Square	C.V.	Root MSE	LOGA Mean
0.834649	-4.248895	0.0637184	-1.4996467

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MEASURE	1	10.41097461	10.41097461	2564.26	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEASURE	1	10.41097461	10.41097461	2564.26	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.356770296 B	-340.03	0.0001	0.00399020
MEASURE	gill	-0.285752870 B	-50.64	0.0001	0.00564300
	pect	0.000000000 B	.	.	.

Appendix C

DIFTA Sole. Allometric growth model

Final reggression Model: Log (Girth)= Int. +(b+b_{mes})* log (lgd)

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	2	gill pect

Number of observations in data set = 510

General Linear Models Procedure

Dependent Variable: LOGGIRTH

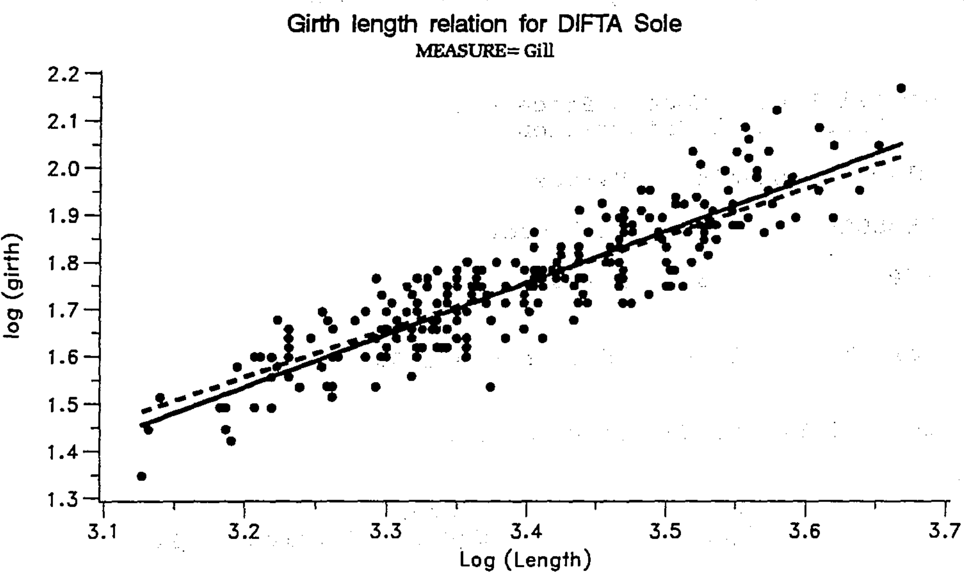
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	18.69541855	9.34770927	2465.24	0.0001
Error	507	1.92244568	0.00379181		
Corrected Total	509	20.61786423			

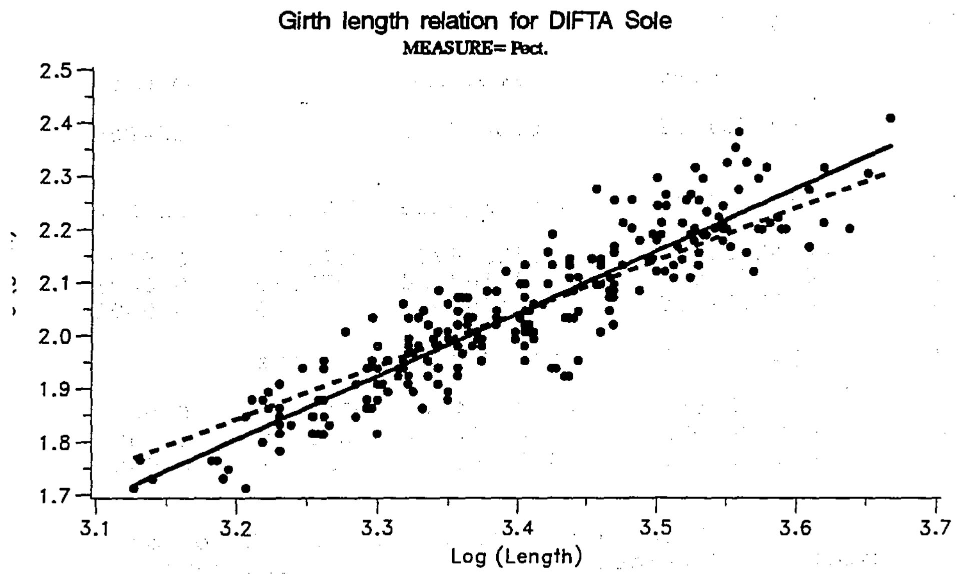
R-Square	C.V.	Root MSE	LOGGIRTH Mean
0.906758	3.238003	0.0615776	1.9017164

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLGD	1	8.27414112	8.27414112	2182.11	0.0001
LOGLGD*MEASURE	1	10.42127742	10.42127742	2748.37	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLGD	1	8.27414112	8.27414112	2182.11	0.0001
LOGLGD*MEASURE	1	10.42127742	10.42127742	2748.37	0.0001

Parameter		Estimate		T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.986556351		-23.85	0.0001	0.08328201
LOGLGD		1.185155209	B	48.40	0.0001	0.02448488
LOGLGD*MEASURE	gill	-0.084007777	B	-52.42	0.0001	0.00160244
	pect	0.000000000	B	.	.	.


Girth length relation for DIFTA Sole
MEASURE= Gill
log (girth)
Log (Length)
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
3.1
3.2
3.3
3.4
3.5
3.6
3.7


Girth length relation for DIFTA Sole
MEASURE= Pect.
Log (Length)
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
3.1
3.2
3.3
3.4
3.5
3.6
3.7

Appendix C

IFREMER Sole. Isometric growth model

Final ANOVA Model log(Girth/length)= Intercept + Mesure+ Mes*Exp

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	2	gill pect
EXP	3	1 2+3 4

Number of observations in data set = 1230

General Linear Models Procedure

Dependent Variable: LOGA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	47.53555801	9.50711160	2224.59	0.0001
Error	1224	5.23093643	0.00427364		
Corrected Total	1229	52.76649445			

R-Square	C.V.	Root MSE	LOGA Mean
0.900866	-4.491499	0.0653731	-1.4554850

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MEASURE	1	42.42536704	42.42536704	9927.22	0.0001
EXP	2	4.88208029	2.44104014	571.19	0.0001
MEASURE*EXP	2	0.22811068	0.11405534	26.69	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEASURE	1	40.85922449	40.85922449	9560.75	0.0001
EXP	2	4.88208029	2.44104014	571.19	0.0001
MEASURE*EXP	2	0.22811068	0.11405534	26.69	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.328124398 B	-270.29	0.0001	0.00491374
MEASURE	gill	-0.411973785 B	-59.28	0.0001	0.00694908
	pect	0.000000000 B	.	.	.
EXP	1	0.044064865 B	7.02	0.0001	0.00627324
	2+3	0.149740159 B	20.89	0.0001	0.00716697
	4	0.000000000 B	.	.	.
MEASURE*EXP	gill 1	0.064730472 B	7.30	0.0001	0.00887170
	gill 2+3	0.042918393 B	4.23	0.0001	0.01013563
	gill 4	0.000000000 B	.	.	.
	pect 1	0.000000000 B	.	.	.
	pect 2+3	0.000000000 B	.	.	.
	pect 4	0.000000000 B	.	.	.

Appendix C

IFREMER Sole. Allometric growth model
Final reggression Model: Log (Girth)= Int.+Exp+Exp*Mes+($b+b_{mes}+b_{exp}$)*log(lgd)

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	2	gill pect
EXP	3	1 2+3 4

Number of observations in data set = 1230

General Linear Models Procedure

Dependent Variable: LOGGIRTH

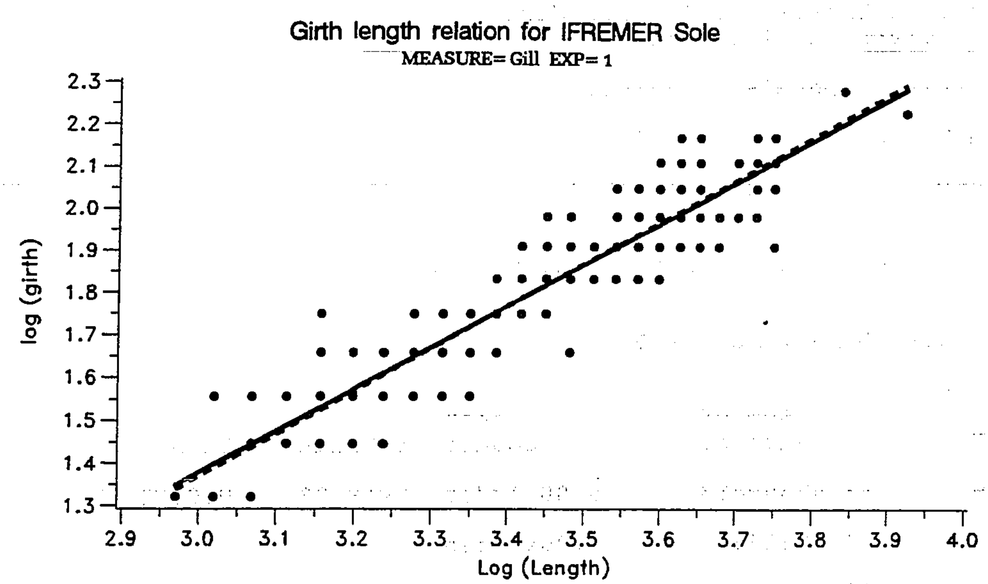
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	88.97559433	9.88617715	2449.83	0.0001
Error	1220	4.92324666	0.00403545		
Corrected Total	1229	93.89884099			

R-Square	C.V.	Root MSE	LOGGIRTH Mean
0.947569	3.186358	0.0635252	1.9936612

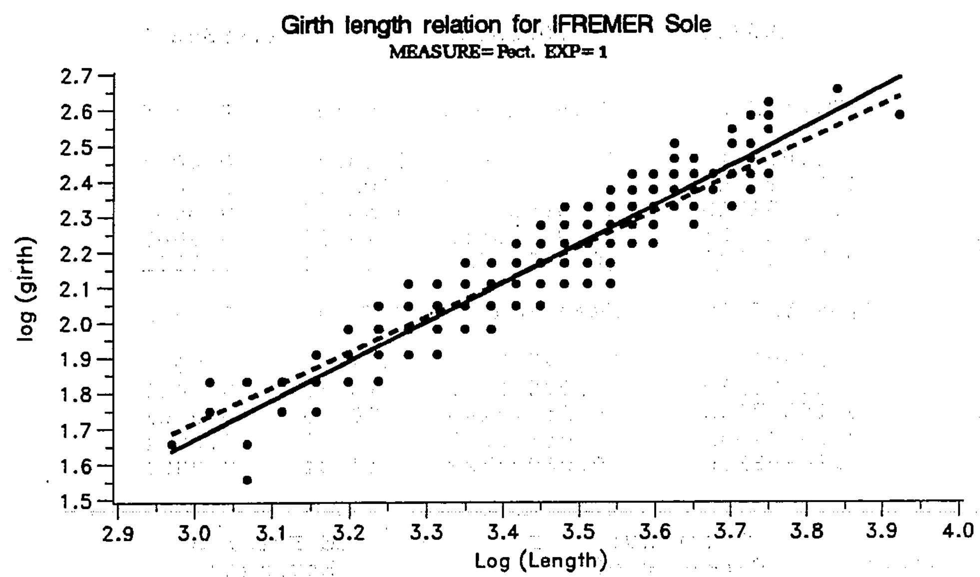
Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLGD	1	41.21613647	41.21613647	10213.52	0.0001
EXP	2	4.86793840	2.43396920	603.15	0.0001
LOGLGD*MEASURE	1	42.59931745	42.59931745	10556.28	0.0001
LOGLGD*EXP	2	0.08227031	0.04113515	10.19	0.0001
MEASURE*EXP	3	0.20993170	0.06997723	17.34	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLGD	1	34.04797407	34.04797407	8437.22	0.0001
EXP	2	0.15092980	0.07546490	18.70	0.0001
LOGLGD*MEASURE	1	0.15577143	0.15577143	38.60	0.0001
LOGLGD*EXP	2	0.08227031	0.04113515	10.19	0.0001
MEASURE*EXP	3	0.20993170	0.06997723	17.34	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.912571597 B	-24.26	0.0001	0.07885024
LOGLGD		1.168774715 B	51.42	0.0001	0.02272832
EXP	1	0.260743286 B	3.05	0.0024	0.08561602
	2+3	0.629936640 B	5.90	0.0001	0.10669745
	4	0.000000000 B	.	.	.
LOGLGD*MEASURE	gill	-0.129389951 B	-6.21	0.0001	0.02082584
	pect	0.000000000 B	.	.	.
LOGLGD*EXP	1	-0.061566770 B	-2.49	0.0130	0.02473795
	2+3	-0.138706729 B	-4.51	0.0001	0.03072445
	4	0.000000000 B	.	.	.
MEASURE*EXP	gill 1	0.096619168 B	1.35	0.1777	0.07164221
	gill 2+3	0.079561135 B	1.10	0.2731	0.07256176
	gill 4	0.036088559 B	0.50	0.6184	0.07243291
	pect 1	0.000000000 B	.	.	.
	pect 2+3	0.000000000 B	.	.	.
	pect 4	0.000000000 B	.	.	.



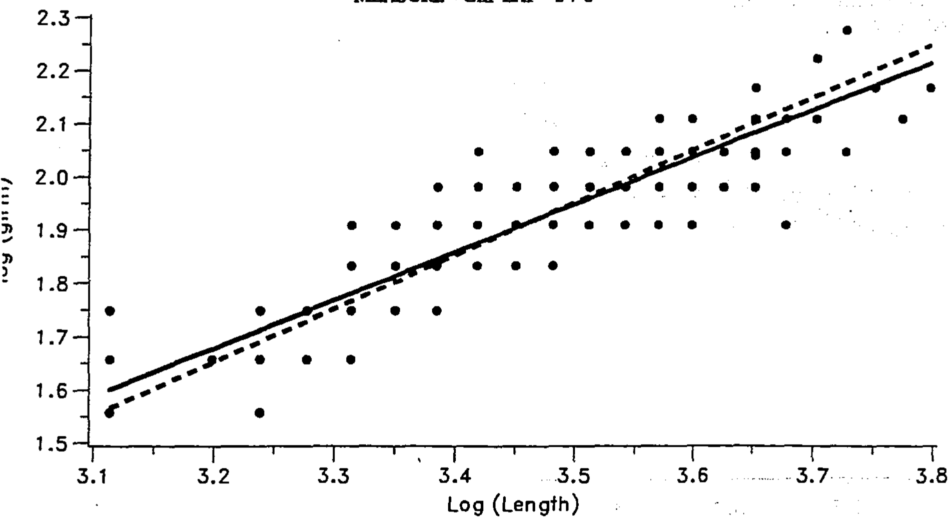
Girth length relation for IFREMER Sole
MEASURE= Gill EXP= 1
log (girth)
Log (Length)
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4.0



Girth length relation for IFREMER Sole
MEASURE= Pect. EXP= 1
log (girth)
Log (Length)
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4.0

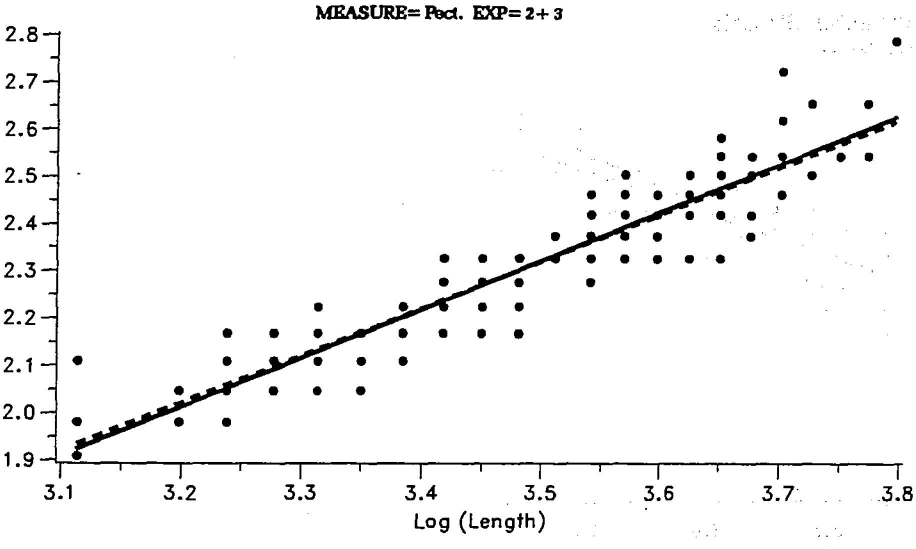
Girth length relation for IFREMER Sole

MEASURE= Gill EXP= 2+3

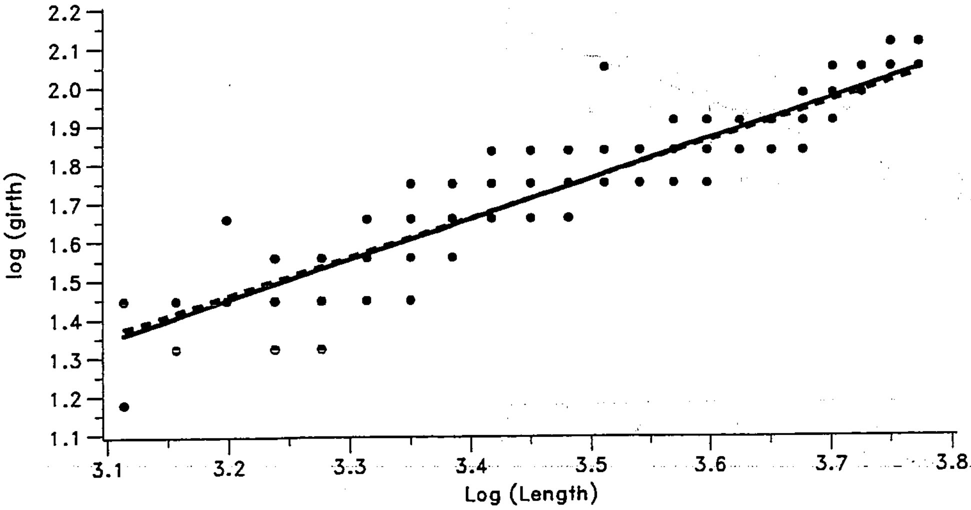


Girth length relation for IFREMER Sole

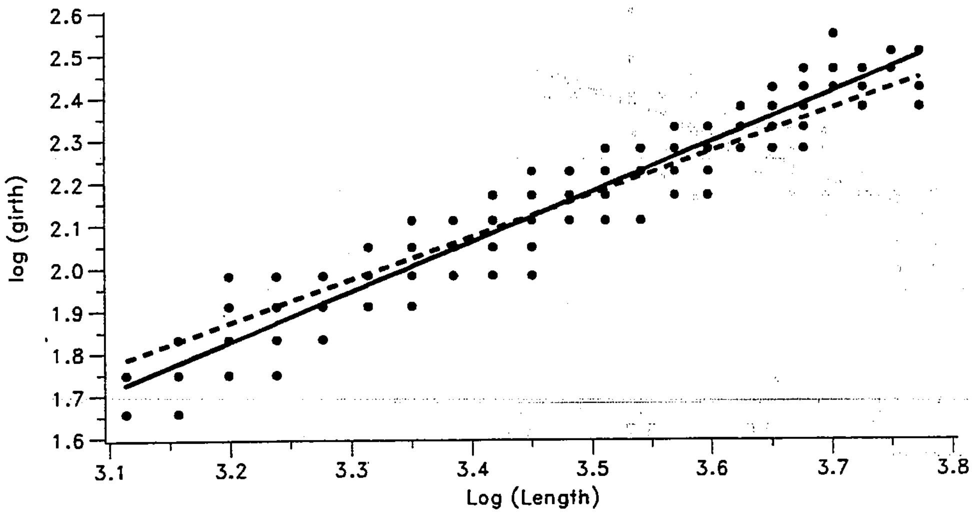
MEASURE= Pect. EXP= 2+3



Girth length relation for IFREMER Sole
MEASURE= Gill EXP= 4



Girth length relation for IFREMER Sole
MEASURE= Pect. EXP= 4



Appendix C

SEAFISH Sole. Isometric growth model

Final ANOVA Model log(Girth/length)= Intercept + Mesure

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	2	gill pect

Number of observations in data set = 200

General Linear Models Procedure

Dependent Variable: LOGA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	5.85365622	5.85365622	1261.20	0.0001
Error	198	0.91898583	0.00464134		
Corrected Total	199	6.77264205			

R-Square	C.V.	Root MSE	LOGA Mean
0.864309	-4.975219	0.0681274	-1.3693347

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MEASURE	1	5.85365622	5.85365622	1261.20	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEASURE	1	5.85365622	5.85365622	1261.20	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-1.198254983 B	-175.88	0.0001	0.00681274
MEASURE	gill	-0.342159501 B	-35.51	0.0001	0.00963467
	pect	0.000000000 B	.	.	.

Appendix C

SEAFISH Sole. Allometric growth model

Final reggression Model: Log (Girth)= Int. +Measure +b* log (lgd)

General Linear Models Procedure
Class Level Information

Class	Levels	Values
MEASURE	2	gill pect

Number of observations in data set = 200

General Linear Models Procedure

Dependent Variable: LOGGIRTH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	8.47236610	4.23618305	960.39	0.0001
Error	197	0.86894528	0.00441089		
Corrected Total	199	9.34131138			

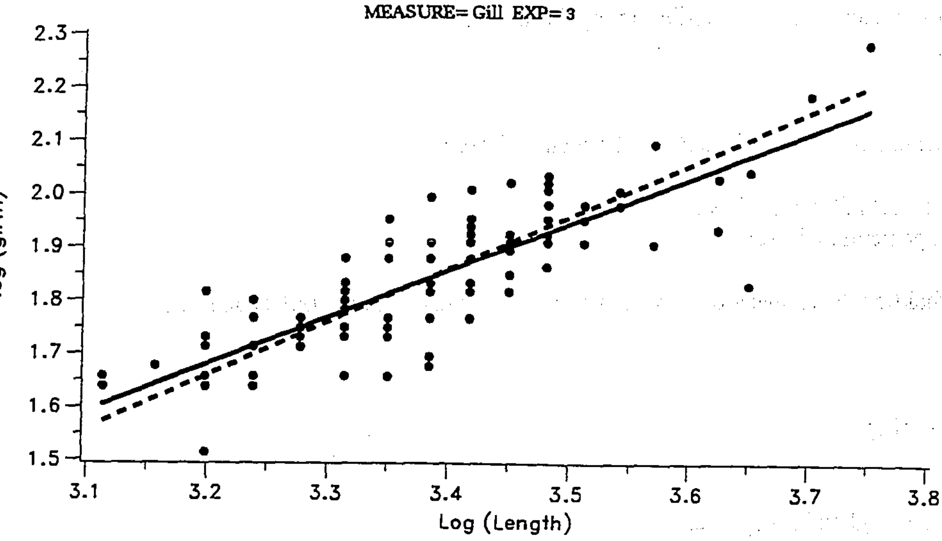
R-Square	C.V.	Root MSE	LOGGIRTH Mean
0.906978	3.302771	0.0664145	2.0108731

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLGD	1	2.61870988	2.61870988	593.69	0.0001
MEASURE	1	5.85365622	5.85365622	1327.09	0.0001

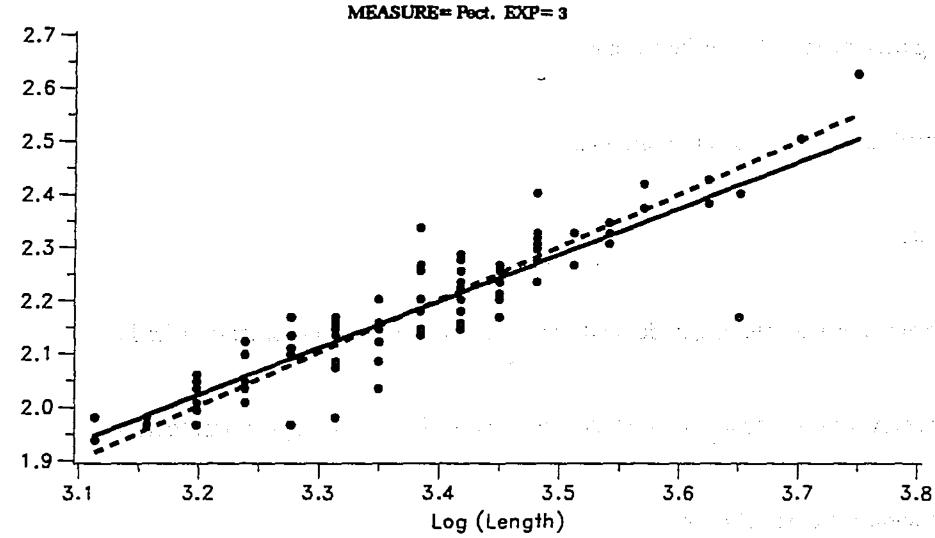
Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLGD	1	2.61870988	2.61870988	593.69	0.0001
MEASURE	1	5.85365622	5.85365622	1327.09	0.0001

Parameter		Estimate		T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-.7877401038	B	-6.45	0.0001	0.12206040
LOGLGD		0.8785533630		24.37	0.0001	0.03605683
MEASURE	gill	-.3421595014	B	-36.43	0.0001	0.00939243
	pect	0.0000000000	B	.	.	.

Girth length relation for SEAFISH Sole
MEASURE= Gill EXP= 3



Girth length relation for SEAFISH Sole
MEASURE= Pect. EXP= 3



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