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STATISTICAL ANALYSIS OF THE ICES COOPERATIVE MONITORING PROGRAMME DATA ON CONTAMINANTS IN FISH MUSCLE TISSUE (1978-1985) FOR DETERMINATION OF TEMPORAL TRENDS

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PREFACE

This report is the first to be published by ICES on the results of its programme to explore the use of fish and shellfish to determine temporal trends in contaminant levels in the marine environment. Since 1986 the work on the analysis of temporal trends in contaminants in marine organisms has been coordinated by the Working Group on the Statistical Aspects of Trend Monitoring, and individual members of this group have been responsible for the development of the statistical models used in this report and their subsequent application to the trend monitoring data. I wish to express particular appreciation to Dr M.D. Nicholson (MAFF Fisheries Laboratory, Lowestoft, UK) for his work in developing the statistical procedures used here, and for conducting the analysis of the ICES data sets, and to Dr S. Wilson, ICES Secretariat, for his work in computer processing of the data, compilation of the statistical analyses and preparation of the plots, and organizing this report for publication.

Dr J. Uthe
Chairman, Working Group on the
Statistical Aspects of Trend Monitoring

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STATISTICAL ANALYSIS OF THE ICES COOPERATIVE MONITORING PROGRAMME DATA ON CONTAMINANTS IN FISH MUSCLE TISSUE FOR DETERMINATION OF TEMPORAL TRENDS (PURPOSE 3)

1 INTRODUCTION

In 1971, the International Council for the Exploration of the Sea (ICES) established a Working Group charged with the development of factual data regarding substances being discharged into the North Sea and its adjacent waters, and the concentrations of these substances in the marine environment. As part of these studies, the collection of baseline data on contaminant levels in food fish was selected as having the highest priority. The two aims of this study were to obtain data addressing: 1) potential human health concerns from ingesting fish, and 2) identification of geographical trends in contaminant levels. In 1974, the geographical area of interest was enlarged to include the North Atlantic.

In 1981, the monitoring programme was reviewed and three separate purposes were developed for monitoring using fish and shellfish (1981 ACMP Report, Coop. Res. Rep. No. 112):

1) The provision of a continuing assurance of the quality of marine foodstuffs with respect to human health.

2) The provision over a wide geographical range of an indication of the health of the marine environment in the entire ICES North Atlantic region.

3) To provide an analysis of trends over time in pollutant [contaminant] concentrations in selected areas, especially in relation to the assessment of the efficacy of control measures.

This report deals with the third purpose, the analysis of the Cooperative ICES Monitoring Studies Programme (CMP) data for time trends in contaminant concentrations up to and including 1985. The report describes the results of the statistical analysis of the CMP data sets for contaminants in fish muscle tissue, submitted for the purpose of assessing temporal trends in contaminant levels.

The development of an appropriate statistical approach for the analysis of these data has been the subject of work over a period of years, initially by the ICES *ad hoc* Group of Statisticians Assisting the Working Group on Marine Pollution Baseline and Monitoring Studies in the North Atlantic (WGMPNA) and later by the Working Group on the Statistical Aspects of Trend Monitoring (WGSATM). For a more detailed historical review, see Annex 1 (see also C.M.1985/E:10, C.M.1986/E:39, and C.M.1987/E:24). In conjunction with the development of the statistical approach, requirements for the composition of samples were established as well as requirements for reporting the appropriate types of data. The guidelines specifying these sampling, sample preparation, and reporting requirements are given in Annex 2.

The resulting statistical model for analysis of the data was based on the application of multiple linear regression techniques, according to the procedures described in Annex 3.

Upon completion of the statistical development work, the data submitted since 1978 on contaminants in fish muscle tissue were reviewed and twenty-five sets of samples were considered for analysis. Each set comprised data on contaminant concentrations and biological parameters for individual specimens of a given species of fish sampled annually from a given area.

The data series were submitted by six countries: Belgium, Denmark, the Federal Republic of Germany, Norway, Sweden and the United Kingdom. They concerned six species: cod, flounder, herring, plaice, sole and whiting, and covered 18 defined areas (based on the ICES statistical rectangle system).

For a given species-area combination, the statistical analysis was applied to data on one or more of the contaminants on which concentrations in muscle tissue had been reported, namely, the six metals (mercury, lead, zinc, copper, nickel and chromium) and polychlorinated biphenyls (PCBs on a formulation basis). A full statistical analysis was completed for, in all, 62 data sets.

The statistical analyses, as applied, produce yearly estimates of the mean contaminant levels and a statistical interpretation of the trend data for the individual species-area-tissue-contaminant combination concerned. It must be stressed, however, that this is a statistical evaluation of the data only.

This report does not attempt to draw any conclusions with respect to the trends in environmental contaminant levels in any given area. Such interpretation procedures would require, in addition to the results of this purely statistical analysis, comprehensive information on a number of environmental factors and processes operating in that area and, furthermore, improved knowledge about the physiological and biochemical processes that determine uptake and metabolism of contaminants by a particular organism.

This being the case, Section 5 of this report includes a brief summary of points relating to the general requirements for the interpretation of data on contaminants in biological tissue for the purpose of determining temporal trends, and also includes some references to additional information relating to the specific data sets analysed here.

The following abbreviations are used throughout this report:

ACMP - 1973: ICES Advisory Committee on Marine Pollution.

WGMPNA - 1971: The Working Group for the International Study of the Pollution of the North Sea and Its Effects on Living Resources and Their Exploitation.

- 1975: The Working Group on Pollution Baseline and Monitoring Studies in the Oslo Commission and ICNAF Areas.

- 1978: The Working Group on Marine Pollution Baseline and Monitoring Studies in the North Atlantic.

MCWG - 1979: The Marine Chemistry Working Group.

CMP - 1974: ICES Coordinated Monitoring Programme.

- 1982: Cooperative ICES Monitoring Studies Programme.

WGSATM - 1985: Ad Hoc Group of Statisticians Assisting the WGMPNA on Trend Monitoring Issues.

- 1986: Working Group on the Statistical Aspects of Trend Monitoring.

2 DATA AND DATA QUALITY

2.1 Data Availability

The data sets analysed in this report cover a variety of commercial species of fish. They are listed below by common name, RUBIN code (used for data processing), and scientific name.

Atlantic Cod	GADU MOR	*Gadus morhua*
European Flounder	PLAT FLE	*Platichthys flesus*
Whiting	MERL MNG	*Merlangius merlangus*
European Plaice	PLEU PLA	*Pleuronectes platessa*
Common Sole	SOLE VUL	*Solea vulgaris*
Common Dab	LIMA LIM	*Limanda limanda*
Atlantic Herring	CLUP HAR	*Clupea harengus harengus*

These fish were generally sampled once per year according to various sampling protocols, with data available covering the years 1978-1985. In 1981, ICES issued revised guidelines for the sampling of fish and shellfish for the analysis of temporal trends in contaminant levels. These guidelines, to be used for sampling in 1982 and thereafter, are reproduced in Annex 2. Some of the data included in this study conform to these guidelines, however, most data sets also include samples taken in the period before the implementation of these guidelines. In addition, the samples for some data sets have been collected according to another protocol, namely, a length-restrictive sampling strategy used by Sweden, in particular, for their cod and herring samples.

Figure 1 shows the locations of the various sampling areas. Whilst each data set is nominally associated with a single ICES statistical rectangle, some sets include data where the samples for one or two years were not collected in the nominal ICES rectangle, but in an adjacent rectangle (cf. Annex 4 for information on sampling location inconsistencies).

Information on the number of contaminants monitored in each area (ICES statistical rectangle) by species and country is given in Table 1. Table 2 shows the numbers of years of data available for each contaminant by species and area.

Contaminant values were reported in units of mg/kg; values not so reported were converted to these units. The values for metals were reported on a wet weight basis and for PCBs on a lipid weight basis; if necessary, a basis conversion was applied, i.e., for all data reported on a dry weight basis or for PCBs reported on a wet weight basis.

Data were reported on a number of biological parameters of the fish: length, weight, age, sex, percentage fat weight, percentage dry weight. However, these values were not available in every data set, and not available consistently throughout the data sets for a given species/area. Annex 4 contains a summary table showing inconsistencies in location and month of sampling and graphical presentations of the length distributions of fish in each data set according to year. A series of data registration forms detailing the information available on a sample-by-sample basis is included in Section 4, which deals with the results of the statistical analysis. 4). Each form preceeds the presentation of the results of the contaminant trend analyses pertaining to that sample, i.e., a particular species from a specific area. All data considered in this report are based on measurements of biological variables and contaminant levels in individually analysed fish.

2.2 Data Quality

There are inconsistencies both in the data and the way the CMP guidelines have been implemented. The data sets are described and annotated in Section 4 and Annex 4, and are discussed below.

There were problems with missing data on biological variables, for example, when the ages of the fish were not reported for one year within a data set. This made the statistical analysis more difficult when testing for the effect of potential covariables, and to some extent enforced the choice of length as a primary covariate. A covariate was, therefore, only included in the analysis when data on that biological variable had been reported in all years. Missing data on biological variables within a data set also made the analysis more complicated. For example, when testing the effect of fish length on contaminant concentration, data on all fish for which the length had been measured were included in the analysis; generally, length data were available for all fish sampled. However, the effect of additional covariates often had to be tested on a reduced data set because data on one or more of these additional covariates were occasionally missing for certain fish. This use of the data sets with some missing data is done on the assumption that observations are missing on a random basis.

In some cases, contaminant concentrations were reported as "less than" some value. This value varied between the laboratories reporting the data as a consequence of the different methodologies applied. When the frequency of "less than" values was below 20% of the values for that contaminant within a year, a concentration value of half the reported "less than" value was used in the statistical analyses. The results using this convention appeared to be reasonable (i.e., the residuals tended to be negative but not too extreme) and did not appear to be subject to bias. If the frequency exceeded 20%, all data on that contaminant for that year were excluded from the regression analysis, but are shown on the plots of estimated mean contaminant levels versus time as a symbol (an arrow) at the reported "less than" concentration.

Data obtained prior to 1982 were not collected according to the present CMP guidelines. Before 1982, samples generally consisted of fewer than 25 fish. This should not introduce any bias, but will reduce the power to detect differences amongst these earlier years. Some samples taken after 1982 were also collected under an alternative sampling scheme (e.g., Swedish herring data). In some cases, this was because length stratification was considered to be unnecessary. For example, herring do not grow continuously throughout their lives and thus do not exhibit a wide spread of lengths. The requirement to sample at the same time each year and in the same area was not always followed. See the data registration forms in Section 4 and the summary table in Annex 4 for details.

The accuracy of the chemical analyses has not been assessed or taken into account in the observed differences between years. However, for some data sets National Coordinators have supplied additional comments, which qualify the observed differences. Such comments are included in the annotations to the data registration forms.

The effects of fish behaviour and other biological factors are unknown. There is an implicit assumption that for each area, only one population or stock of fish has been sampled, for which the data are compared between years. Again, additional commentary from the National Coordinators may suggest that this assumption is not justified.

Figure 1 Locations of areas sampled according to ICES Statistical Rectangle.

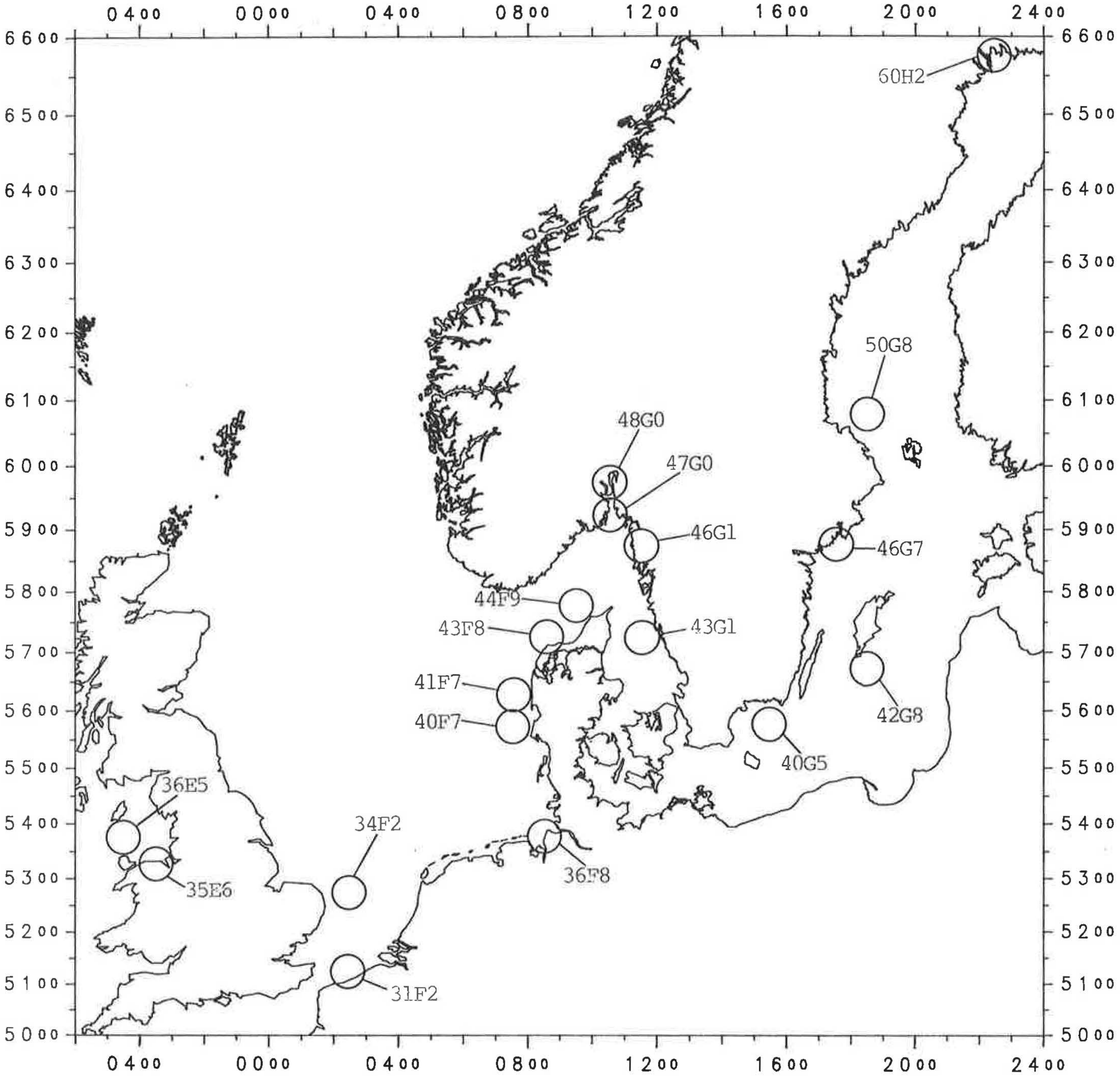


Table 1 Numbers of contaminants monitored according to area and species.

Area	Country	Species							Total
		Cod	Flounder	Sole	Plaice	Whiting	Herring	Dab	
31F2	Belgium	7	7	6	-	-	-	-	20
36E5	Belgium	-	-	6	-	-	-	-	6
40F7	Denmark	-	-	-	1	-	-	-	1
41F7	Denmark	-	-	-	1	-	-	-	1
43F8	Denmark	-	-	-	1	-	-	-	1
44F9	Denmark	-	-	-	1	-	-	-	1
36F8	Fed.Rep.of Germ	-	1	-	-	-	-	-	1
47G0	Norway	1	-	-	-	-	-	-	1
48G0	Norway	1	1	-	-	-	-	-	2
40G5	Sweden	-	-	-	-	-	2	-	2
42G8	Sweden	1	-	-	-	-	-	-	1
43G1	Sweden	1	-	-	-	-	2	2	5
46G1	Sweden	-	2	-	-	-	-	-	2
46G7	Sweden	-	-	-	-	-	2	-	2
50G8	Sweden	-	-	-	-	-	2	-	2
60H2	Sweden	-	-	-	-	-	2	-	2
34F2	United Kingdom	3	-	-	3	-	-	-	6
35E6	United Kingdom	-	-	-	3	3	-	-	6
Total		14	11	12	10	3	10	2	62

Table 2 Number of years of data available for each contaminant according to area and species.

Area	Country	Species	Contaminant						
			Cr	Cu	Hg	Ni	Pb	Zn	PCB
31F2	Belgium	Cod	7	8	8	6	6	8	3
31F2	Belgium	Flounder	6	8	8	7	7	8	3
31F2	Belgium	Sole	4	5	5	5	3	5	-
36E5	Belgium	Sole	4	5	5	5	5	5	-
40F7	Denmark	Plaice	-	-	3	-	-	-	-
41F7	Denmark	Plaice	-	-	5	-	-	-	-
43F8	Denmark	Plaice	-	-	5	-	-	-	-
44F9	Denmark	Plaice	-	-	5	-	-	-	-
36F8	Fed.Rep.of Germany	Flounder	-	-	3	-	-	-	-
47G0	Norway	Cod	-	-	5	-	-	-	-
48G0	Norway	Cod	-	-	4	-	-	-	-
48G0	Norway	Flounder	-	-	3	-	-	-	-
40G5	Sweden	Herring	-	-	6	-	-	-	7
42G8	Sweden	Cod	-	-	5	-	-	-	-
43G1	Sweden	Cod	-	-	6	-	-	-	-
43G1	Sweden	Dab	-	-	5	-	-	-	5
43G1	Sweden	Herring	-	-	6	-	-	-	6
46G1	Sweden	Flounder	-	-	6	-	-	-	6
46G7	Sweden	Herring	-	-	6	-	-	-	7
50G8	Sweden	Herring	-	-	6	-	-	-	8
60H2	Sweden	Herring	-	-	6	-	-	-	8
34F2	United Kingdom	Cod	-	3	4	-	-	4	-
34F2	United Kingdom	Plaice	-	3	4	-	-	4	-
35E6	United Kingdom	Whiting	-	3	4	-	-	4	-
35E6	United Kingdom	Plaice	-	3	4	-	-	4	-

3 DESCRIPTION OF THE STATISTICAL ANALYSIS

Before discussing the results of the various analyses, it may be useful to provide a basic description of the underlying concepts and introduce the terminology used in the subsequent sections. This section, therefore, gives a brief overview of the analysis applied to the data; a full description of the statistical procedure is presented in Annex 3 (this description has previously been published as Annex 1 to the 1986 Report of the ICES Advisory Committee on Marine Pollution, ICES Cooperative Research Report No. 142).

The underlying principle is that where contaminant levels are affected by biological variations, the mean contaminant levels for each sampling occasion must be adjusted to refer to common values of the biological (co)variables. These adjusted contaminant levels can then be compared.

If contaminant concentration y is linearly related to a covariate x, the estimated mean concentration calculated at a suitably chosen reference value, x', is given by

$$y = \bar{y} - b(\bar{x} - x')$$

where $\bar{y}$ and $\bar{x}$ are the observed averages in the sample. (In practice, we often find that it is log(y) which is linearly related to x.)

In accordance with the trend monitoring guidelines (Annex 2), the trend data include information on a range of biological variables (length, weight, age, sex, etc.), all of which may contribute towards the variation in contaminant levels, and which should be taken into account when comparing annual estimates of average contaminant concentrations. The relationship between these (co)variables and contaminant levels will, however, be considerably simplified if one covariable can be used to represent all of the covariables. For example, if contaminant concentration varies with the size of a fish, any one of the variables length, weight or age might prove to be satisfactory representatives of size.

Length is an obvious candidate for the role of a 'primary biological covariable', as discussed in C.M. 1986/E:39, Annex 4. It has a number of advantages. Being a relatively straightforward parameter to measure, length is more frequently reported than, e.g., age. Furthermore, the CMP trend monitoring guidelines support <u>length-stratified sampling schemes</u> as a means of improving the precision of the estimated yearly mean concentrations. The success of length in this role is discussed in Section 4.2.2, below.

In summary, the analysis provides a systematic approach for investigating the data using <u>multiple linear regression</u> (MLR), and for estimating the annual mean contaminant concentrations along with a measure of their precision. These estimates provide the basis for assessing the temporal trends of the contaminant levels in a given area for a given matrix (species/tissue combination).

A schematic diagram of the complete statistical procedure is given in Figure 2. Annex 3 provides a full description. Briefly, the procedure consists of:

1) screening the data, detecting and treating outliers, and confirming the linearity of the relationships;

2) fitting a series of models to:

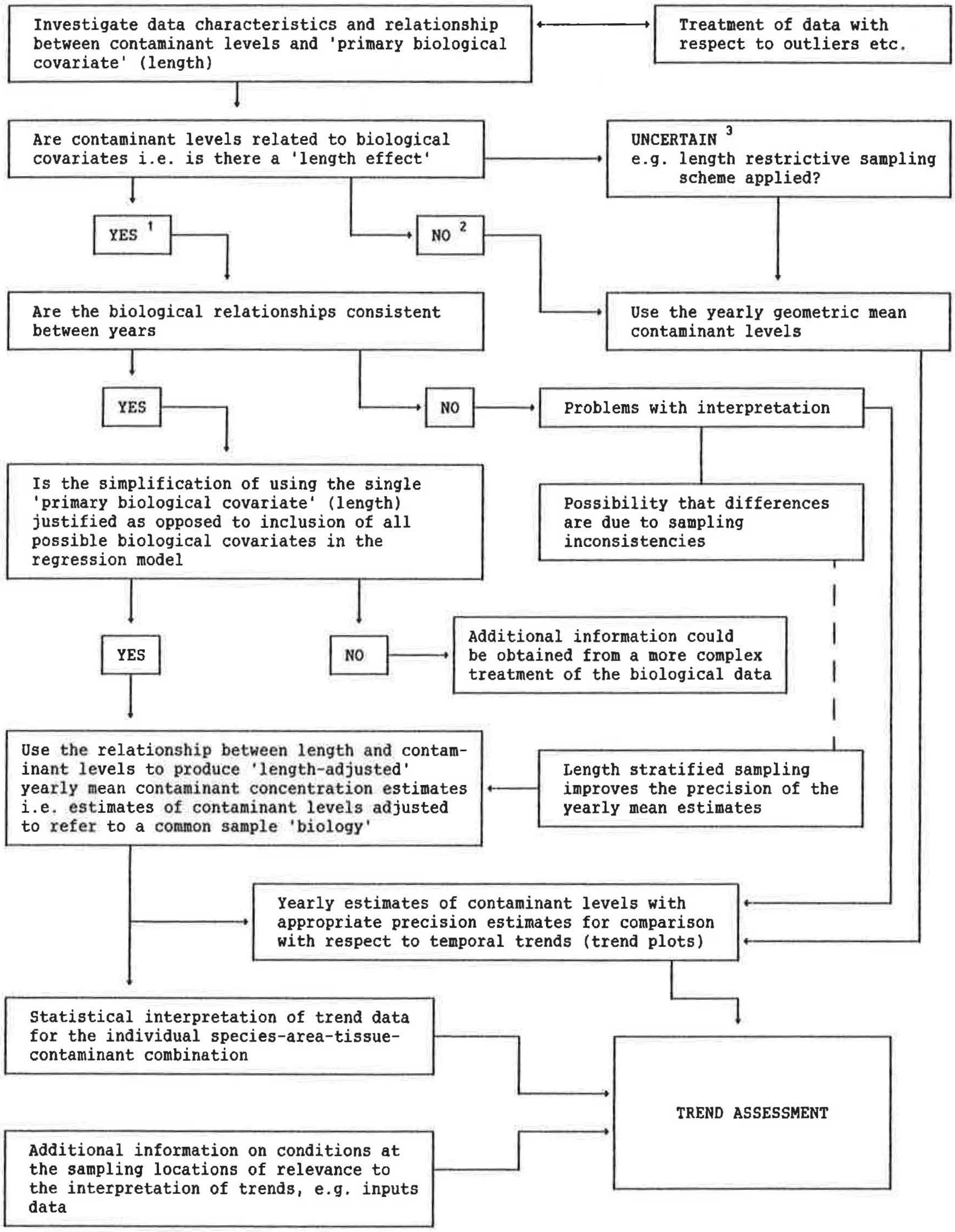
   - define the relationship between biological variables and contaminant levels and check the consistency of these relationships between years;

   - assess the validity and the consequences of using the single biological variable (length) in the regression models as opposed to the full set of available biological variables;

   - assess the nature of any trends in contaminant levels;

3) provide yearly estimates of mean contaminant concentrations along with a measure of their precision; if appropriate, the estimates are normalised for biological effects, i.e., 'length-adjusted' to refer to a fish of a particular length (size).

Figure 2 SCHEMATIC DIAGRAM OF THE STATISTICAL ANALYSIS PROCEDURE.



[1,2,3] - In the generalised statistical procedure presented in the diagram, three possible alternative courses of action are identified. In the specific example of the analysis of the ICES CMP data sets detailed in this report, different courses employed for the different data sets were as follows:

[1] - YES : for Hg, Pb and Zn
[2] - NO : for Cu, Cr, Ni, PCB
[3] - UNCERTAIN : for Hg in herring

4 RESULTS

4.1 Initial Analysis using the Six-Model Stepwise Regression Approach

The six-model stepwise statistical approach described in Annex 3 was applied in the first instance to all available data sets (species-area-contaminant combinations). There were 53 data sets for metals and 9 for PCBs.

At first sight, the results of the analysis were disappointing. For many of the data sets there was a suggestion that: (a) more covariates should be included in the model, (b) length (the selected primary covariate) is an unnecessary covariate, or (c) there is a length covariate effect, but this varied from year to year. There was no obvious grouping of species or contaminants which might allow these results to be given a meaningful biological interpretation.

A large number of the data sets revealed anomalous observations which, when checked against the original data submissions, were not transcription errors and were judged to be outliers. The analyses for these data sets were repeated with the outlying observations excluded. In seven of the twenty-three repeat analyses, the results of the analyses were changed in some respect. However, after outlier deletion, in a number of cases questions still remained about the suitability of the analysis in that either:

i) the relationship between the primary covariate (length) and log-contaminant concentration was not significant (but in no instance was it not significant for all cases of either a single species or a particular contaminant, suggesting a lack of a chemical or biological rationale for these observations); and/or

ii) the length regression coefficients (i.e. contaminant - length relationship) varied between years; and/or

iii) the model using all covariates with separate regression coefficients in each year (model 5) was significantly better than the model using only length with the same regression coefficient in each year (model 2).

This suggested that the model using only the primary covariate (length) with the same regression coefficient in each year (model 2) may not be appropriate for all species and contaminants. However, as exemplified in Table A (Annex 4), the CMP sampling guidelines have not always been followed. Thus, it may be not that model 2 does not fit the data, but rather that the structure of the data is inadequate for fitting model 2.

4.2 Evaluation of the Initial Analysis

This question was explored by an extended analysis of the data sets, the details and results of which are reported in C.M. 1987/E:24, Annex 3.2. The conclusions of that study are presented below.

4.2.1 Are more covariates necessary?

The question of whether additional information could be obtained from a more complex statistical analysis, involving the inclusion of other biological covariates in addition to length, is addressed by a comparison of two alternative regression models; one where only the length covariate is included (with the same regression slope in each year - model 2), and a second where all available covariates are included (with different regression coefficients in each year -

model 5). The decrease in the residual standard deviation of model 5 relative to that of the simpler model 2 provides an indication of the extent to which the inclusion of additional covariates might improve the analysis.

The results obtained from the comparisons of these two models showed that, in most cases, the model 5 residual standard deviation was decreased by less than 10%; in only two cases was the decrease greater than 20%. It was concluded, therefore, that the improvement in the residual standard deviation of model 5 (all available covariates) over model 2 (length covariate only) may not be too important.

If covariates which are related to contaminant level are not included in the model, then the fitted relationship between, for example, length and contaminant level will be biased. However, there is also the danger that if a large pool of potential covariates is available, some of them will be selected even when they are unrelated to contaminant level. This is made worse both when a stepwise regression approach is used, and when the covariates are correlated, in which case the probability of selecting the correct covariates is low. It is clear that in the analysis of contaminants in fish muscle tissue, a number of the available covariates, such as length, weight, age, etc., will be mutually correlated as they are related to fish size and growth.

Although approximately half of the data sets showed that, statistically, model 5 was significantly better than model 2, the argument in favour of routinely fitting model 5 is not strong, especially when the poor quality of much of the data is taken into account. Considering the advantages of the simplicity of application and interpretation of model 2, the small reduction in precision and the small distortion in the estimated trends resulting from the use of model 2 are acceptable. The disadvantage is that a somewhat longer time series may be needed to detect a significant trend.

It was concluded that the suggestion that more covariates should be included could, with reasonable justification, be ignored. It is unwise to build complex multiple regression models on statistical evidence alone and, in any case, the indications were that the potential improvement in precision would be small in many cases, particularly those where the data structure was poor.

4.2.2 Do contaminant levels need to be adjusted for length?

The inconsistency of the length effect on contaminant concentrations in fish muscle tissue is a more serious consideration in relation to the application of the six-model stepwise regression analysis. The analysis of covariance method using length as a primary covariate was applied to contaminants and species for which it was not developed, but it is not clear from the results that any failure in the model is associated with any particular species or contaminant.

The CMP length-stratified sampling protocol was designed to ensure that the distribution of lengths within years is wide, and the distribution of mean lengths between years is narrow. When the within-year length range is too narrow, it will not be possible to properly define the effect of length on contaminant levels. If the mean lengths vary between years, there may be spurious trends. There may also be apparent differences in the regression coefficients, arising solely from the poor structure of the data (Nicholson and Portmann, 1985).

In order to investigate further this aspect of the data, an analysis of the mean lengths from year to year for each species/area was conducted to identify poor data structure (cf. Tables 3 and 4). It should be noted that, of the data sets considered, the Swedish data sets, in particular the herring data, had been collected under a different sampling scheme whereby length variation had been deliberately controlled by selecting 2-3 year old, mainly female, fish. In general, where poor structure was indicated, this was not due to a large variation in the mean lengths between years, but to a very small variation of length within years.

Plots showing a graphical representation of the length structure of the various data sets are presented in the figures in Annex 4.

Table 4 shows the distribution of the within-year standard deviations of length (cm) and the standard deviation pooled over all years for each species/area.

Although changes in sample structure from year to year are undesirable, it is more important that the standard deviation of length should be large within each year in order to be able to define the log-contaminant concentration vs. length regression in a given year. For the Swedish data, where length variation has been restricted, the standard deviations are intentionally small, but in several other data sets the standard deviation is only a few centimetres. For some data sets (e.g., cod 31F2, cod 47G0), the spread is large for some years but small in others.

Clearly many of the data sets do not have the properties that the CMP guidelines for sampling were designed to achieve. The consequence of this will be that any relationship between contaminant level and length will not be clearly revealed for such sets. Statistical tests suggesting changes in the regression coefficients from year to year, or no length effect at all, could be misleading, simply a consequence of poor data structure.

The tests applied in the six-model procedure to assess model 2 are sensitive to data quality which, in the previous discussion, has been demonstrated to be poor. Thus, an alternative method for assessing the consistency and magnitude of the length effect, by looking at the empirical distributions of the estimated regression coefficients for metals, was conducted (cf. C.M. 1987/E:24, Annex 3.2, Section 5). The results of this alternative assessment of the length regression coefficients were successful to some extent. For example, for mercury in cod, there was a reasonably well-defined normal distribution of estimated regression slopes centered on 0.0026. The occasions when the length effect was not significant were seen to correspond to the lower tail of the normal distribution, which includes zero. For mercury in herring, however, the distribution of estimated regression coefficients was centred on a value which is not significantly different from zero. This may mean that there is no length effect for herring or, more likely, reflects the absence of length variation in the herring samples, which were all collected by Sweden according to the protocol used in the Baltic Sea.

On the basis of this alternative analysis, a very broad conclusion may be drawn, namely, that there is a length effect on log concentration for mercury (not proven for herring), lead and zinc, but not for chromium, nickel or copper in the following species: cod, whiting, flounder, sole, plaice and dab. It must be stressed that these conclusions are, with the exception of mercury, derived from the analysis of a very limited number of samples available and should not, therefore, be considered definitive outside the context of this report.

4.3 Revised Statistical Analysis

On the basis of the discussions in the previous sections, the six-model stepwise regression analysis, using length as a primary covariate, was applied to the data on mercury (for all species except herring), lead and zinc. The results from the application of this analysis are presented in the summary table, Table 5. Table 6(a) shows the resulting anti-logged length-adjusted mean log concentration values used to assess the trends for these contaminants.

In order to compare the contaminant level estimates for samples collected according to the CMP guidelines with those for samples where the length-restrictive sampling protocol had been applied, length adjustment to lengths appropriate to a mean length for 2-3 year old female fish was applied for the various species concerned. The lengths used are as follows: cod 425 mm; dab 235 mm; flounder 270 mm; herring 180 mm; plaice 265 mm; sole 280 mm; whiting 300 mm.

For the remaining contaminants, copper, nickel, chromium and PCB in fish muscle tissue, the trends were estimated by geometric means, the equivalent of the six-model analysis with no length adjustment. These results are presented in Table 6(b).

The detailed results of all the above-mentioned analyses are then presented for each sample series (i.e., species-area combination), beginning each new series with the data registration form describing the characteristics of the data supplied, followed by the plots pertaining to the contaminant data analysed in that sample series. Two types of plot are presented; the plot on the upper half of the page shows the yearly estimates of concentration levels, with appropriate precision estimates, for comparison with respect to temporal trends (the so-called 'trend plot'). The plot on the lower half of the page shows the regression lines, relating the natural logarithm of the contaminant concentration and fish length, for each year of data, i.e. the results of model 1 in the six-model statistical analysis. The lines are plotted within the length range of the fish sampled in each year.

An overview page precedes this presentation of the results, providing an explanation of the symbols, abbreviations and conventions applied on the data registration forms and the plots.

Table 3 Mean lengths by years (cm), pooled mean length and F, the ratio of the between years error mean square of length and the within-year error mean square. An asterisk denotes that F exceeded the 95% critical value the variance ratio distribution.

Species	Area	Country	Mean fish length (cm)								$\bar{l}$	F
			1978	1979	1980	1981	1982	1983	1984	1985		
Cod	31F2	Belgium	52	25	38	53	57	51	37	52	46.3	13.7*
Flounder	31F2	Belgium	34	32	34	31	30	29	28	29	30.8	4.2*
Sole	31F2	Belgium		28	30	31	28	27			20.6	4.0*
Sole	36E5	Belgium		31	32	31	32	30			31.1	0.6
Plaice	40F7	Denmark				25	27	26			26.2	0.8
Plaice	41F7	Denmark				27	30	27	33	31	29.6	7.8*
Plaice	43F8	Denmark		38		27		30	37	35	34.1	13.0*
Plaice	44F9	Denmark		27		28	20		33	30	29.5	6.0*
Flounder	36F8	FRG						28	26	27	27.5	5.8*
Cod	47G0	Norway				51	53	52	51	56	52.3	0.5
Cod	48G0	Norway				44	52		44	35	43.9	17.1*
Flounder	48G0	Norway				30		27		25	27.7	27.6*
Herring	40G5	Sweden			19	16	20	18	16	20	18.1	50.5*
Cod	42G8	Sweden				38	32	33	33	32	33.7	19.7*
Cod	43G1	Sweden			30	28	29	30	31	40	31.5	65.2*
Dab	43G1	Sweden				25	27	24	27	25	25.6	16.0*
Herring	43G1	Sweden			20	18	19	18	21	20	19.2	31.9*
Flounder	46G1	Sweden			33	21	32	23	32	23	27.8	72.0*
Herring	46G7	Sweden			19	21	23	10	20	20	20.2	61.3*
Herring	50G8	Sweden			18	18	18	18	18	16	17.9	21.8*
Herring	60H2	Sweden			16	16	17	16	16	18	16.4	22.0*
Cod	34F2	UK					53	48	49	50	50.4	0.7
Plaice	34F2	UK					41	35	34	35	36.1	3.4*
Whiting	35E6	UK					24	24	23	23	23.4	0.1
Plaice	35E6	UK					24	24	24	24	23.9	0.1

Table 4 Standard deviation of length (cm) by years and pooled standard deviation.

Species	Area	Country	1978	1979	1980	1981	1982	1983	1984	1985	S_{pooled}
Cod	31F2	Belgium	18	7	5	7	11	12	16	14	13
Flounder	31F2	Belgium	5	4	4	4	5	6	6	5	5
Sole	31F2	Belgium		2	3	4	5	4			4
Sole	36E5	Belgium		5	5	5	4	5			5
Plaice	40F7	Denmark				2	5	4			4
Plaice	41F7	Denmark				3	4	5	5	4	5
Plaice	43F8	Denmark		6		2		4	6	5	5
Plaice	44F9	Denmark		1		2	4		7	4	4
Flounder	36F8	FRG						2	2	3	2
Cod	47G0	Norway				3	12	16	9	9	11
Cod	48G0	Norway				13	11		7	3	9
Flounder	48G0	Norway				11		3		1	4
Herring	40G5	Sweden			1	1	1	1	1	1	1
Cod	42G8	Sweden				4	4	2	1	1	2
Cod	43G1	Sweden			1	1	1	3	1	0	3
Dab	43G1	Sweden				2	1	1	2	1	2
Herring	43G1	Sweden			1	1	1	1	1	0	1
Flounder	46G1	Sweden			2	2	3	2	2	2	3
Herring	46G7	Sweden			1	1	1	1	0	1	1
Herring	50G8	Sweden			1	1	1	1	0	1	1
Herring	60H2	Sweden			1	1	1	1	0	1	1
Cod	34F2	UK					15	12	14	12	13
Plaice	34F2	UK					10	8	8	9	9
Whiting	35E6	UK					6	6	5	6	6
Plaice	35E6	UK					6	5	6	6	6

Table 5 OVERVIEW OF STATISTICAL ANALYSES OF CONTAMINANT TRENDS IN FISH MUSCLE TISSUE

Species	Area	Contaminant	Number of outliers	Is length covariate necessary?	Significant differences between regression coefficients of length in each year	% Increase in res. st. dev. of model 2 versus model 5: All data	% Increase in res. st. dev. of model 2 versus model 5: Outliers excluded	Significant differences in length adjusted contaminant levels between years	Evidence of a linear trend	Is linear trend a good fit?
Cod	31F2	Hg	1	Yes	No	2	4	Yes	Yes	No
Flounder	31F2	Hg		Yes	No	10[1]		Yes	No	-
Sole	31F2	Hg		Yes	No	15[1]		Yes	Yes	No
Sole	36E5	Hg		No	No	6		No	-	-
Plaice	40F7	Hg	1	Yes	Yes	20[1]	3	Yes	Yes*	No*
Plaice	41F7	Hg	3	Yes	Yes*	6	11[1]	Yes	Yes	No
Plaice	43F8	Hg	2	Yes	Yes	8[1]	7	Yes	No	-
Plaice	44F9	Hg	4	Yes*	Yes*	6	6	Yes	No	-
Flounder	36F8	Hg		Yes	No	1		Yes	Yes	No
Cod	47G0	Hg	1	Yes	Yes*	0	9[1]	Yes	No	-
Cod	48G0	Hg	1	Yes	No	9[1]	11[1]	Yes	Yes	-
Flounder	48G0	Hg		No	Yes	20[1]		Yes	No	-
Cod	42G8	Hg		Yes	No	18[1]		Yes	Yes	No
Cod	43G1	Hg		Yes	No	0		Yes	Yes	No
Dab	43G1	Hg		Yes	No	8[1]		Yes	Yes	No
Flounder	46G1	Hg		No	No	12[1]		Yes	Yes	Yes
Cod	34F2	Hg	1	Yes	No	0	2	Yes	Yes	No*
Plaice	34F2	Hg		Yes	No	19[1]		Yes	No	-
Whiting	35E6	Hg	3	Yes	No	7[1]	4	No	-	-
Plaice	35E6	Hg	3	Yes	No	43[1]	30[1]	Yes	Yes	No
Cod	31F2	Pb	1	No	No	3	1	Yes	Yes	No
Flounder	31F2	Pb	1	Yes	No	7[1]	1	Yes	Yes	No
Sole	31F2	Pb	1	Yes	No*	7	0	Yes	No	-
Sole	36E5	Pb		Yes	Yes	2		Yes	No	-
Cod	31F2	Zn	3	Yes	Yes	10[1]	1	Yes	Yes	No
Flounder	31F2	Zn		Yes	No	8[1]		Yes	Yes	No
Sole	31F2	Zn	1	No*	No	2	0	Yes	No	-
Sole	36E5	Zn	1	No*	Yes	8[1]	7[1]	Yes	Yes	Yes
Cod	34F2	Zn	1	No	No	8[1]	8[1]	Yes	Yes	No
Plaice	34F2	Zn		Yes	Yes	6		No	-	-
Whiting	35E6	Zn	2	Yes	Yes*	4	10[1]	No	-	-
Plaice	35E6	Zn		Yes	No	0		No	-	-

[1] Increase in s.d. is significant

* Results given are for outlier deleted data, an asterix denotes that the result changes if outliers are included.

Table 6(a) YEARLY MEAN CONCENTRATION VALUES AS DERIVED FROM STATISTICAL ANALYSES OF FISH MUSCLE TISSUE DATA

Antilogged adjusted mean log concentrations for outlier deleted data, as mg/kg wet weight.

Species	Area	Cont.	Mean length[1] A	Mean length[1] B	Average sample size	% Residual standard deviation	Year 1978	1979	1980	1981	1982	1983	1984	1985
Cod	31F2	Hg[2]	464	425	22	35	0.174	0.120	0.150	0.079	0.082	0.073	0.111	0.073
Flounder	31F2	Hg	308	270	22	53	0.163	0.190	0.275	0.203	0.145	0.201	0.157	0.189
Sole	31F2	Hg	287	280	22	34		0.117	0.246	0.220	0.104	0.102		
Sole	36E5	Hg	311	280	22	48		0.312	0.252	0.213	0.288	0.287		
Plaice	40F7	Hg[2]	262	265	28	27				0.041	0.037	0.048		
Plaice	41F7	Hg[2]	297	265	23	24				0.041	0.053	0.066	0.058	0.061
Plaice	43F8	Hg[2]	340	265	20	38		0.039		0.070		0.046	0.041	0.047
Plaice	44F9	Hg[2]	296	265	20	32		0.025		0.043	0.042		0.037	0.027
Flounder	36F8	Hg	276	270	32	37						0.137	0.194	0.186
Cod	47G0	Hg[2]	522	425	19	38				0.051	0.074	0.094	0.086	0.059
Cod	48G0	Hg[2]	440	425	22	31				0.040	0.074		0.134	0.115
Flounder	48G0	Hg	278	270	19	34				0.056		0.136		0.096
Cod	42G8	Hg	338	425	20	31				0.032	0.032	0.053	0.057	0.036
Cod	43G1	Hg	316	425	22	32			0.049	0.069	0.078	0.116	0.087	0.067
Dab	43G1	Hg	257	235	23	39				0.058	0.054	0.061	0.065	0.113
Flounder	46G1	Hg	278	270	16	56			0.016	0.027	0.030	0.030	0.034	0.041
Cod	34F2	Hg[2]	503	425	26	26					0.070	0.076	0.060	0.057
Plaice	34F2	Hg	362	265	25	43					0.031	0.050	0.041	0.034
Whiting	35E6	Hg[2]	235	300	26	30					0.182	0.205	0.178	0.188
Plaice	35E6	Hg[2]	242	265	24	26					0.116	0.141	0.118	0.088
Cod	31F2	Pb[2]	446	425	22	44		0.041	0.022		0.032	0.032	0.017	0.080
Flounder	31F2	Pb[2]	304	270	22	58		0.026	0.054	0.018	0.069	0.019	0.030	0.087
Sole	31F2	Pb[2]	276	280	23	66		0.027			0.048	0.017		
Sole	36E5	Pb	311	280	22	64		0.145	0.239	0.051	0.151	0.190		
Cod	31F2	Zn[2]	464	425	21	20	5.91	4.58	4.42	4.05	3.65	4.51	4.74	4.00
Flounder	31F2	Zn	308	270	22	42	17.0	6.71	9.49	11.0	6.36	9.13	8.47	8.03
Sole	31F2	Zn[2]	289	280	22	12		4.83	4.53	5.11	4.89	4.98		
Sole	36E5	Zn[2]	311	280	22	12		4.51	4.72	4.95	4.62	5.08		
Cod	34F2	Zn[2]	503	425	26	6					4.39	3.42	3.17	3.39
Plaice	34F2	Zn	362	265	25	18					4.45	4.46	4.33	4.39
Whiting	35E6	Zn[2]	235	300	26	14					3.32	3.11	3.06	3.28
Plaice	35E6	Zn	242	265	25	21					4.69	5.14	5.28	4.95

[1] Mean lengths: A - mean fish length in data set (species/area/contaminant - all years)
B - mean length used in calculation of length adjusted mean concentrations

[2] denotes data sets where outliers were identified

Table 6(b) YEARLY MEAN CONCENTRATION VALUES AS DERIVED FROM STATISTICAL ANALYSES OF FISH MUSCLE TISSUE DATA

Geometric mean concentrations for outlier deleted data, all metals as mg/kg wet weight, PCBs as mg/kg lipid weight.

Species	Area	Cont.	Mean length A	Average sample size	% Residual standard deviation	Year							
						1978	1979	1980	1981	1982	1983	1984	1985
Cod	31F2	Cr	456	22	48	0.156	0.125	0.019		0.028	0.012	0.184	0.145
Flounder	31F2	Cr	304	23	46	0.226	0.145			0.023	0.237	0.262	0.135
Sole	31F2	Cr	280	22	43		0.184	0.086		0.037	0.126		
Sole	36E5	Cr	311	22	40		0.067	0.046		0.020	0.269		
Cod	31F2	Cu[2]	464	22	22	0.325	0.328	0.273	0.206	0.254	0.265	0.405	0.410
Flounder	31F2	Cu[2]	308	21	25	0.440	0.396	0.303	0.335	0.337	0.331	0.409	0.488
Sole	31F2	Cu[2]	287	22	27		0.393	0.374	0.253	0.421	0.329		
Sole	36E5	Cu	311	22	20		0.223	0.246	0.242	0.266	0.290		
Cod	34F2	Cu	492	25	29						0.323	0.142	0.274
Plaice	34F2	Cu	346	25	34						0.210	0.121	0.207
Whiting	35E6	Cu	238	25	27						0.296	0.185	0.311
Plaice	35E6	Cu	241	25	33						0.266	0.173	0.353
Herring	40G5	Hg	182	20	35			0.012	0.009	0.013	0.016	0.023	0.016
Herring	43G1	Hg	192	22	32			0.020	0.015	0.017	0.024	0.032	0.023
Herring	46G7	Hg	202	19	60			0.014	0.017	0.041	0.031	0.031	0.027
Herring	50G8	Hg	179	20	64			0.193	0.124	0.094	0.057	0.080	0.023
Herring	60H2	Hg	164	20	41			0.040	0.031	0.051	0.034	0.037	0.032
Cod	31F2	Ni[2]	446	22	26		0.363	0.179		0.111	0.098	0.078	0.028
Flounder	31F2	Ni[2]	304	22	43		0.394	0.213	0.022	0.106	0.106	0.092	0.039
Sole	31F2	Ni	287	22	49		0.302	0.063	0.017	0.079	0.076		
Sole	36E5	Ni	312	22	34		0.277	0.192	0.065	0.082	0.093		
Cod	31F2	PCB	478	23	28						3.43	7.36	3.37
Flounder	31F2	PCB	287	23	42						11.9	9.82	9.46
Herring	40G5	PCB	181	20	19		2.57	3.08	1.18	1.73	2.06	1.77	2.49
Dab	43G1	PCB	257	21	49				1.15	1.15	0.62	1.56	1.12
Herring	43G1	PCB[2]	192	22	34			1.18	1.00	0.67	1.18	0.73	0.57
Flounder	46G1	PCB[2]	283	18	49			3.07	1.59	2.60	1.82	1.36	3.64
Herring	46G7	PCB[2]	196	20	37	2.66		3.82	2.53	3.45	2.12	2.88	2.90
Herring	50G8	PCB	174	20	38	3.86	1.95	2.97	2.99	2.70	1.81	2.91	1.16
Herring	60H2	PCB	162	20	25	2.75	1.15	2.36	1.56	1.56	1.58	1.32	1.48

[1] Mean lengths: A - mean fish length in data set (species/area/contaminant - all years)

[2] denotes data sets where outliers were identified

DESCRIPTION OF ABBREVIATIONS, SYMBOLS, ETC., USED IN THE TABULAR AND GRAPHICAL PRESENTATIONS OF RESULTS

Data registration form example:

SPECIES: English (RUBIN) TISSUE : muscle				NOMINAL AREA: ICES Rectangle COUNTRY :				
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length				o	o	o	o	o
Weight				o	o	o	o	o
Age				2	o	o	o	
Sex				o	●	●	F	o
Tissue wt.								
Fat %				o	o			
Dry %				o	●	o	o	o
CONTAMINANTS								
Hg				o	o	o	o	o
Cd				<.005	o	o	<.005	o
Cu								
Pb								
Zn								
Cr								
Ni								
PCB				o	<.05	<.05	<.05	<.05
SAMPLING								
sampling periods				Dec	Sept	Dec	Dec	Dec
sampling locations				XXAX	XXAX	XXAX	XXAX	XXAX
number of specimens				20	25	25	25	25

o : observations reported for all specimens.

● : observations reported, but missing for some specimens.

F : in the 'sex' field indicates that all specimens in that year were female.

: a numeric entry (e.g. '2') in the biological data record indicates that all specimens in that year had the same value (the value printed) for that parameter.

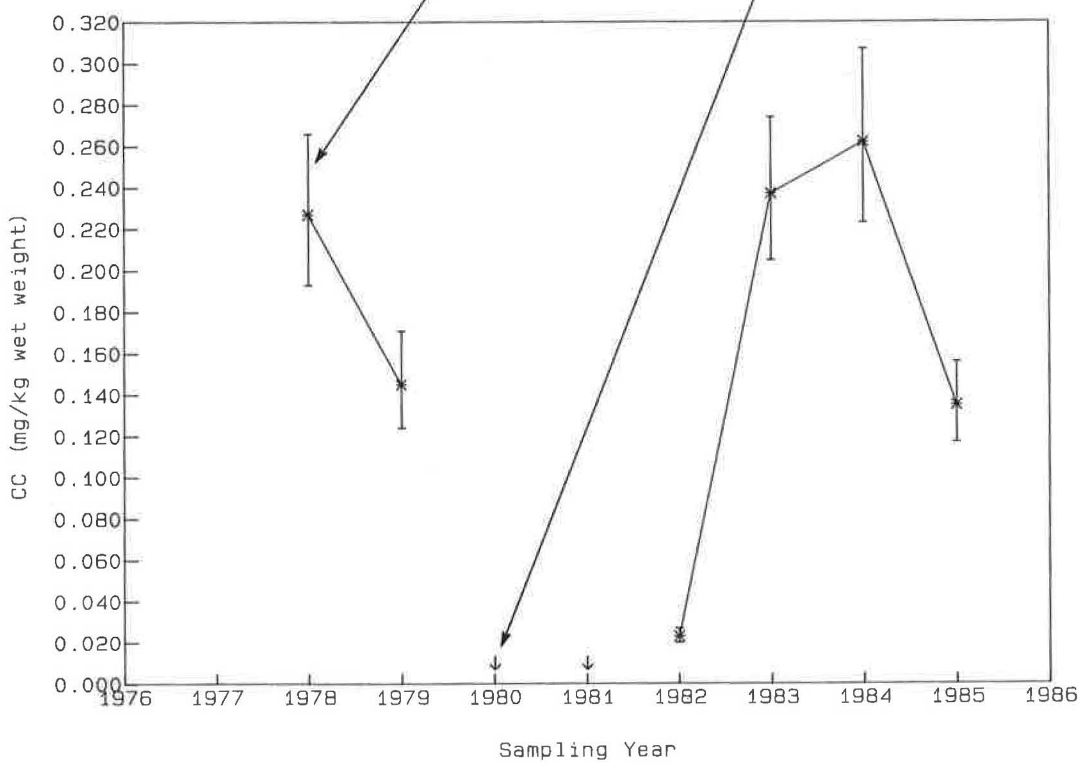
: a 'less than' value (e.g. '<.05') in the contaminant data record indicates that 20% or more of the values for that year were reported as '<' the value indicated. The data for these years were not included in the statistical analyses but are represented by a (↓) symbol on the 'trend plots'.

'Trend plot' example:

(GM) : estimates based on yearly geometric mean contaminant levels, or
(LA) : estimates are length-adjusted yearly mean contaminant levels.

In either case, the 'bars' on the data points are the pairwise 95% significance bands.

(GM) Estimates of CC in fish muscle - species in area



SPECIES: Cod (GADU MOR) TISSUE : muscle	NOMINAL AREA: 31F2 COUNTRY : Belgium

DATA CHARACTERISTICS

BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length	o	o	o	o	o	o	o	o
Weight	o	o	o	o	o	o	o	o
Age	o	o	o	o	o	●	o	●
Sex	o	o	o	o		●	o	
Tissue wt.								
Fat %						o	o	o
Dry %								
CONTAMINANTS								
Hg	o	o	o	o	o	o	o	o
Cd		<.005	<.005	<.005	<.005	<.005	<.005	<.005
Cu	o	o	o	o	o	o	o	o
Pb		o	o	<.01	o	o	o	o
Zn	o	o	o	o	o	o	o	o
Cr	o	o	o	<.01	o	o	o	o
Ni		o	o	<.01	o	o	o	o
PCB						o	o	o
SAMPLING								
sampling periods	Dec	Nov	Sept	Nov	Dec	Dec	Apr	Dec
sampling locations	31F2	31F2	31F2	31F2	31F2	31F2	31F2	31F2
number of specimens	20	20	20	20	25	25	18	25

<u>Results of analyses:</u>

Chromium[1]; Copper; Nickel[1]; PCB

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

[1]The data originator has notified that, due to a change in the analytical methodologies for chromium and nickel, values for the period 1978-1979 are considered unreliable and should be rejected; values from 1980 onwards should be acceptable, but may be subject to rather high analytical errors.

Mercury

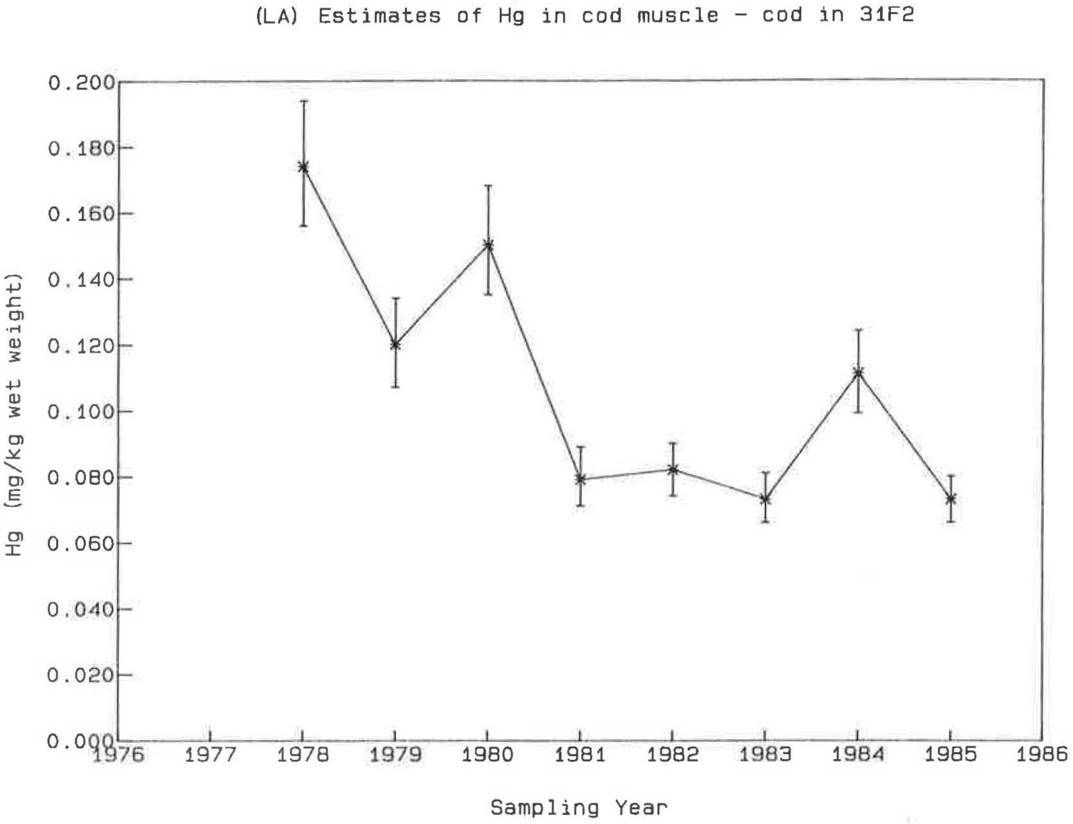
- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot).

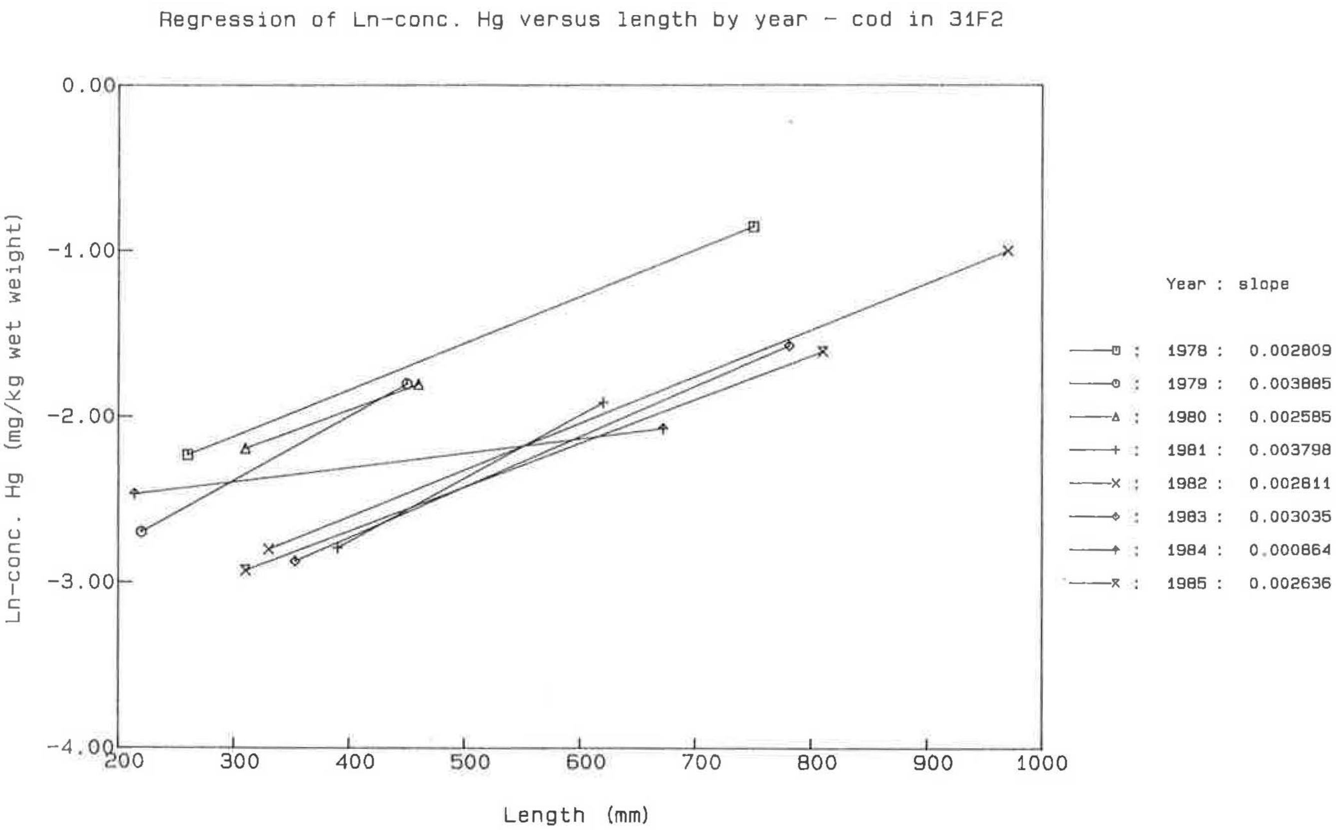
Lead

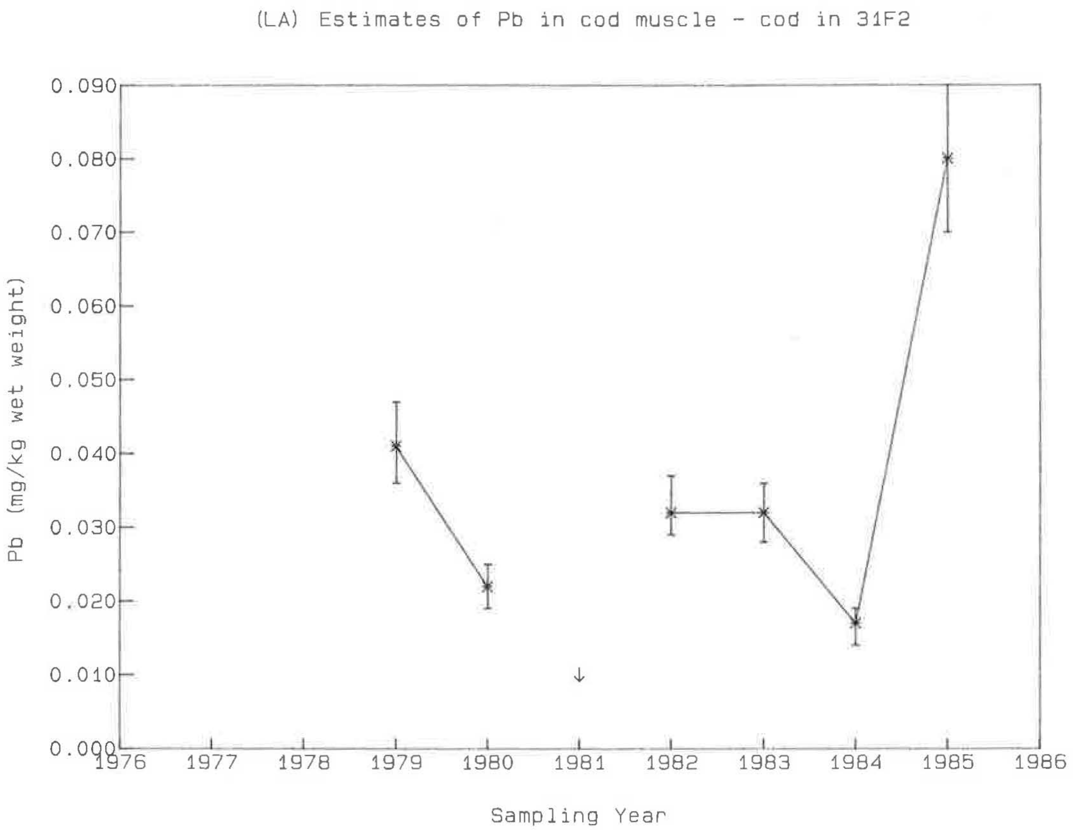
- Results do not indicate evidence of a significant relationship between length and the contaminant levels; length-adjustment was still, however, applied in the computation of yearly mean contaminant levels (refer to plot).

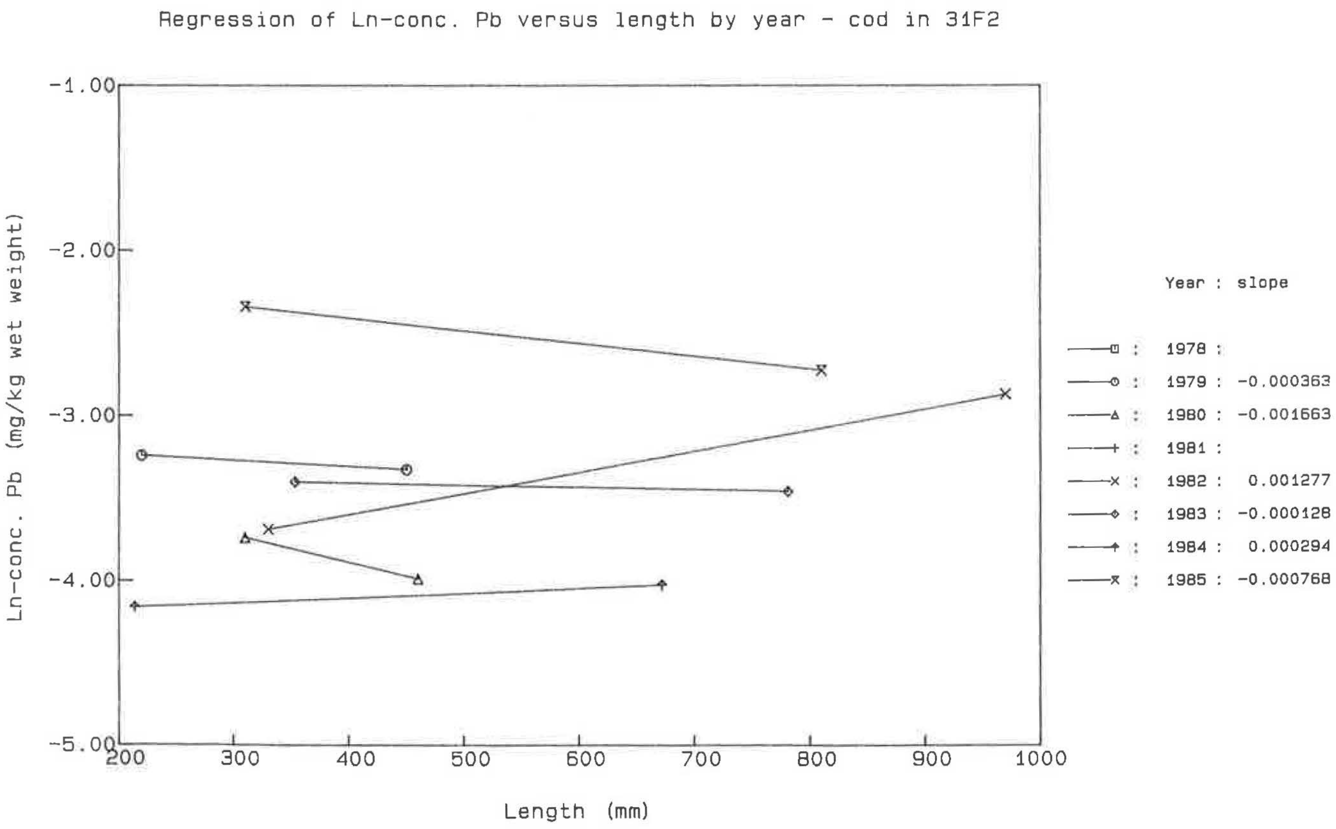
Zinc

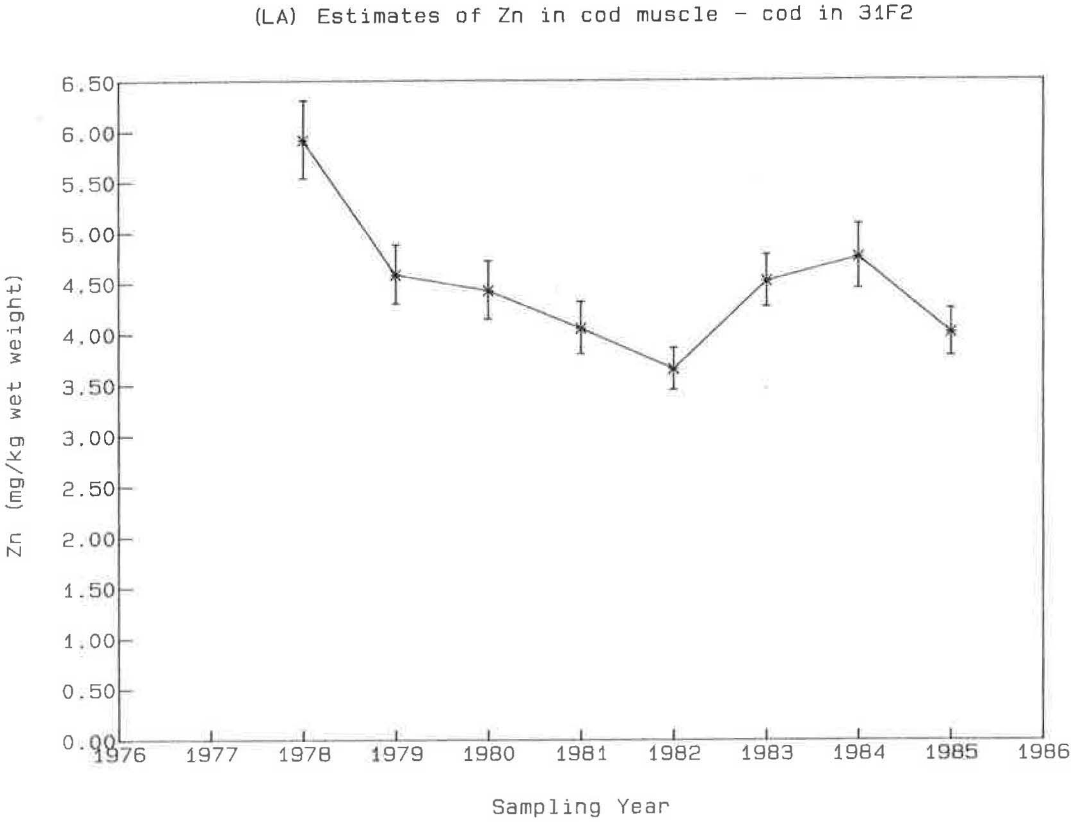
- Results show significant differences between years in the slopes of the linear relationships between contaminant level and length.

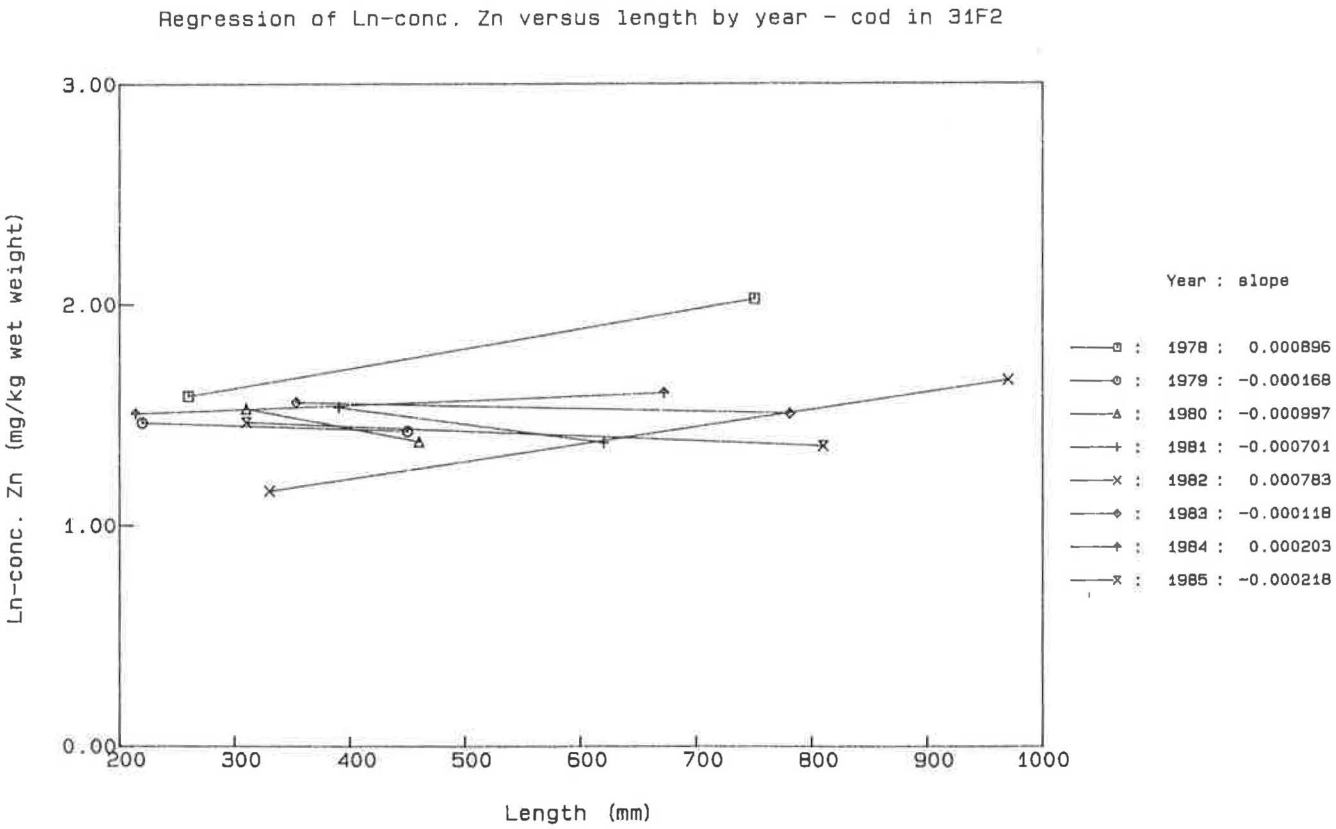

(LA) Estimates of Hg in cod muscle - cod in 31F2
Hg (mg/kg wet weight)
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Hg versus length by year - cod in 31F2
Ln-conc. Hg (mg/kg wet weight)
0.00
-1.00
-2.00
-3.00
-4.00
200
300
400
500
600
700
800
900
1000
Length (mm)
Year : slope
1978 : 0.002809
1979 : 0.003885
1980 : 0.002585
1981 : 0.003798
1982 : 0.002811
1983 : 0.003035
1984 : 0.000664
1985 : 0.002636

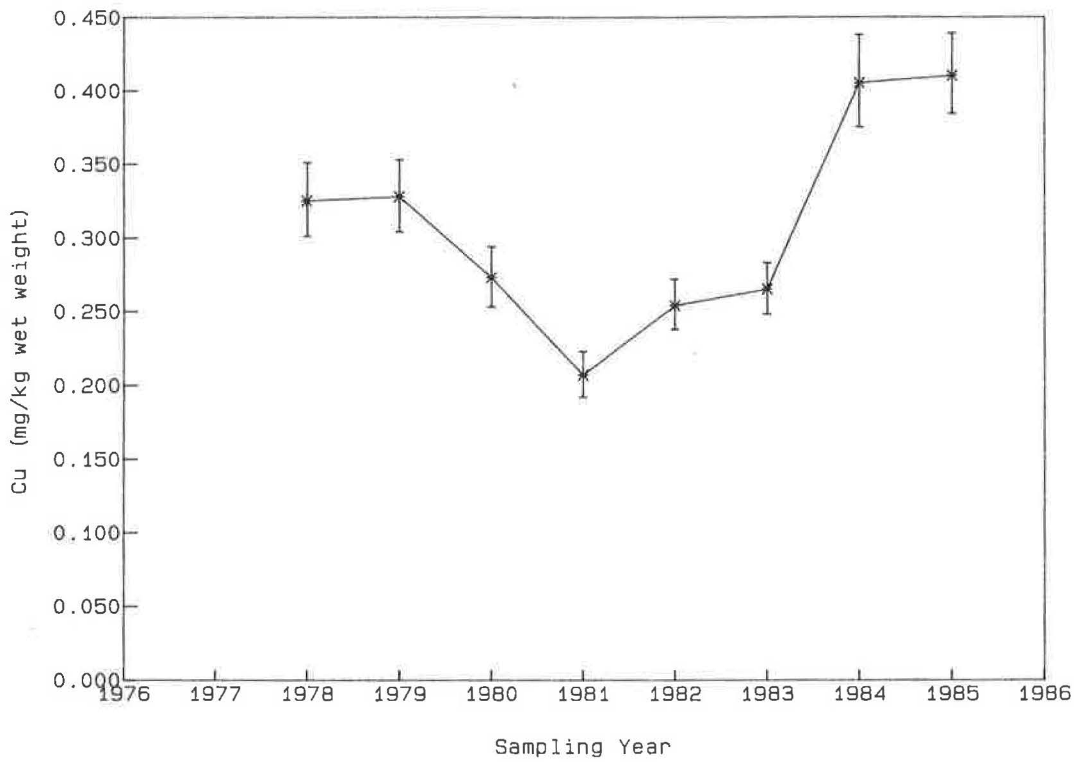

(LA) Estimates of Pb in cod muscle - cod in 31F2
Pb (mg/kg wet weight)
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Pb versus length by year - cod in 31F2
Ln-conc. Pb (mg/kg wet weight)
-1.00
-2.00
-3.00
-4.00
-5.00
200
300
400
500
600
700
800
900
1000
Length (mm)
Year : slope
1978 :
1979 : -0.000363
1980 : -0.001663
1981 :
1982 : 0.001277
1983 : -0.000128
1984 : 0.000294
1985 : -0.000768

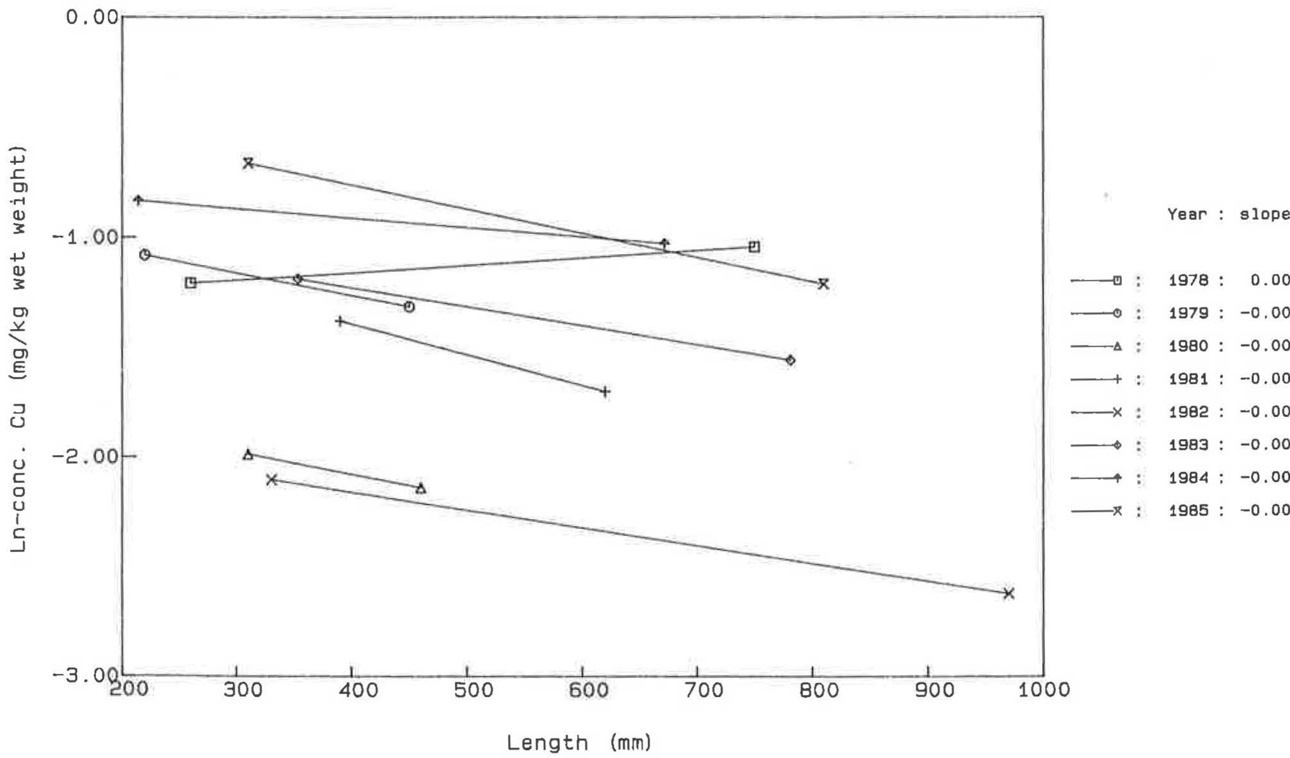

(LA) Estimates of Zn in cod muscle - cod in 31F2
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Zn (mg/kg wet weight)
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Zn versus length by year - cod in 31F2
3.00
2.00
1.00
0.00
Ln-conc. Zn (mg/kg wet weight)
200
300
400
500
600
700
800
900
1000
Length (mm)
Year : slope
1978 : 0.000896
1979 : -0.000168
1980 : -0.000997
1981 : -0.000701
1982 : 0.000783
1983 : -0.000118
1984 : 0.000203
1985 : -0.000218

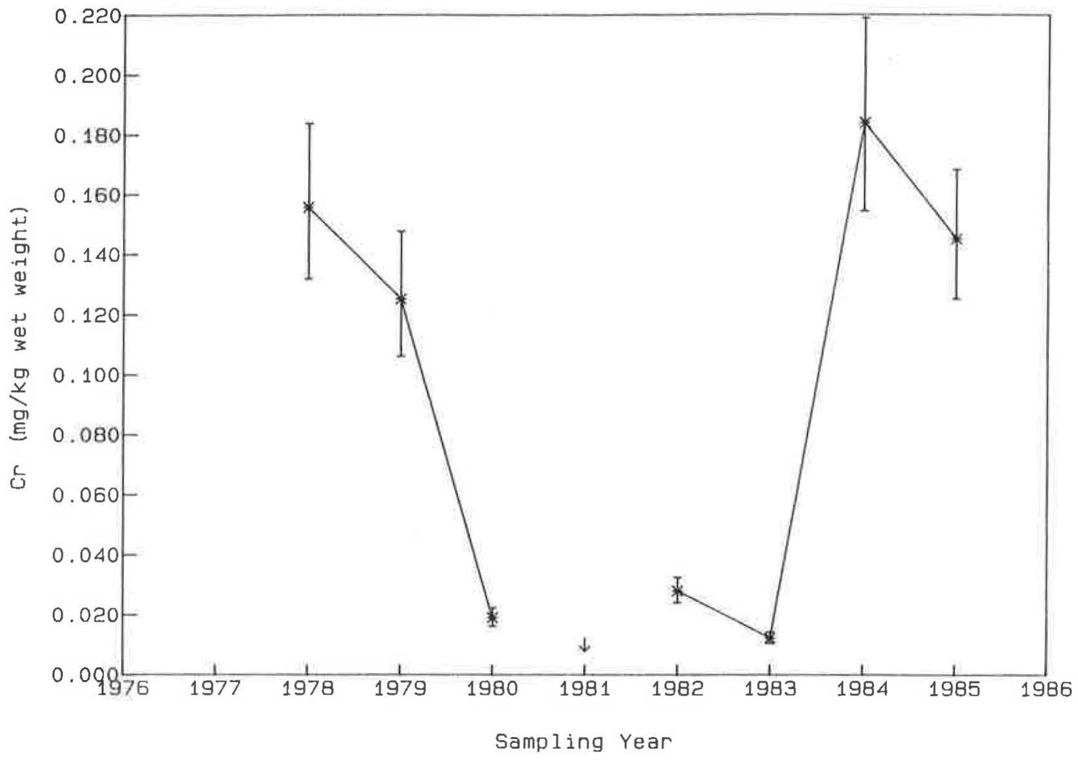
(GM) Estimates of Cu in cod muscle - cod in 31F2



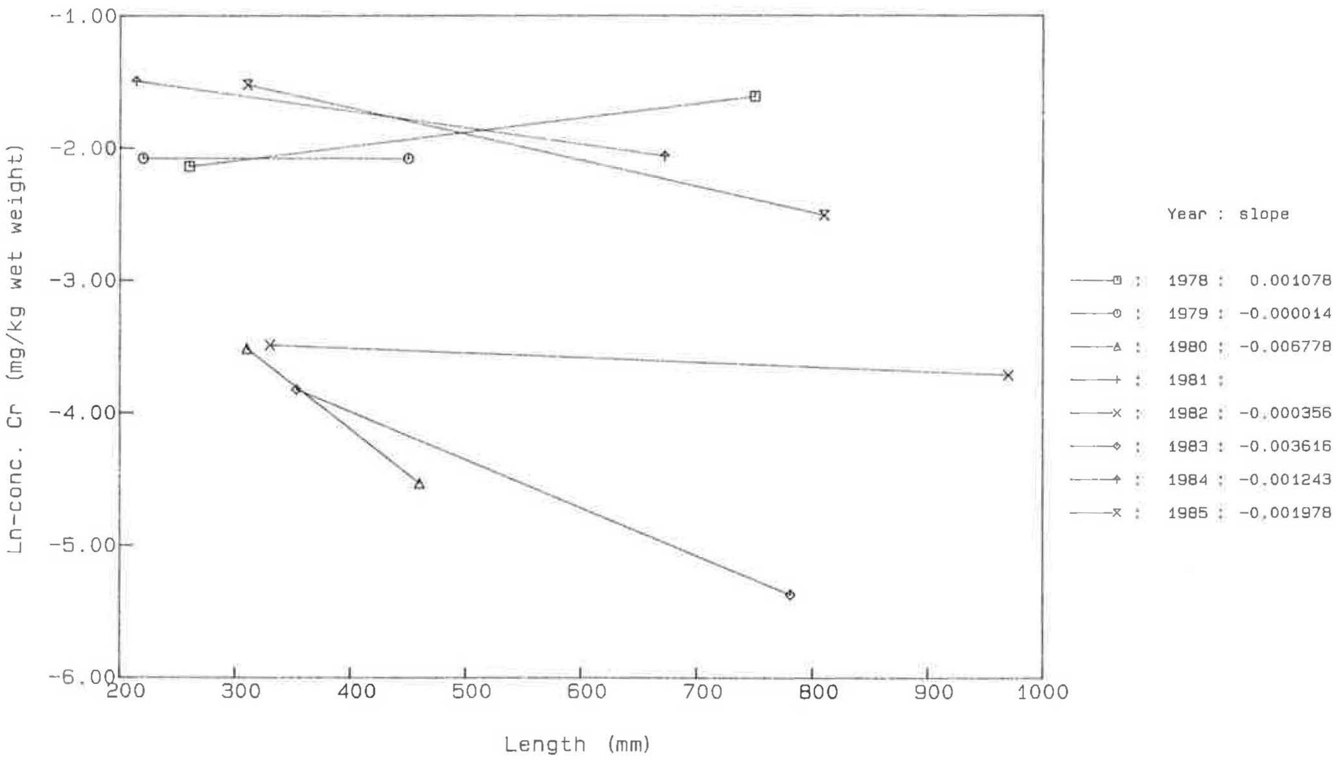
Regression of Ln-conc. Cu versus length by year - cod in 31F2



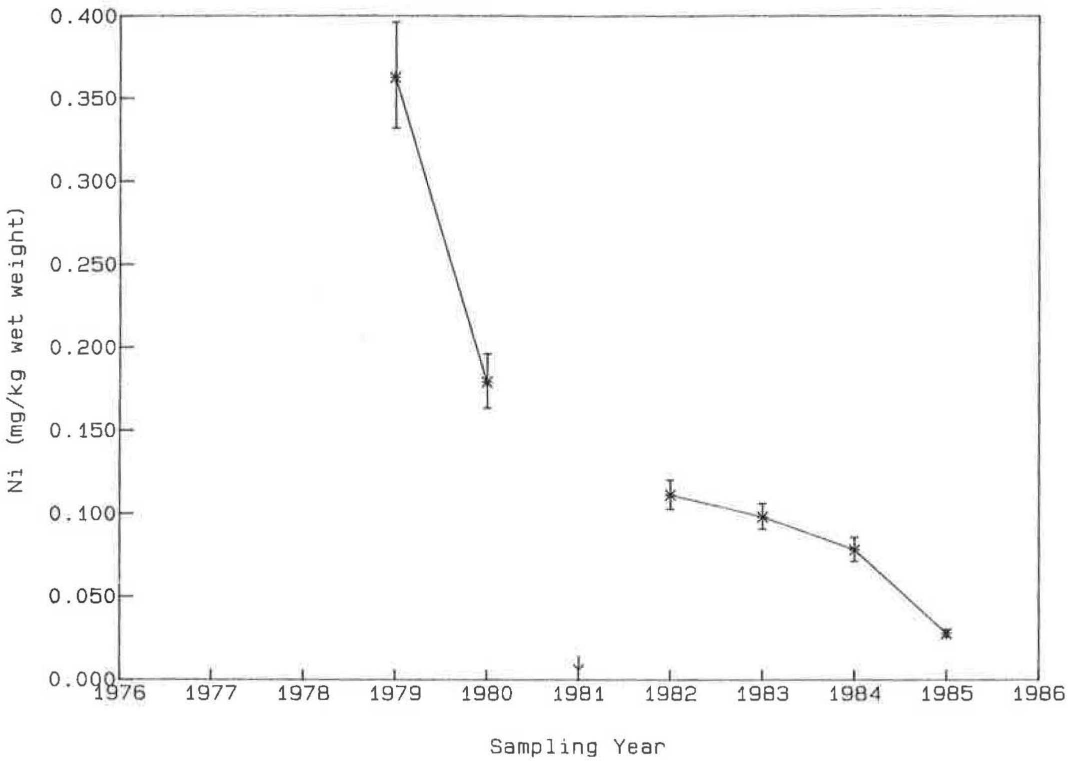
(GM) Estimates of Cr in cod muscle - cod in 31F2



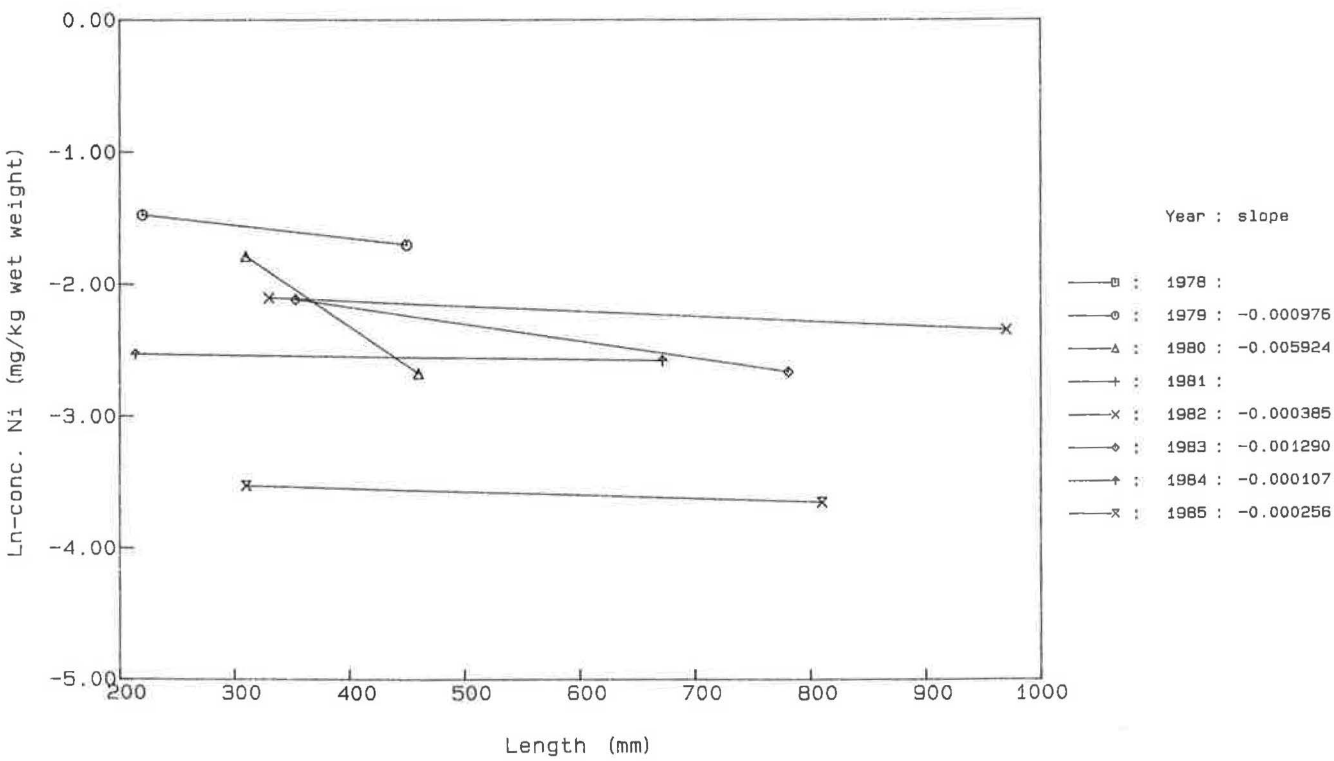
Regression of Ln-conc. Cr versus length by year - cod in 31F2



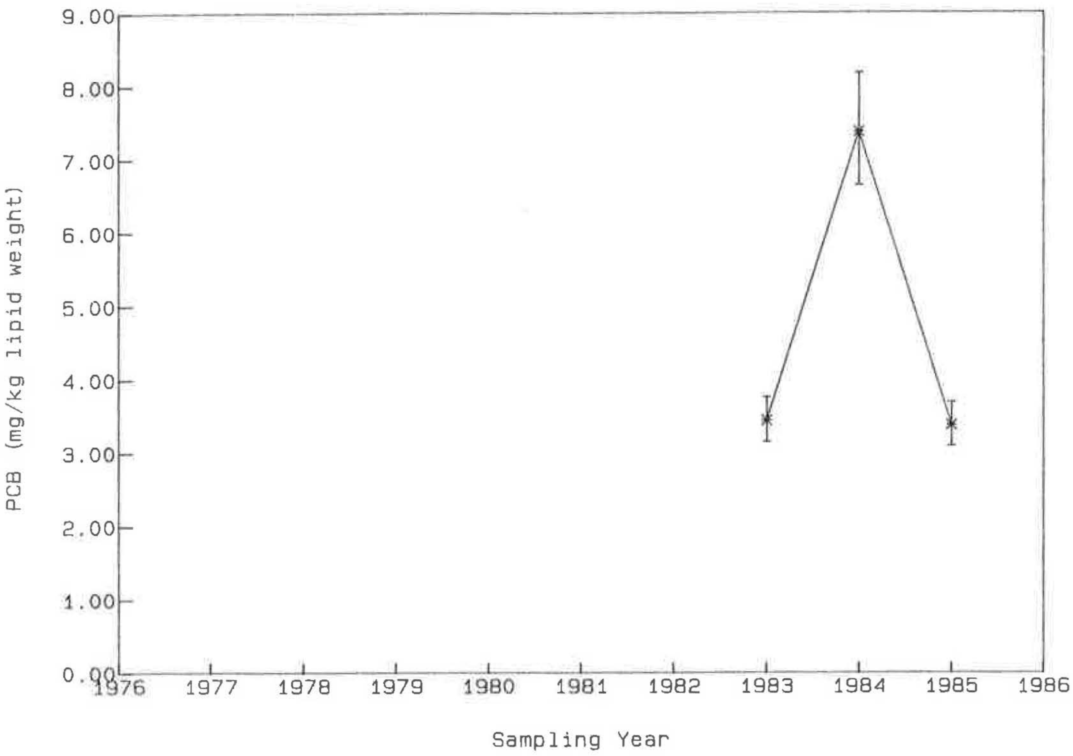
(GM) Estimates of Ni in cod muscle - cod in 31F2



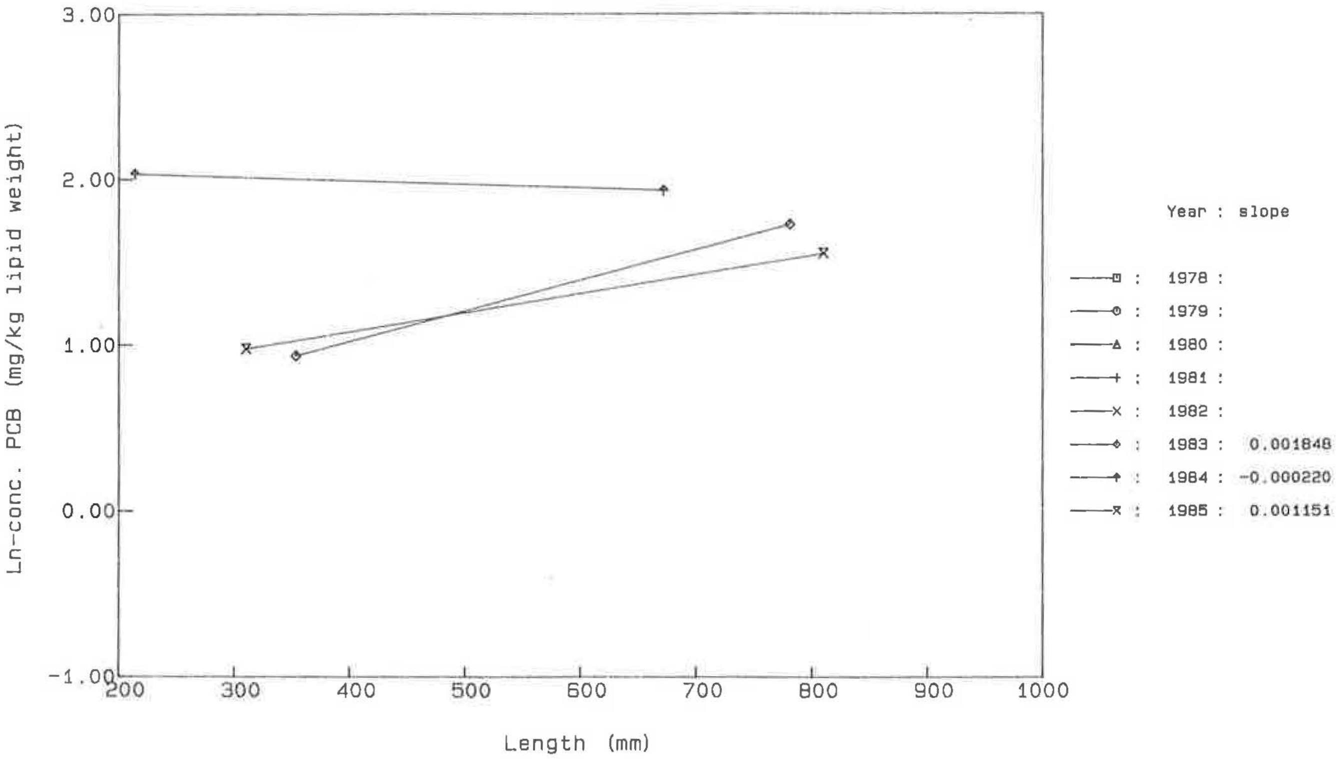
Regression of Ln-conc. Ni versus length by year - cod in 31F2



(GM) Estimates of PCB in cod muscle - cod in 31F2



Regression of Ln-conc. PCB versus length by year - cod in 31F2



SPECIES: Cod (GADU MOR) TISSUE : muscle								NOMINAL AREA: 34F2 COUNTRY : United Kingdom
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length					o	o	o	o
Weight					o	o	o	o
Age					o	o	o	o
Sex					o	o	o	o
Tissue wt.								
Fat %								
Dry %					o	o	o	o
CONTAMINANTS								
Hg					o	o	o	o
Cd					<.1			
Cu					<.2	o	o	o
Pb								
Zn					o	o	o	o
Cr								
Ni								
PCB								
SAMPLING								
sampling periods					July	July	Sep	Aug
sampling locations					34F2	34F2	37F2	35F2
number of specimens					30	25	25	25

Commentary:

The 1984 sample was taken in an open-sea area of the Southern Bight of the North Sea somewhat to the north of the normal sampling area, owing to the lack of availability of fish in the normal sampling area. As such, it may not be entirely comparable with the samples from other years in the time series, with regard to the objective of consistent sampling of the same fish stock.

Results of analyses:

Copper

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

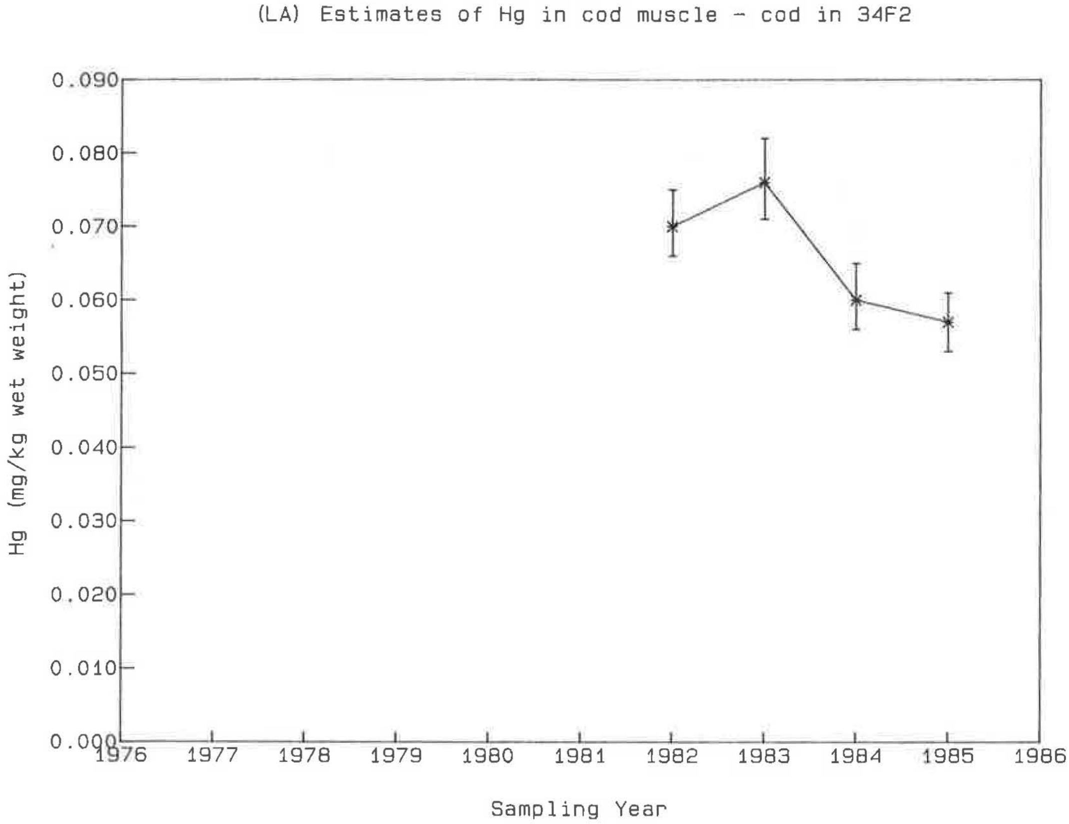
  Due to analytical limitations, the quality of the data for copper may not be suitable for analysis of temporal trends; values were reported only to the nearest 0.1 mg/kg wet weight.

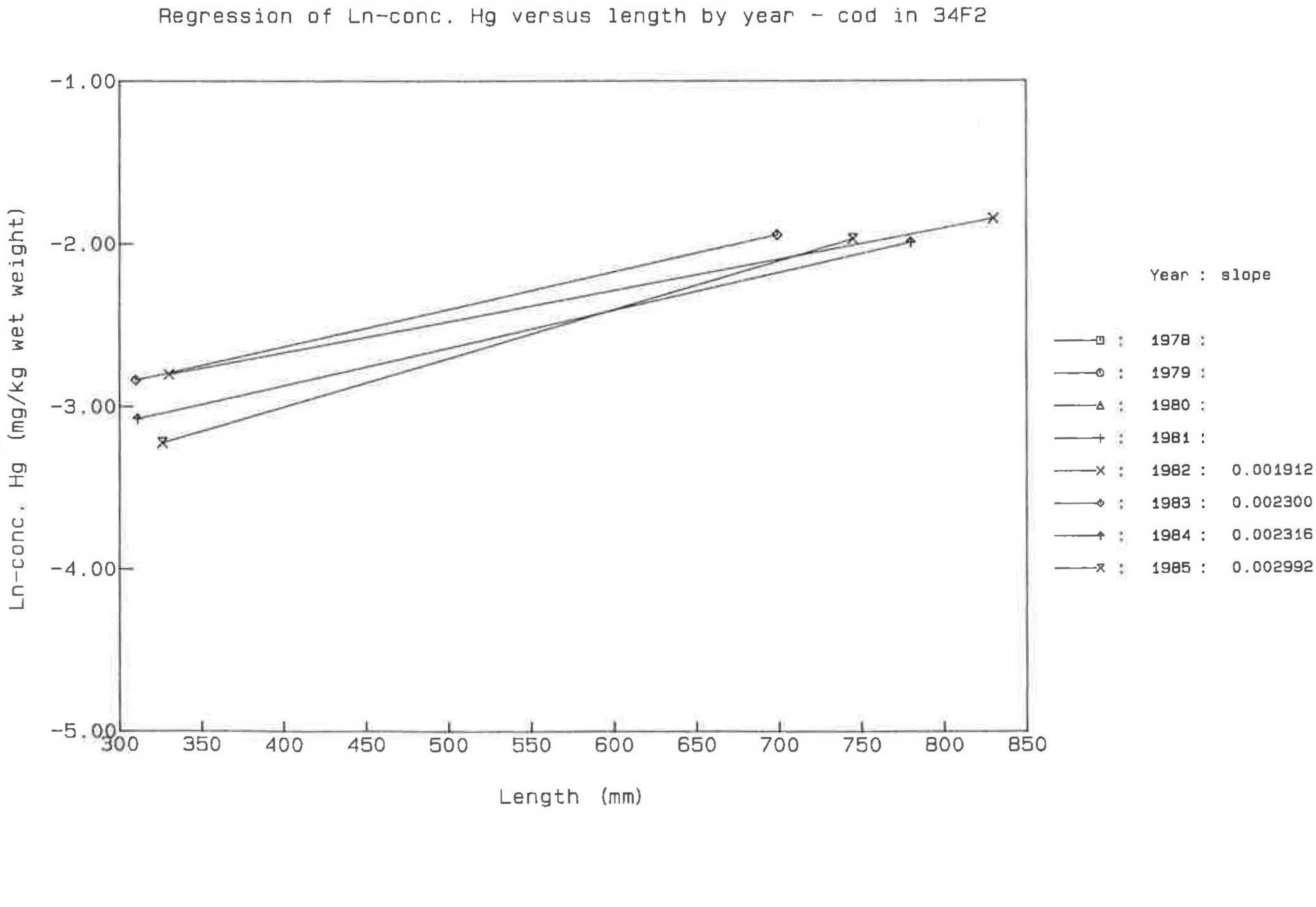
Mercury

- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot).

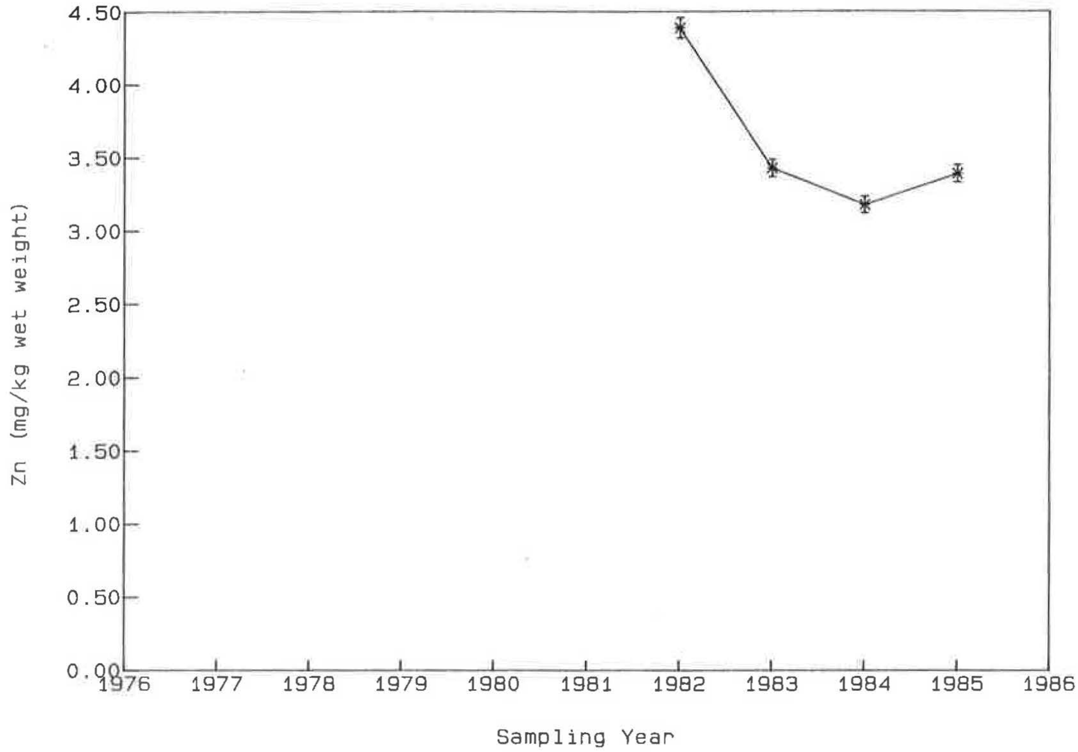
Zinc

- Results do not indicate evidence of a significant relationship between length and the contaminant levels; length-adjustment was still, however, applied in the computation of yearly mean contaminant levels (refer to plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

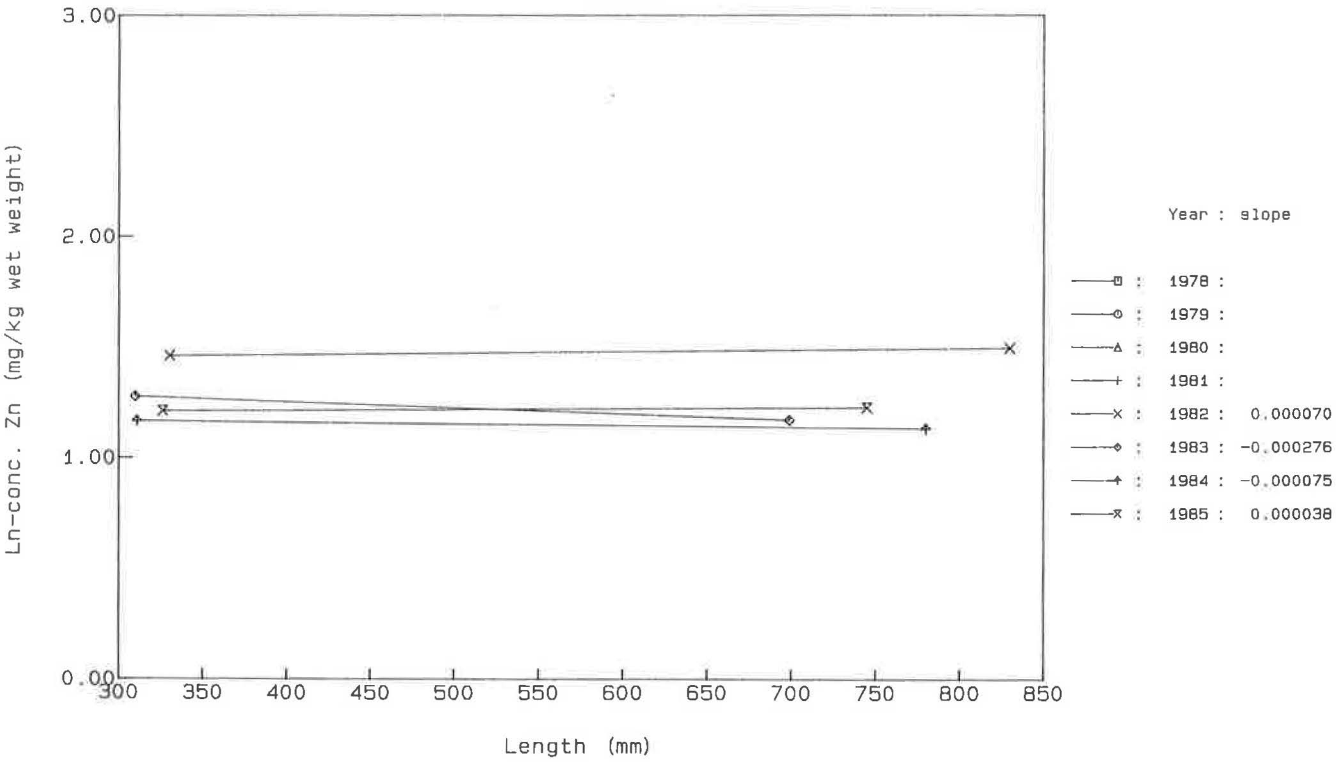

(LA) Estimates of Hg in cod muscle - cod in 34F2
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Hg (mg/kg wet weight)
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
Sampling Year

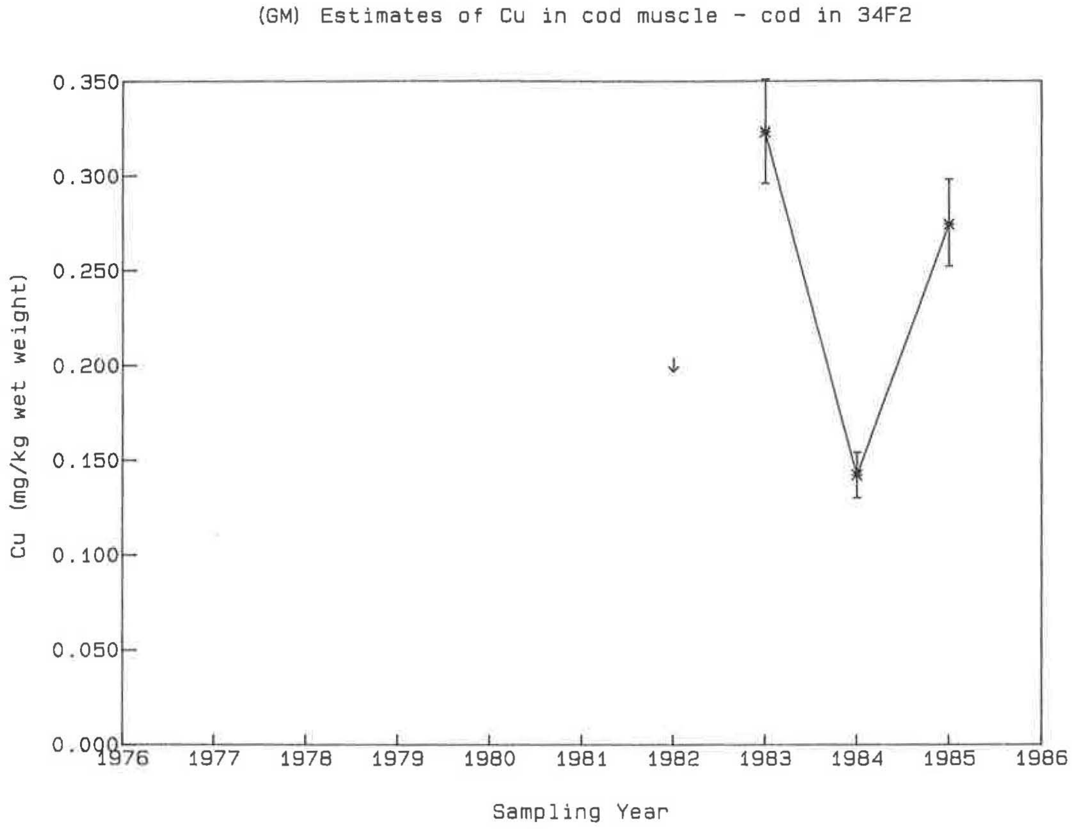

Regression of Ln-conc. Hg versus length by year - cod in 34F2
-1.00
-2.00
-3.00
-4.00
-5.00
Ln-conc. Hg (mg/kg wet weight)
300 350 400 450 500 550 600 650 700 750 800 850
Length (mm)
Year : slope
1978 :
1979 :
1980 :
1981 :
1982 : 0.001912
1983 : 0.002300
1984 : 0.002316
1985 : 0.002992

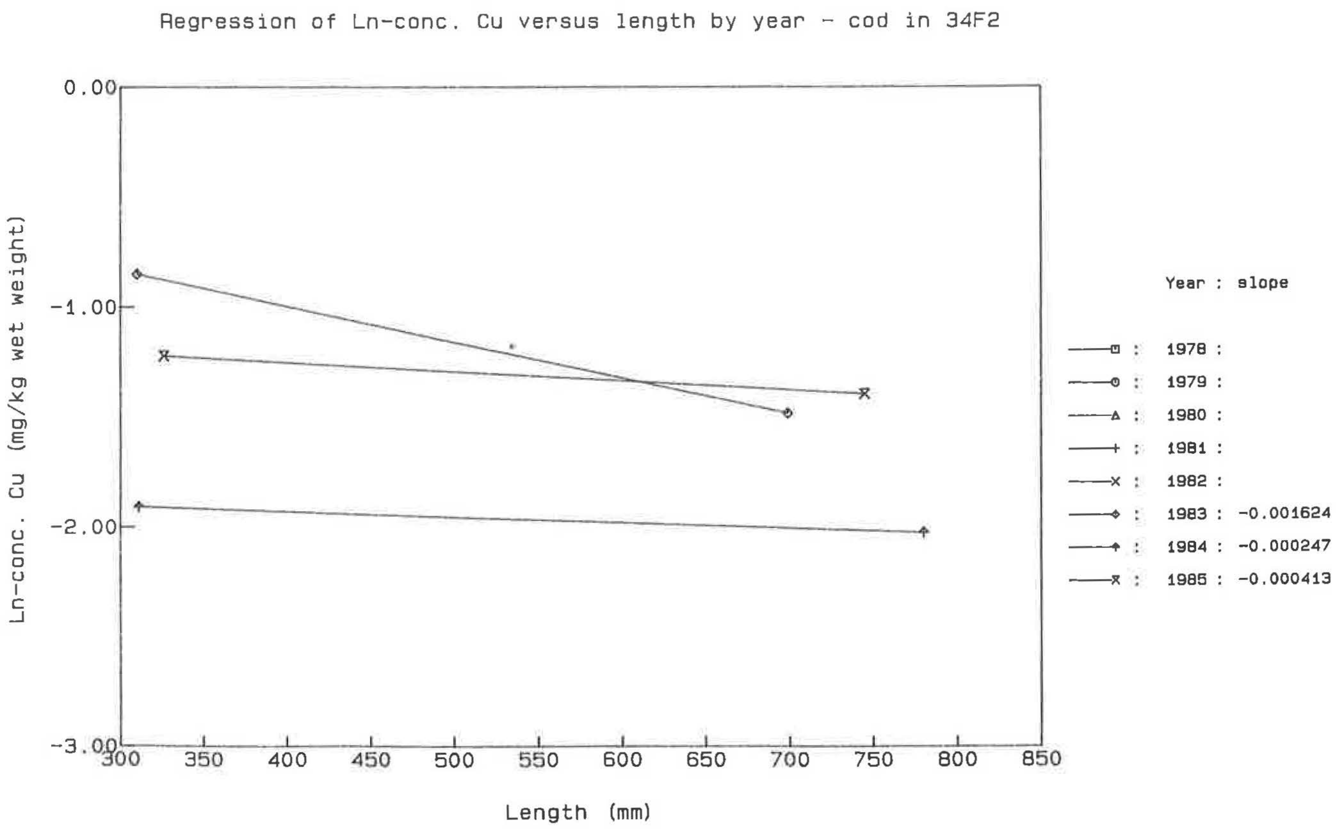
(LA) Estimates of Zn in cod muscle - cod in 34F2



Regression of Ln-conc. Zn versus length by year - cod in 34F2




(GM) Estimates of Cu in cod muscle - cod in 34F2
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year
Cu (mg/kg wet weight)


Regression of Ln-conc. Cu versus length by year - cod in 34F2
0.00
-1.00
-2.00
-3.00
300
350
400
450
500
550
600
650
700
750
800
850
Length (mm)
Ln-conc. Cu (mg/kg wet weight)
Year : slope
1978 :
1979 :
1980 :
1981 :
1982 :
1983 : -0.001624
1984 : -0.000247
1985 : -0.000413

SPECIES: Cod (GADU MOR) TISSUE : muscle	NOMINAL AREA: 42G8 COUNTRY : Sweden

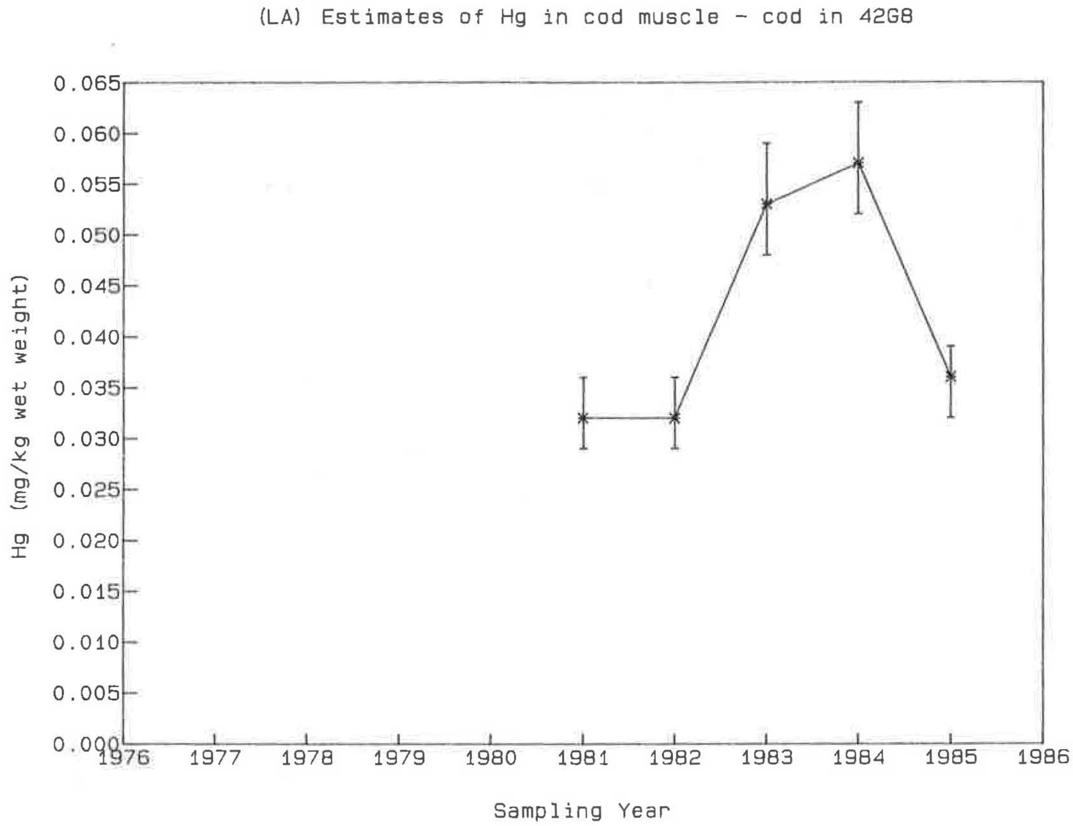
DATA CHARACTERISTICS

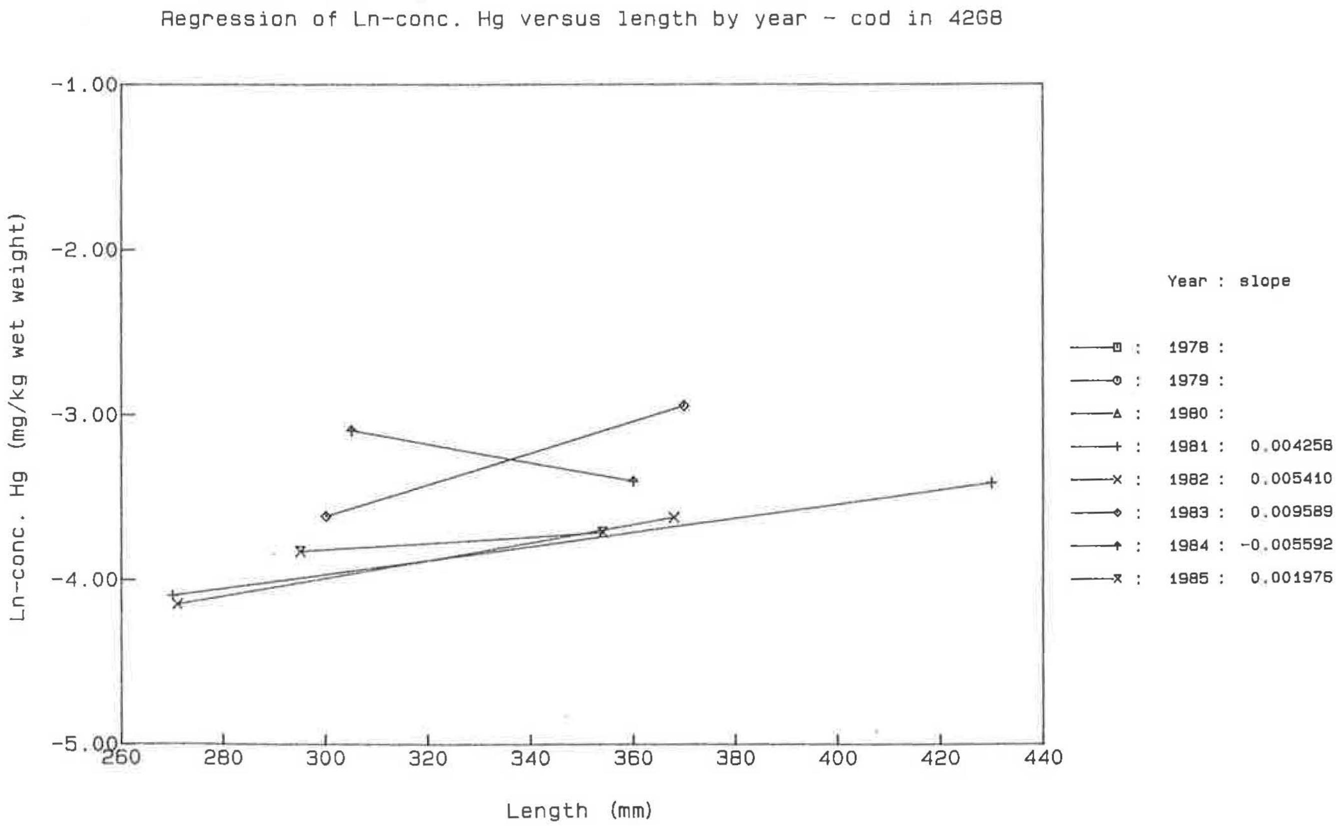
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length	o	o		o	o	o	o	o
Weight	o	o		o	o	o	o	o
Age	o	o		o	o	o	o	o
Sex	o	o		o	o	o	o	o
Tissue wt.						o		
Fat %	o	o						
Dry %						o	o	o
CONTAMINANTS								
Hg				o	o	o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB	o	o						
SAMPLING								
sampling periods	Aug	Dec		Oct	Sept	Sept	Sept	Sept
sampling locations	42G8	42G8		42G8	42G8	42G8	42G8	42G8
number of specimens	20	20		20	20	20	20	20

Results of analyses:

Mercury

- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.


(LA) Estimates of Hg in cod muscle - cod in 42G8
Hg (mg/kg wet weight)
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Hg versus length by year - cod in 42G8
Ln-conc. Hg (mg/kg wet weight)
-1.00
-2.00
-3.00
-4.00
-5.00
260
280
300
320
340
360
380
400
420
440
Length (mm)
Year : slope
1978 :
1979 :
1980 :
1981 : 0.004258
1982 : 0.005410
1983 : 0.009589
1984 : -0.005592
1985 : 0.001976

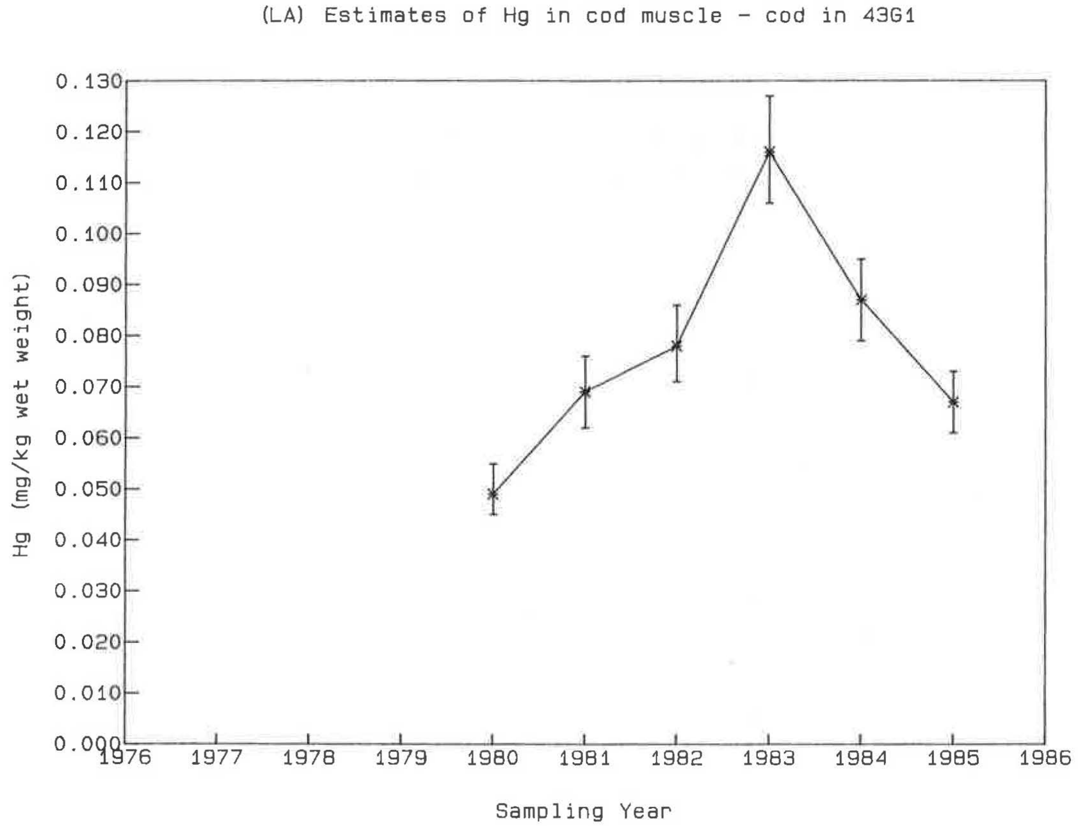
SPECIES: Cod (GADU MOR) TISSUE : muscle	NOMINAL AREA: 43G1 COUNTRY : Sweden

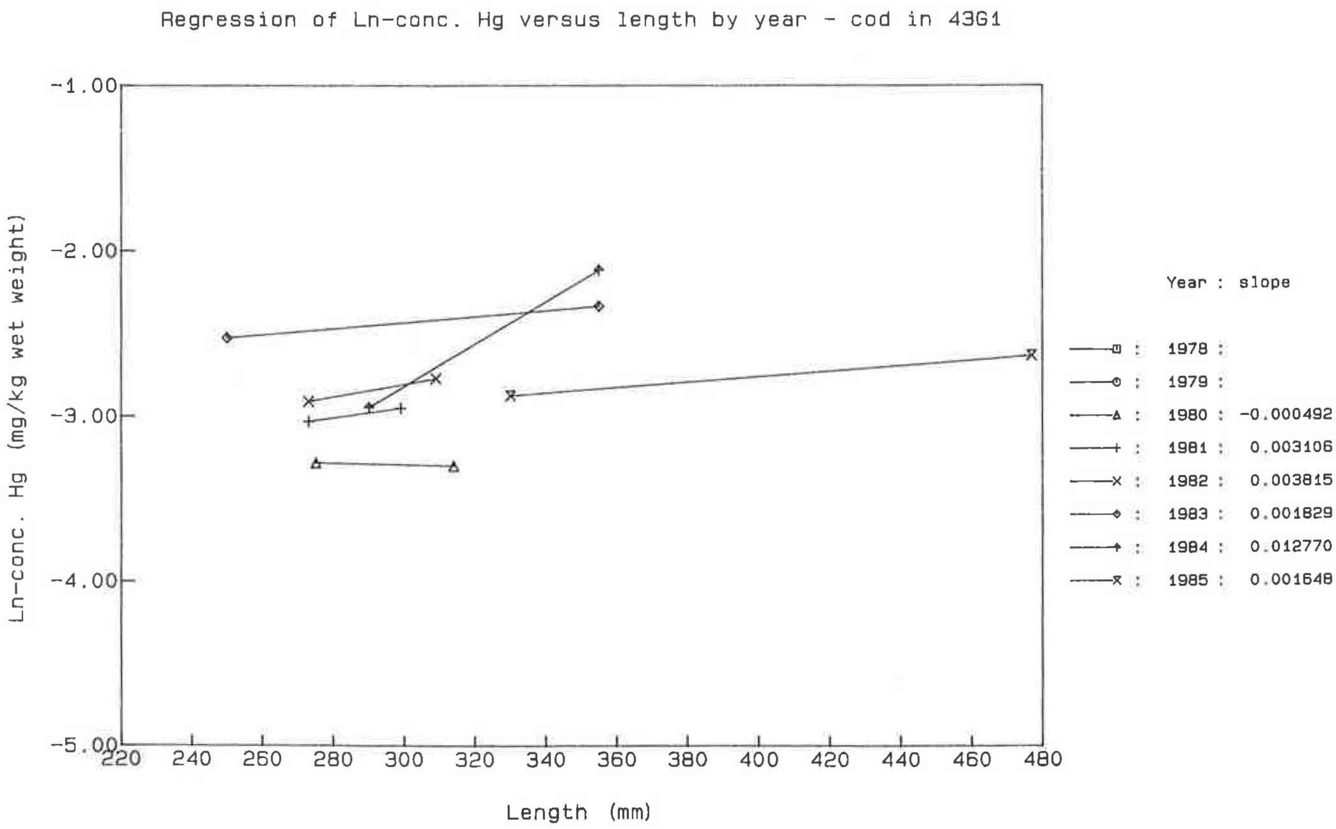
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length		o	o	o	o	o	o	o
Weight		o	o	o	o	o	o	o
Age		o	o	o	2	o	o	o
Sex		o	o	o	o	o	o	o
Tissue wt.						o		
Fat %		o						
Dry %						o	o	o
CONTAMINANTS								
Hg			●	o	o	o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB		o						
SAMPLING								
sampling periods		Nov	Sept	Sept	Sept	Sept	Oct	Dec
sampling locations		43G1	43G1	43G1	43G1	43G1	43G1	43G1
number of specimens		20	20	20	20	25	25	25

Results of analyses:

Mercury

- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot).


(LA) Estimates of Hg in cod muscle - cod in 43G1
Hg (mg/kg wet weight)
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
Sampling Year


Regression of Ln-conc. Hg versus length by year - cod in 43G1
Ln-conc. Hg (mg/kg wet weight)
-1.00
-2.00
-3.00
-4.00
-5.00
220 240 260 280 300 320 340 360 380 400 420 440 460 480
Length (mm)
Year : slope
1978 :
1979 :
1980 : -0.000492
1981 : 0.003106
1982 : 0.003815
1983 : 0.001829
1984 : 0.012770
1985 : 0.001648

SPECIES: Cod (GADU MOR) TISSUE : muscle	NOMINAL AREA: 47G0 COUNTRY : Norway

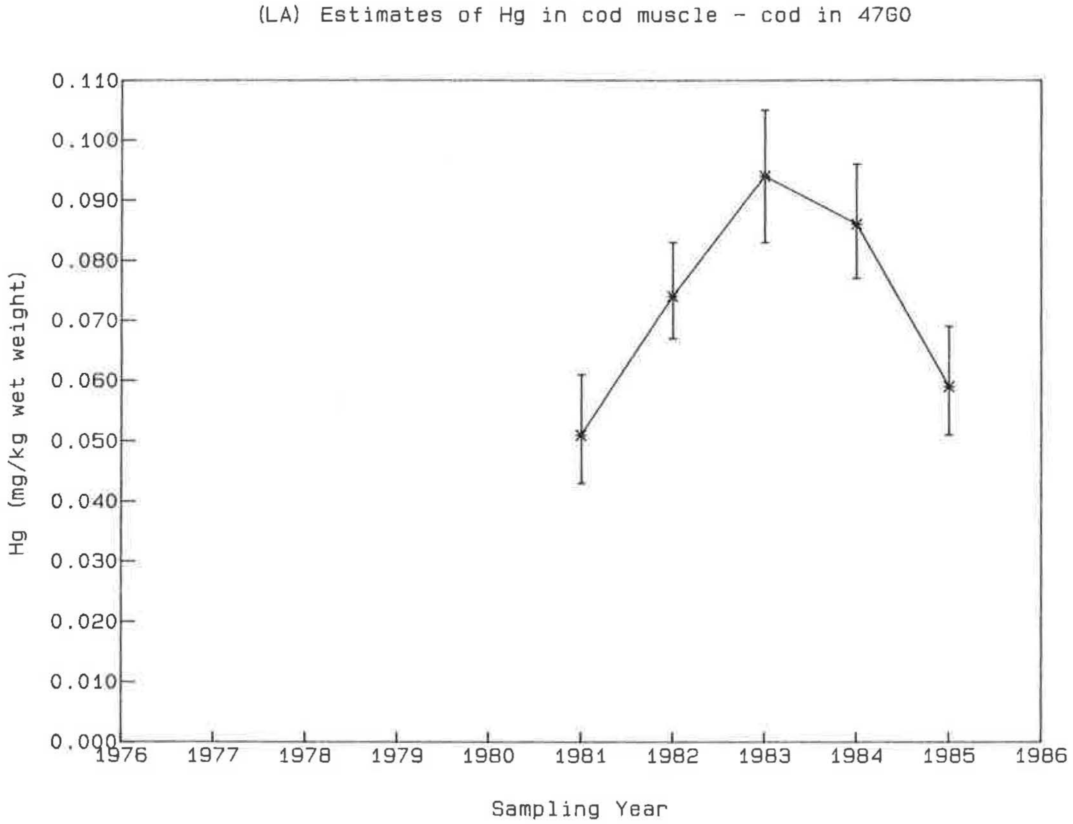
DATA CHARACTERISTICS

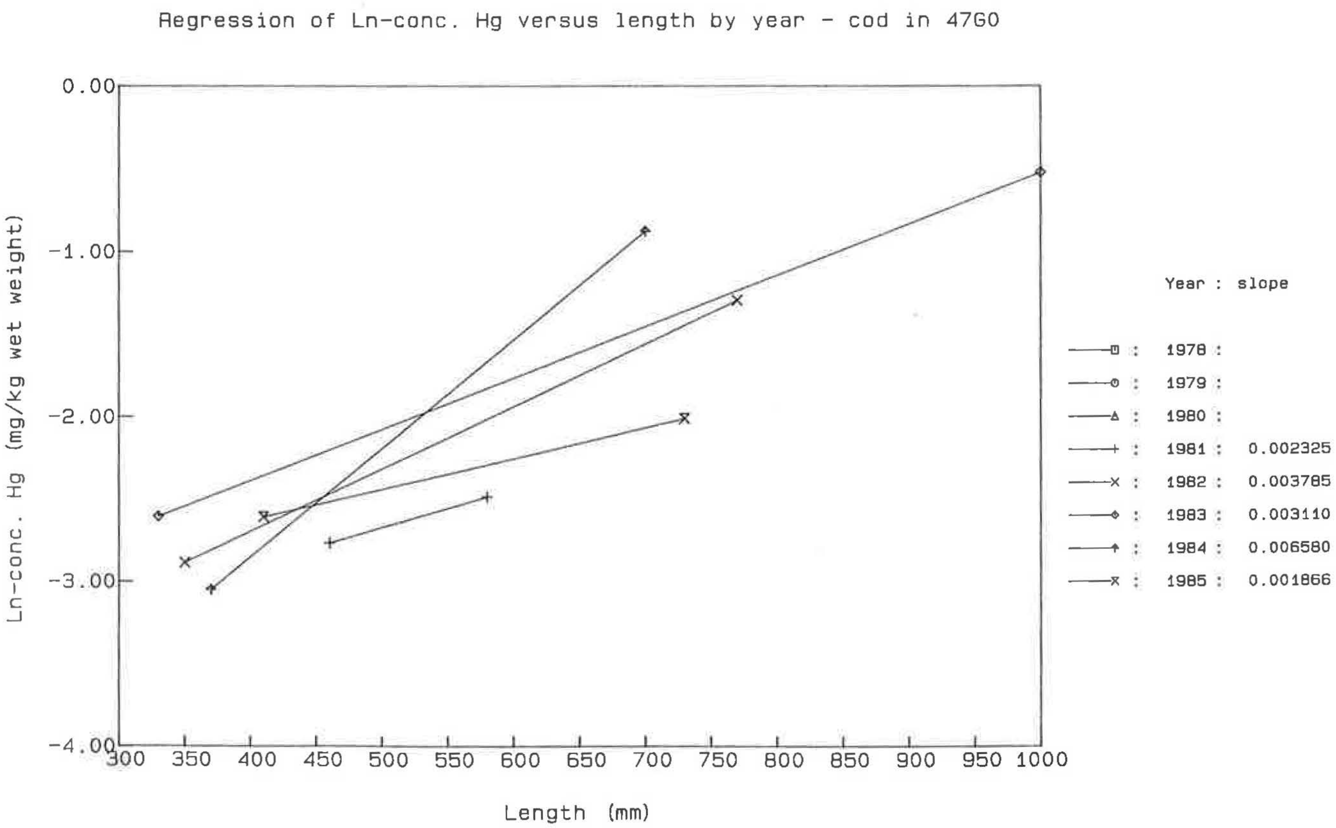
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length				o	o	o	o	o
Weight				o	o	o	o	o
Age				2	o	o	o	
Sex				o	●	●	o	o
Tissue wt.								
Fat %				o	o			
Dry %				o	●	o	o	o
CONTAMINANTS								
Hg				o	o	o	o	o
Cd				<.005				
Cu								
Pb								
Zn								
Cr								
Ni								
PCB				o	<.05	<.05	<.05	<.05
SAMPLING								
sampling periods				Dec	Feb 83	Dec	Dec	Dec
sampling locations				47G0	47G0	47G0	47G0	47G0
number of specimens				10	27	23	24	14

Results of analyses:

Mercury

- Results show significant differences between years in the slopes of the linear relationships between contaminant level and length. The results suggesting that a significant increase in the explanatory power of the statistical analysis could be achieved by inclusion of additional biological covariates may not be valid under these circumstances.


(LA) Estimates of Hg in cod muscle - cod in 47G0
Hg (mg/kg wet weight)
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Hg versus length by year - cod in 47G0
Ln-conc. Hg (mg/kg wet weight)
0.00
-1.00
-2.00
-3.00
-4.00
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
Length (mm)
Year : slope
1978 :
1979 :
1980 :
1981 : 0.002325
1982 : 0.003785
1983 : 0.003110
1984 : 0.006580
1985 : 0.001866

SPECIES: Cod (GADU MOR) TISSUE : muscle				NOMINAL AREA: 48GO COUNTRY : Norway				
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length				o	●		o	o
Weight				o	●		o	o
Age				o	o		o	o
Sex				●	o		o	o
Tissue wt.								
Fat %				o	o			
Dry %				o	o		o	o
CONTAMINANTS								
Hg				o	o		o	o
Cd				●				
Cu								
Pb								
Zn								
Cr								
Ni								
PCB				o	<.05		<.05	<.05
SAMPLING								
sampling periods				Dec	Dec[2]		Nov	Nov
sampling locations				48GO[1]	48GO[1]		48GO[1]	48GO[1]
number of specimens				10	27		29	25

<u>Commentary:</u>

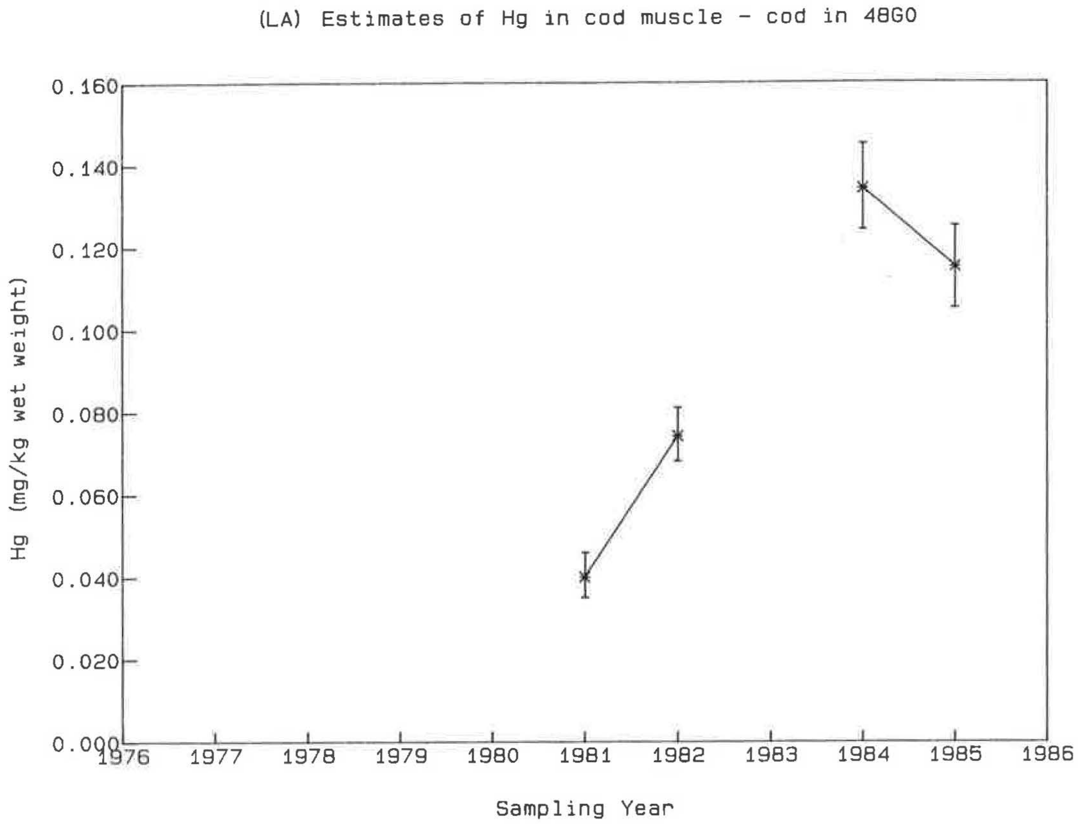
[1]Samples were taken at two sites within the Oslofjord; in 1981 and 1982 at Solbergstrand (59^{0} 36.9' N, 10^{0} 39.4' E), and in 1984 and 1985 near Oslo harbour (59^{0} 44.8' N, 10^{0} 43.0' E). These locations, in the mid- and inner parts of the Oslofjord, respectively, are separated by a shallow sill and have differing hydrographic and chemical conditions. This sill also restricts fish migration between the two areas and the fish populations of the two areas are considered to represent two distinct stocks. These circumstances do not comply with the objective of monitoring a single fish population consistently over time, a fact to be noted when considering the results obtained.

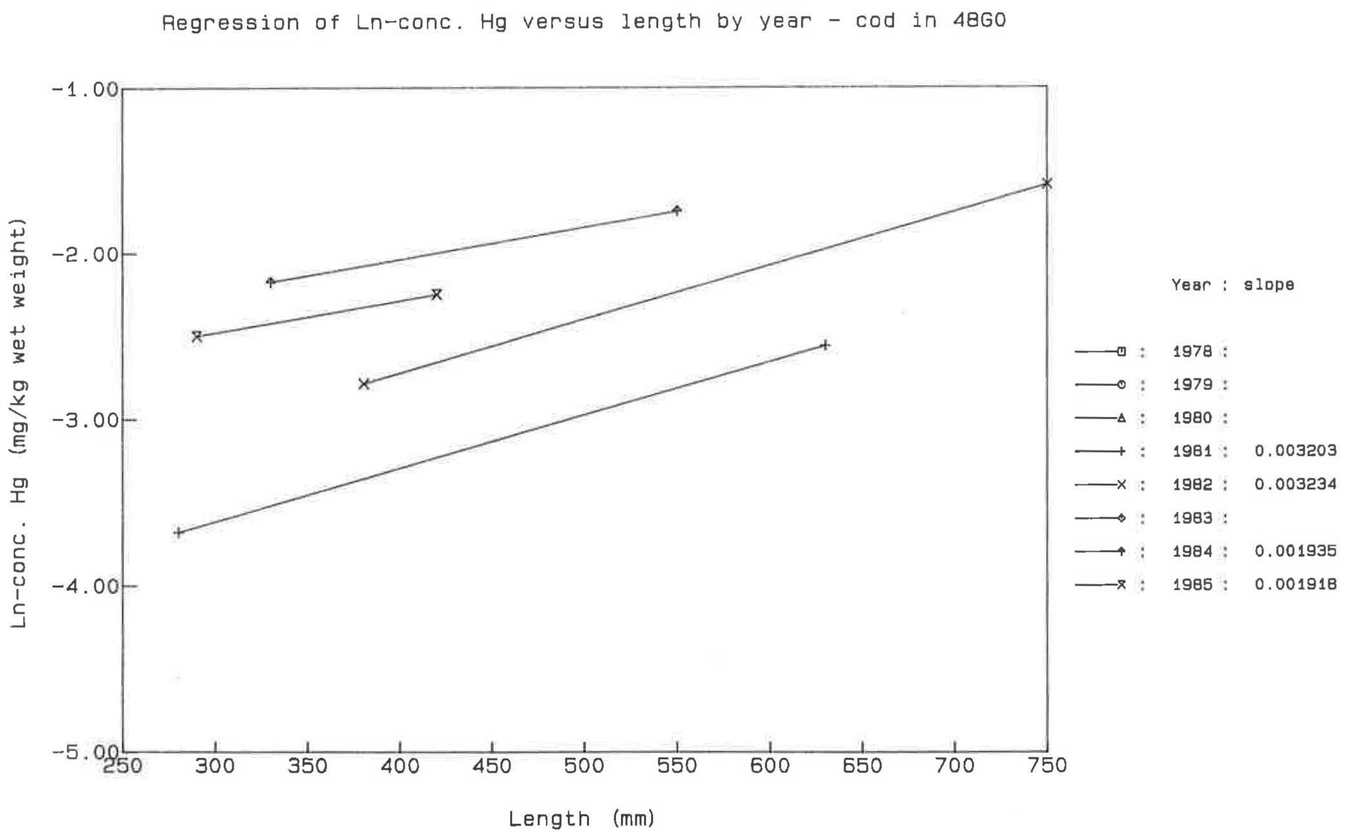
[2]The 'winter' sample for 1982, included specimens sampled between October 1982 and February 1983.

<u>Results of analyses:</u>

Mercury

- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.


(LA) Estimates of Hg in cod muscle - cod in 48G0
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
Hg (mg/kg wet weight)
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Hg versus length by year - cod in 48G0
-1.00
-2.00
-3.00
-4.00
-5.00
Ln-conc. Hg (mg/kg wet weight)
250
300
350
400
450
500
550
600
650
700
750
Length (mm)
Year : slope
1978 :
1979 :
1980 :
1981 : 0.003203
1982 : 0.003234
1983 :
1984 : 0.001935
1985 : 0.001918

SPECIES: Plaice (PLEU PLA) TISSUE : muscle					NOMINAL AREA: 34F2 COUNTRY : United Kingdom			
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length					o	o	o	o
Weight					o	o	o	o
Age					o	o	o	o
Sex					o	o	o	o
Tissue wt.								
Fat %								
Dry %					o	o	o	o
CONTAMINANTS								
Hg					o	o	o	o
Cd					<.1			
Cu					<.2	o	o	o
Pb								
Zn					o	o	o	o
Cr								
Ni								
PCB								
SAMPLING								
sampling periods					Nov	Dec	Nov	Nov
sampling locations					34F2	33F2	34F2	34F2
number of specimens					25	25	25	25

Results of analyses:

Copper

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

  Due to analytical limitations, the quality of the data for copper may not be suitable for analysis of temporal trends; values were reported only to the nearest 0.1 mg/kg wet weight.

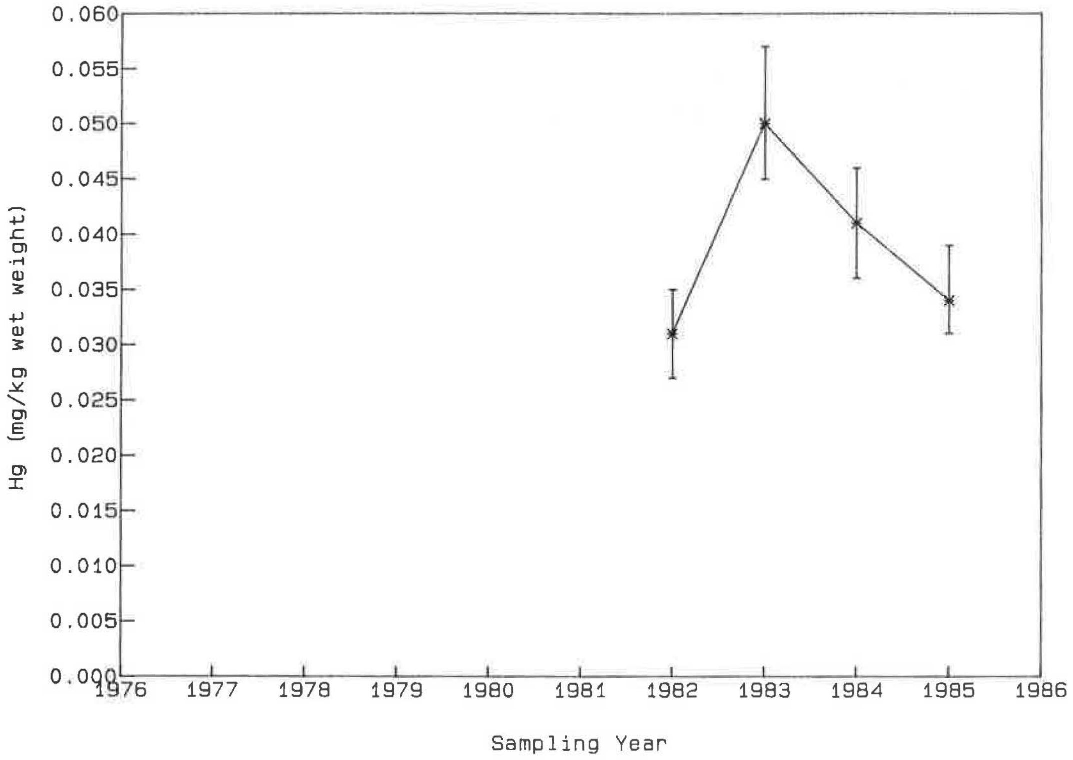
Mercury

- Results confirm the validity of the statistical analysis; the length-adjusted yearly mean contaminant levels differ significantly between years but there is no evidence of a linear trend (see plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

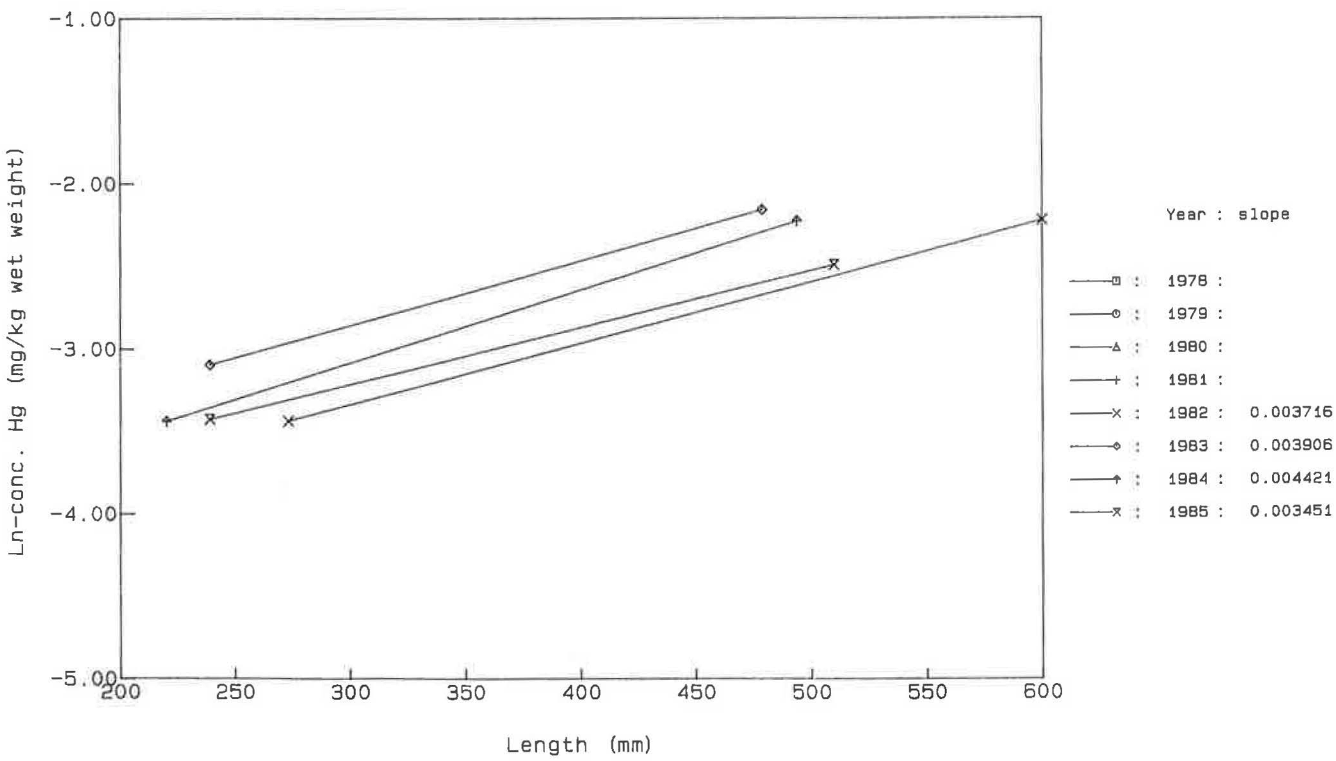
Zinc

- Results show significant differences between years in the slopes of the linear relationships between contaminant level and length.

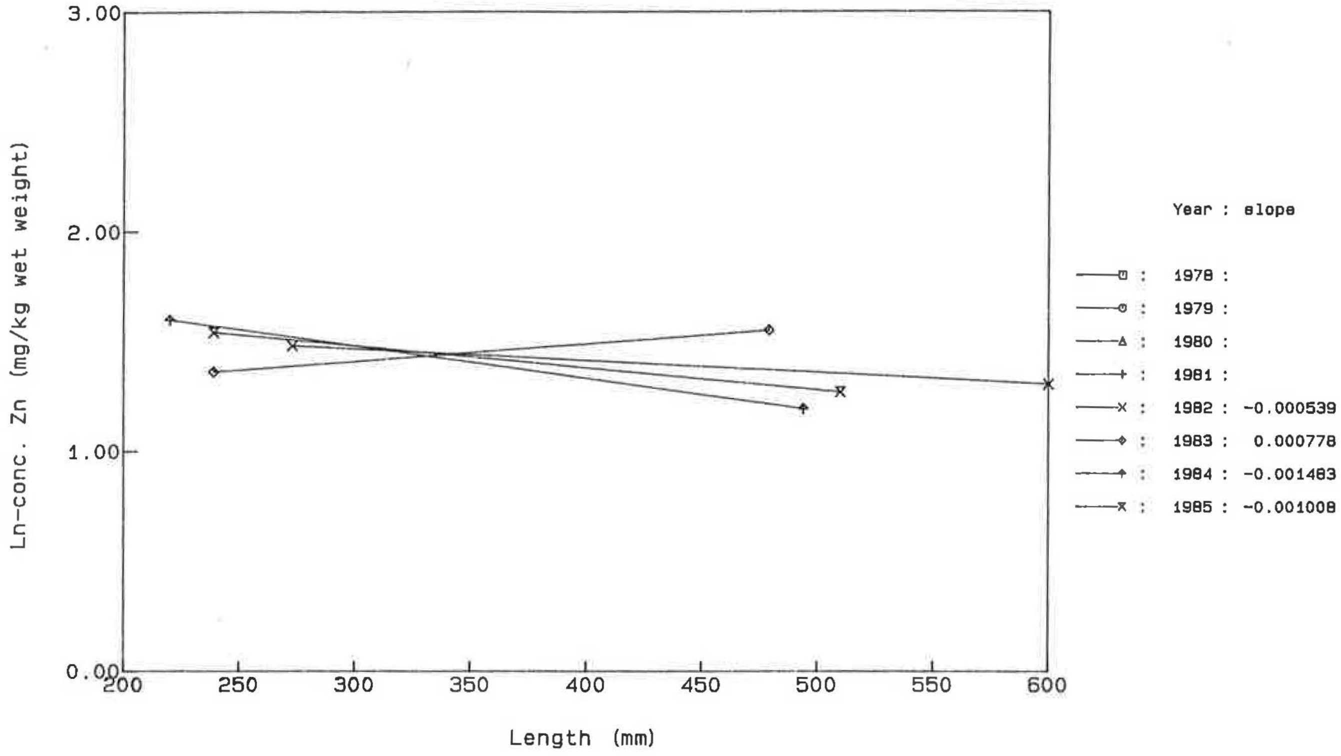
(LA) Estimates of Hg in plaice muscle - plaice in 34F2



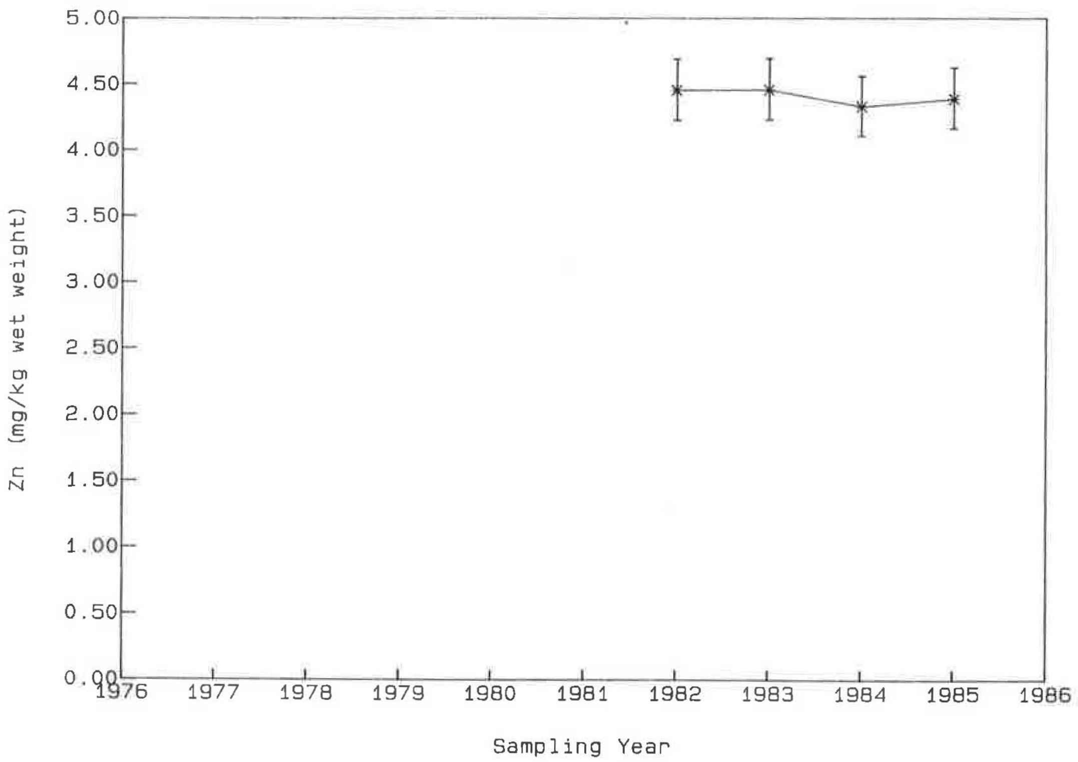
Regression of Ln-conc. Hg versus length by year - plaice in 34F2



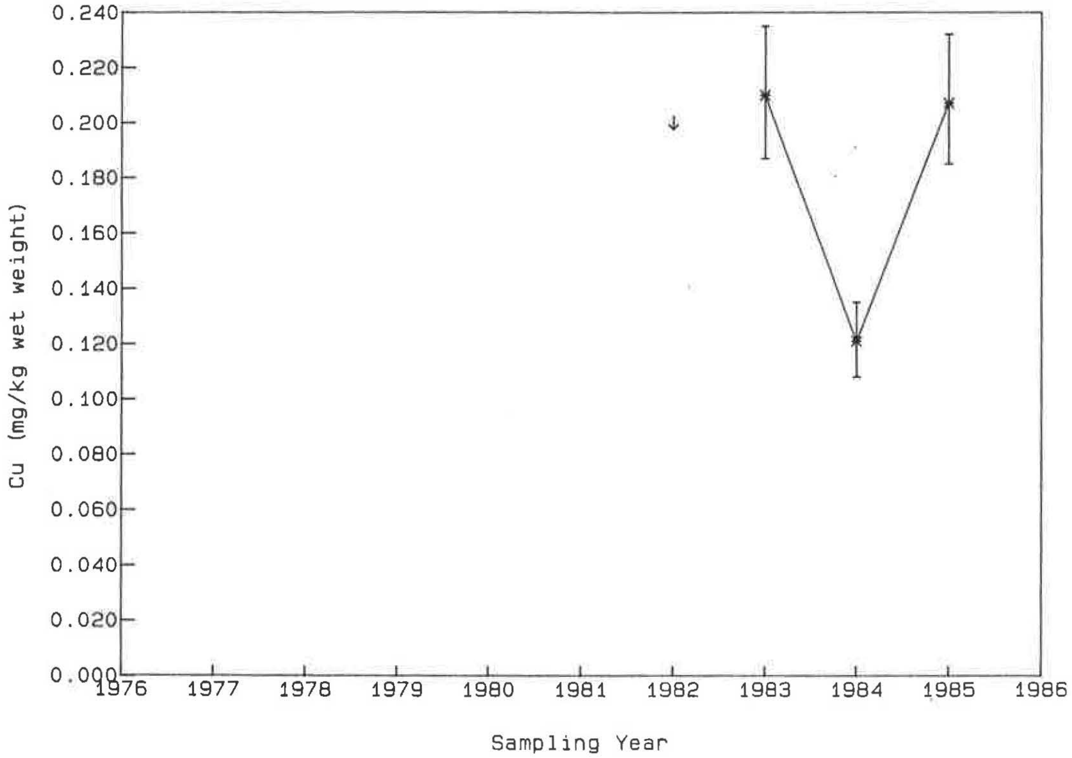
Regression of Ln-conc. Zn versus length by year - plaice in 34F2



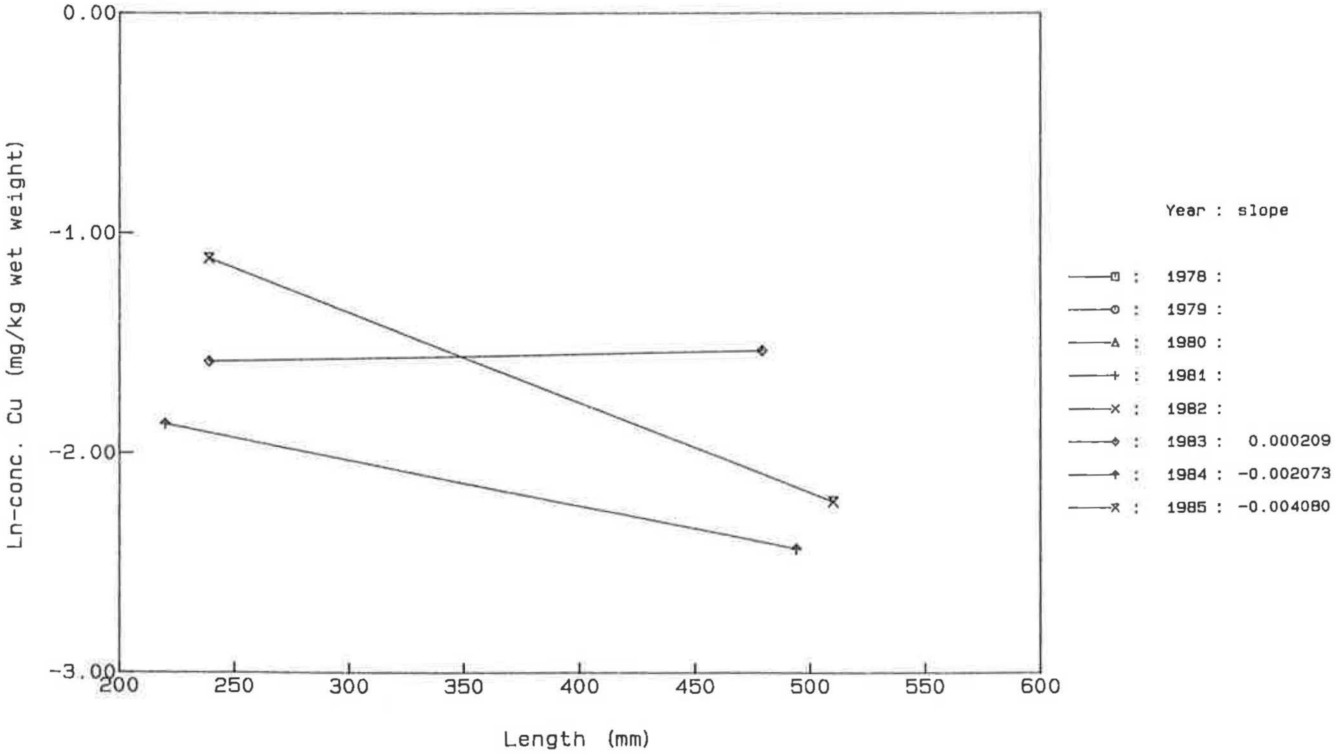
(LA) Estimates of Zn in plaice muscle - plaice in 34F2



(GM) Estimates of Cu in plaice muscle - plaice in 34F2



Regression of Ln-conc. Cu versus length by year - plaice in 34F2



SPECIES: Plaice (PLEU PLA) TISSUE : muscle	NOMINAL AREA: 35E6 COUNTRY : United Kingdom

DATA CHARACTERISTICS

BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length					o	o	o	o
Weight					o	o	o	o
Age					o	o	o	o
Sex					o	o	o	o
Tissue wt.								
Fat %								
Dry %					o	o	o	o
CONTAMINANTS								
Hg					o	o	o	o
Cd					<.1			
Cu					<.2	o	o	o
Pb								
Zn					o	o	o	o
Cr								
Ni								
PCB								
SAMPLING								
sampling periods					Oct	Oct	Nov	Oct
sampling locations					35E6	35E6	35E6	35E6
number of specimens					25	25	25	25

Results of analyses:

Copper

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

  Due to analytical limitations, the quality of the data for copper may not be suitable for analysis of temporal trends; values were reported only to the nearest 0.1 mg/kg wet weight.

Mercury

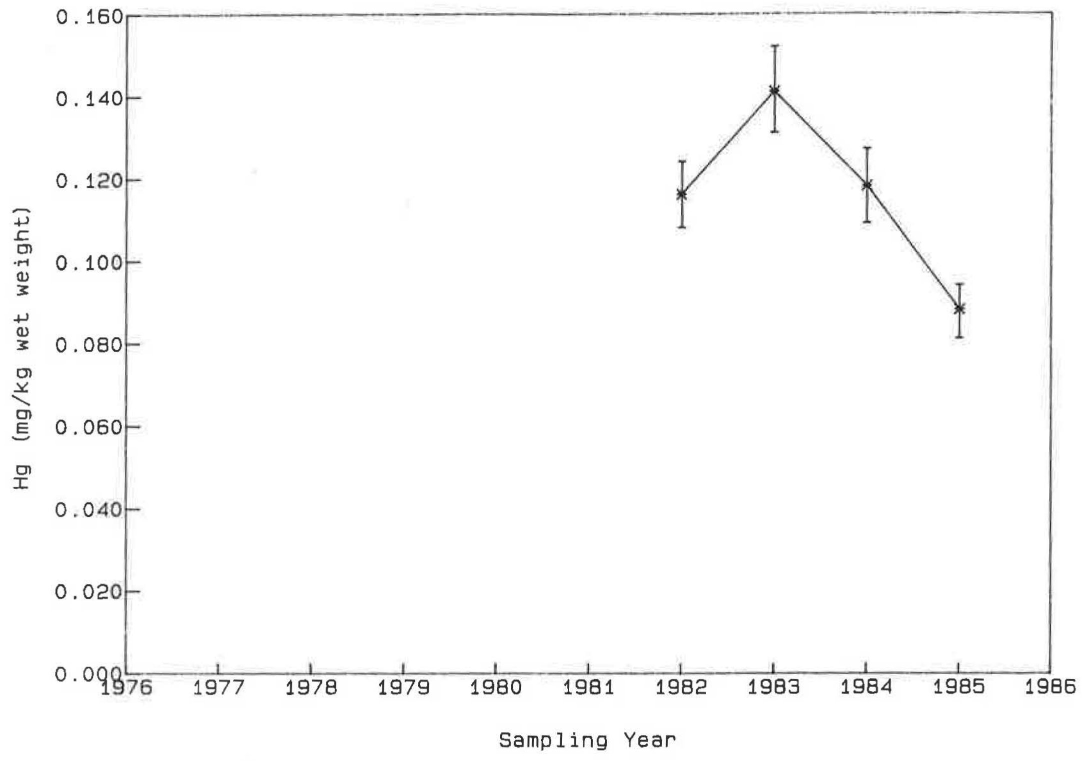
- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

Information provided by the data originator states that although inputs of mercury to Liverpool Bay have been reduced, continued contamination may result from the release of mercury from historically contaminated sediments.

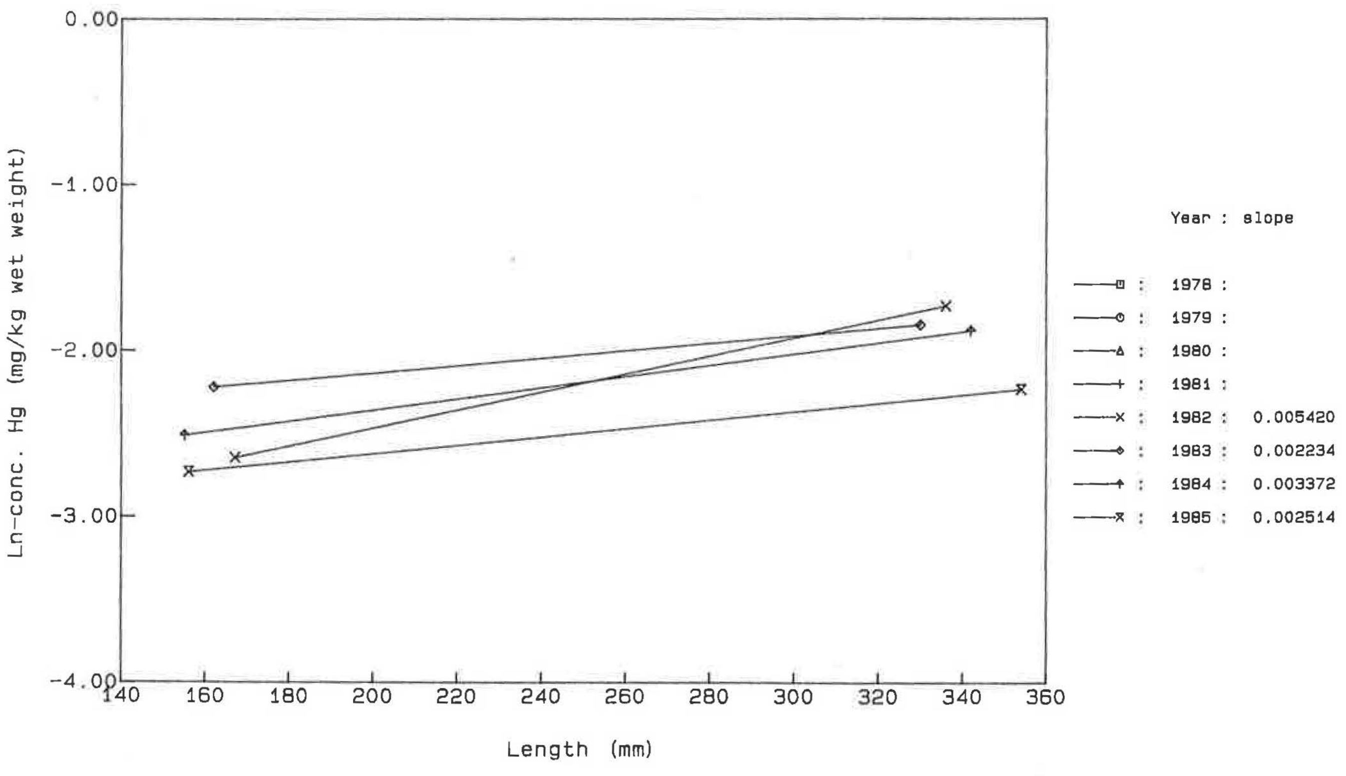
Zinc

- Results confirm the validity of the statistical analysis; there is no evidence of significant differences in the length-adjusted yearly mean contaminant levels between years (see plot).

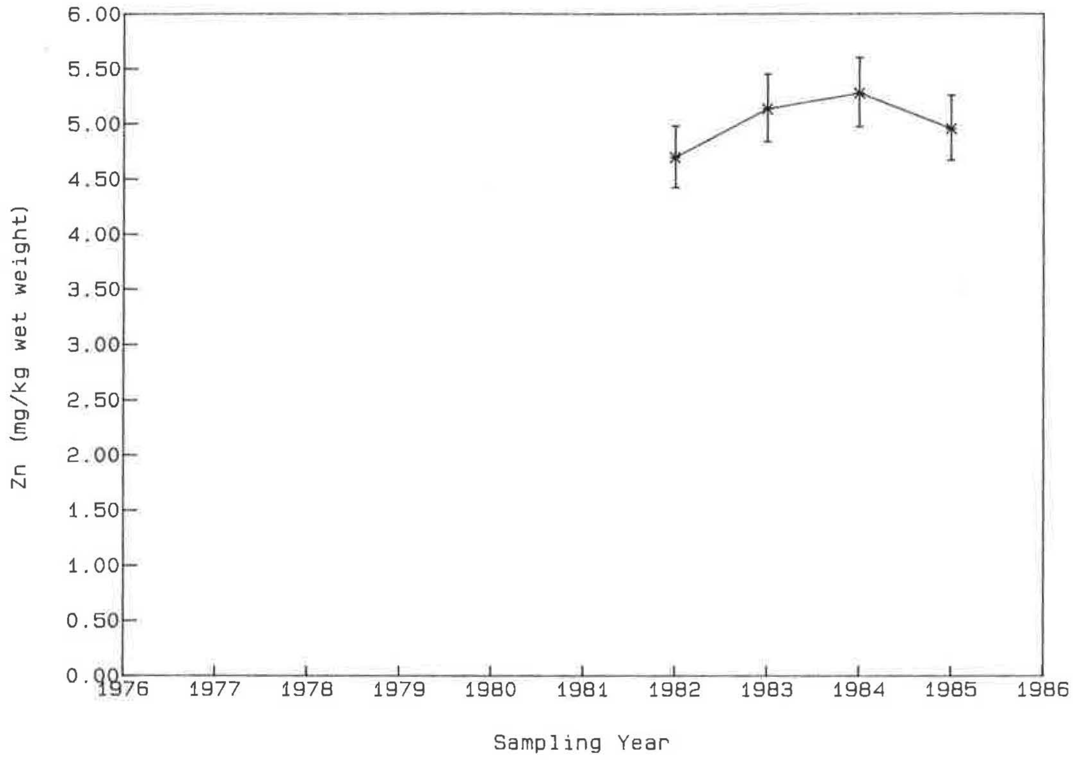
(LA) Estimates of Hg in plaice muscle - plaice in 35E6



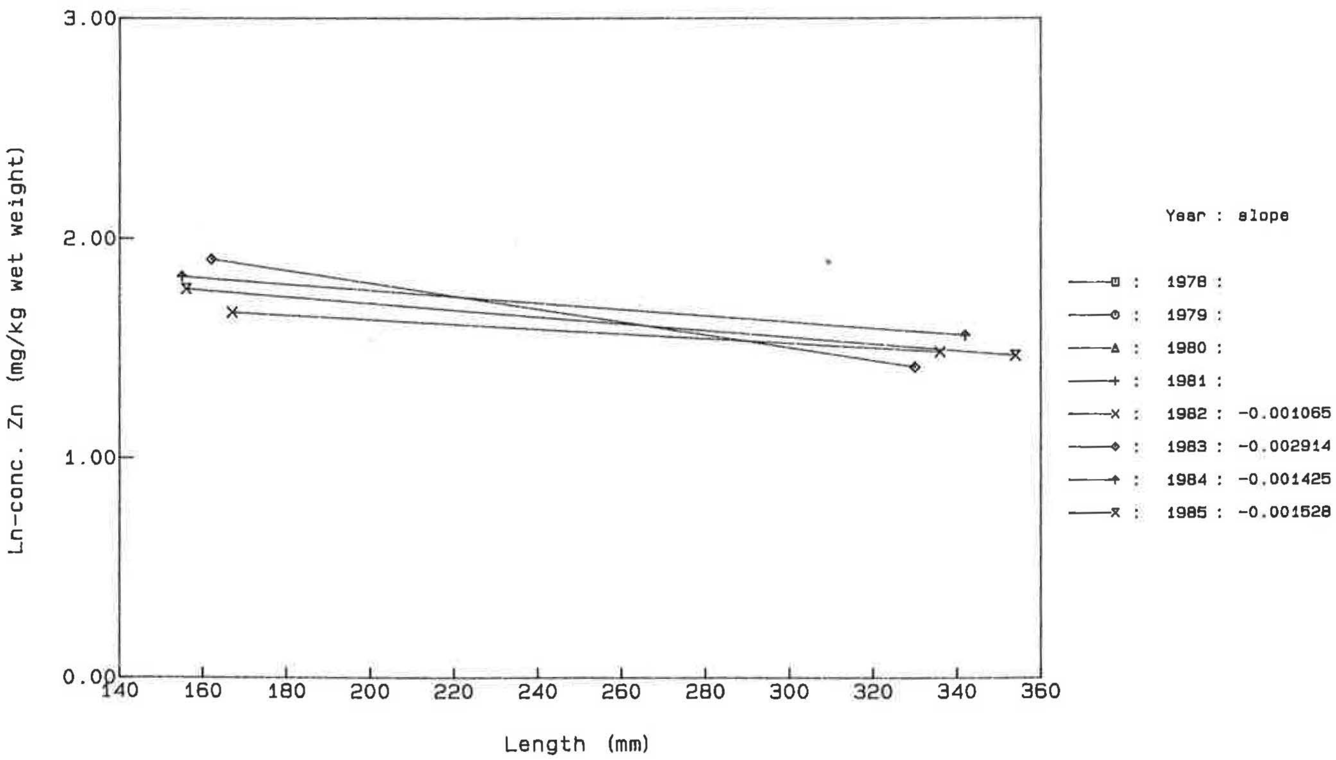
Regression of Ln-conc. Hg versus length by year - plaice in 35E6



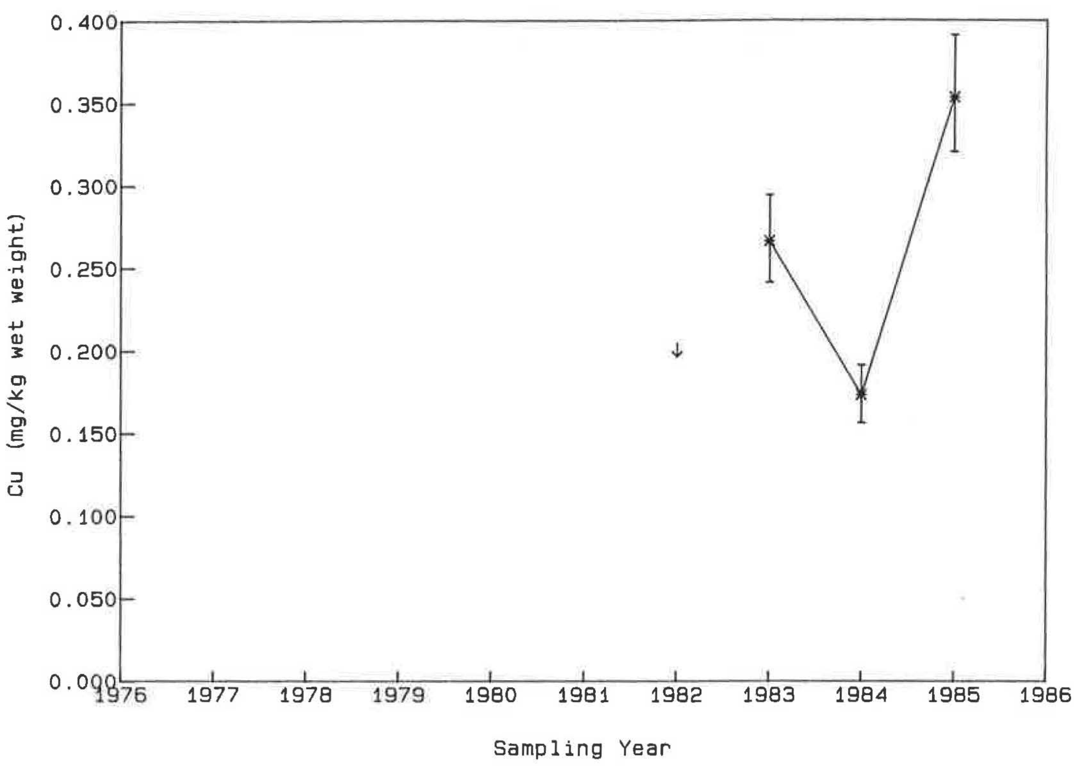
(LA) Estimates of Zn in plaice muscle - plaice in 35E6



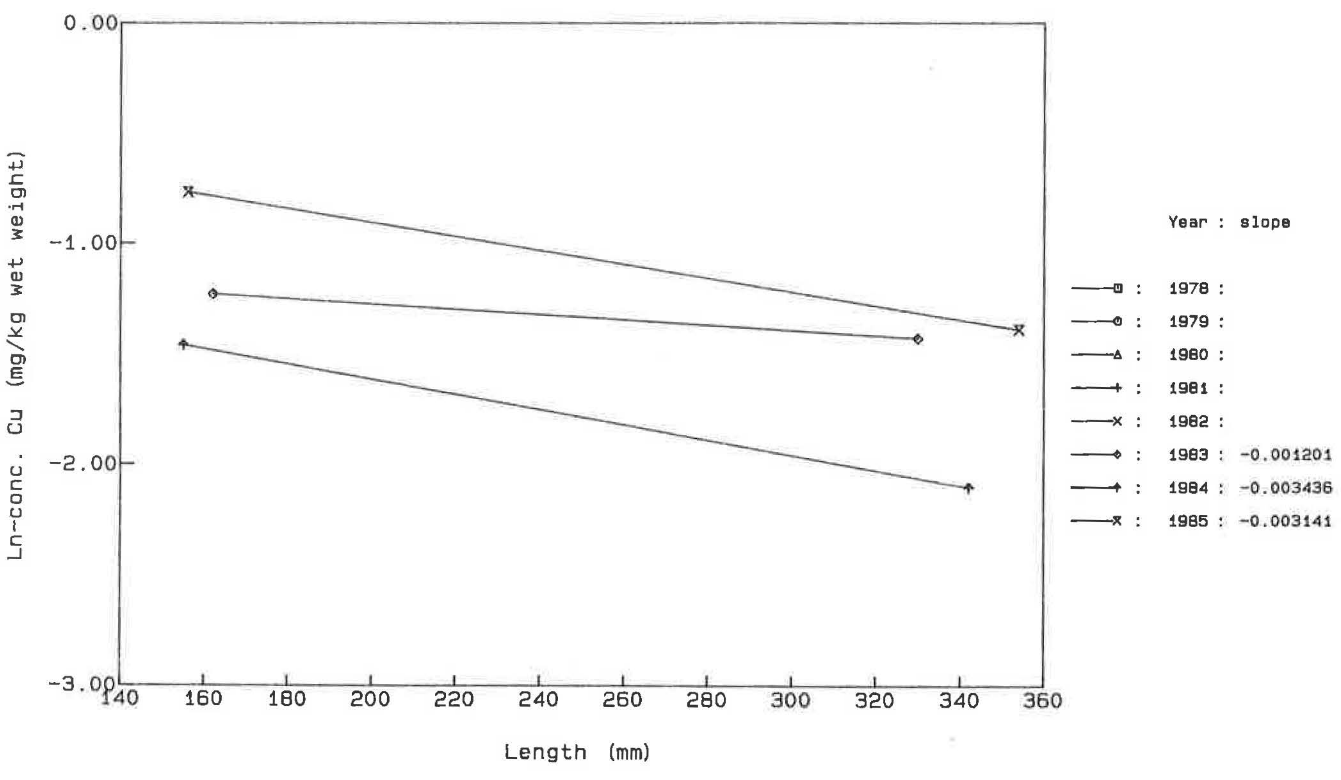
Regression of Ln-conc. Zn versus length by year - plaice in 35E6



(GM) Estimates of Cu in plaice muscle - plaice in 35E6



Regression of Ln-conc. Cu versus length by year - plaice in 35E6



SPECIES: Plaice (PLEU PLA) TISSUE : muscle	NOMINAL AREA: 40F7 COUNTRY : Denmark

DATA CHARACTERISTICS

BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length				o	o	o		
Weight				o	o	o		
Age				o	●	●		
Sex				o	o	o		
Tissue wt.								
Fat %						o[1]		
Dry %						o[1]		
CONTAMINANTS								
Hg				o	o	o		
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB						o[1]		
SAMPLING								
sampling periods				Aug	Ap+Oc[2]	May		
sampling locations				40F7	40F7	40F7		
number of specimens				13	25+23	25		

Commentary:

[1]Measured in a single homogenate of the muscle tissue of 25 specimens.

[2]The 1982 data set included samples taken on two occasions, one in April and one in October.

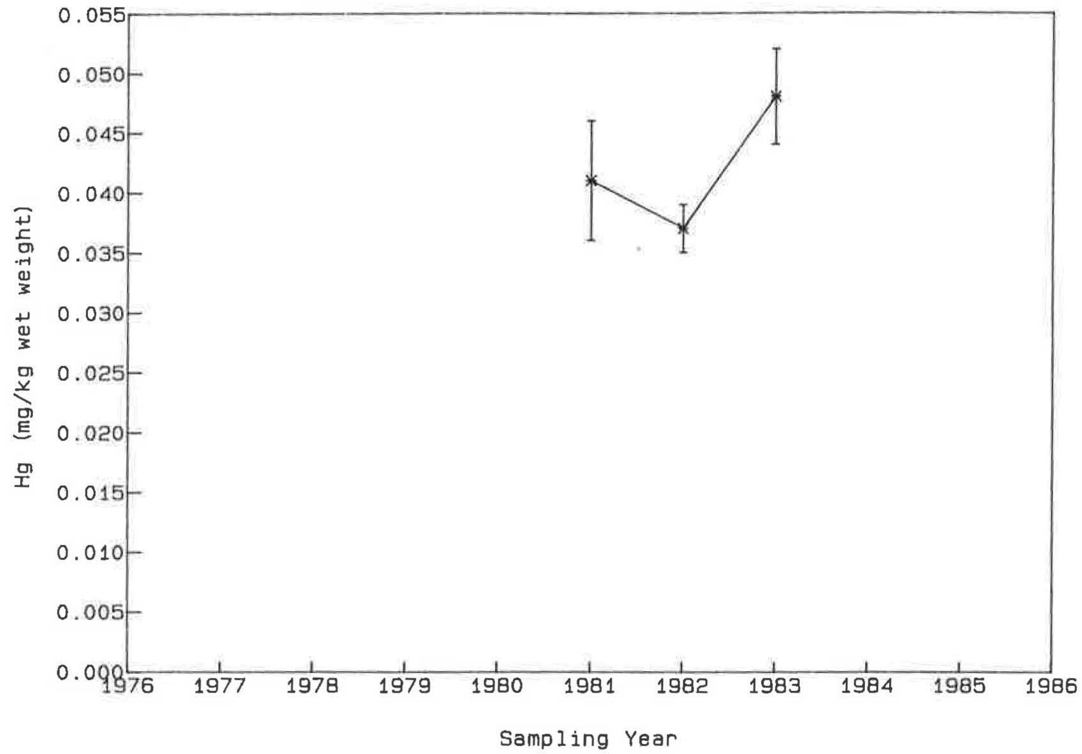
The data originator has informed that, due to the problems of sampling fish in this area, monitoring of plaice in 40F7 will no longer be included in the Danish trend monitoring programme.

Results of analyses:

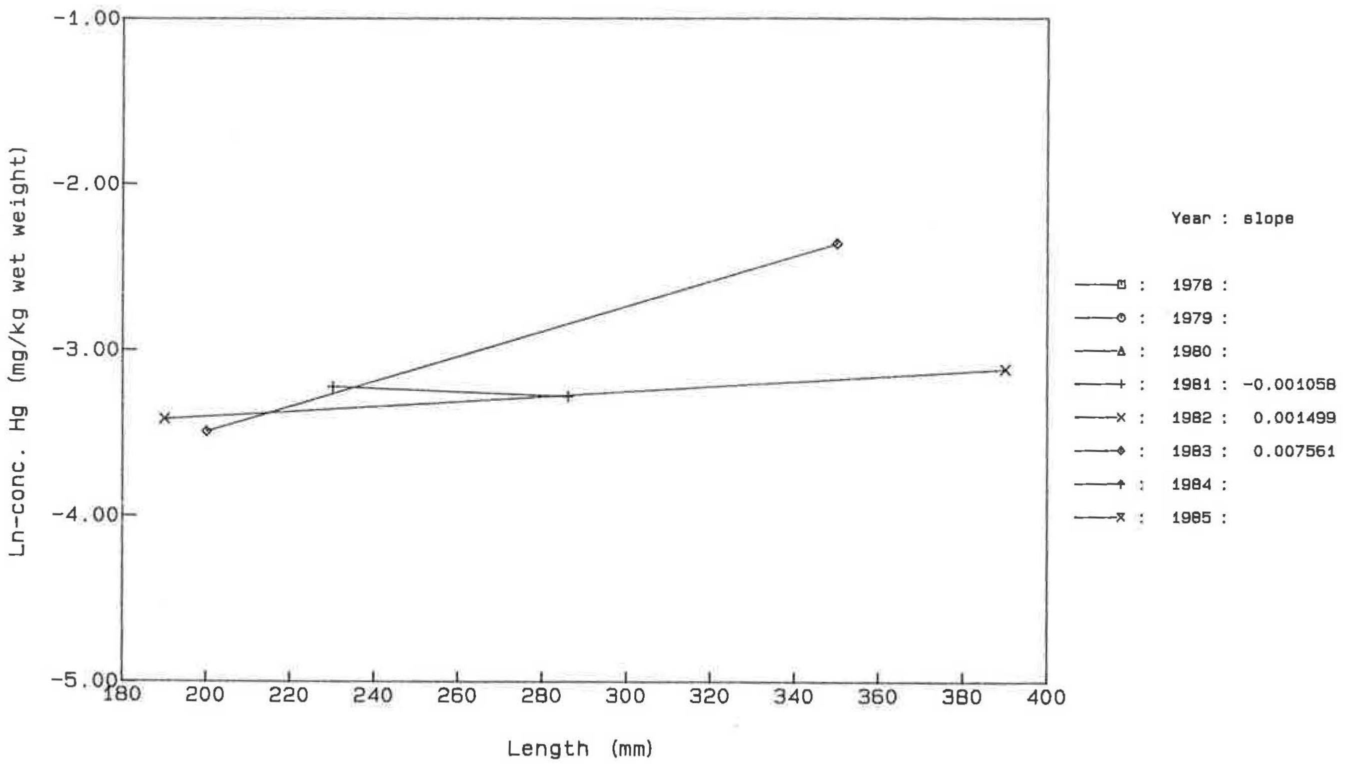
Mercury

- Results show significant differences between years in the slopes of the linear relationships between contaminant level and length.

(LA) Estimates of Hg in plaice muscle - plaice in 40F7



Regression of Ln-conc. Hg versus length by year - plaice in 40F7



SPECIES: Plaice (PLEU PLA) TISSUE : muscle	NOMINAL AREA: 41F7 COUNTRY : Denmark

DATA CHARACTERISTICS

BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length				o	o	o	o	o
Weight				o	o	o	o	o
Age				o	o	●	o	o
Sex				o	o	o	o	o
Tissue wt.								
Fat %						o[1]		
Dry %						o[1]	o[1]	
CONTAMINANTS								
Hg				o	o	o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB						o[1]	o[1]	
SAMPLING								
sampling periods				Aug	Oct	May[2]	Dec	Oct
sampling locations				41F7	41F7	41F7	41F7	41F7
number of specimens				20	22	25	25	24

Commentary:

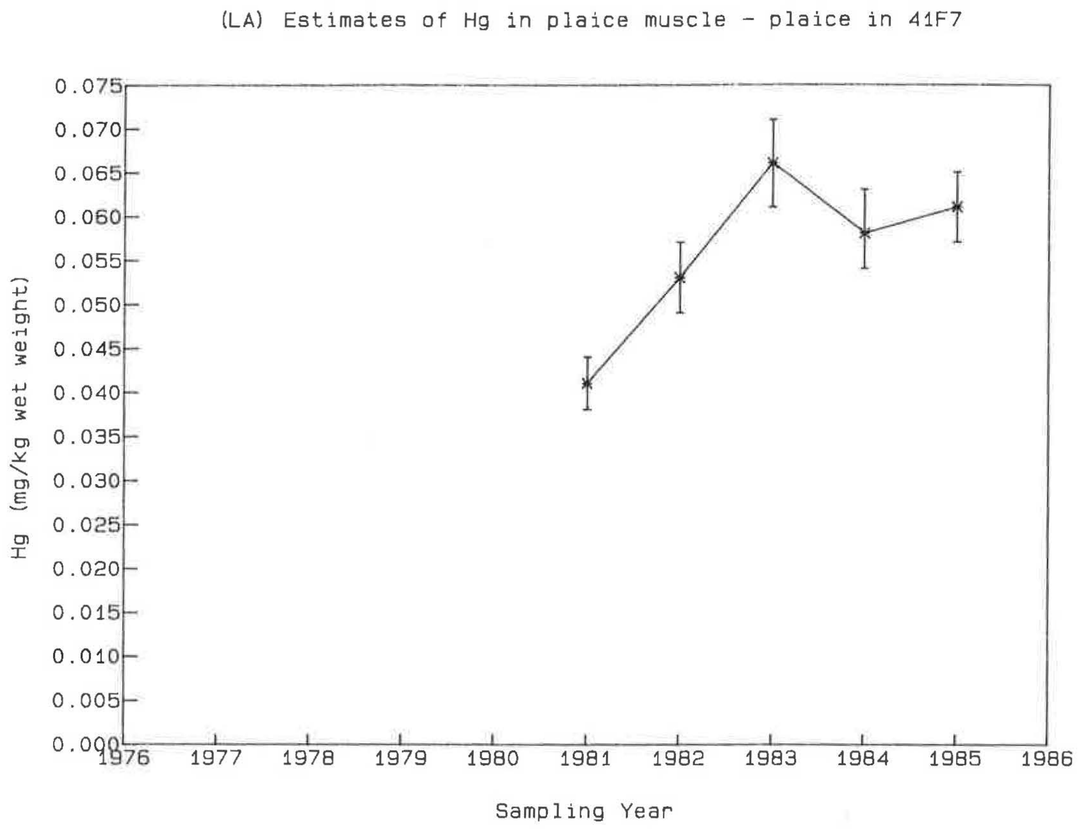
[1] Measured in a single homogenate of the muscle tissue of 25 specimens.

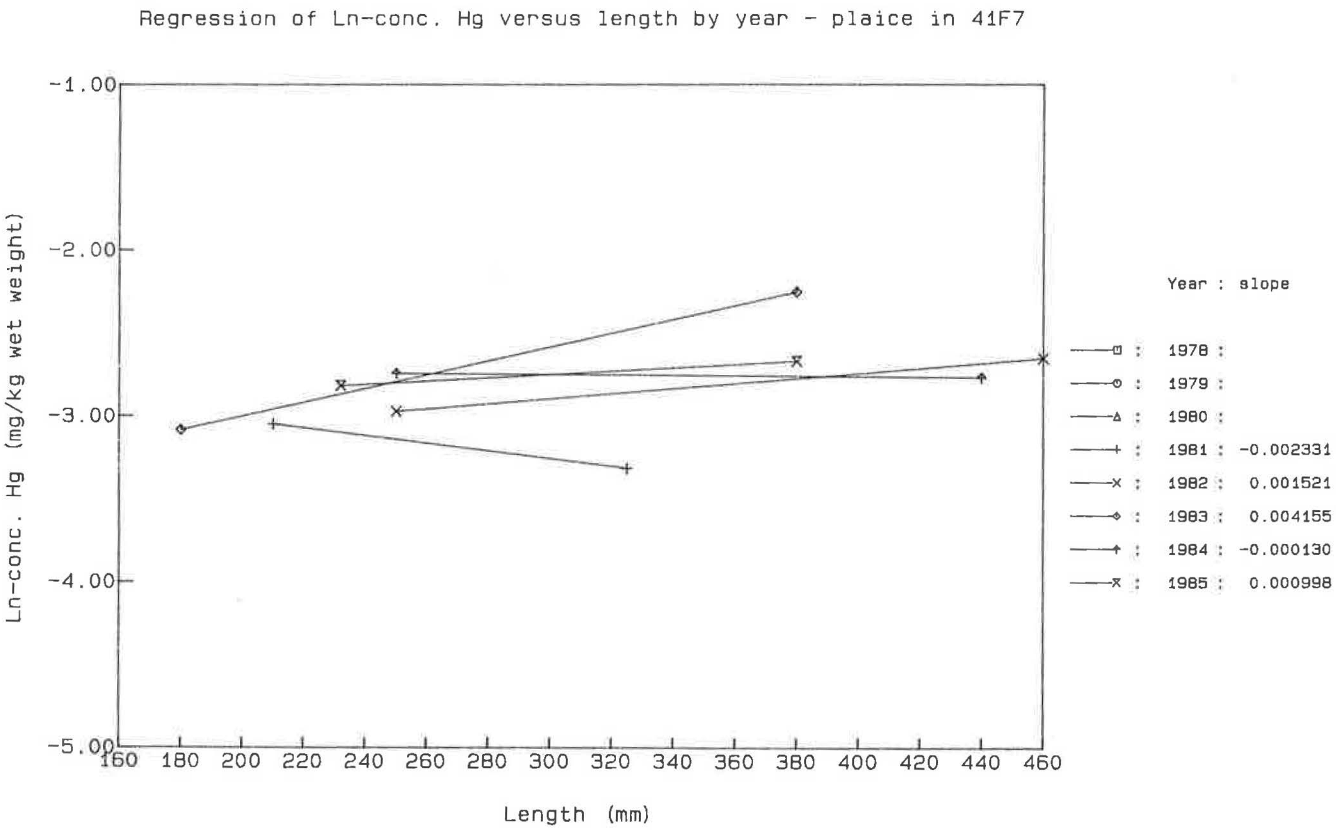
[2] The data originator has informed that the statistical analyses may be influenced by biological differences between samples taken in May and those taken during the August-December period. It has been noted, for example, that the size of the fish liver increases from spring to autumn.

Results of analyses:

Mercury

- Results show significant differences between years in the slopes of the linear relationships between contaminant level and length. The results suggesting that a significant increase in the explanatory power of the statistical analysis could be achieved by inclusion of additional biological covariates may not be valid under these circumstances


(LA) Estimates of Hg in plaice muscle - plaice in 41F7
Hg (mg/kg wet weight)
0.075
0.070
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Hg versus length by year - plaice in 41F7
Ln-conc. Hg (mg/kg wet weight)
-1.00
-2.00
-3.00
-4.00
-5.00
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
Length (mm)
Year : slope
1978 :
1979 :
1980 :
1981 : -0.002331
1982 : 0.001521
1983 : 0.004155
1984 : -0.000130
1985 : 0.000998

SPECIES: Plaice (PLEU PLA) TISSUE : muscle	NOMINAL AREA: 43F8 COUNTRY : Denmark

DATA CHARACTERISTICS

BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length		o		o		o	o	o
Weight		o		o		o	o	o
Age		o		o		o	o	o
Sex		o		o		o	o	o
Tissue wt.								
Fat %						o[1]	o[1]	
Dry %						o[1]		
CONTAMINANTS								
Hg		o		o		o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB						o[1]	o[1]	
SAMPLING								
sampling periods		Aug		Aug		May[2]	Nov	Sept
sampling locations		43F8		43F8		43F8	43F8	43F8
number of specimens		20		10		25	25	20

<u>Commentary:</u>

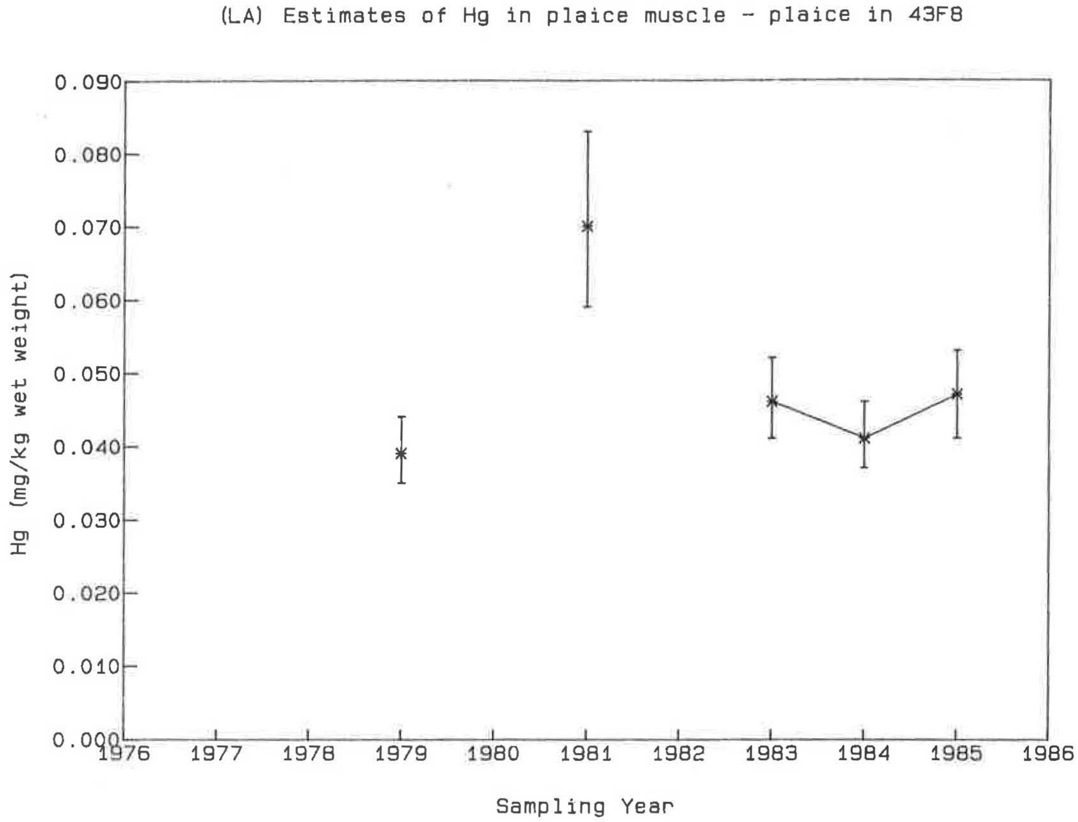
[1] Measured in a single homogenate of the muscle tissue of 25 specimens.

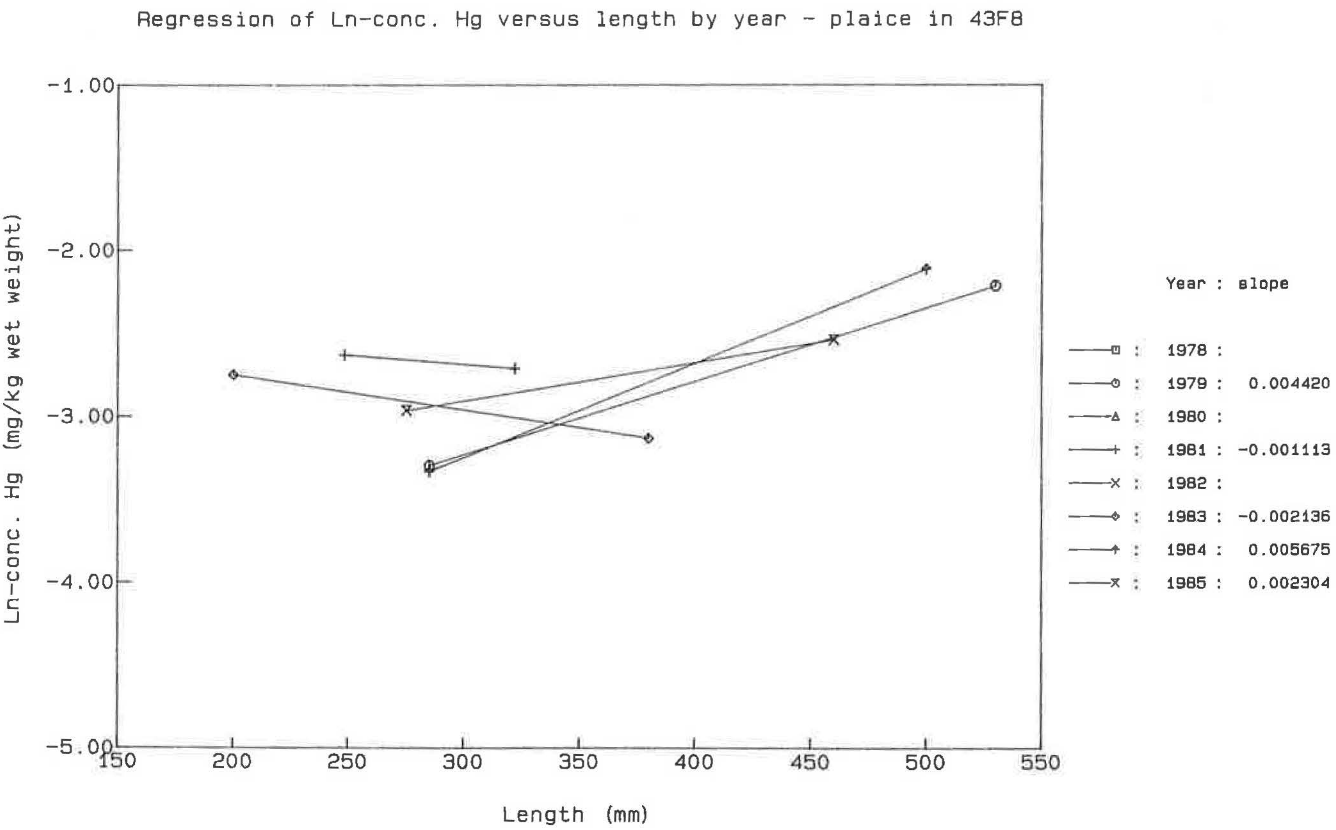
[2] The data originator has informed that the statistical analyses may be influenced by biological differences between samples taken in May and those taken during the August-November period. In 1981 it was not possible to catch more than 10 fish in this area.

<u>Results of analyses:</u>

Mercury

- Results show significant differences between years in the slopes of the linear relationships between contaminant level and length.


(LA) Estimates of Hg in plaice muscle - plaice in 43F8
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Hg (mg/kg wet weight)
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Hg versus length by year - plaice in 43F8
-1.00
-2.00
-3.00
-4.00
-5.00
Ln-conc. Hg (mg/kg wet weight)
150
200
250
300
350
400
450
500
550
Length (mm)
Year : slope
1978 :
1979 : 0.004420
1980 :
1981 : -0.001113
1982 :
1983 : -0.002136
1984 : 0.005675
1985 : 0.002304

SPECIES: Plaice (PLEU PLA) TISSUE : muscle								NOMINAL AREA: 44F9 COUNTRY : Denmark
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length		o		o	o		o	o
Weight		o		o	o		o	o
Age		o		o	o		o	o
Sex		o		●	o		o	o
Tissue wt.								
Fat %							o[1]	
Dry %								
CONTAMINANTS								
Hg		o		o	o		o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB							o[1]	
SAMPLING								
sampling periods		Aug		Aug	Oct		Oct	Sept
sampling locations		44F9		44F9	44F9		44F9	44F9
number of specimens		10[2]		20	25		24	24

Commentary:

[1] Measured in a single homogenate of the muscle tissue of 24 specimens.

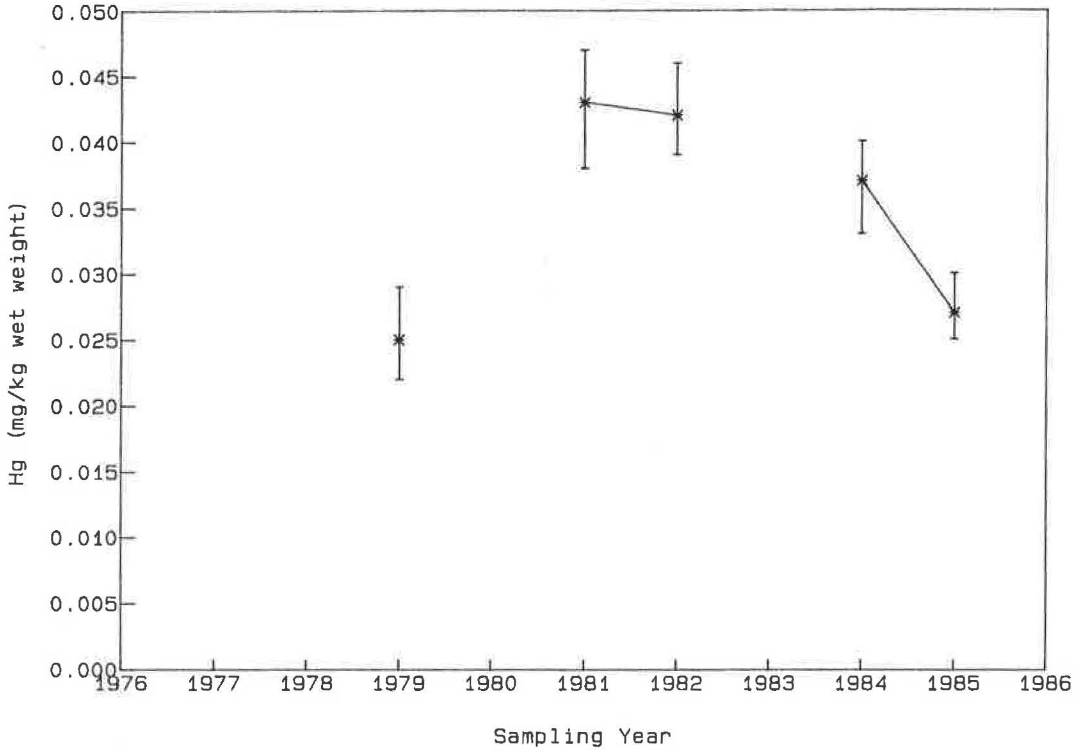
[2] The data originator has informed that the statistical analyses may be influenced by the limited number and restricted size range of the fish which it was possible to sample in 1979.

Results of analyses:

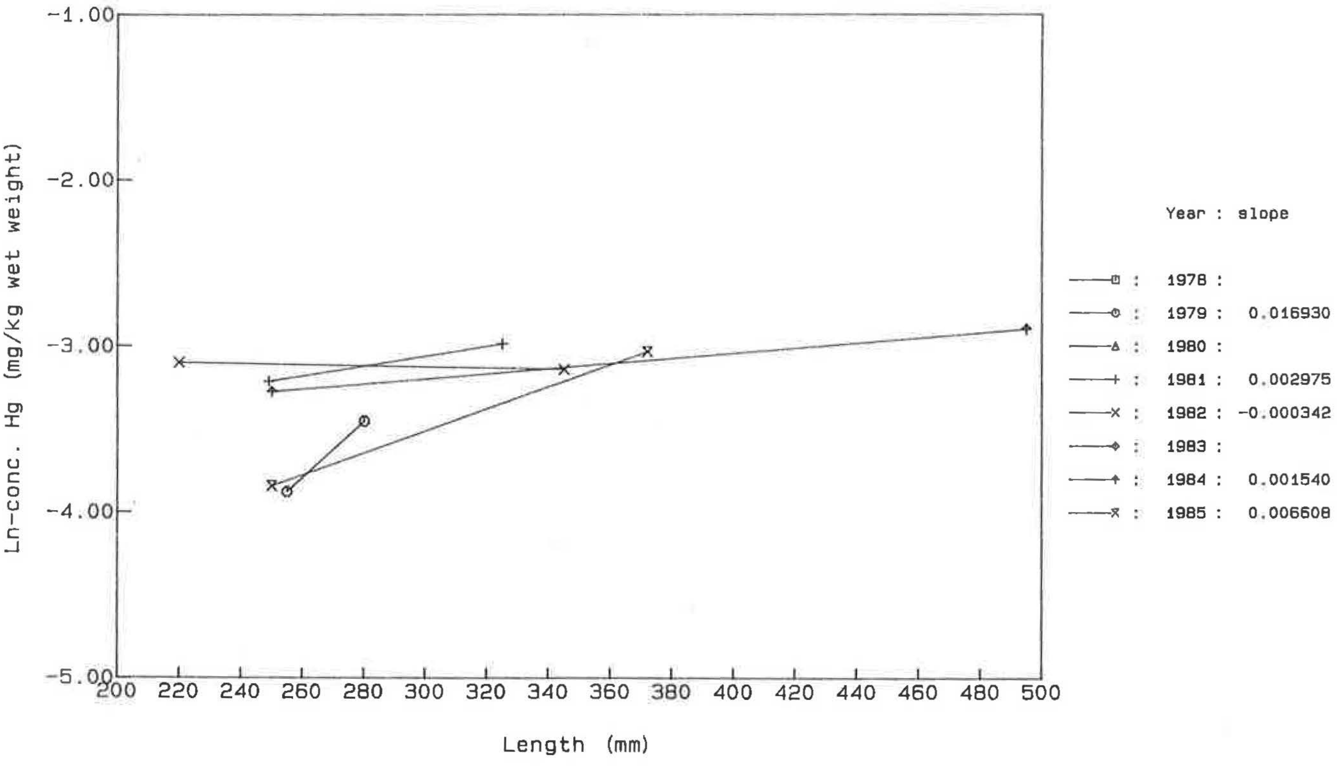
Mercury

- Results show significant differences between years in the slopes of the linear relationships between contaminant level and length. This could be a result of a poor definition of the contaminant-length relationship for 1979, due to the restricted range of lengths sampled.

(LA) Estimates of Hg in plaice muscle - plaice in 44F9



Regression of Ln-conc. Hg versus length by year - plaice in 44F9



SPECIES: Flounder (PLAT FLE) TISSUE : muscle				NOMINAL AREA: 31F2 COUNTRY : Belgium				
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length	o	o	o	o	o	o	o	o
Weight	o	o	o	o	o	o	o	o
Age	o	o	o	o	o	o	o	o
Sex	o	o	o	o	o	o	o	o
Tissue wt.								
Fat %						o	o	o
Dry %								
CONTAMINANTS								
Hg	o	o	o	o	o	o	o	o
Cd		<.005	<.005	<.005	<.005	<.005	<.005	<.005
Cu	o	o	o	o	o	o	o	o
Pb		o	o	o	o	o	o	o
Zn	o	o	o	o	o	o	o	o
Cr	o	o	<.01	<.01	o	o	o	o
Ni		o	o	o	o	o	o	o
PCB						o	o	o
SAMPLING								
sampling periods	Dec	June	Sept	Apr	Oct	Apr	Apr	Apr
sampling locations	31F2	31F2	31F2	31F2	31F2	31F2	31F2	31F2
number of specimens	20	20	19	20	28	25	20	25

Results of analyses:

Chromium[1]; Copper; Nickel[1]; PCB

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

[1]The data originator has notified that, due to a change in the analytical methodologies for chromium and nickel, values for the period 1978-1979 are considered unreliable and should be rejected; values from 1980 onwards should be acceptable, but may be subject to rather high analytical errors.

Mercury

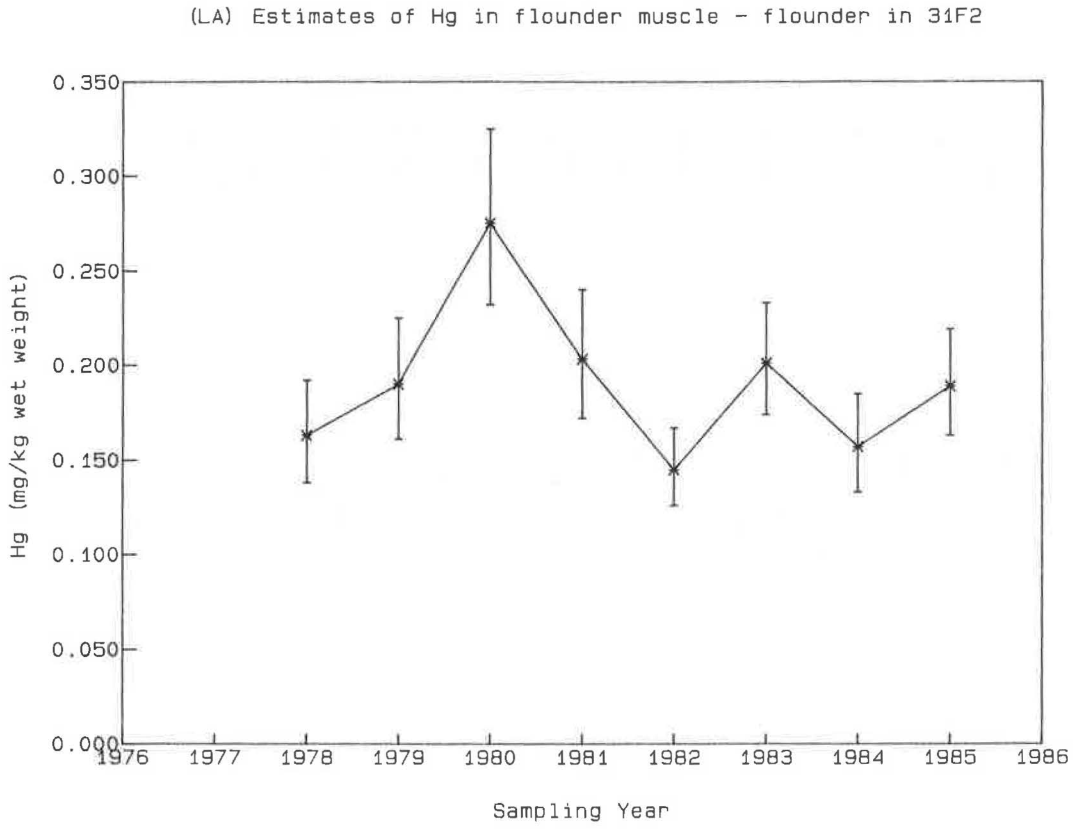
- Results confirm the validity of the statistical analysis; the length-adjusted yearly mean contaminant levels differ significantly between years but there is no evidence of a linear trend (see plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

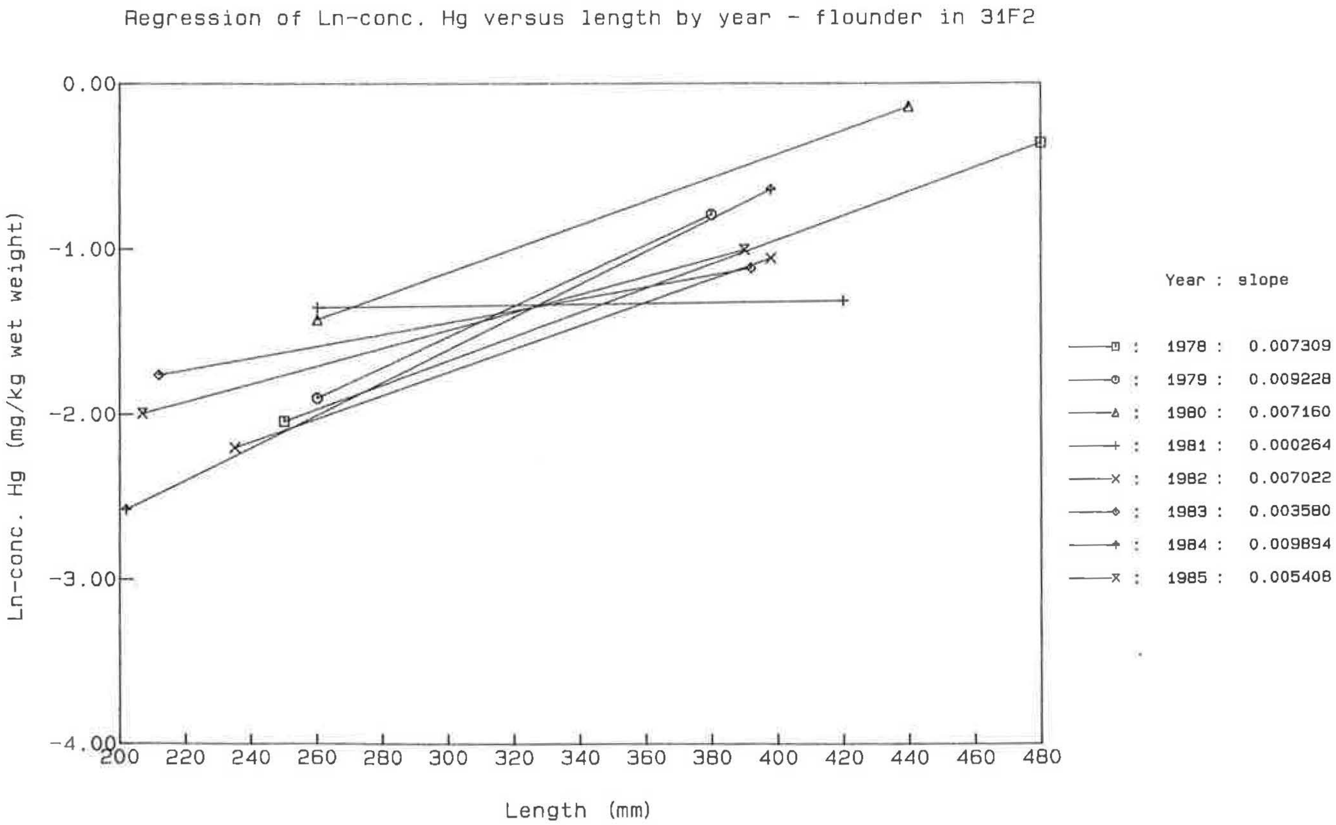
Lead

- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot).

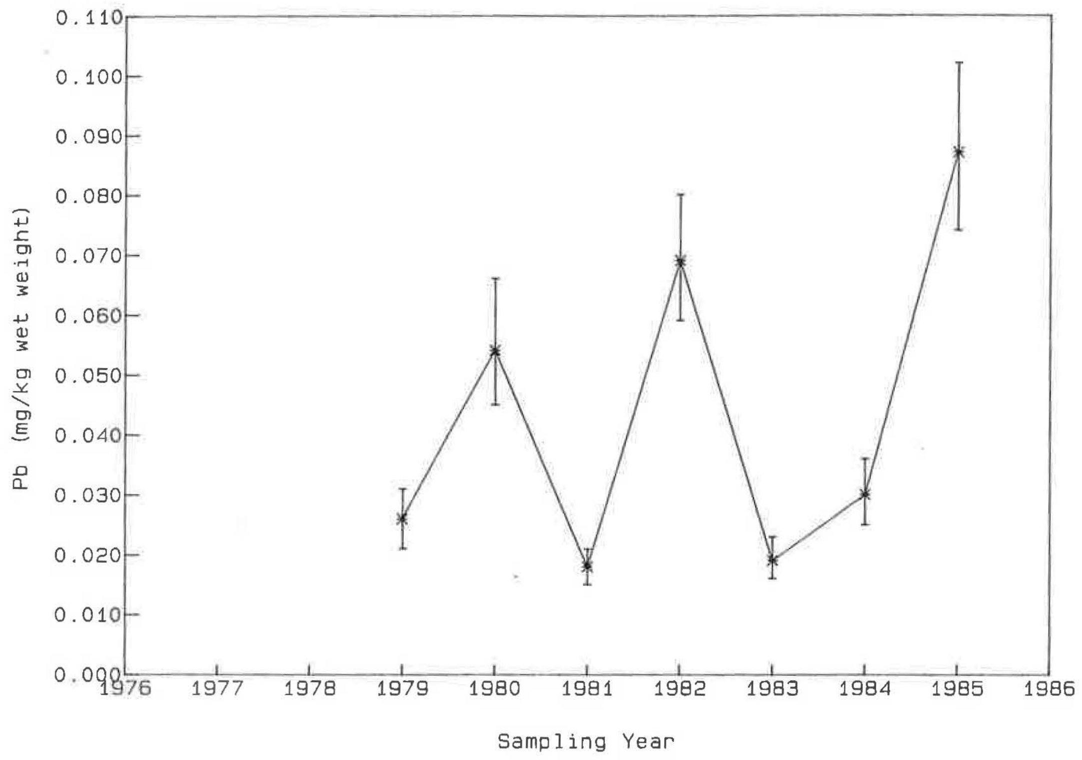
Zinc

- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

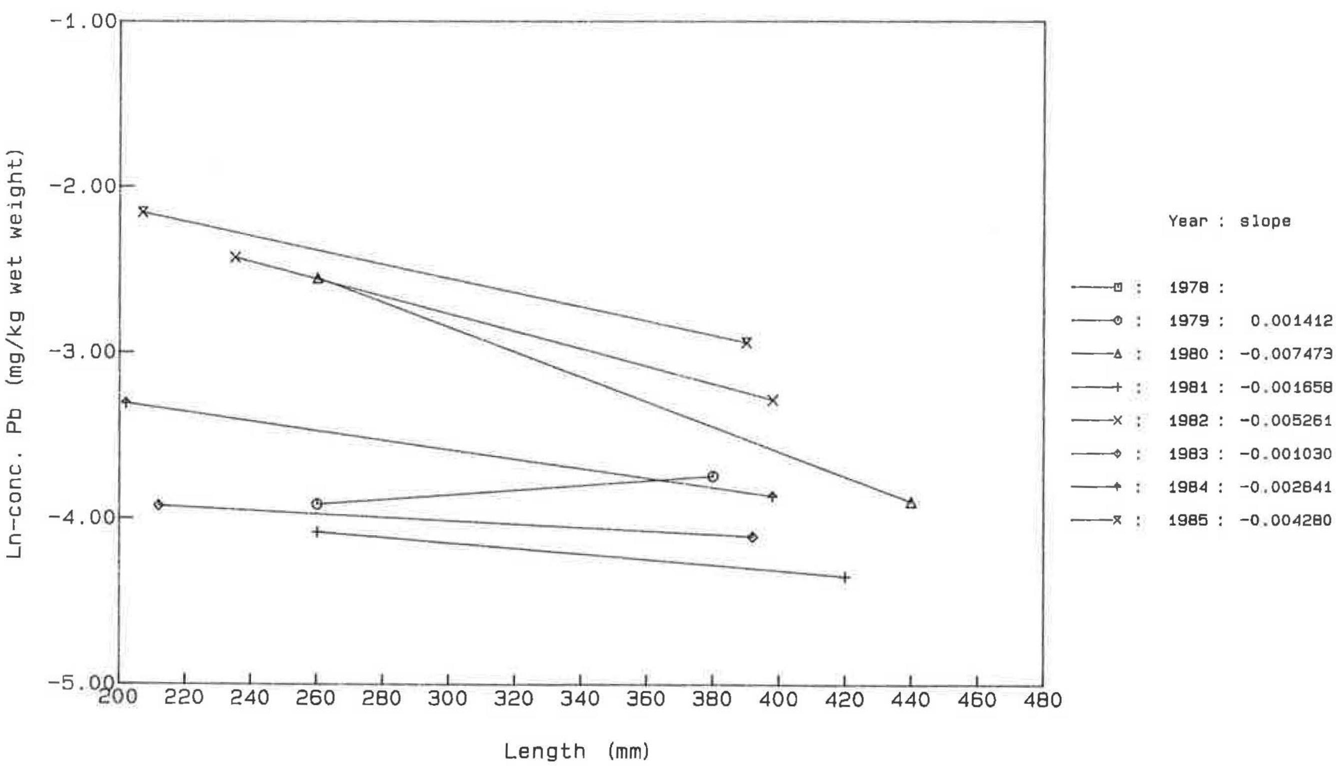

(LA) Estimates of Hg in flounder muscle - flounder in 31F2
Hg (mg/kg wet weight)
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
Sampling Year

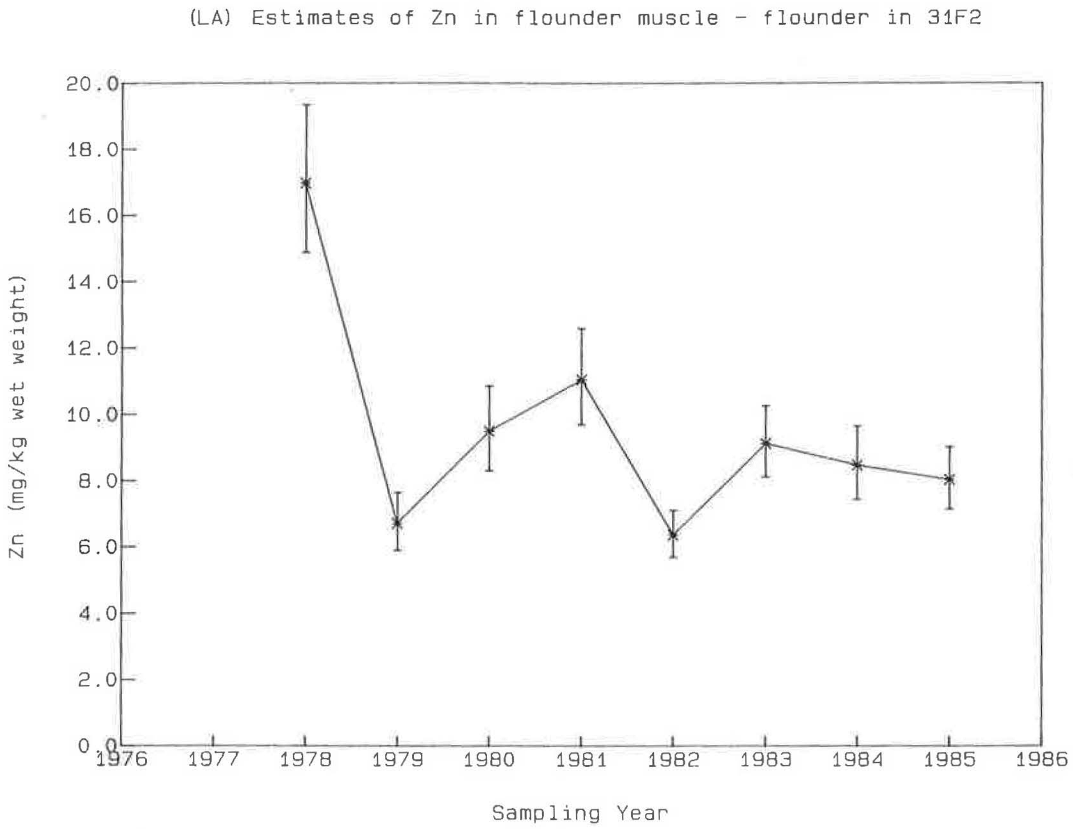

Regression of Ln-conc. Hg versus length by year - flounder in 31F2
Ln-conc. Hg (mg/kg wet weight)
0.00
-1.00
-2.00
-3.00
-4.00
200 220 240 260 280 300 320 340 360 380 400 420 440 460 480
Length (mm)
Year : slope
1978 : 0.007309
1979 : 0.009228
1980 : 0.007160
1981 : 0.000264
1982 : 0.007022
1983 : 0.003580
1984 : 0.009894
1985 : 0.005408

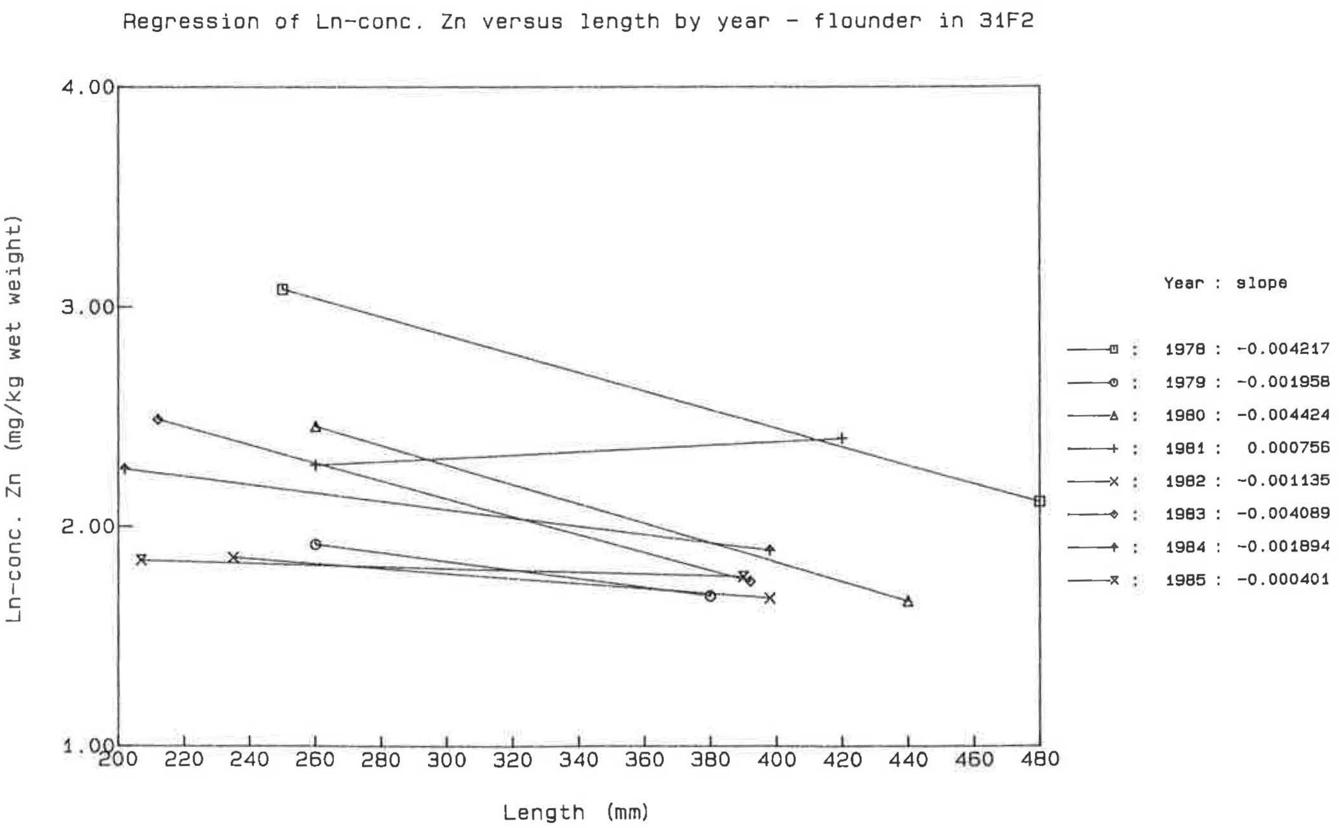
(LA) Estimates of Pb in flounder muscle - flounder in 31F2



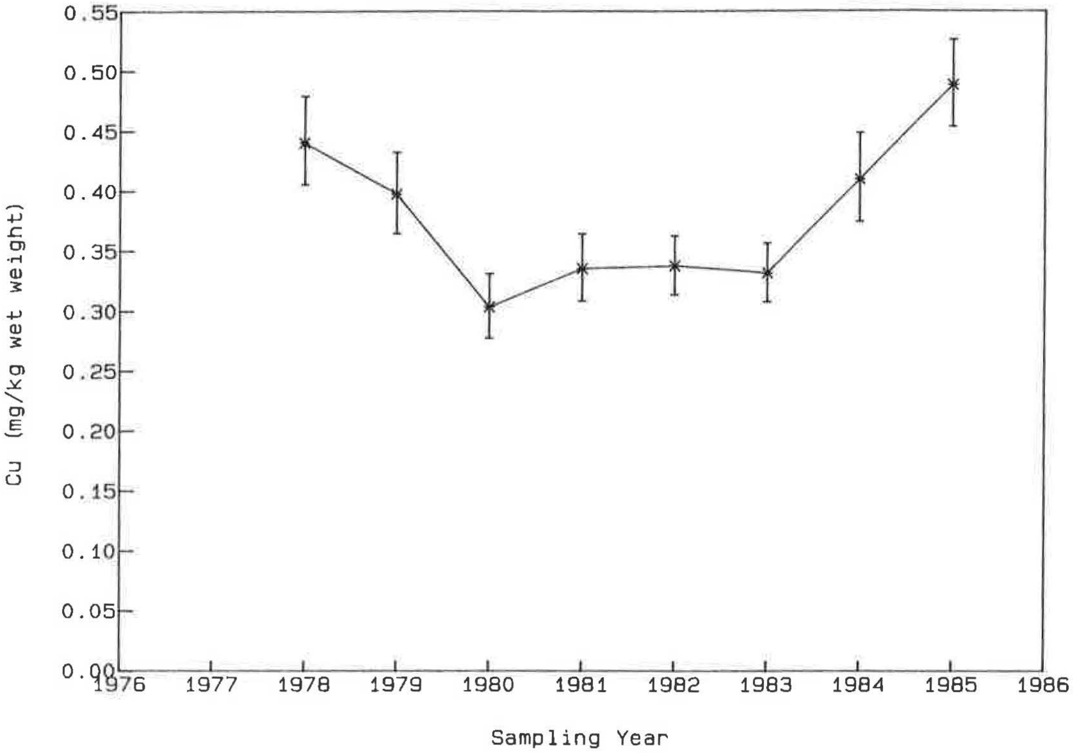
Regression of Ln-conc. Pb versus length by year - flounder in 31F2



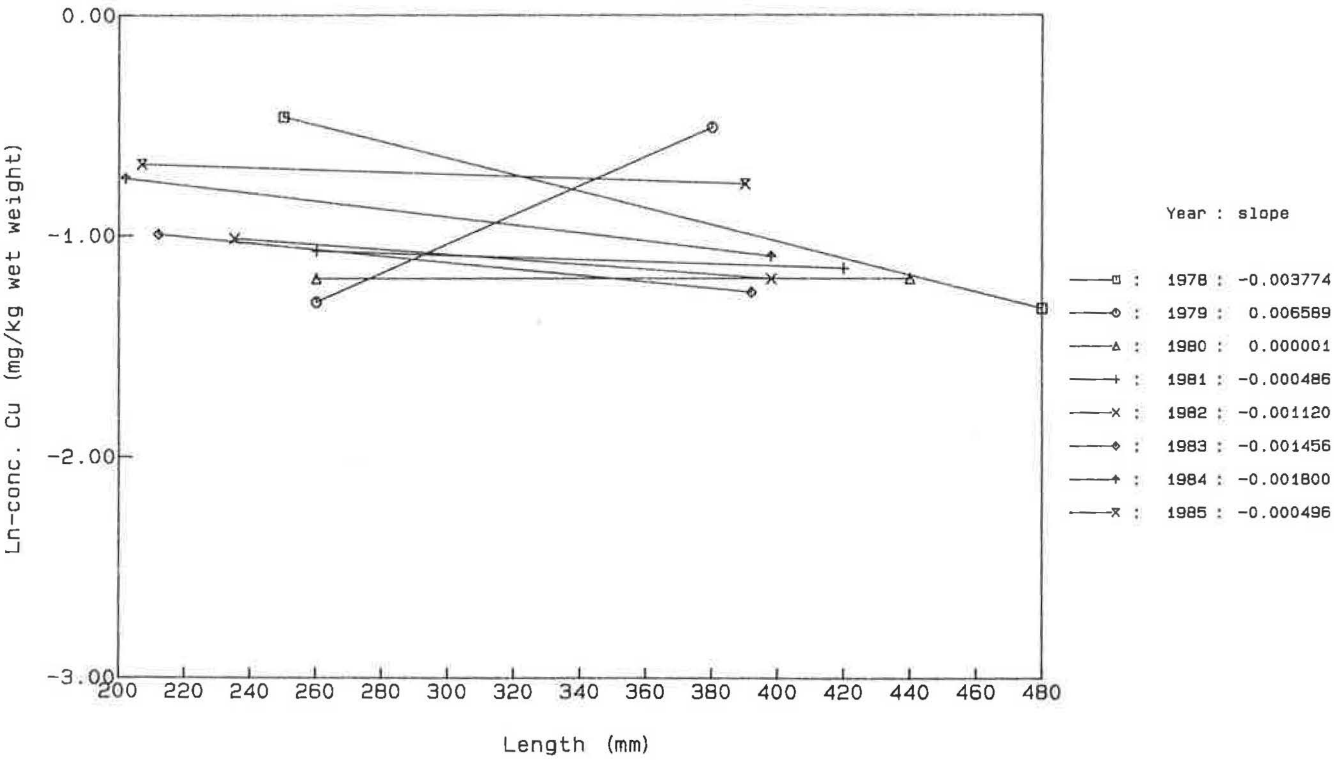

(LA) Estimates of Zn in flounder muscle - flounder in 31F2
Zn (mg/kg wet weight)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Zn versus length by year - flounder in 31F2
Ln-conc. Zn (mg/kg wet weight)
4.00
3.00
2.00
1.00
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
Length (mm)
Year : slope
1978 : -0.004217
1979 : -0.001958
1980 : -0.004424
1981 : 0.000756
1982 : -0.001135
1983 : -0.004089
1984 : -0.001894
1985 : -0.000401

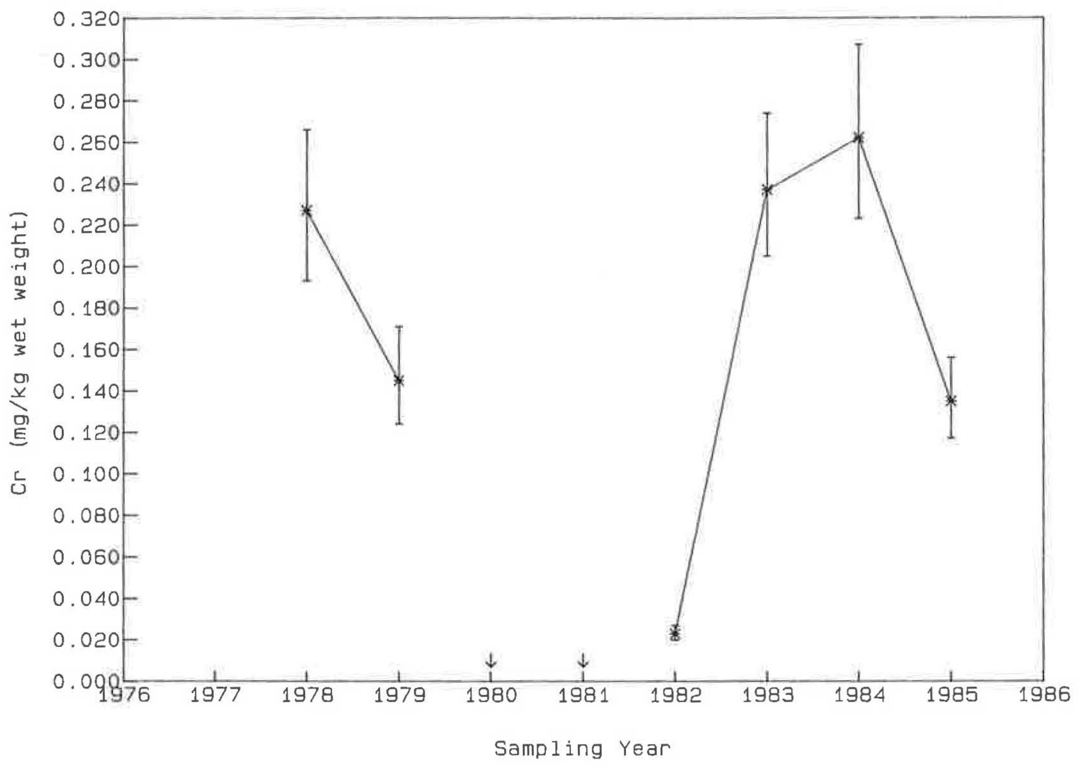
(GM) Estimates of Cu in flounder muscle - flounder in 31F2



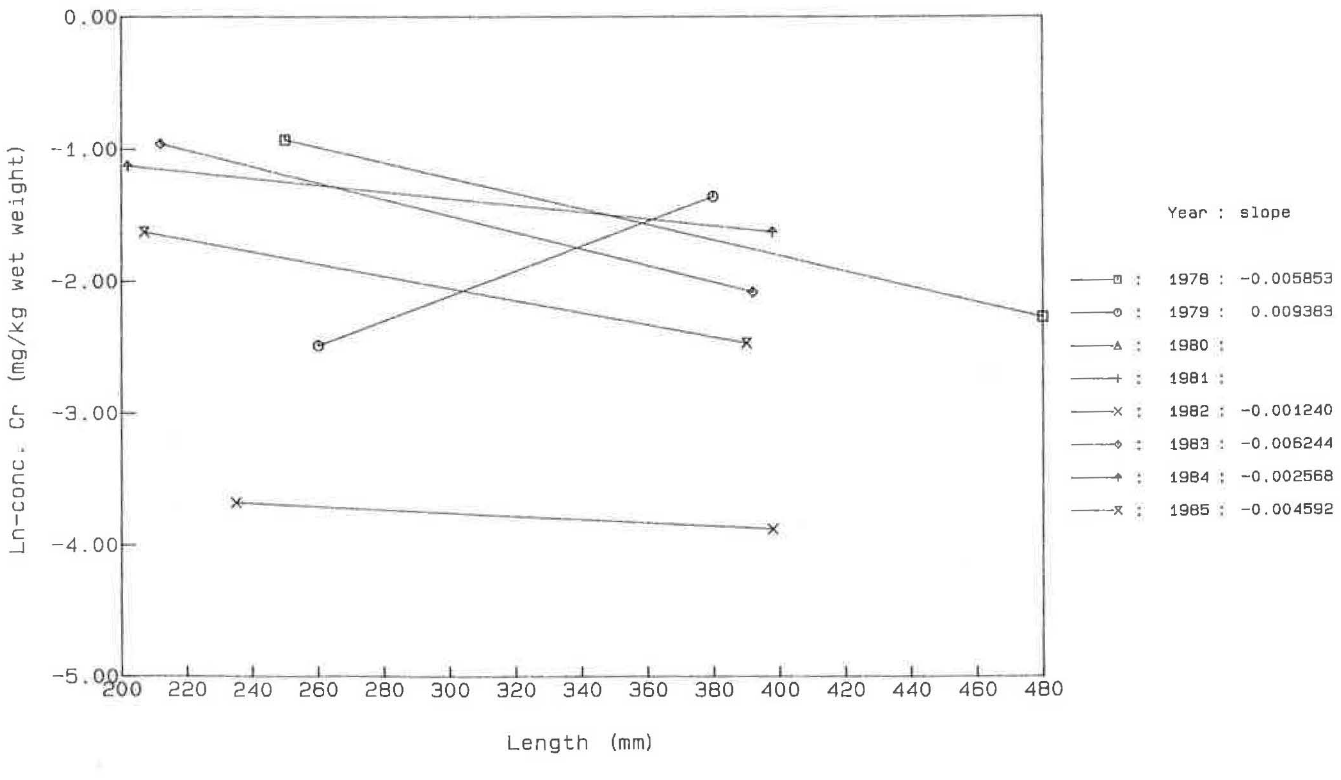
Regression of Ln-conc. Cu versus length by year - flounder in 31F2

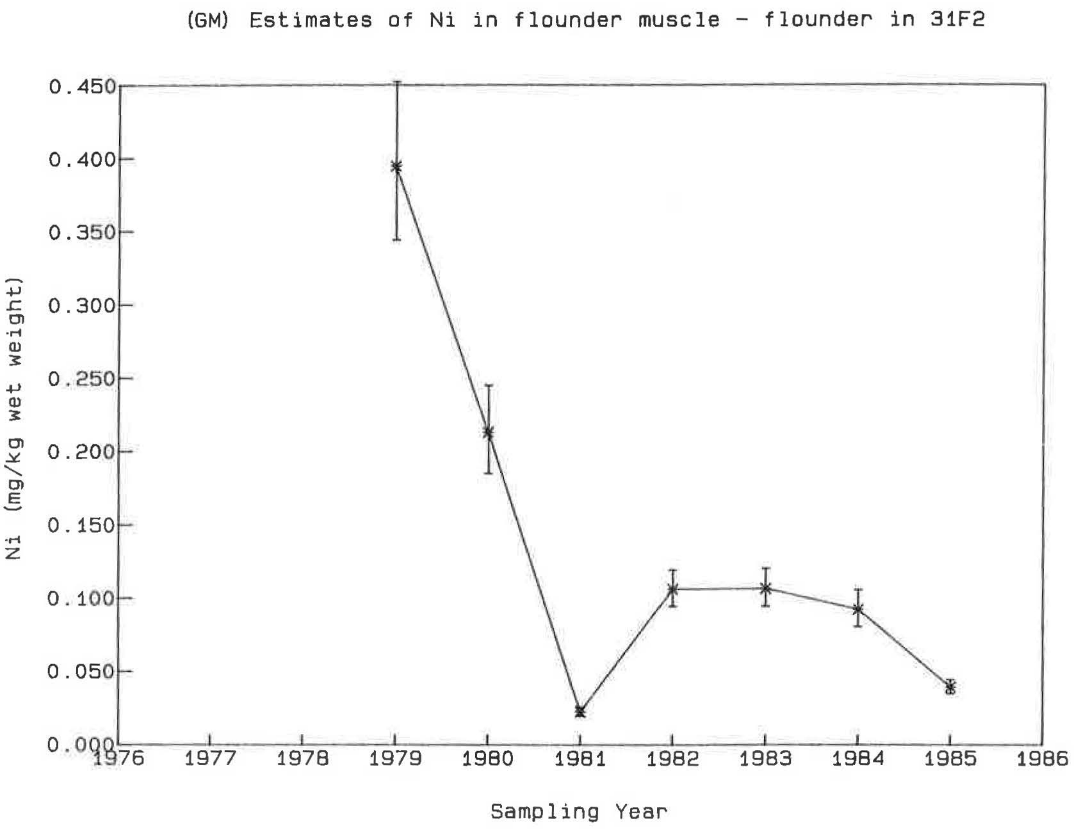


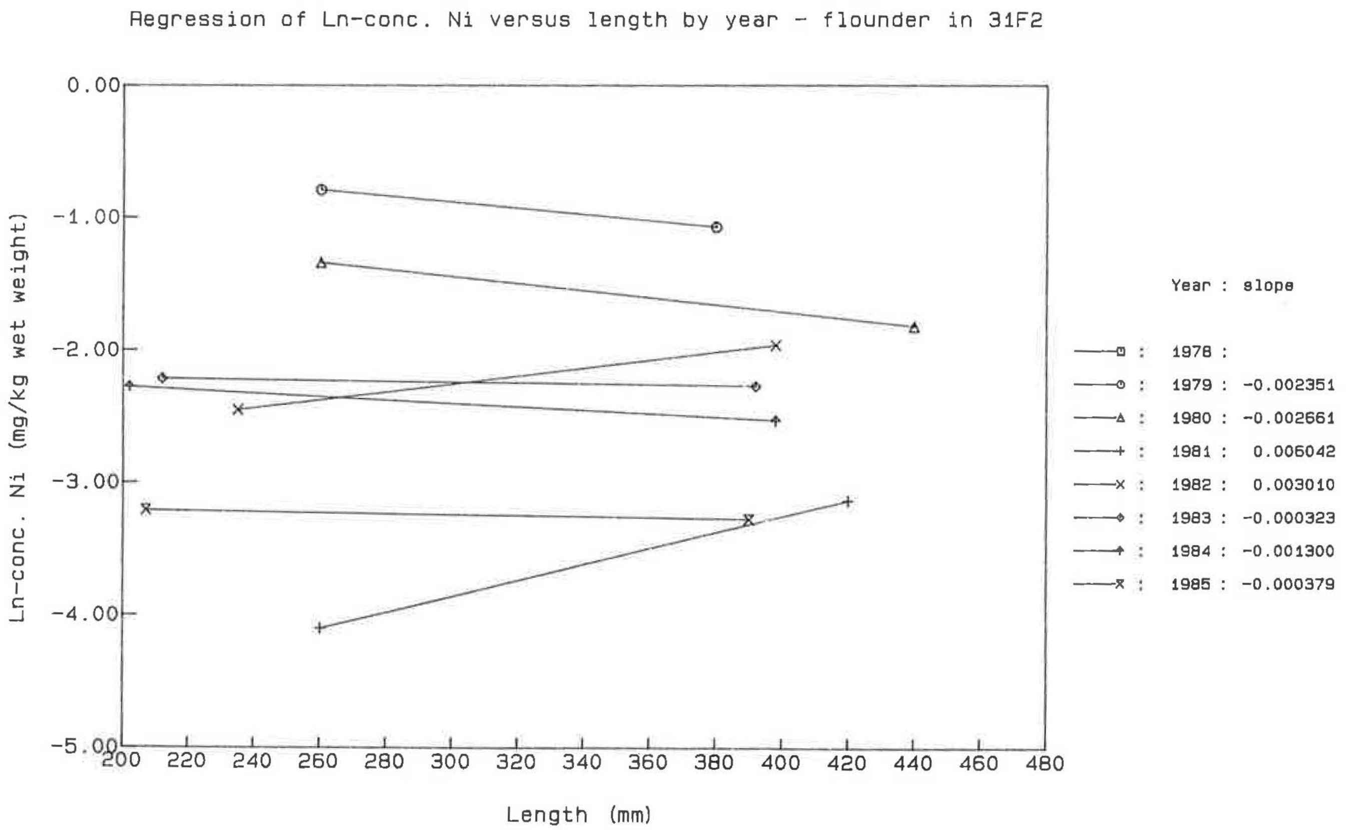
(GM) Estimates of Cr in flounder muscle - flounder in 31F2



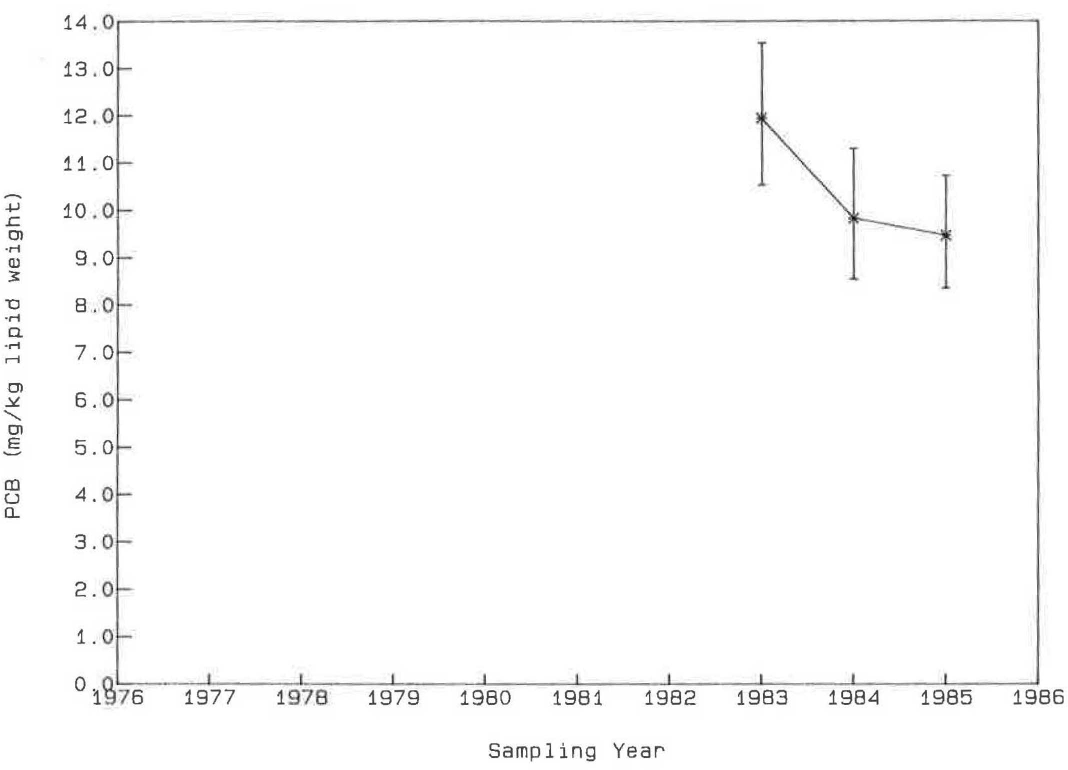
Regression of Ln-conc. Cr versus length by year - flounder in 31F2



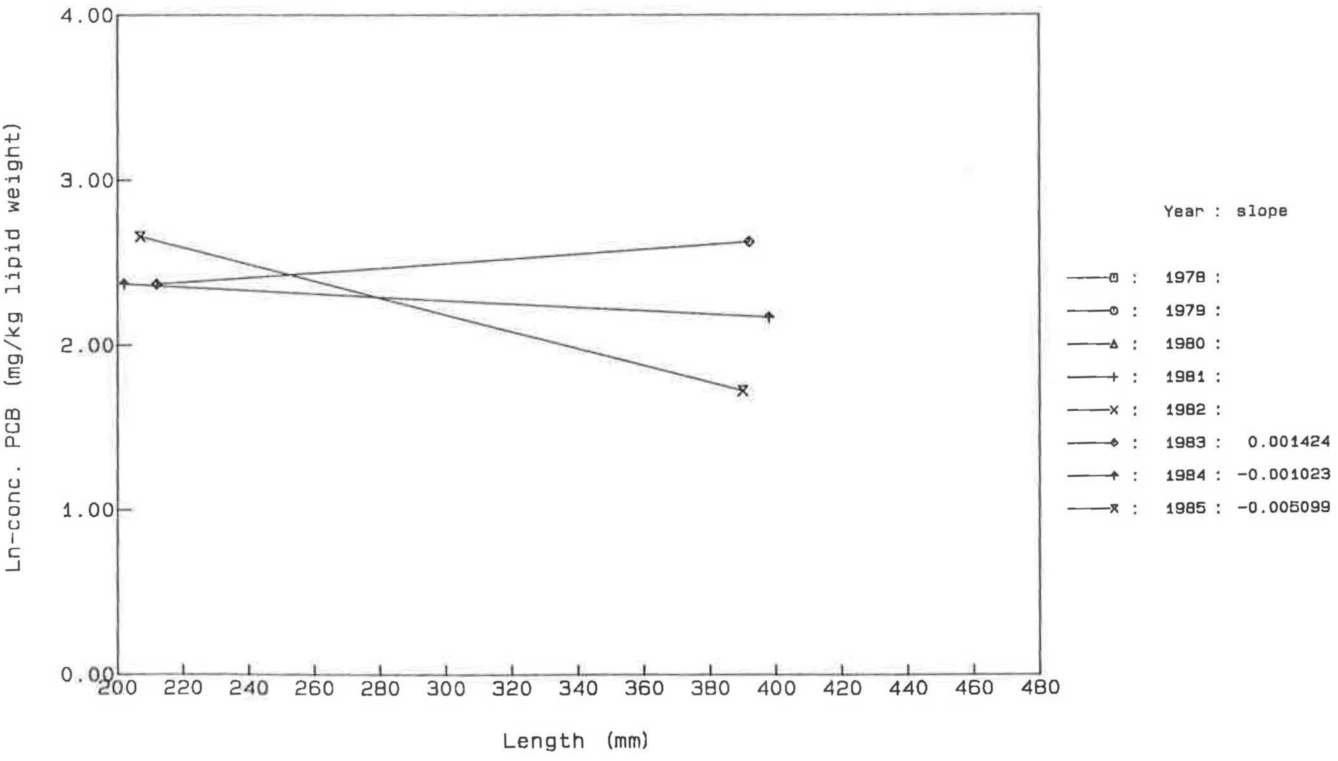

(GM) Estimates of Ni in flounder muscle - flounder in 31F2
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
Sampling Year
Ni (mg/kg wet weight)


Regression of Ln-conc. Ni versus length by year - flounder in 31F2
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
200 220 240 260 280 300 320 340 360 380 400 420 440 460 480
Length (mm)
Ln-conc. Ni (mg/kg wet weight)
Year : slope
1978 :
1979 : -0.002351
1980 : -0.002661
1981 : 0.006042
1982 : 0.003010
1983 : -0.000323
1984 : -0.001300
1985 : -0.000379

(GM) Estimates of PCB in flounder muscle - flounder in 31F2



Regression of Ln-conc. PCB versus length by year - flounder in 31F2



SPECIES: Flounder (PLAT FLE) TISSUE : muscle	NOMINAL AREA: 36F8 COUNTRY : Fed. Rep. Germany

DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length						o	o	o
Weight						o	o	o
Age						o	o	o
Sex						o		o
Tissue wt.								
Fat %								
Dry %							o	o
CONTAMINANTS								
Hg						o	o	o
Cd								
Cu								o
Pb								
Zn						o		o
Cr								
Ni								
PCB								
SAMPLING								
sampling periods						Sept	Sept	Sept
sampling locations						36F8	36F8	37F8
number of specimens						41	25	31

Commentary:

The data originator informed that national data evaluations indicate that the levels of certain contaminants in the German Bight are influenced to a large extent by the inflows of water from the major rivers. In the case of mercury, river-borne inputs into the North Sea have been estimated at ca. 20 t/yr, with a (pronounced) gross input of mercury to the German Bight through the river Elbe of ca. 7-8 t/yr, figures which do not seem to have changed considerably during the period concerned. The (mercury) contamination of the German Bight, using flounder as a bio-indicator, exhibits a concentration decrease going north from the outer Elbe estuary along the Danish North Sea coast.

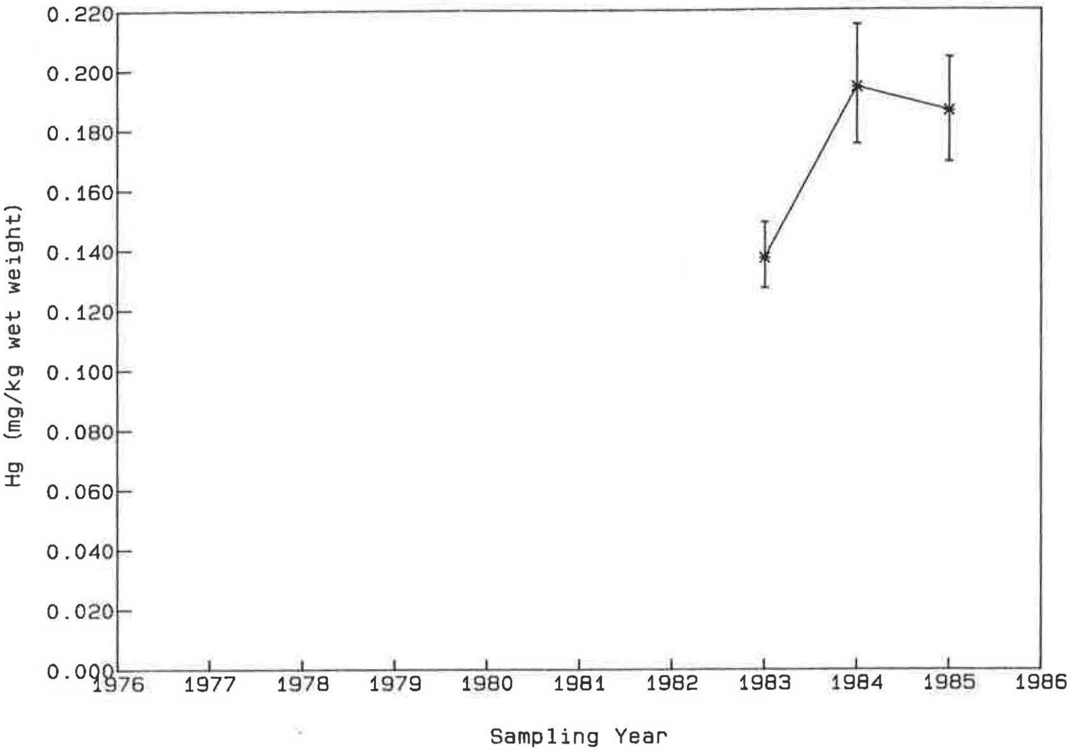
The 'avoidance' behaviour of flounder in relation to certain deteriorating environmental conditions was noted as a possible influence on the extent to which the data collected to date can be used to reliably identify temporal trends in the environment. It might well be that inter-annual fluctuations of mercury levels in flounder are linked with the migration and mixing of flounder populations of different origins (with differing environmental contamination) rather than reflecting variations in the inputs and levels of relevant contaminants in the area under study.

Results of analyses:

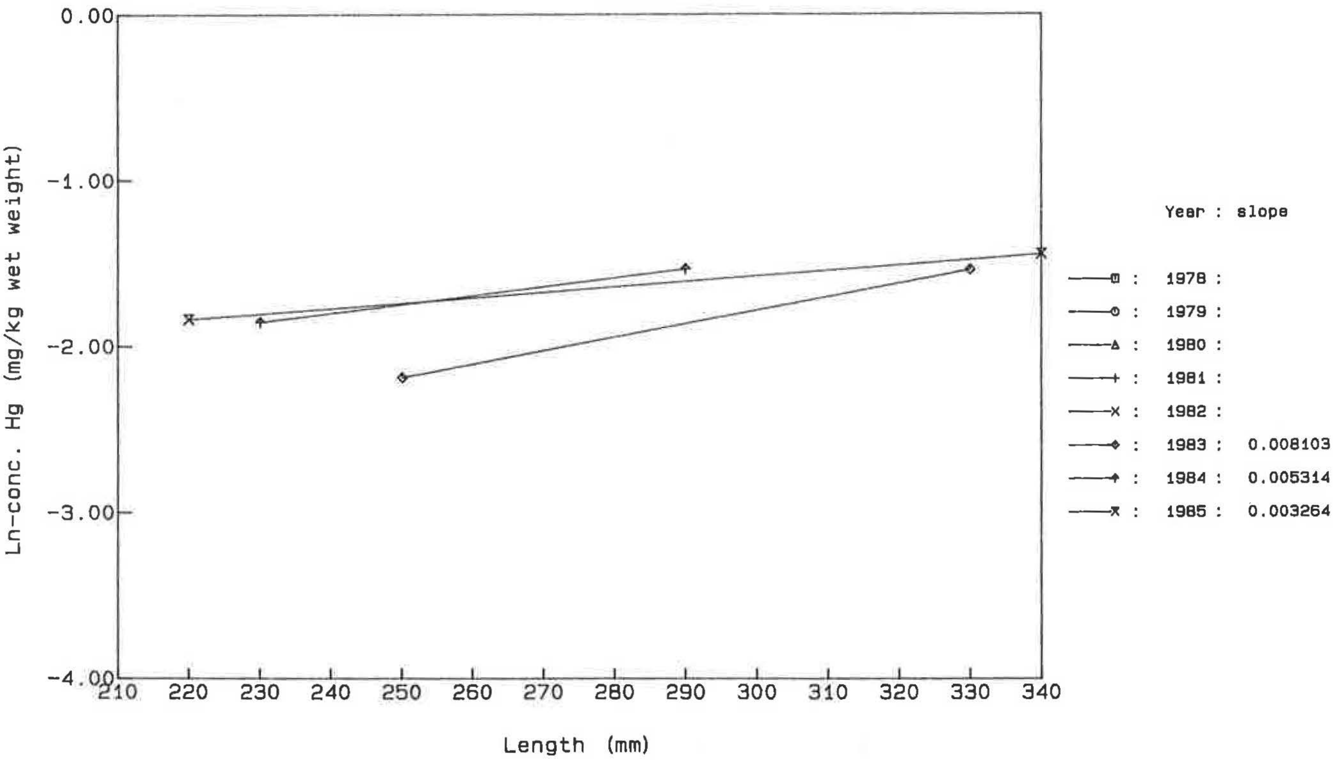
Mercury

- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot).

(LA) Estimates of Hg in flounder muscle - flounder in 36F8



Regression of Ln-conc. Hg versus length by year - flounder in 36F8



SPECIES: Flounder (PLAT FLE) TISSUE : muscle			NOMINAL AREA: 46G1 COUNTRY : Sweden					
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length			o	o	o	o	o	o
Weight			o	o	o	o	o	o
Age			o	o	o	o	o	4-5
Sex			o	o	o	o	o	o
Tissue wt.								
Fat %			o	o	o	o	o	o
Dry %						o	o	o
CONTAMINANTS								
Hg			●	●	o	o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB			o	o	o	o	o	●
SAMPLING								
sampling periods			Sept	Oct	Oct	Sept	Aug	Oct
sampling locations			46G1	46G1	46G1	46G1	46G1	46G1
number of specimens			20	20	20	17	25	7

Commentary:

Mercury of the data were reported for 1980, however values were missing for more than 20% of the specimens.

Results of analyses:

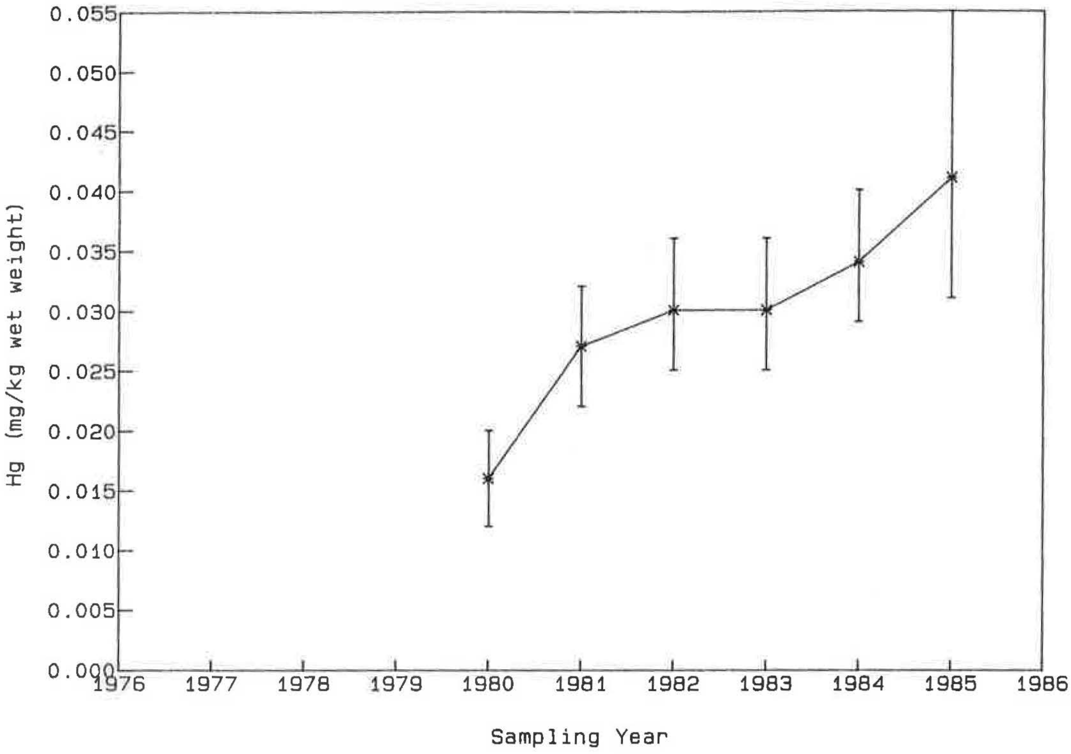
PCB

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

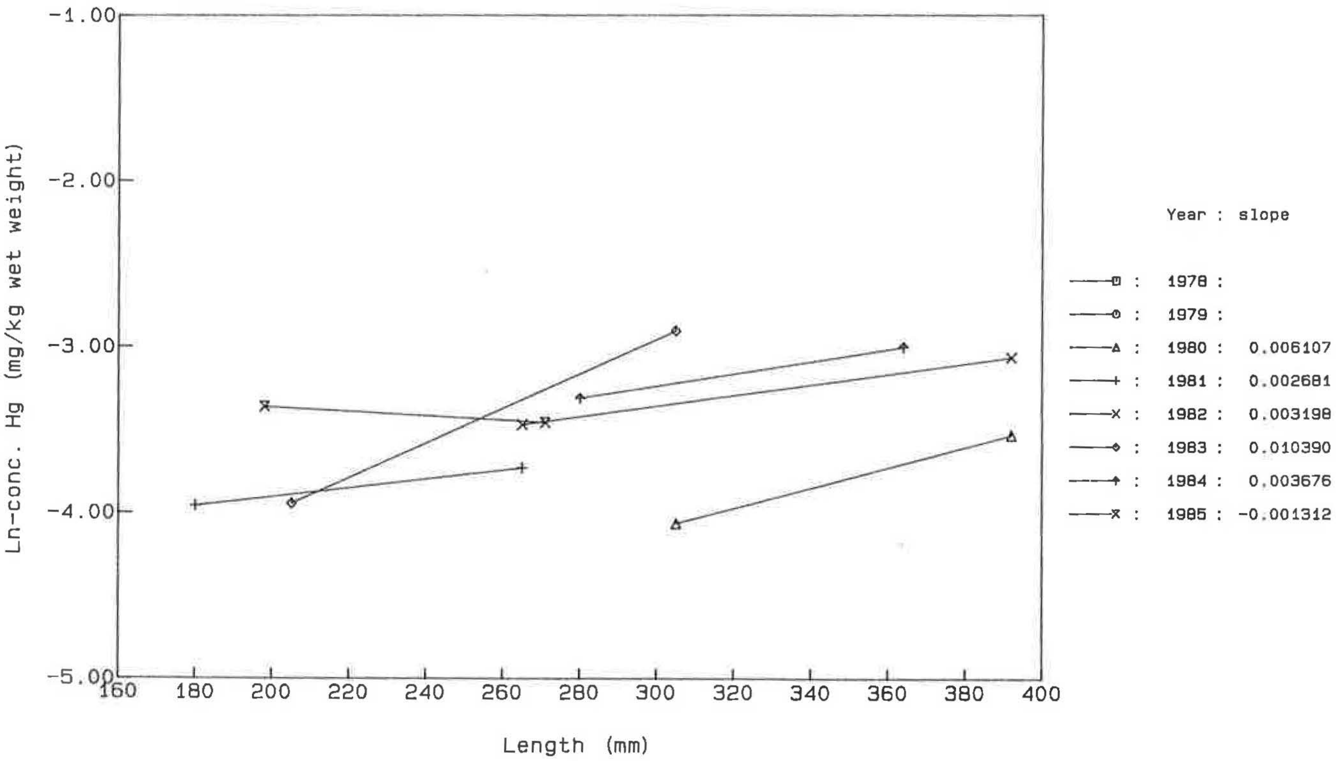
Mercury

- Results do not indicate evidence of a significant relationship between length and the contaminant levels; length-adjustment was still, however, applied in the computation of yearly mean contaminant levels (refer to plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

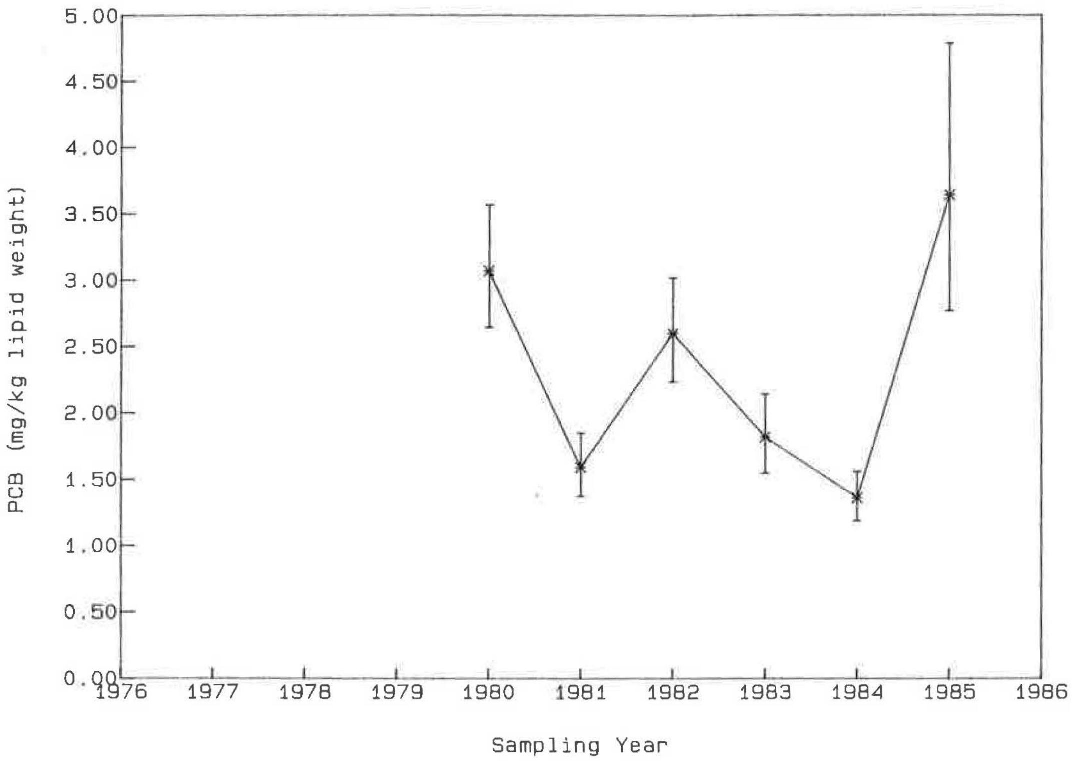
(LA) Estimates of Hg in flounder muscle - flounder in 46G1



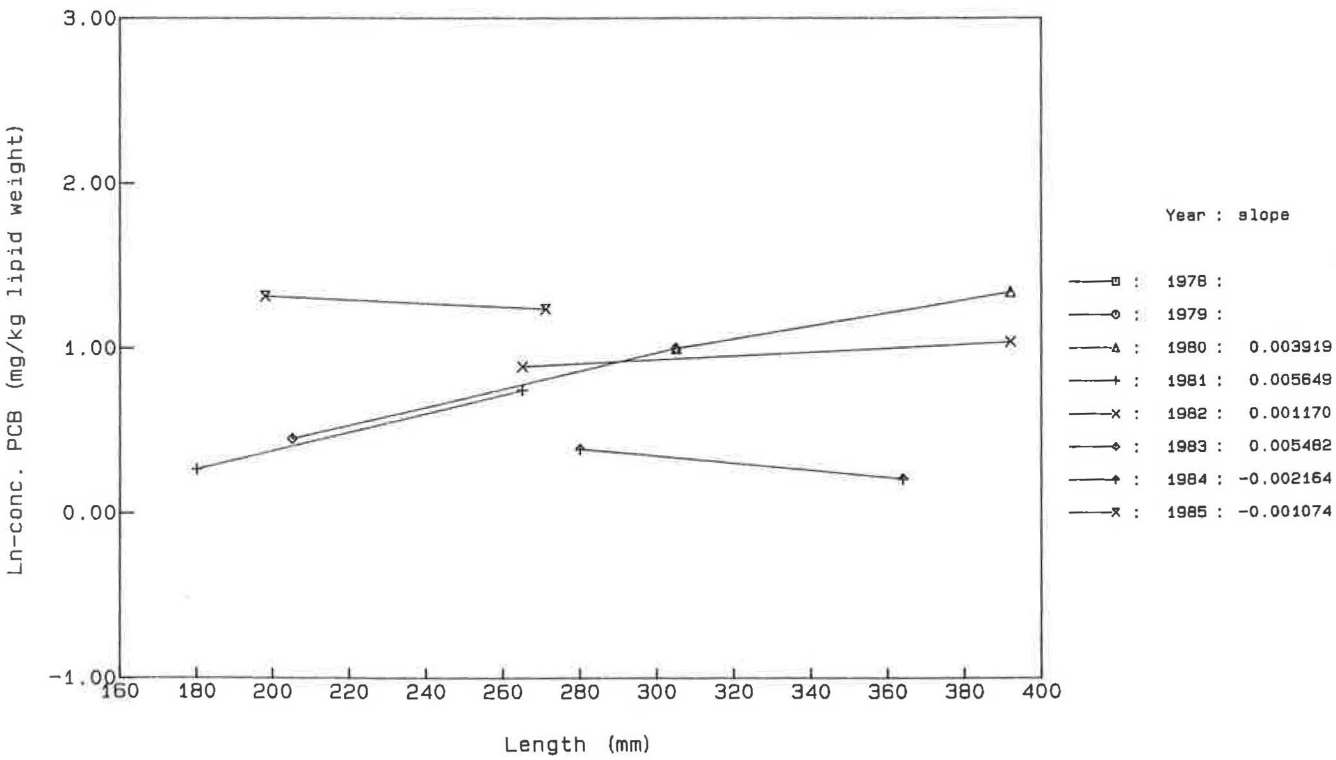
Regression of Ln-conc. Hg versus length by year - flounder in 46G1



(GM) Estimates of PCB in flounder muscle - flounder in 46G1



Regression of Ln-conc. PCB versus length by year - flounder in 46G1



SPECIES: Flounder (PLAT FLE) TISSUE : muscle	NOMINAL AREA: 48GO COUNTRY : Norway

DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length				o		o		o
Weight				o		o		o
Age				o		o		
Sex				●		o		●
Tissue wt.								
Fat %				o				
Dry %				o		o		o
CONTAMINANTS								
Hg				o		o		o
Cd				<.005				
Cu								
Pb								
Zn								
Cr								
Ni								
PCB				o		<.05		<.05
SAMPLING								
sampling periods				Dec		Dec		Nov
sampling locations				48GO[1]		48GO[1]		48GO[1]
number of specimens				8		25		25

Commentary:

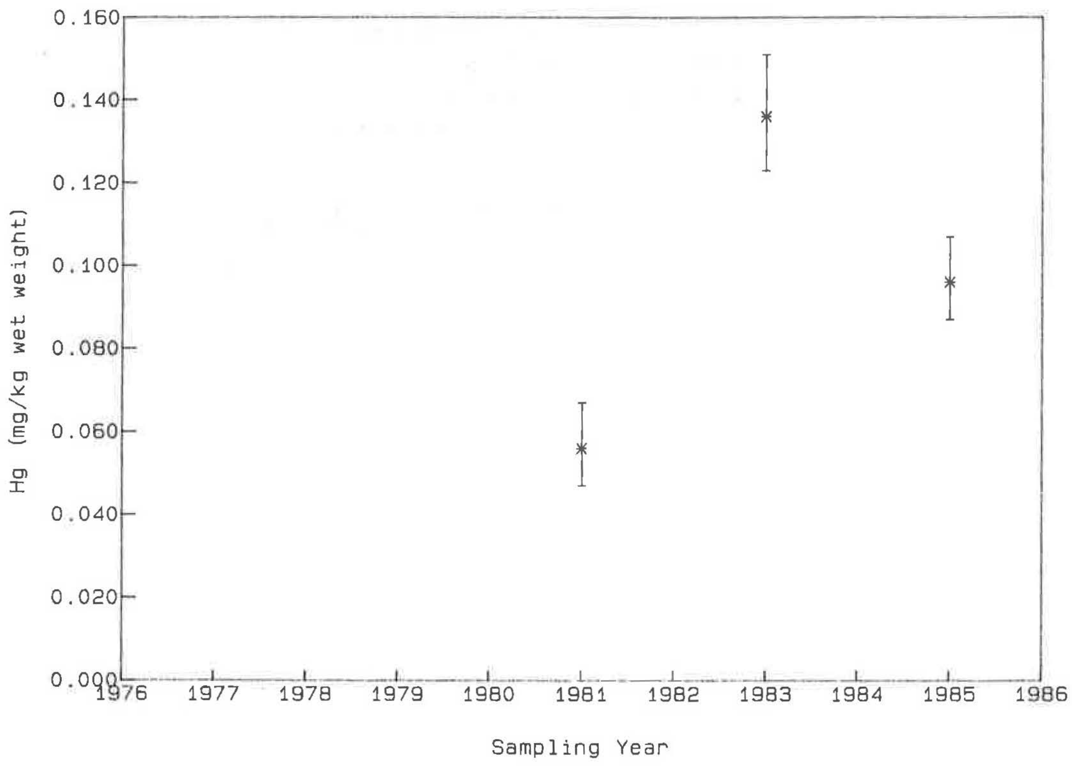
[1] Samples were taken at two sites within the Oslofjord: in 1981 in the middle part of the fjord, at Solbergstrand (59° 36.9' N, 10° 39.4' E), and in 1983 and 1985 in the inner Oslofjord, at Sande (59° 29.2' N, 10° 30.1' E).

Results of analyses:

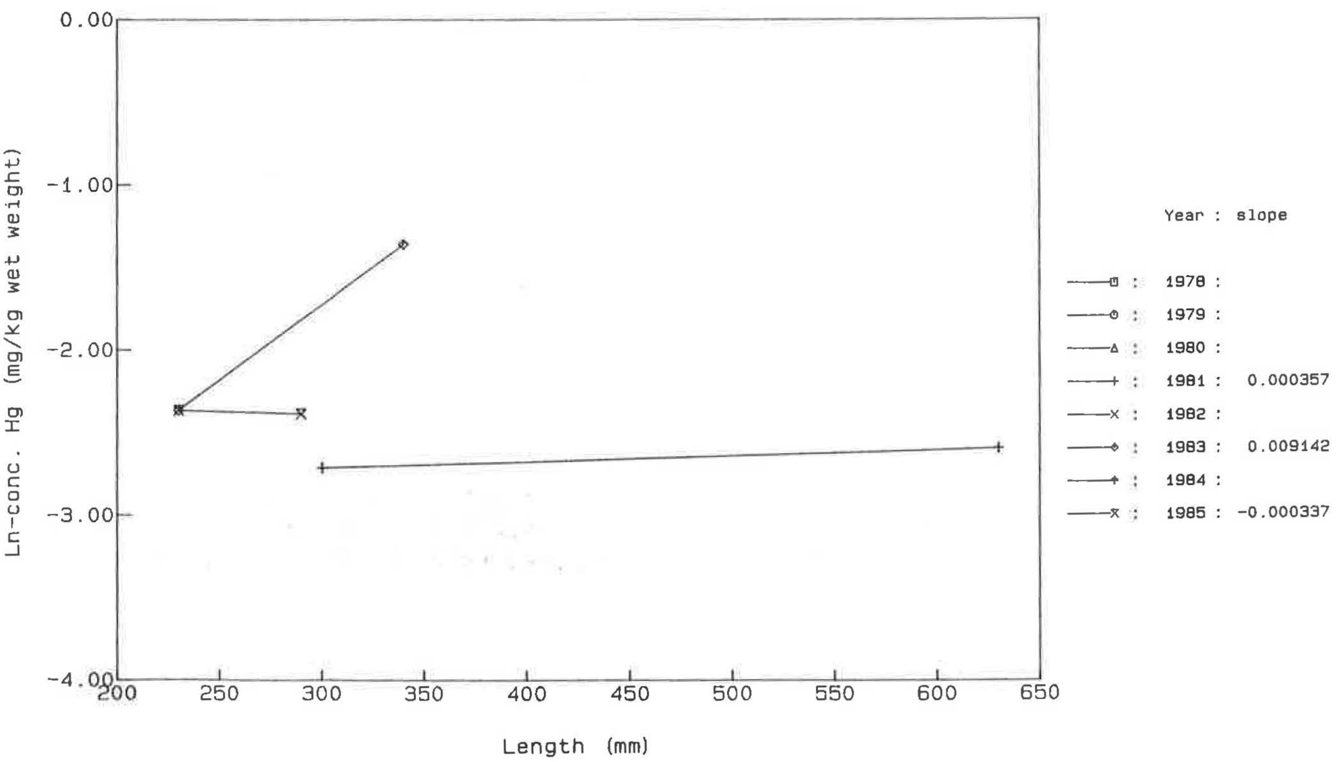
Mercury

- Results do not indicate evidence of a significant relationship between length and the contaminant levels; length-adjustment was still, however, applied in the computation of yearly mean contaminant levels (refer to plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

(LA) Estimates of Hg in flounder muscle - flounder in 48G0



Regression of Ln-conc. Hg versus length by year - flounder in 48G0



SPECIES: Dab (LIMA LIM) TISSUE : muscle	NOMINAL AREA: 43G1 COUNTRY : Sweden

DATA CHARACTERISTICS

BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length				o	o	o	o	o
Weight				o	o	o	o	o
Age				o	o	o	o	o
Sex				o	o	o	o	o
Tissue wt.								
Fat %				●	o	●	o	o
Dry %						o	o	o
CONTAMINANTS								
Hg				o	o	o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB				●[1]	o	●	o	o
SAMPLING								
sampling periods				Sept	Aug	Sept	Aug	Sept
sampling locations				43G1	43G1	43G1	43G1	43G1
number of specimens				20[1]	20	25	25	25

Commentary:

[1]Only 10 of the 20 specimens sampled in 1981 were analyzed for PCB.

Results of analyses:

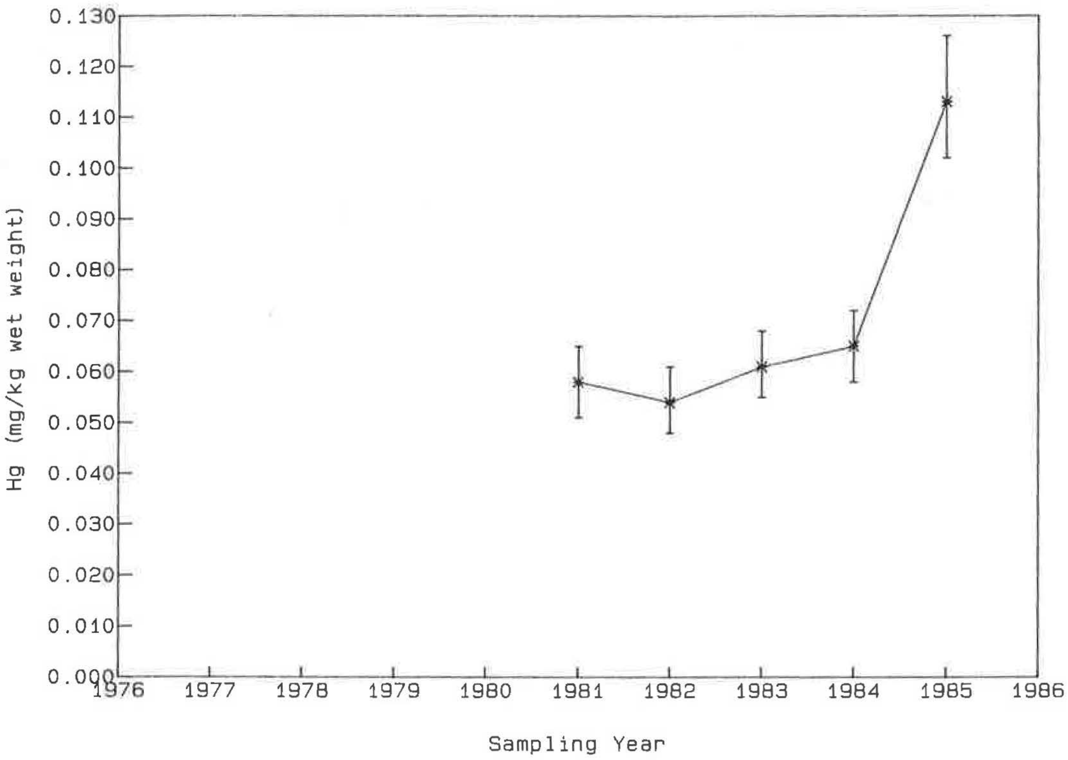
PCB

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

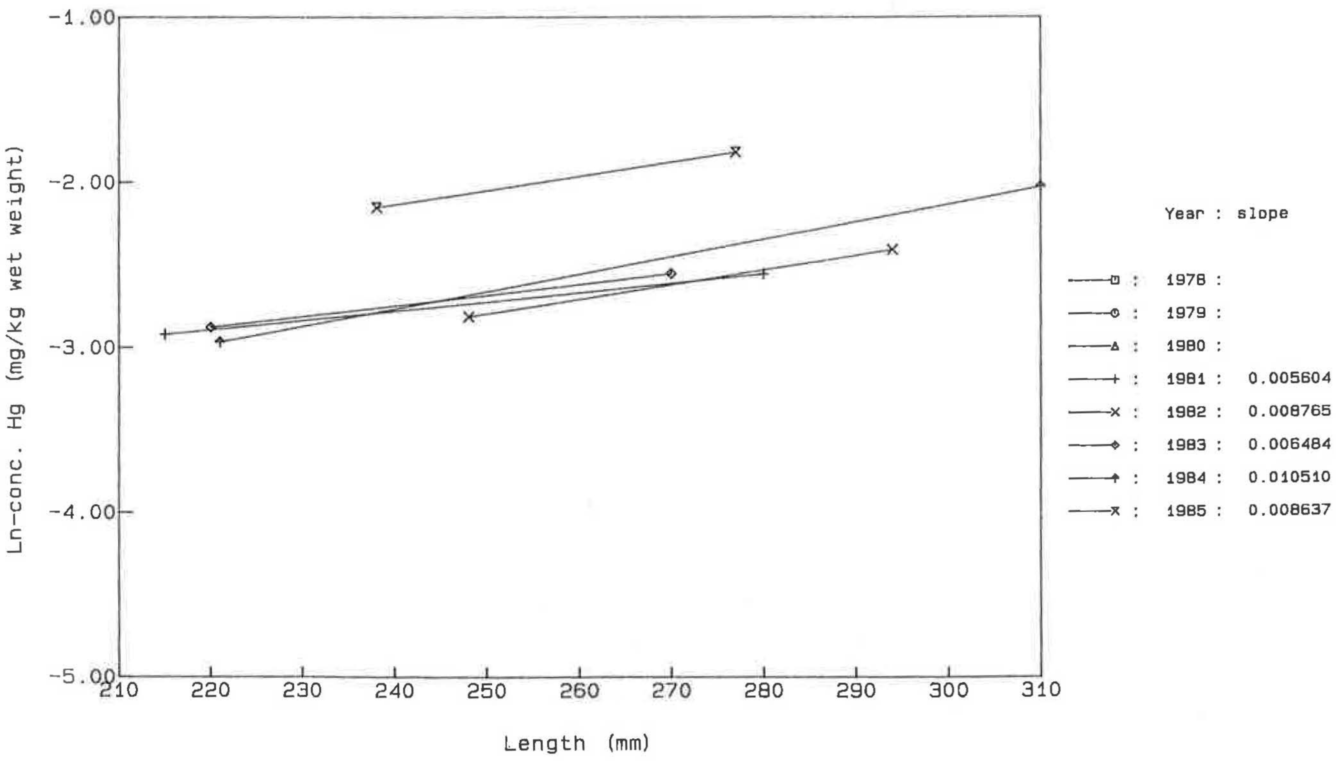
Mercury

- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

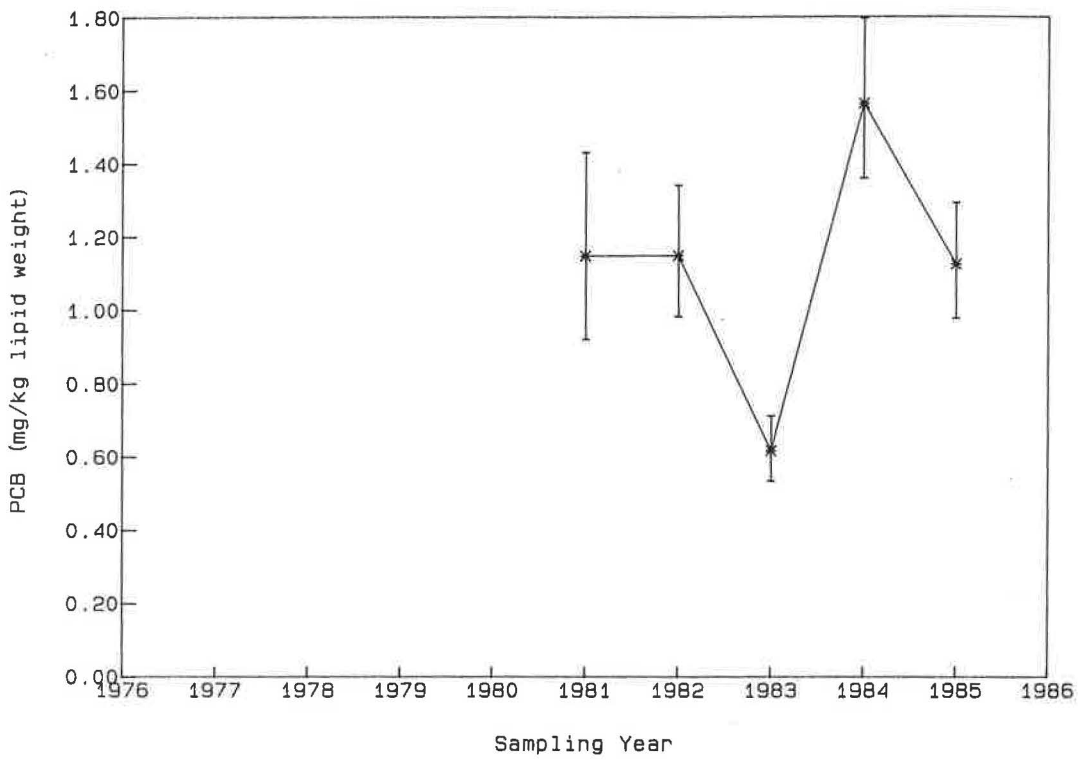
(LA) Estimates of Hg in dab muscle - dab in 43G1



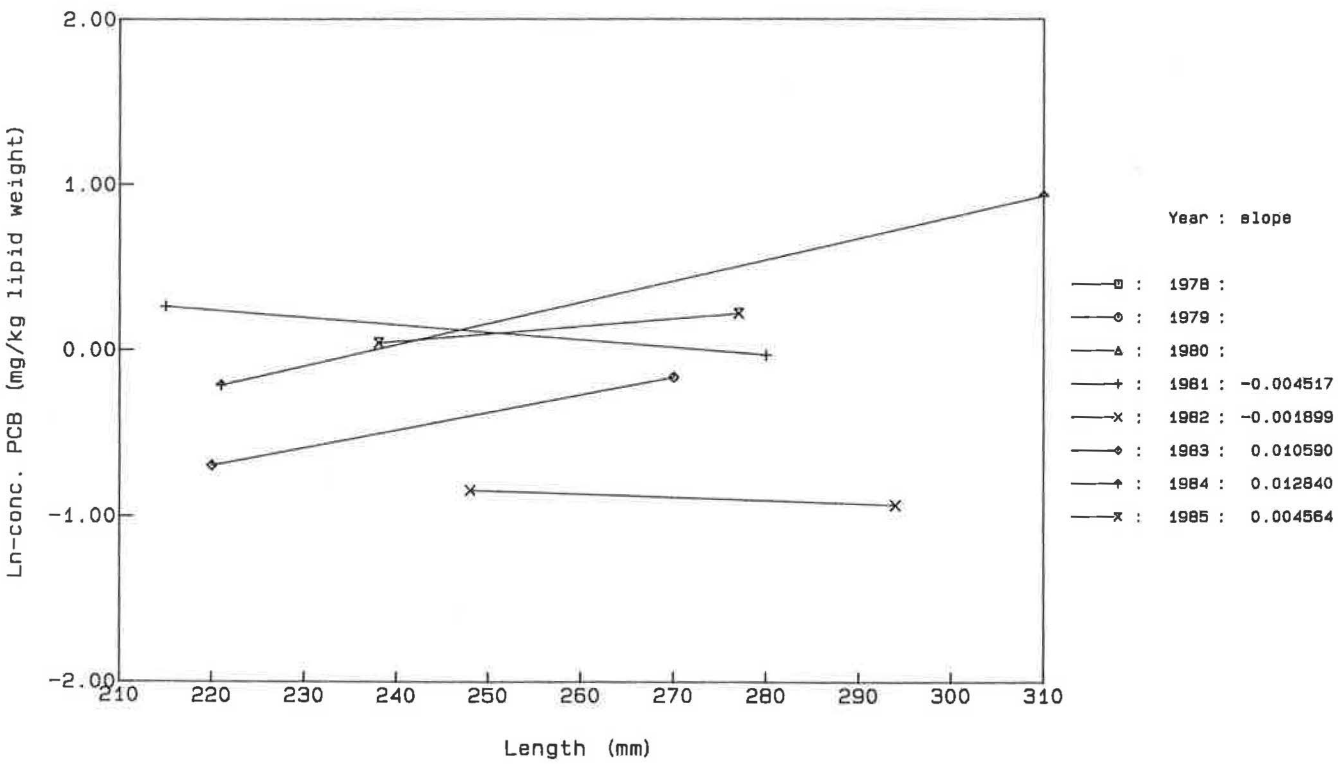
Regression of Ln-conc. Hg versus length by year - dab in 43G1



(GM) Estimates of PCB in dab muscle - dab in 43G1



Regression of Ln-conc. PCB versus length by year - dab in 43G1



SPECIES: Sole (SOLE VUL) TISSUE : muscle	NOMINAL AREA: 31F2 COUNTRY : Belgium

DATA CHARACTERISTICS

BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length		o	o	o	o	o		
Weight		o	o	o	o	o		
Age		o	o	o	o	o		
Sex		o	o	o	o	o		
Tissue wt.								
Fat %						o		
Dry %								
CONTAMINANTS								
Hg		o	o	o	o	o		
Cd		<.005	<.005	<.005	<.005	<.005		
Cu		o	o	o	o	o		
Pb		o	<.01	<.01	o	o		
Zn		o	o	o	o	o		
Cr		o	o	<.01	o	o		
Ni		o	o	o	o	o		
PCB						o		
SAMPLING								
sampling periods		Apr	June	May	Jan	Apr		
sampling locations		32F1	32F1	32F2	31F2	31F2		
number of specimens		20	20	20	25	25		

Results of analyses:

Chromium[1]; Copper; Nickel[1]

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

[1]The data originator has notified that, due to a change in the analytical methodologies for chromium and nickel, values for the period 1978-1979 are considered unreliable and should be rejected; values from 1980 onwards should be acceptable, but may be subject to rather high analytical errors.

Mercury

- Results confirm the validity of the statistical analysis and indicate evidence of a linear trend in the length-adjusted yearly mean contaminant levels, but do not demonstrate the linear trend to be a good fit of the data (see plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

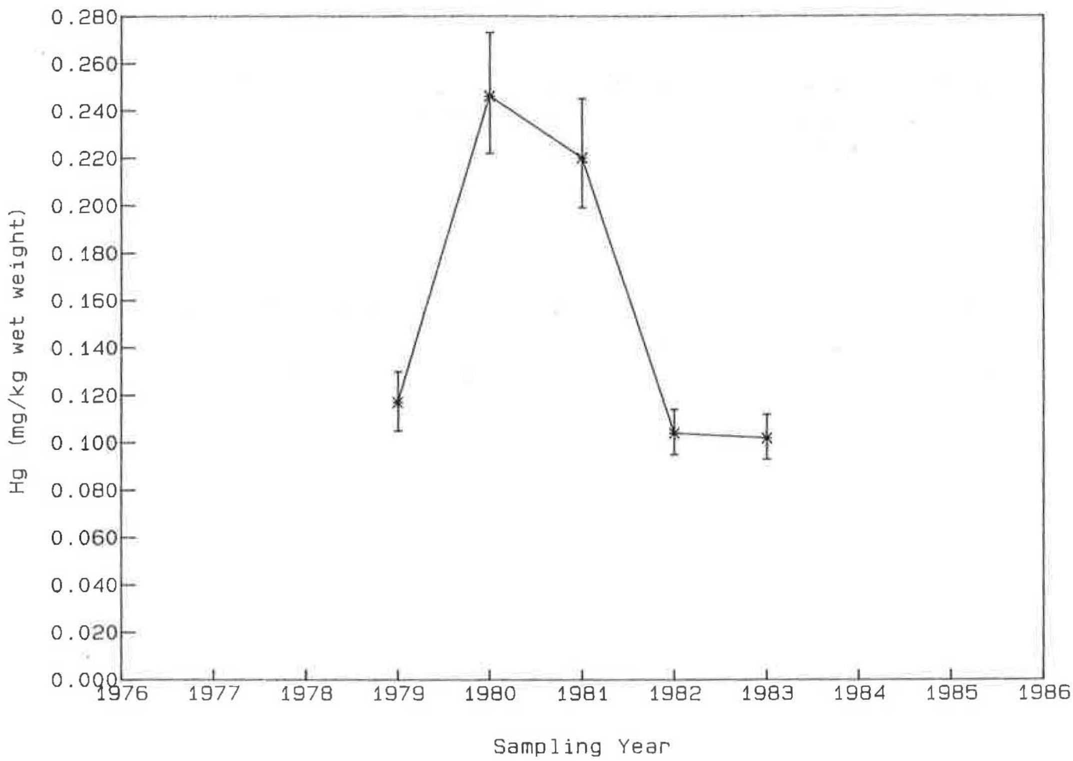
Lead

- Results confirm the validity of the statistical analysis; the length-adjusted yearly mean contaminant levels differ significantly between years but there is no evidence of a linear trend (see plot).

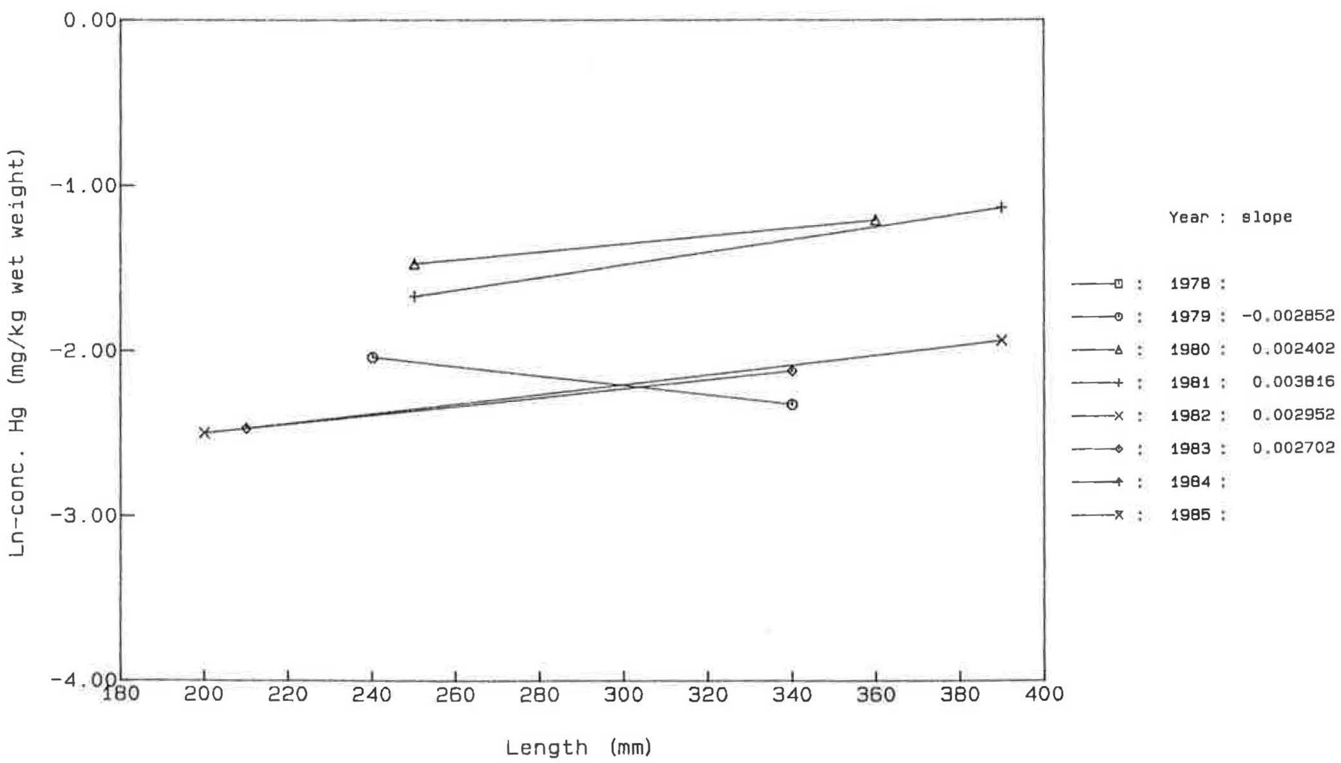
Zinc

- Results do not indicate evidence of a significant relationship between length and the contaminant levels; length-adjustment was still, however, applied in the computation of yearly mean contaminant levels (refer to plot).

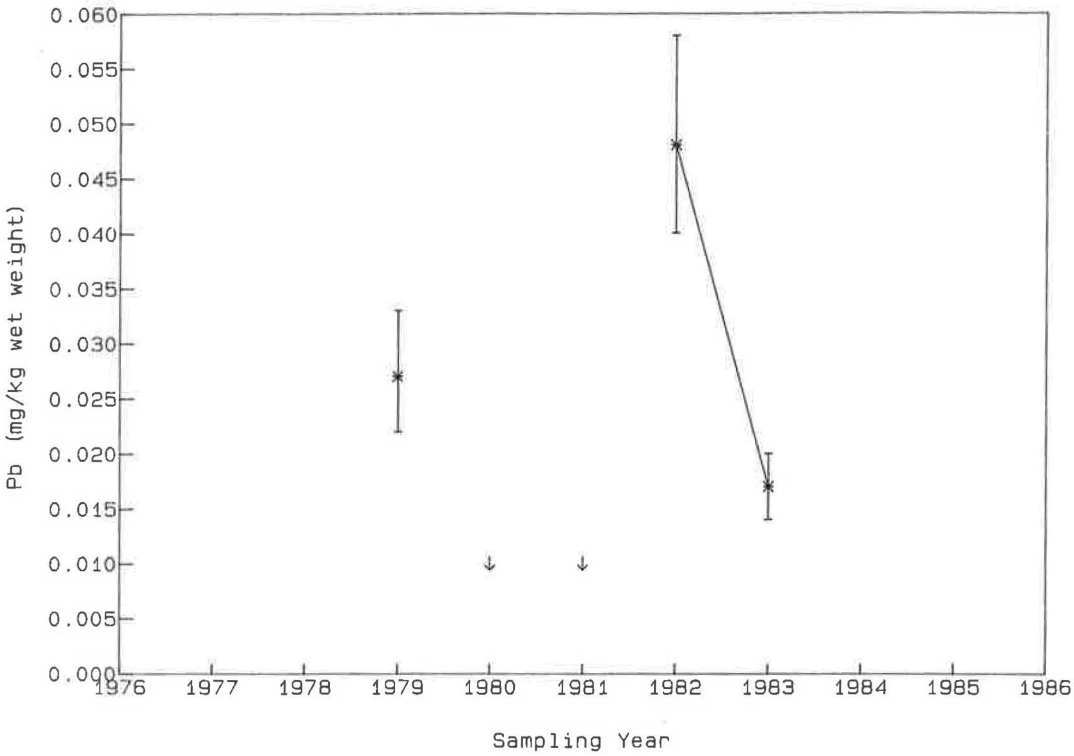
(LA) Estimates of Hg in sole muscle - sole in 31F2



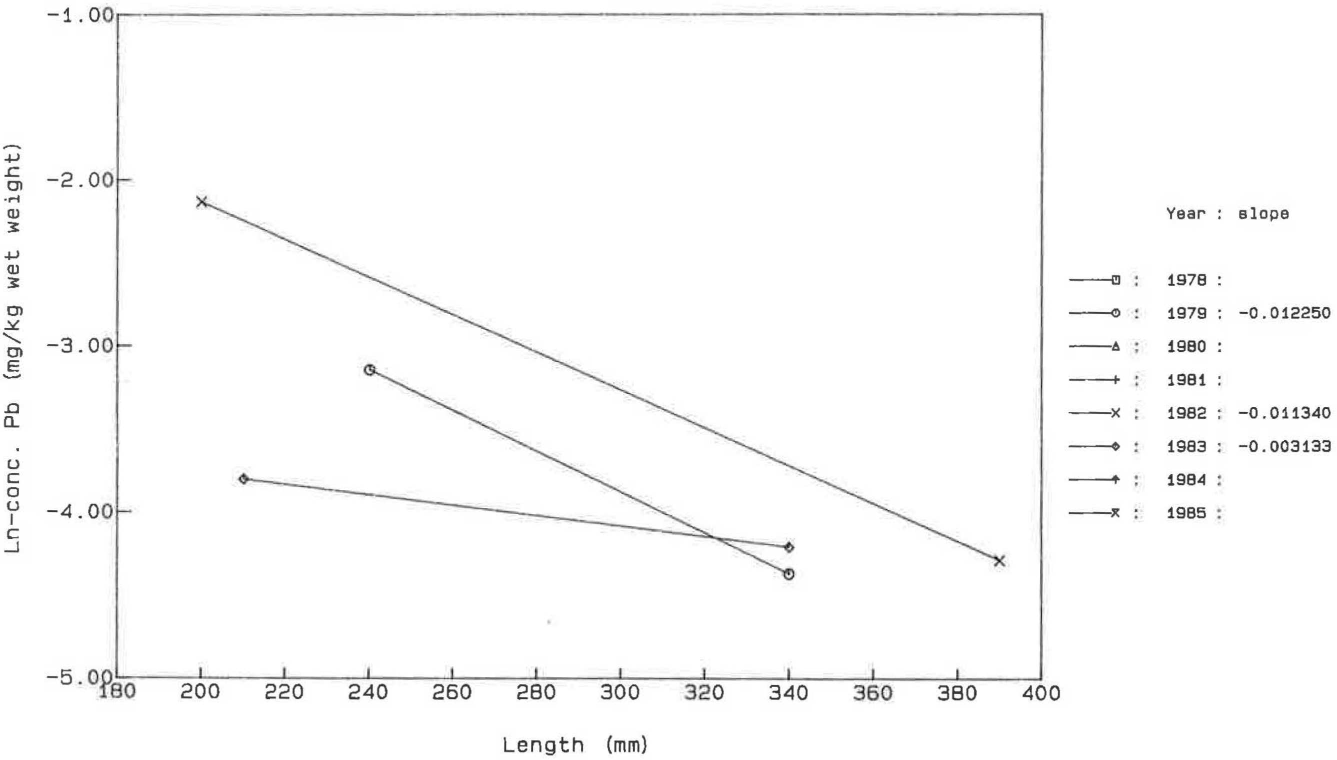
Regression of Ln-conc. Hg versus length by year - sole in 31F2

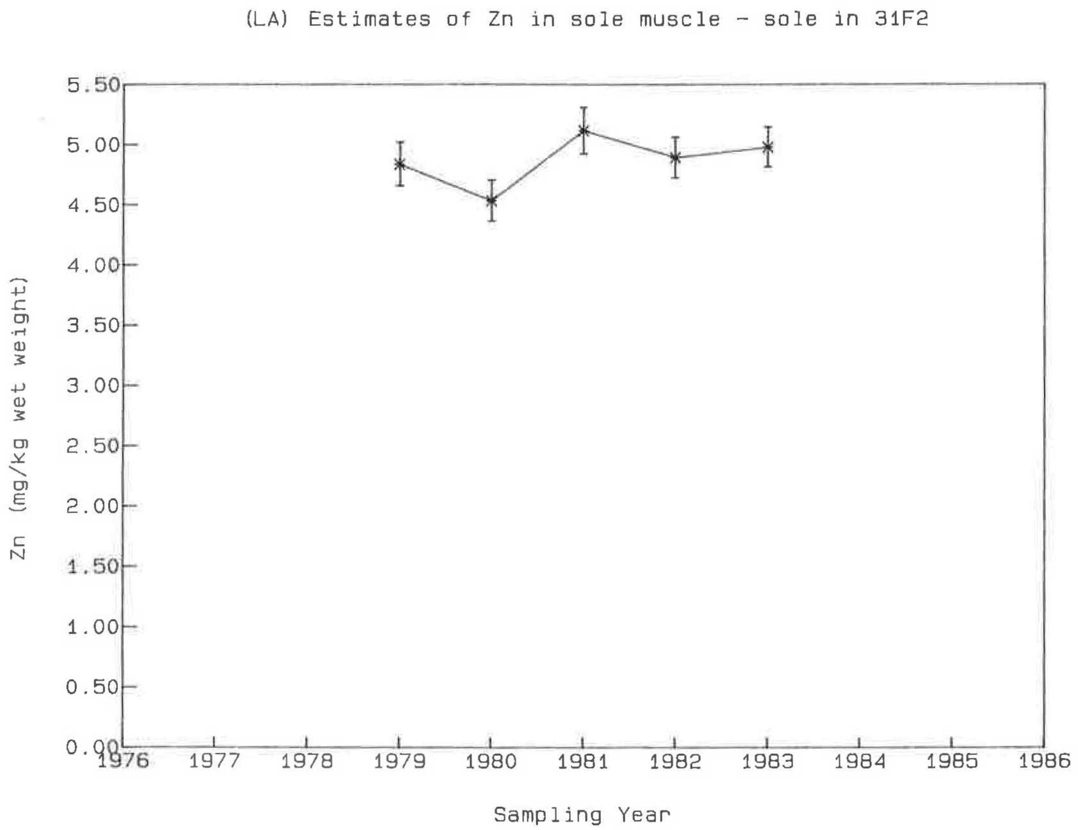


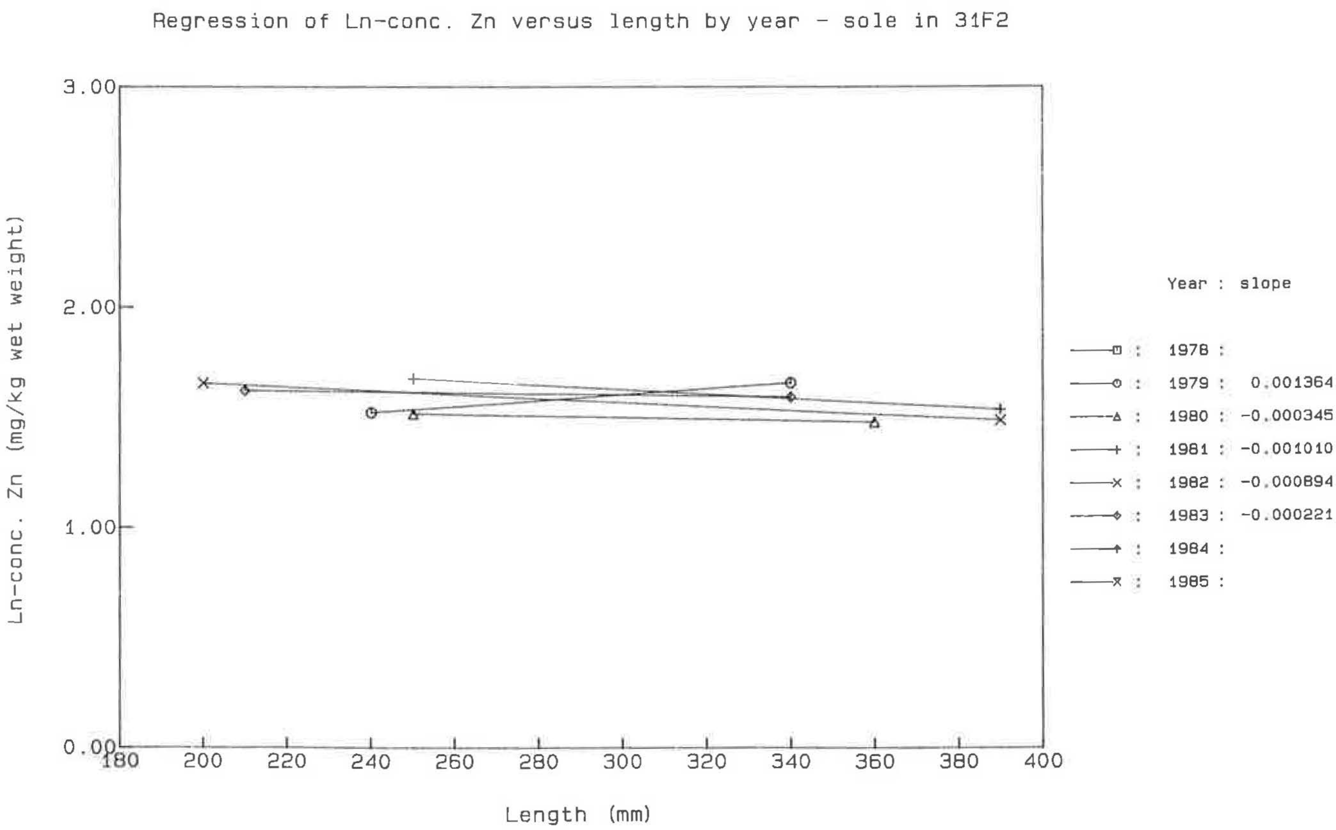
(LA) Estimates of Pb in sole muscle - sole in 31F2

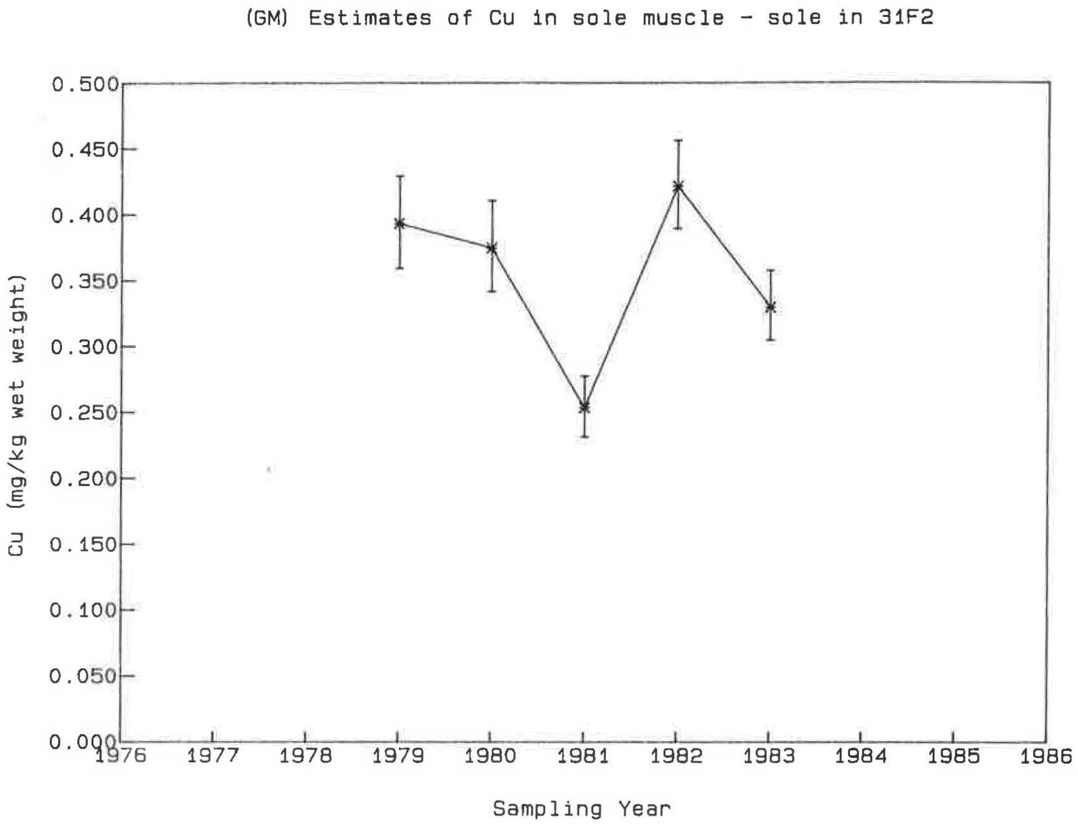


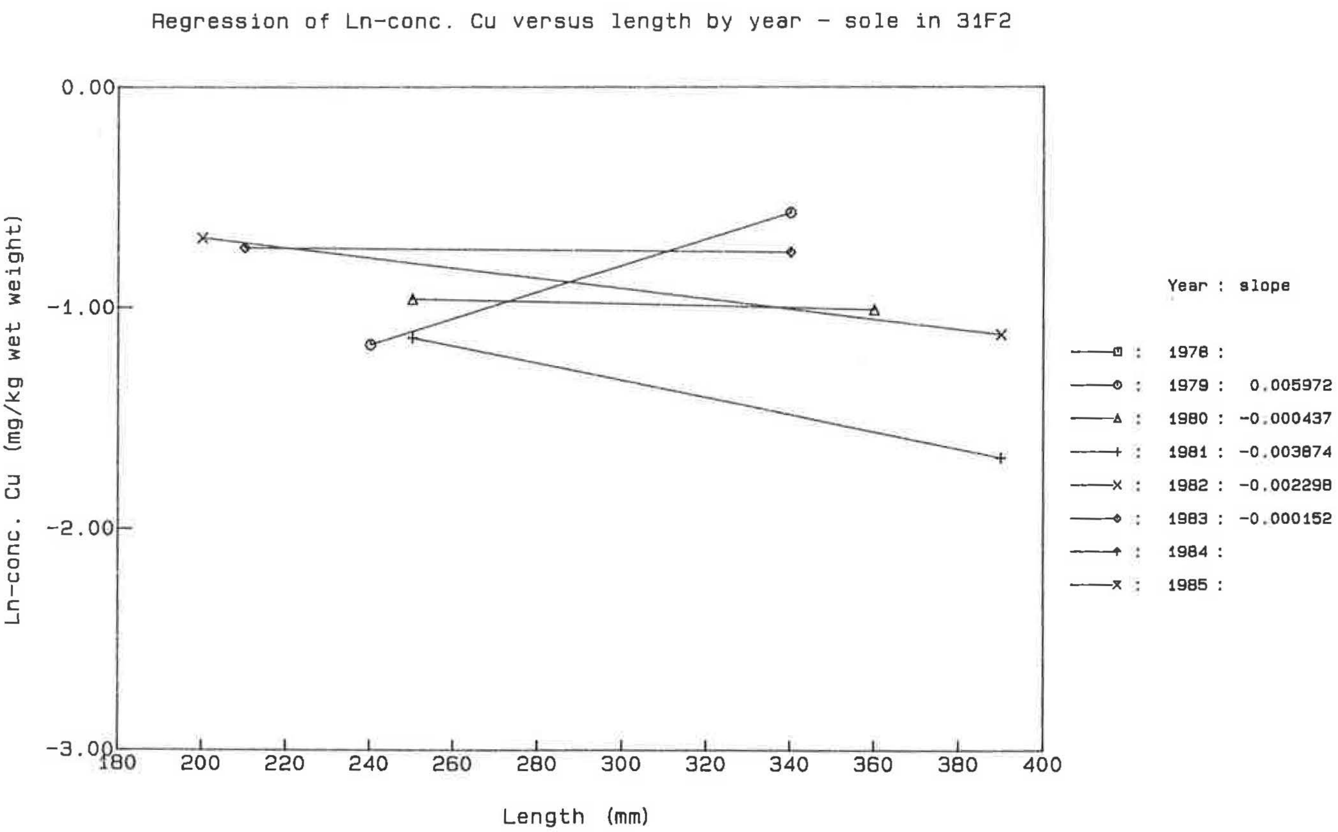
Regression of Ln-conc. Pb versus length by year - sole in 31F2



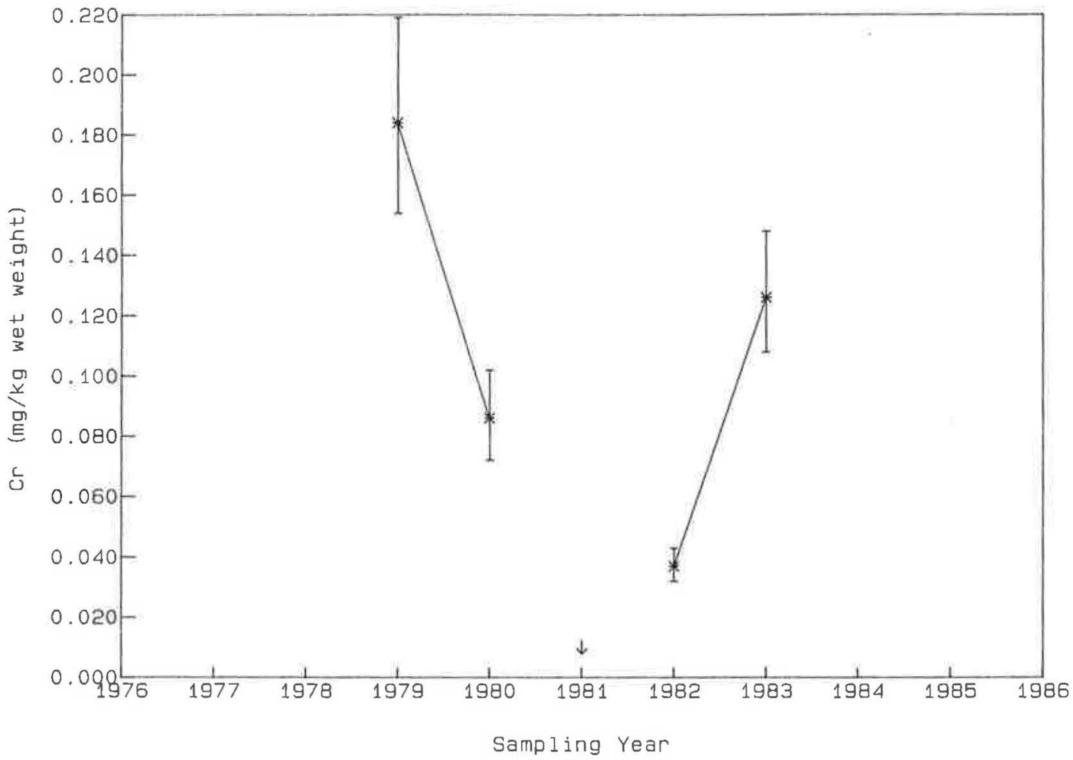

(LA) Estimates of Zn in sole muscle - sole in 31F2
Zn (mg/kg wet weight)
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Zn versus length by year - sole in 31F2
Ln-conc. Zn (mg/kg wet weight)
3.00
2.00
1.00
0.00
180
200
220
240
260
280
300
320
340
360
380
400
Length (mm)
Year : slope
1978 :
1979 : 0.001364
1980 : -0.000345
1981 : -0.001010
1982 : -0.000894
1983 : -0.000221
1984 :
1985 :

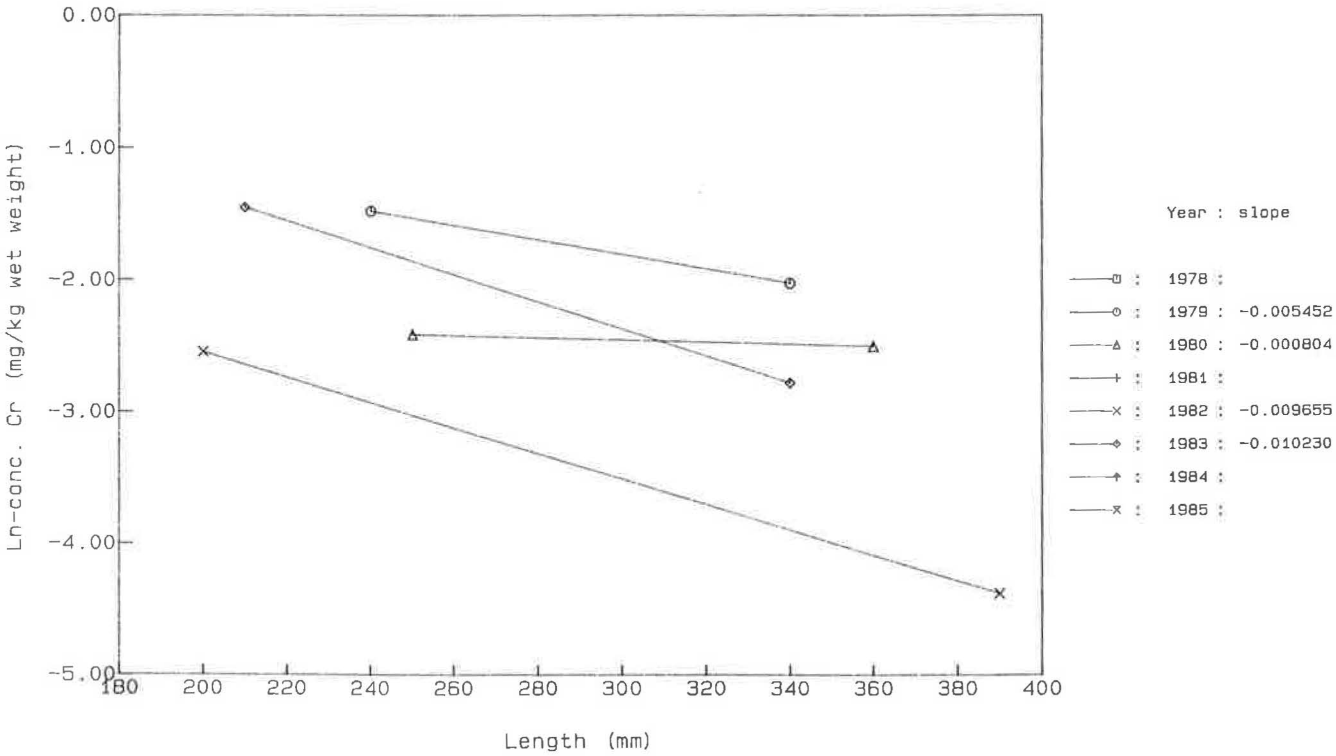

(GM) Estimates of Cu in sole muscle - sole in 31F2
Cu (mg/kg wet weight)
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year

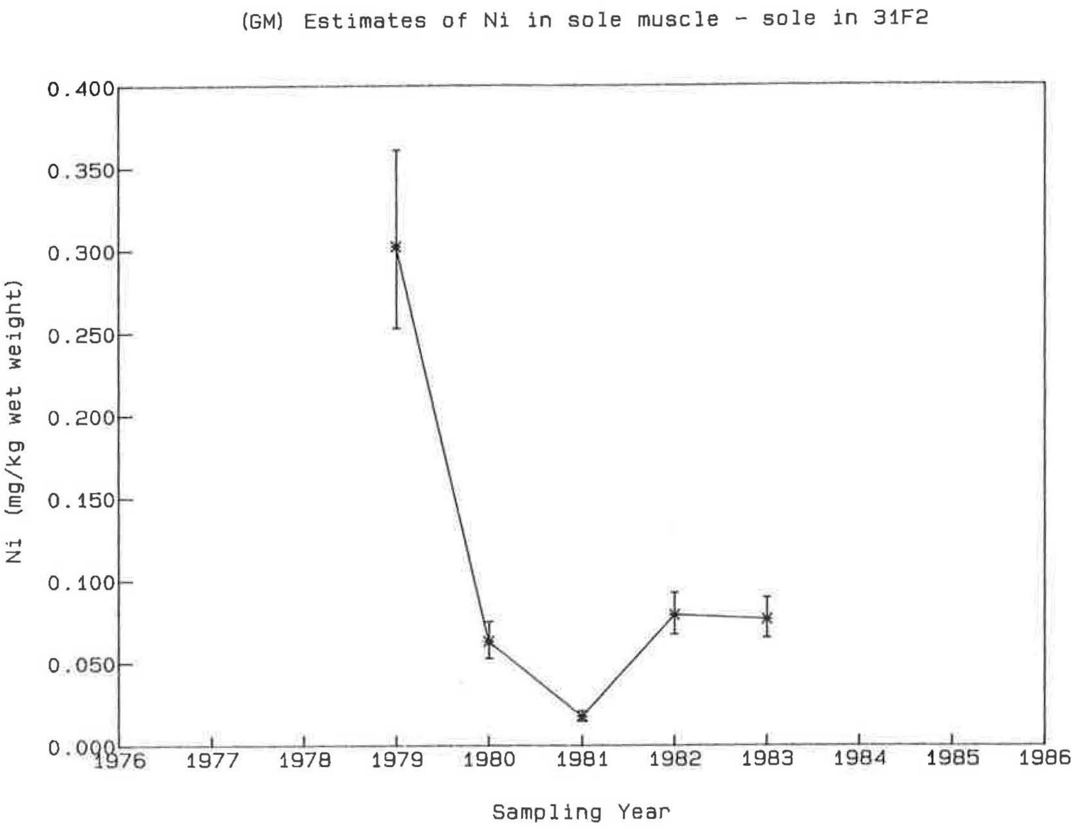

Regression of Ln-conc. Cu versus length by year - sole in 31F2
Ln-conc. Cu (mg/kg wet weight)
0.00
-1.00
-2.00
-3.00
180
200
220
240
260
280
300
320
340
360
380
400
Length (mm)
Year : slope
1978 :
1979 : 0.005972
1980 : -0.000437
1981 : -0.003874
1982 : -0.002298
1983 : -0.000152
1984 :
1985 :

(GM) Estimates of Cr in sole muscle - sole in 31F2

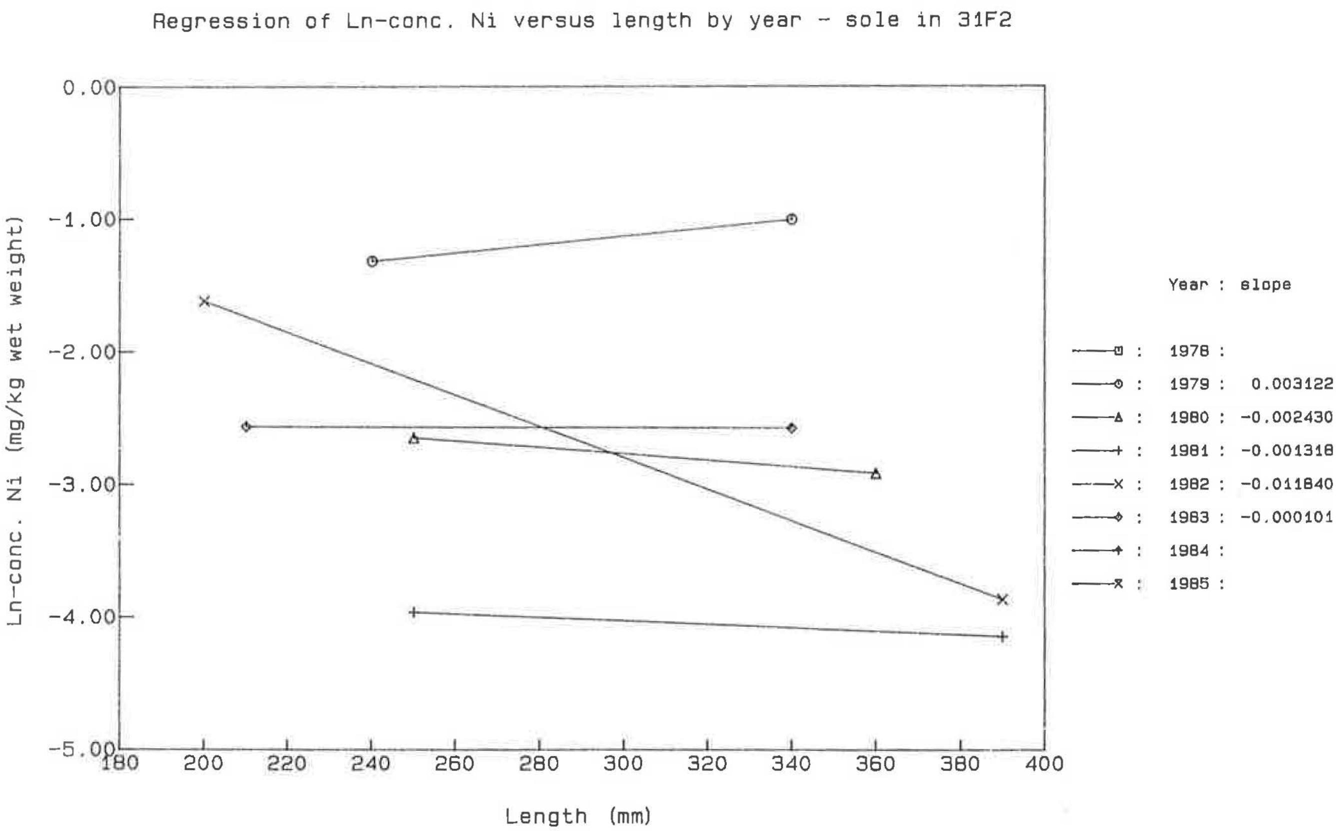


Regression of Ln-conc. Cr versus length by year - sole in 31F2





(GM) Estimates of Ni in sole muscle - sole in 31F2
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Ni (mg/kg wet weight)
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year



Regression of Ln-conc. Ni versus length by year - sole in 31F2
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
Ln-conc. Ni (mg/kg wet weight)
180
200
220
240
260
280
300
320
340
360
380
400
Length (mm)
Year : slope
1978 :
1979 : 0.003122
1980 : -0.002430
1981 : -0.001318
1982 : -0.011840
1983 : -0.000101
1984 :
1985 :

SPECIES: Sole (SOLE VUL) TISSUE : muscle	NOMINAL AREA: 36E5 COUNTRY : Belgium

DATA CHARACTERISTICS

BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length		o	o	o	o	o		
Weight		o	o	o	o	o		
Age		o	o	o	o	o		
Sex		o	o	o	o	o		
Tissue wt.								
Fat %								
Dry %								
CONTAMINANTS								
Hg		o	o	o	o	o		
Cd		<.005	<.005	<.005	<.005	<.005		
Cu		o	o	o	o	o		
Pb		o	o	o	o	o		
Zn		o	o	o	o	o		
Cr		o	o	<.01	o	o		
Ni		o	o	o	o	o		
PCB								
SAMPLING								
sampling periods		Dec	Jan	Mar	Feb	Apr		
sampling locations		36E5	36E5	36E5	36E5	36E5		
number of specimens		20	20	20	25	25		

Results of analyses:

Chromium[1] ; Copper; Nickel[1]

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

[1] The data originator has notified that, due to a change in the analytical methodologies for chromium and nickel, values for the period 1978-1979 are considered unreliable and should be rejected; values from 1980 onwards should be acceptable, but may be subject to rather high analytical errors.

Mercury

- Results do not indicate evidence of a significant relationship between length and the contaminant levels; length-adjustment was still, however, applied in the computation of yearly mean contaminant levels (refer to plot).

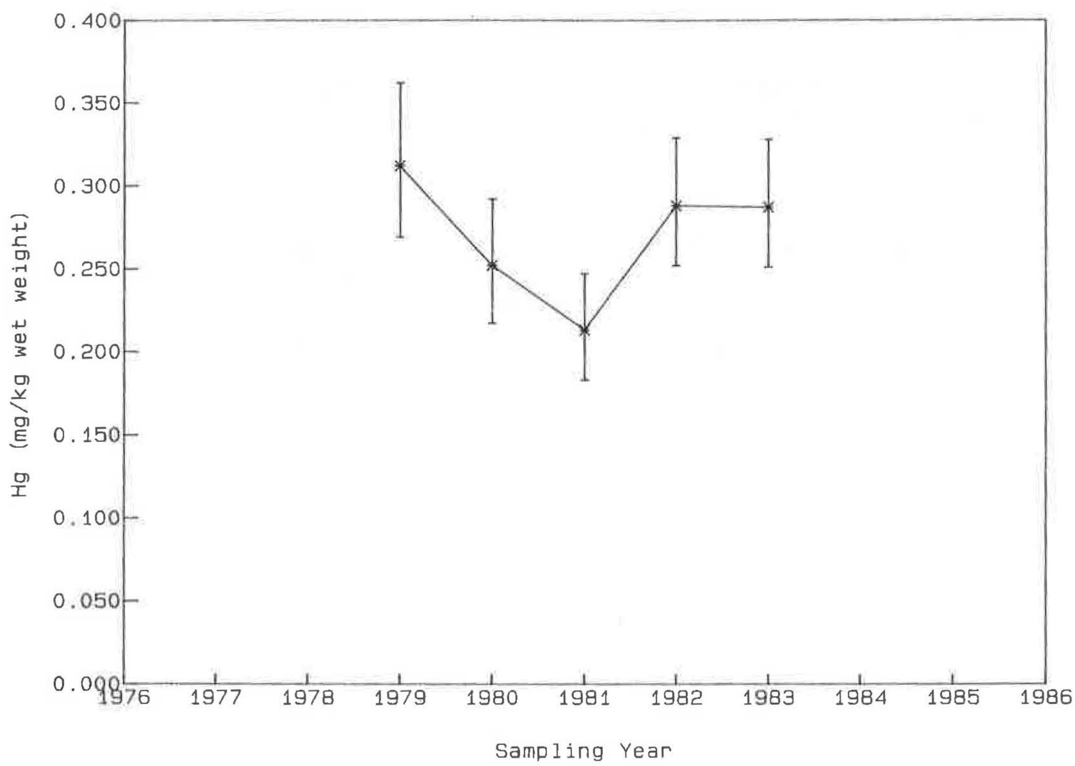
Lead

- Results show significant differences between years in the slopes of the linear relationships between contaminant level and length.

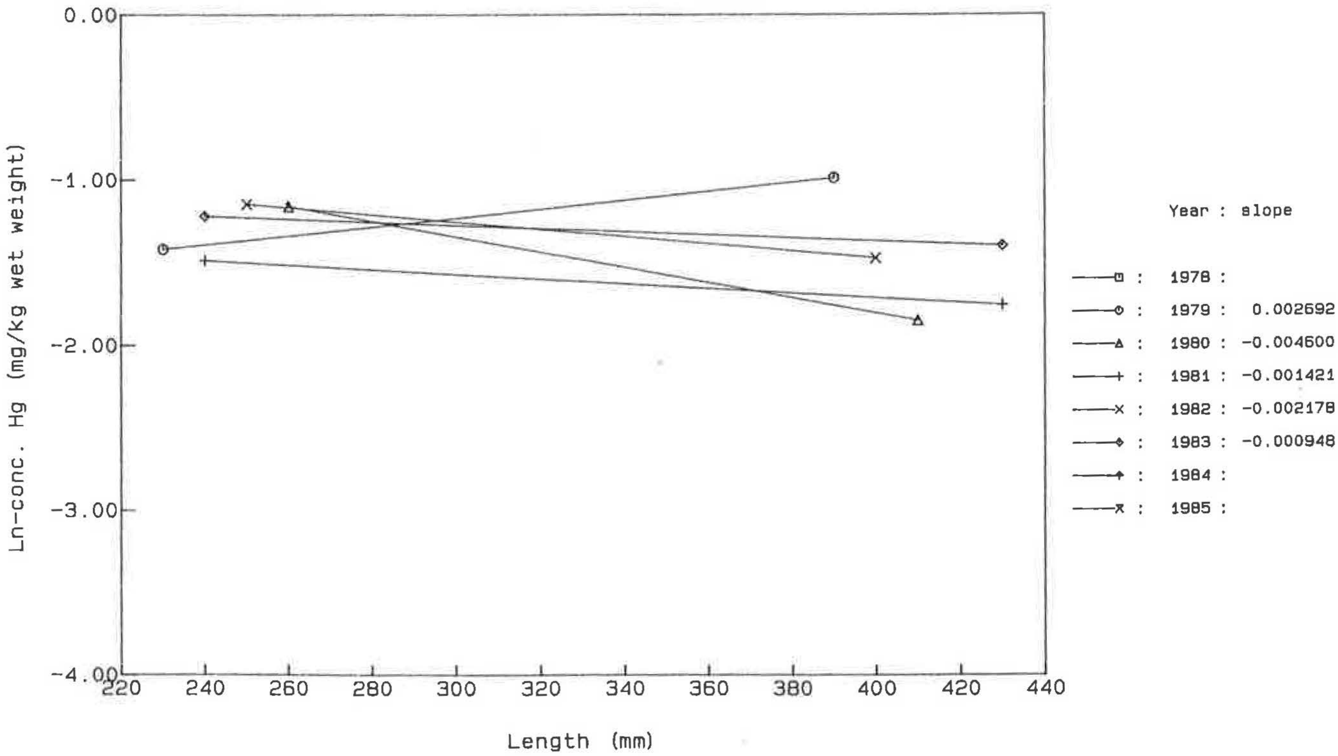
Zinc

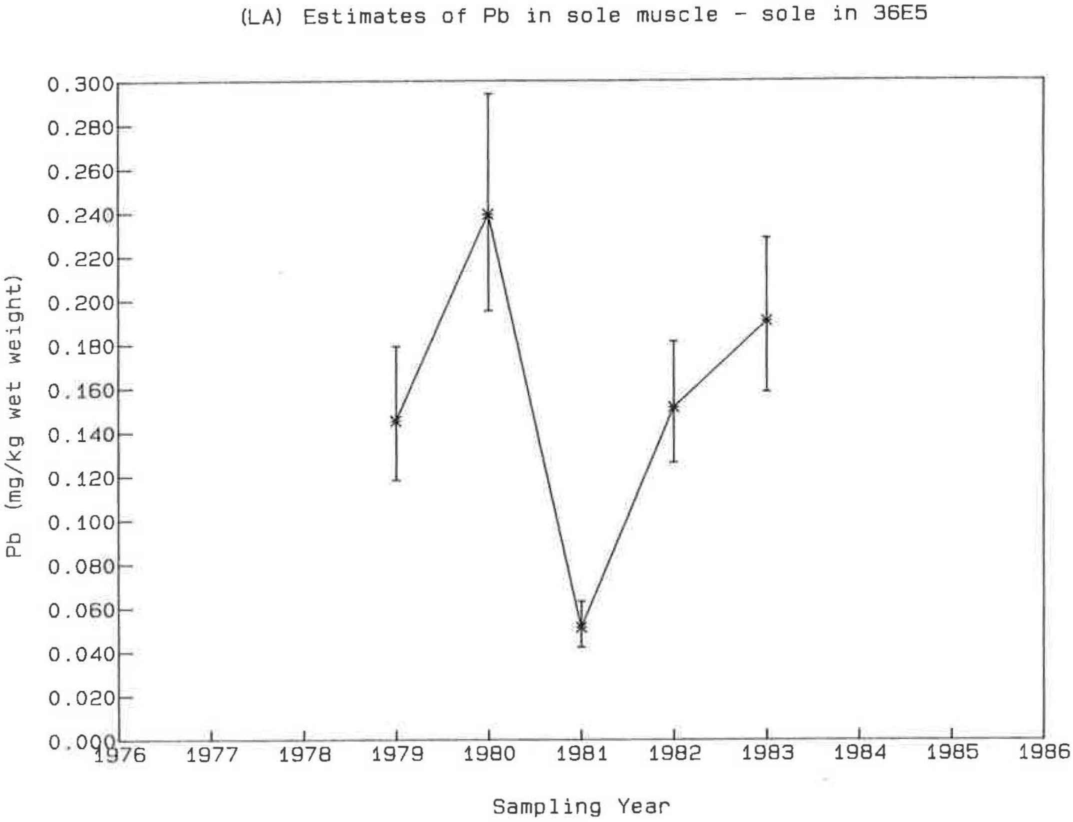
- Results do not indicate evidence of a significant relationship between length and the contaminant levels; length-adjustment was still, however, applied in the computation of yearly mean contaminant levels (refer to plot). The results suggest that a significant increase in the explanatory power of the statistical analysis may be achieved by inclusion of additional biological covariates.

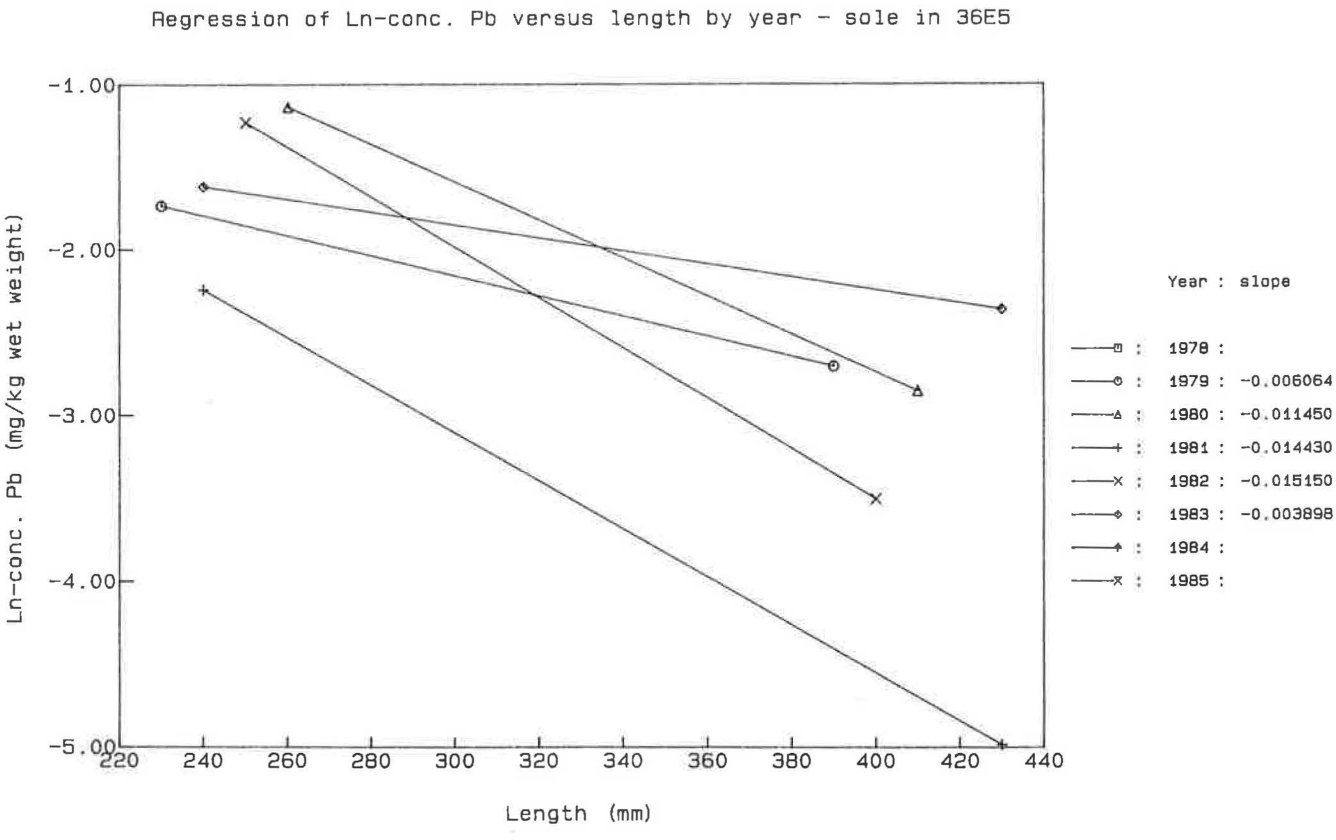
(LA) Estimates of Hg in sole muscle - sole in 36E5



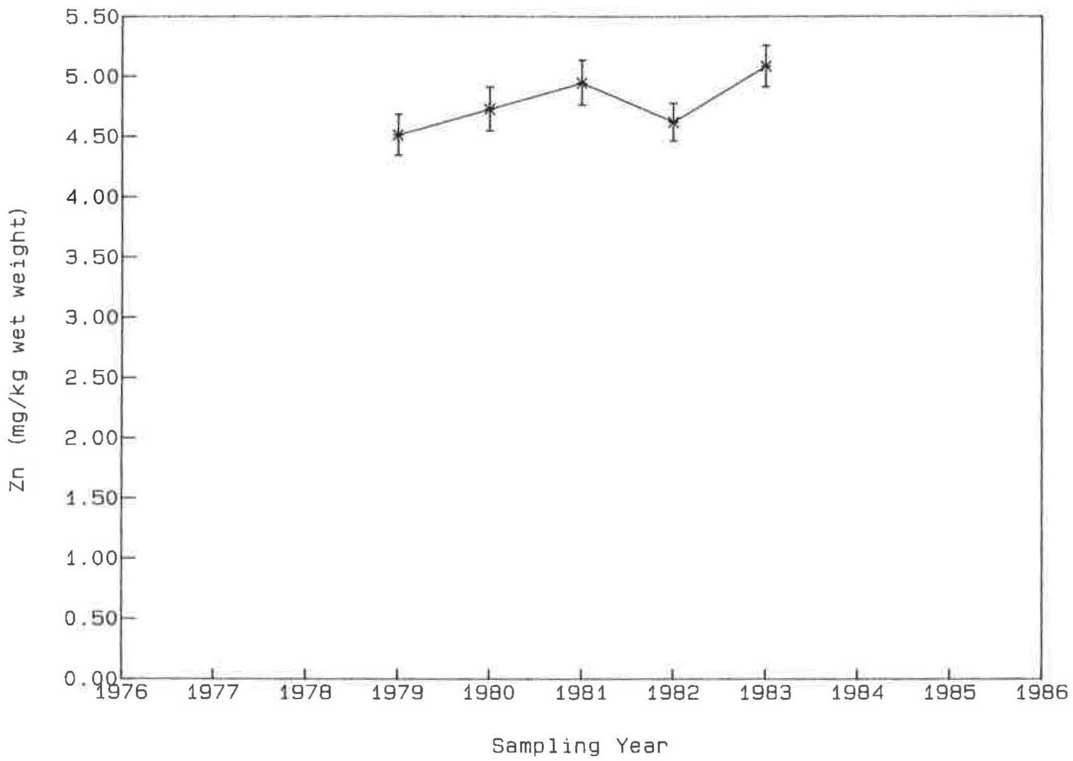
Regression of Ln-conc. Hg versus length by year - sole in 36E5



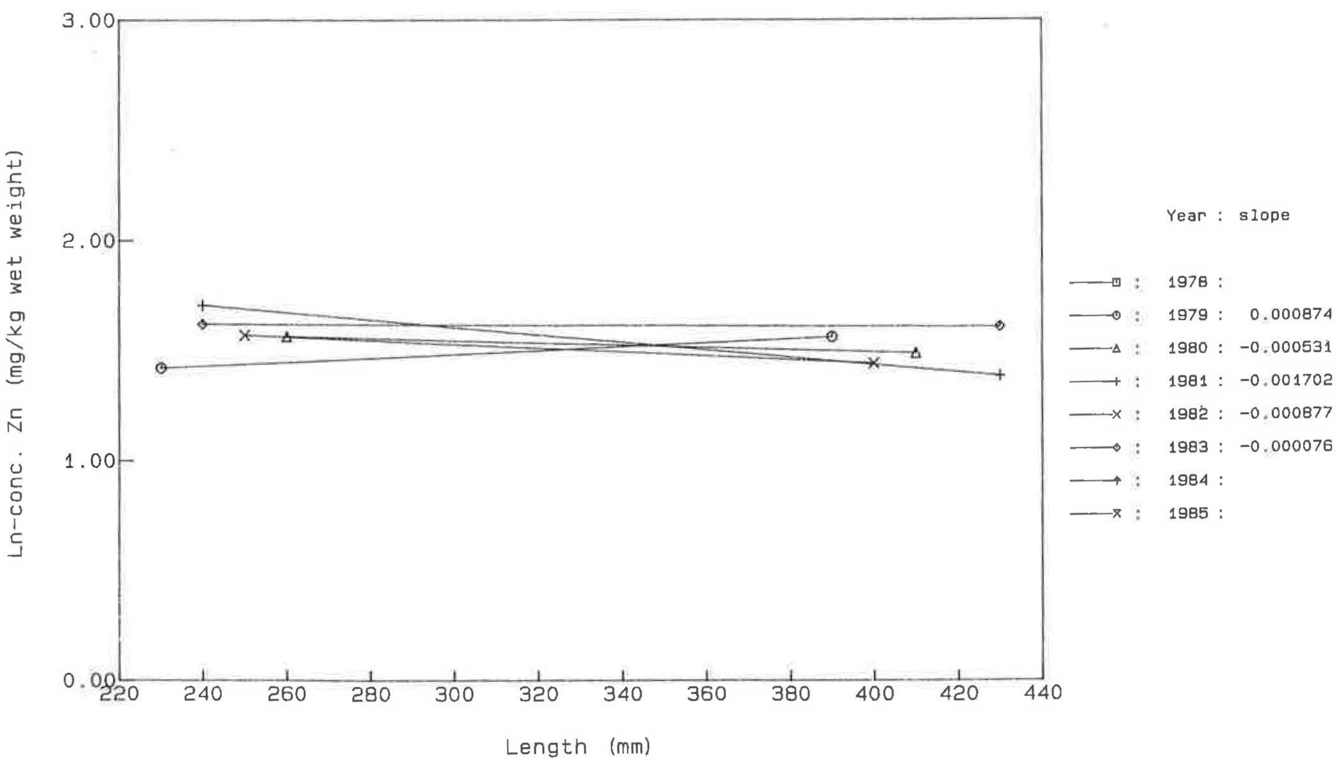

(LA) Estimates of Pb in sole muscle - sole in 36E5
Pb (mg/kg wet weight)
0.000
0.020
0.040
0.060
0.080
0.100
0.120
0.140
0.160
0.180
0.200
0.220
0.240
0.260
0.280
0.300
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year

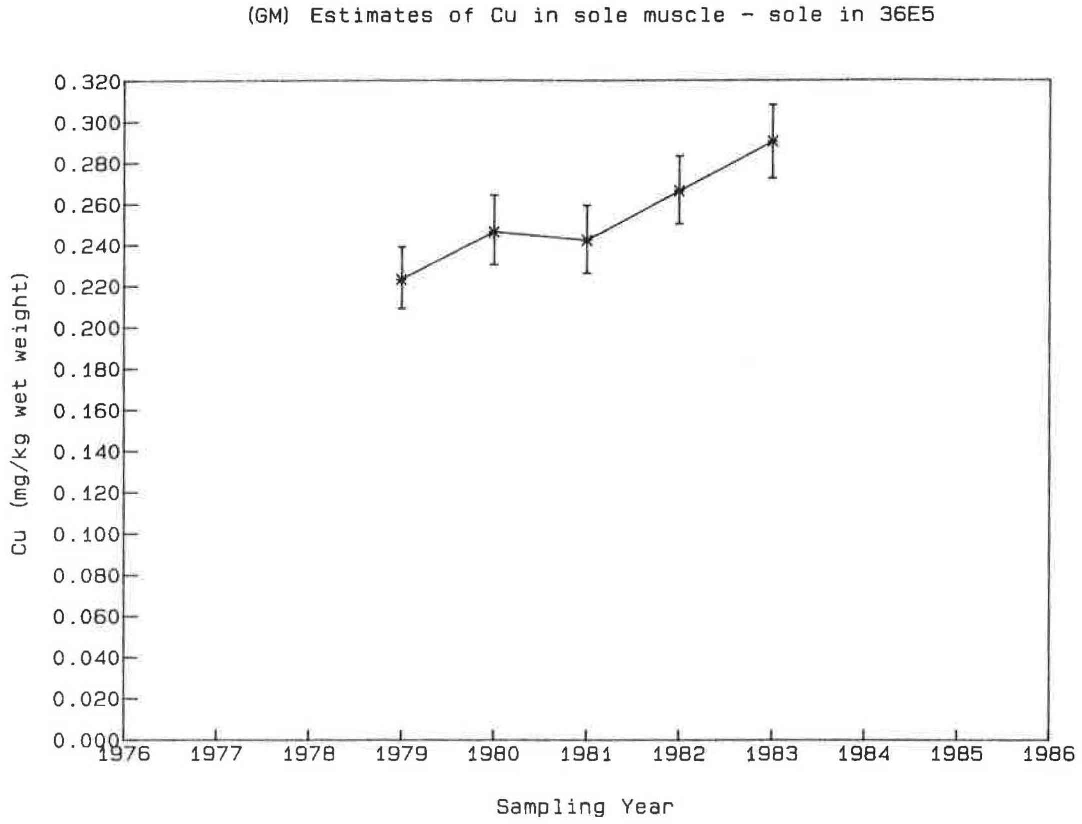

Regression of Ln-conc. Pb versus length by year - sole in 36E5
Ln-conc. Pb (mg/kg wet weight)
-1.00
-2.00
-3.00
-4.00
-5.00
220
240
260
280
300
320
340
360
380
400
420
440
Length (mm)
Year : slope
1978 :
1979 : -0.006064
1980 : -0.011450
1981 : -0.014430
1982 : -0.015150
1983 : -0.003898
1984 :
1985 :

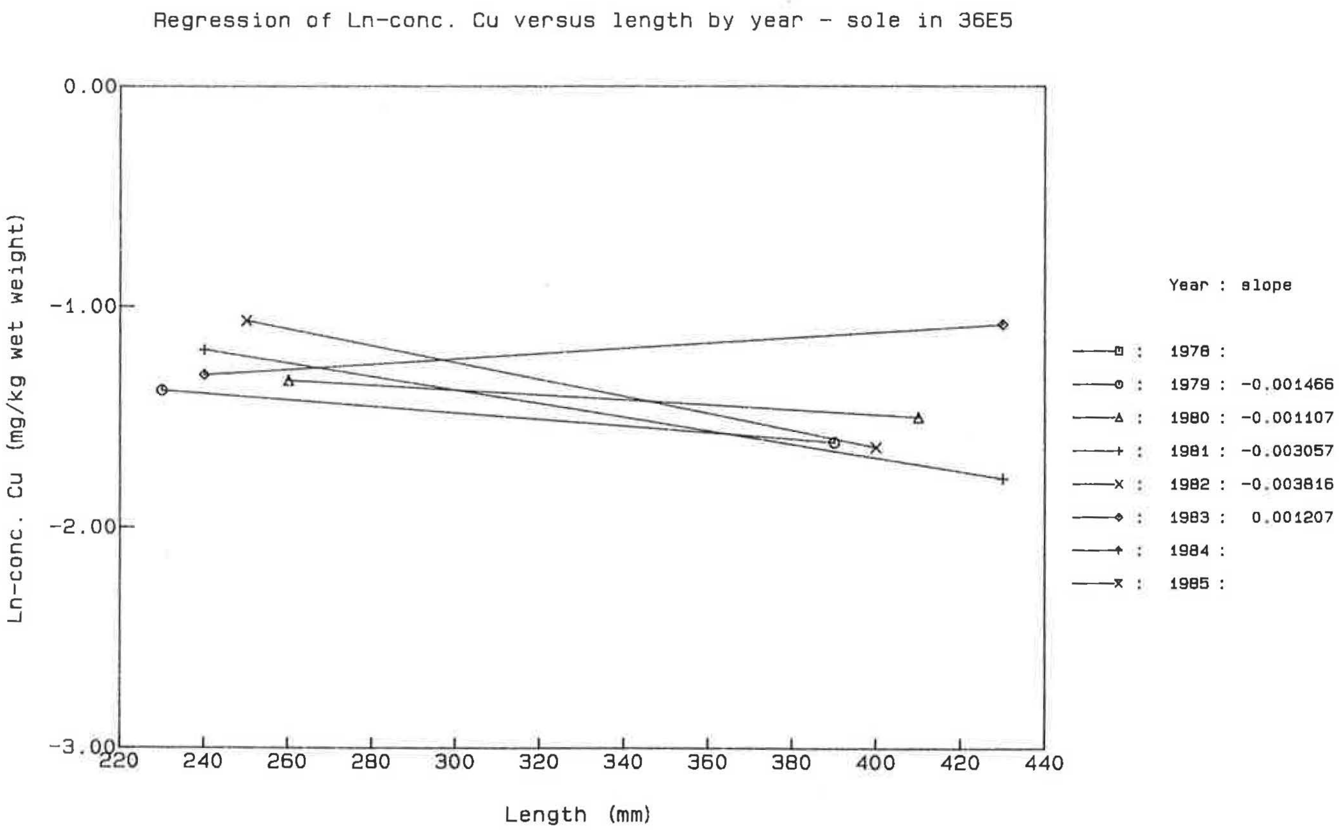
(LA) Estimates of Zn in sole muscle - sole in 36E5

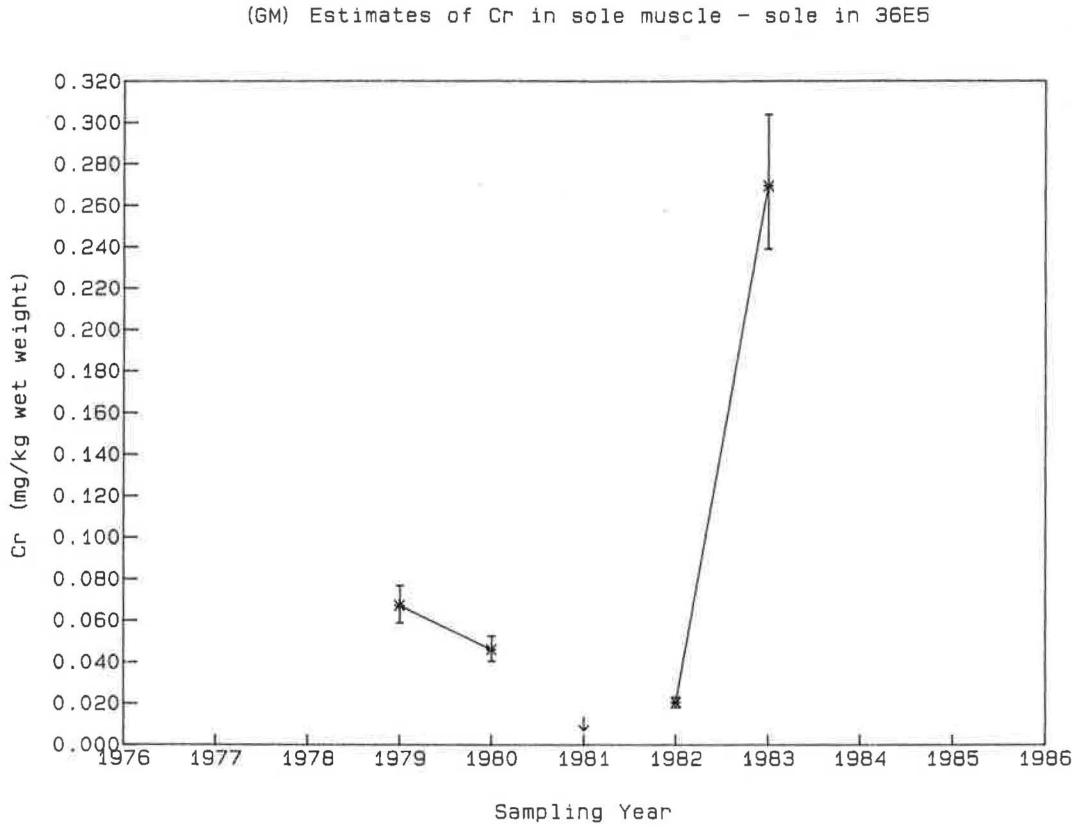


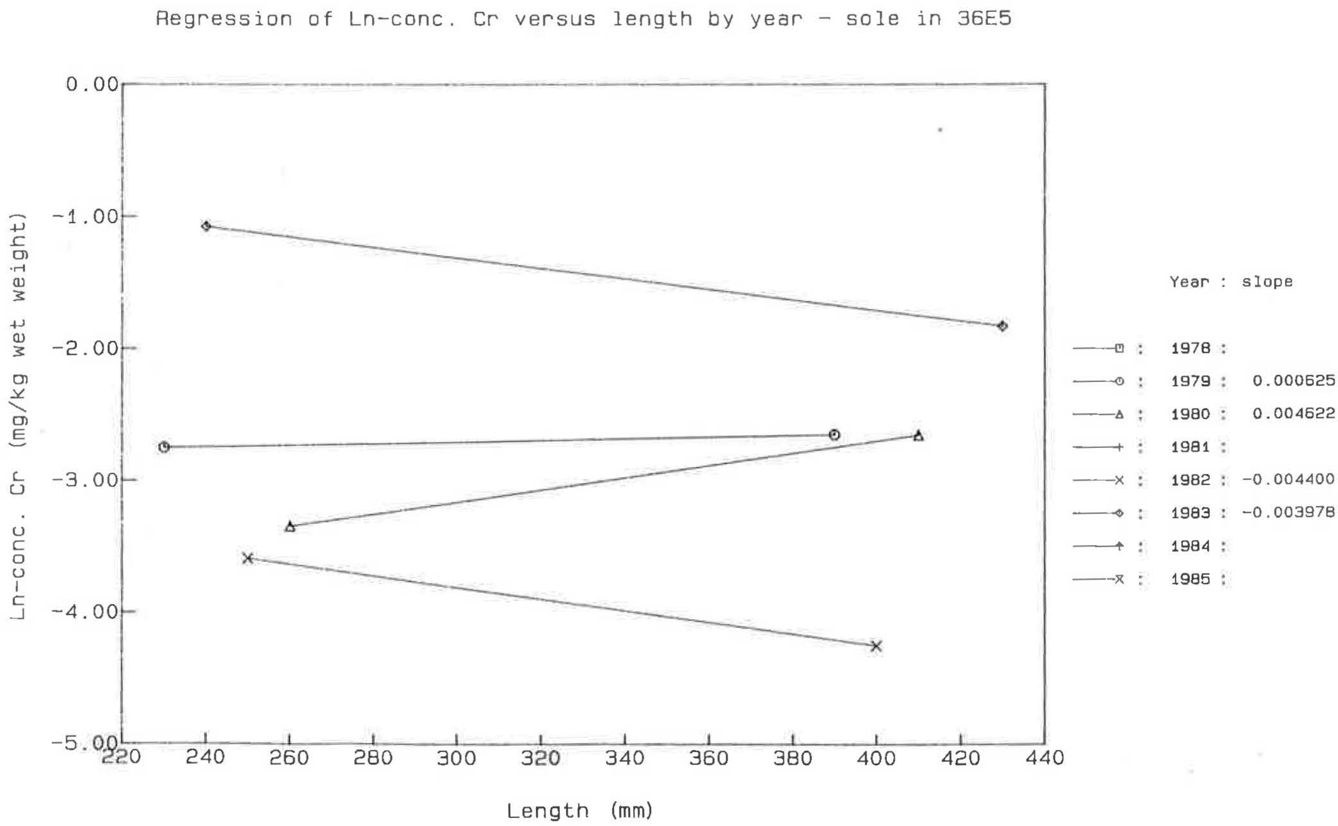
Regression of Ln-conc. Zn versus length by year - sole in 36E5



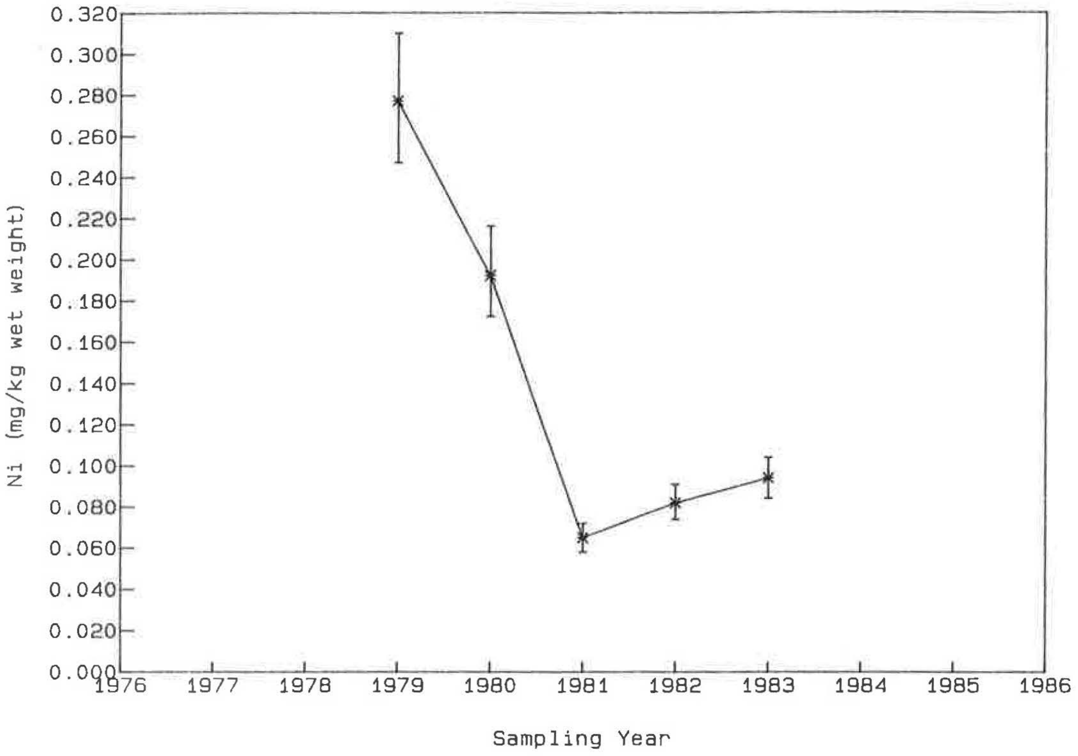

(GM) Estimates of Cu in sole muscle - sole in 36E5
Cu (mg/kg wet weight)
0.000
0.020
0.040
0.060
0.080
0.100
0.120
0.140
0.160
0.180
0.200
0.220
0.240
0.260
0.280
0.300
0.320
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Cu versus length by year - sole in 36E5
Ln-conc. Cu (mg/kg wet weight)
0.00
-1.00
-2.00
-3.00
220
240
260
280
300
320
340
360
380
400
420
440
Length (mm)
Year : slope
1978 :
1979 : -0.001466
1980 : -0.001107
1981 : -0.003057
1982 : -0.003816
1983 : 0.001207
1984 :
1985 :

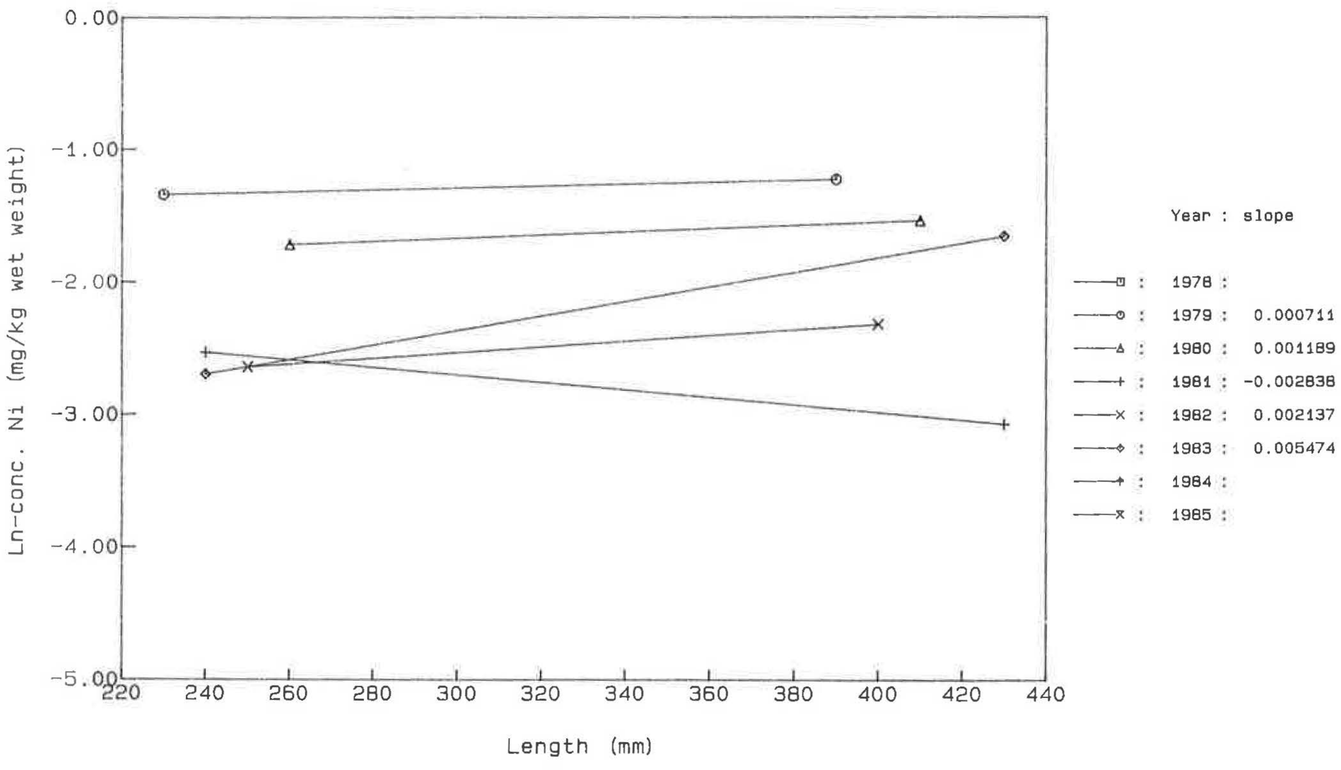

(GM) Estimates of Cr in sole muscle - sole in 36E5
Cr (mg/kg wet weight)
0.000
0.020
0.040
0.060
0.080
0.100
0.120
0.140
0.160
0.180
0.200
0.220
0.240
0.260
0.280
0.300
0.320
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Cr versus length by year - sole in 36E5
Ln-conc. Cr (mg/kg wet weight)
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
220
240
260
280
300
320
340
360
380
400
420
440
Length (mm)
Year : slope
1978 :
1979 : 0.000625
1980 : 0.004622
1981 :
1982 : -0.004400
1983 : -0.003978
1984 :
1985 :

(GM) Estimates of Ni in sole muscle - sole in 36E5



Regression of Ln-conc. Ni versus length by year - sole in 36E5



SPECIES: Whiting (MERL MNG) TISSUE : muscle					NOMINAL AREA: 35E6 COUNTRY : United Kingdom			
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length					o	o	o	o
Weight					o	o	o	o
Age					o	o	●	o
Sex					o	o	o	o
Tissue wt.								
Fat %								
Dry %					o	o	o	o
CONTAMINANTS								
Hg					o	o	o	o
Cd					<.1			
Cu					<.2	o	o	o
Pb								
Zn					o	o	o	o
Cr								
Ni								
PCB								
SAMPLING								
sampling periods					Oct	Oct	Nov	Oct
sampling locations					35E6	35E6	35E6	35E6
number of specimens					30	25	25	25

Results of analyses:

Copper

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

  Due to analytical limitations, the quality of the data for copper may not be suitable for analysis of temporal trends; values were reported only to the nearest 0.1 mg/kg wet weight.

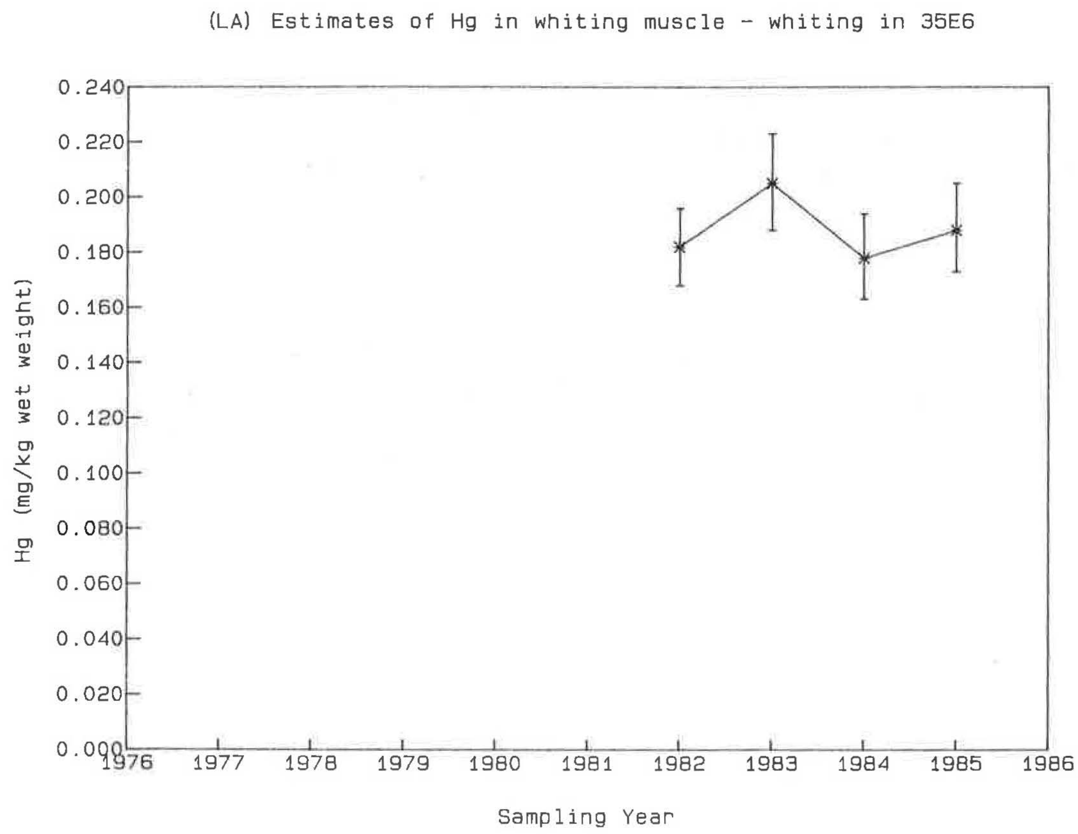
Mercury

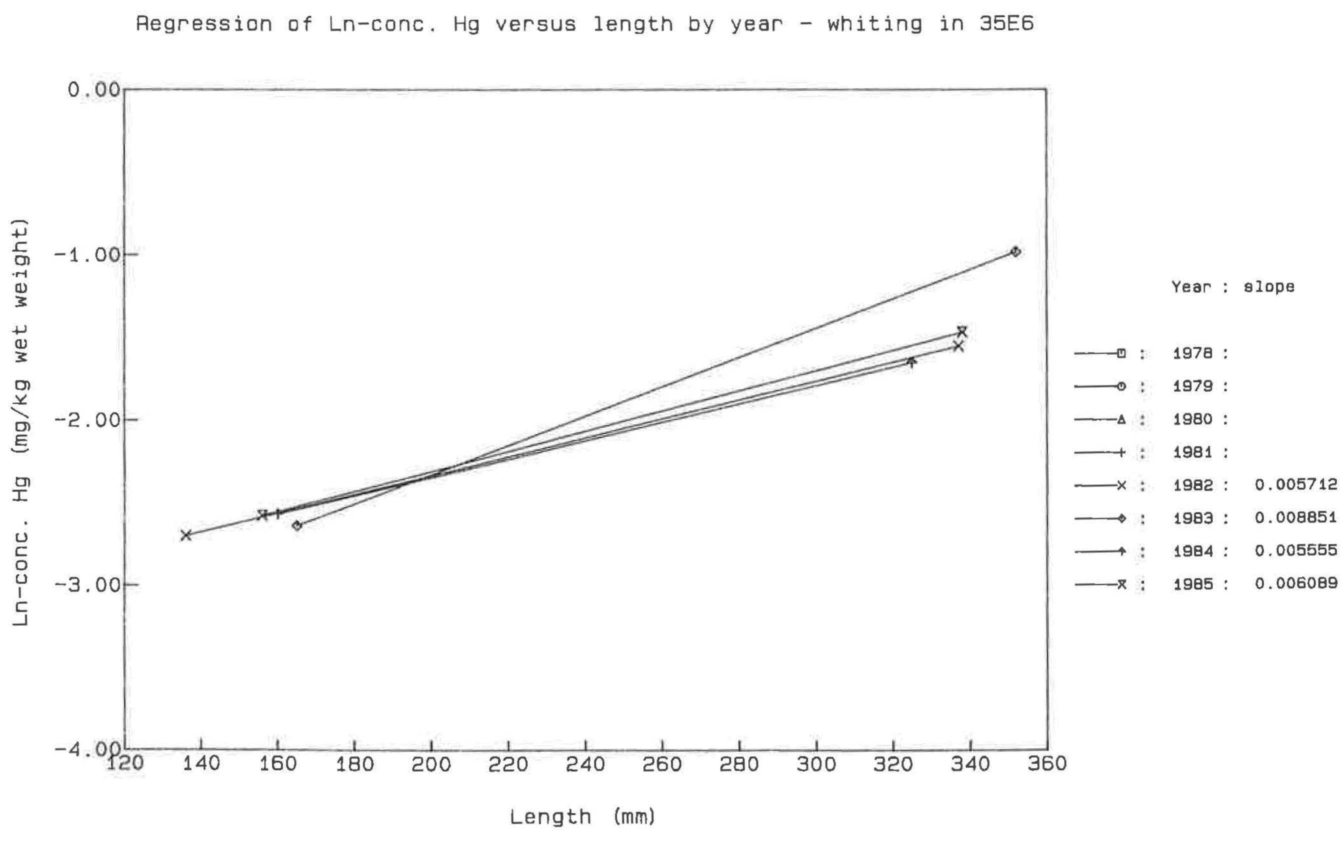
- Results confirm the validity of the statistical analysis; there is no evidence of significant differences in the length-adjusted yearly mean contaminant levels between years (see plot).

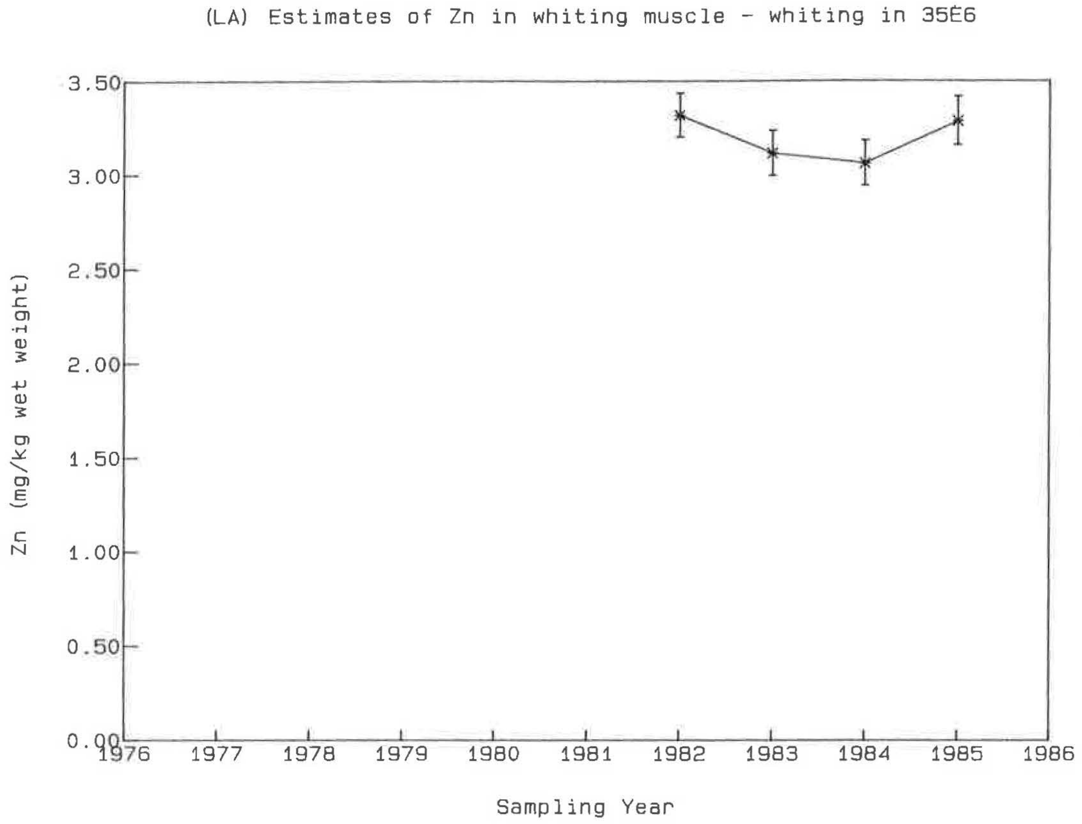
Information provided by the data originator states that, although inputs of mercury to Liverpool Bay have been reduced, continued contamination may result from the release of mercury from historically contaminated sediments.

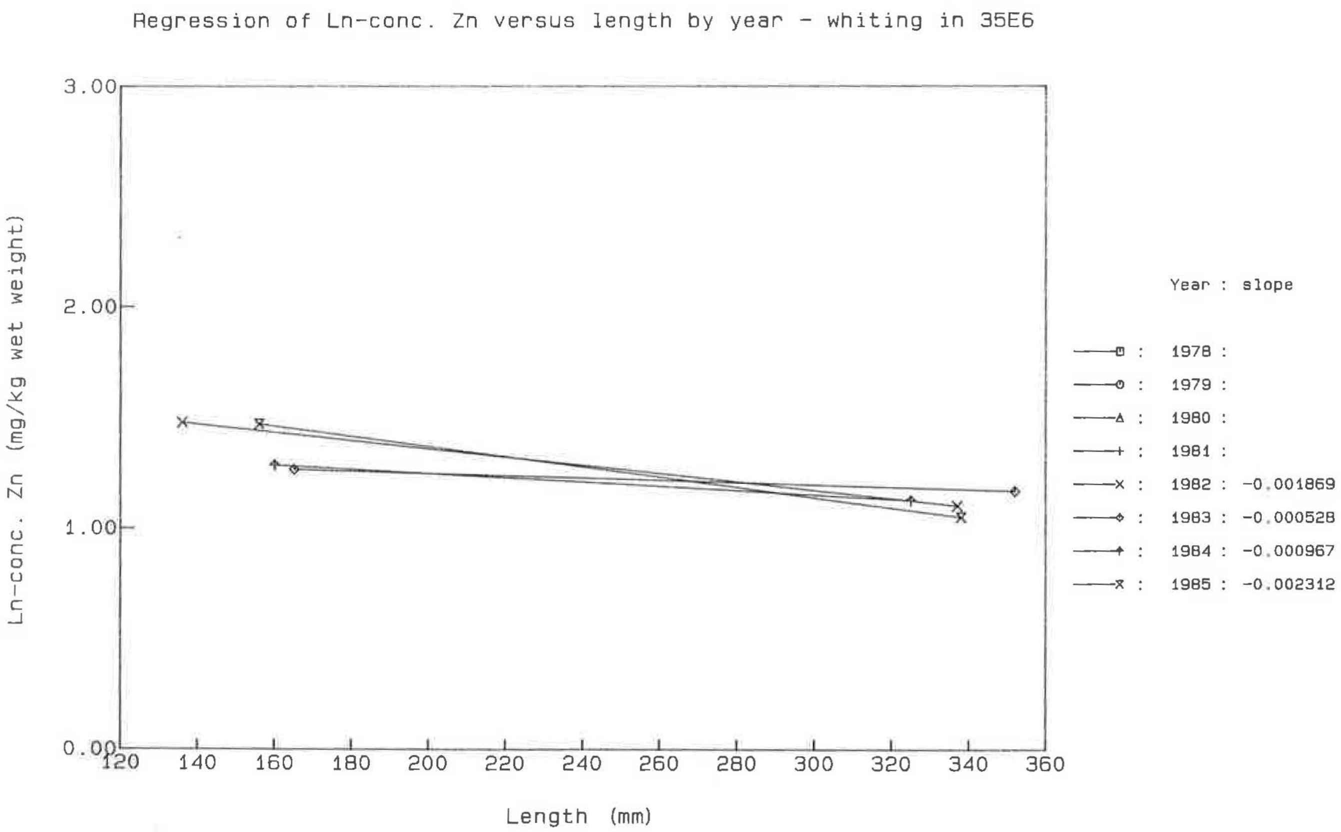
Zinc

- Results show significant differences between years in the slopes of the linear relationships between contaminant level and length. The results suggesting that a significant increase in the explanatory power of the statistical analysis could be achieved by inclusion of additional biological covariates may not be valid under these circumstances.

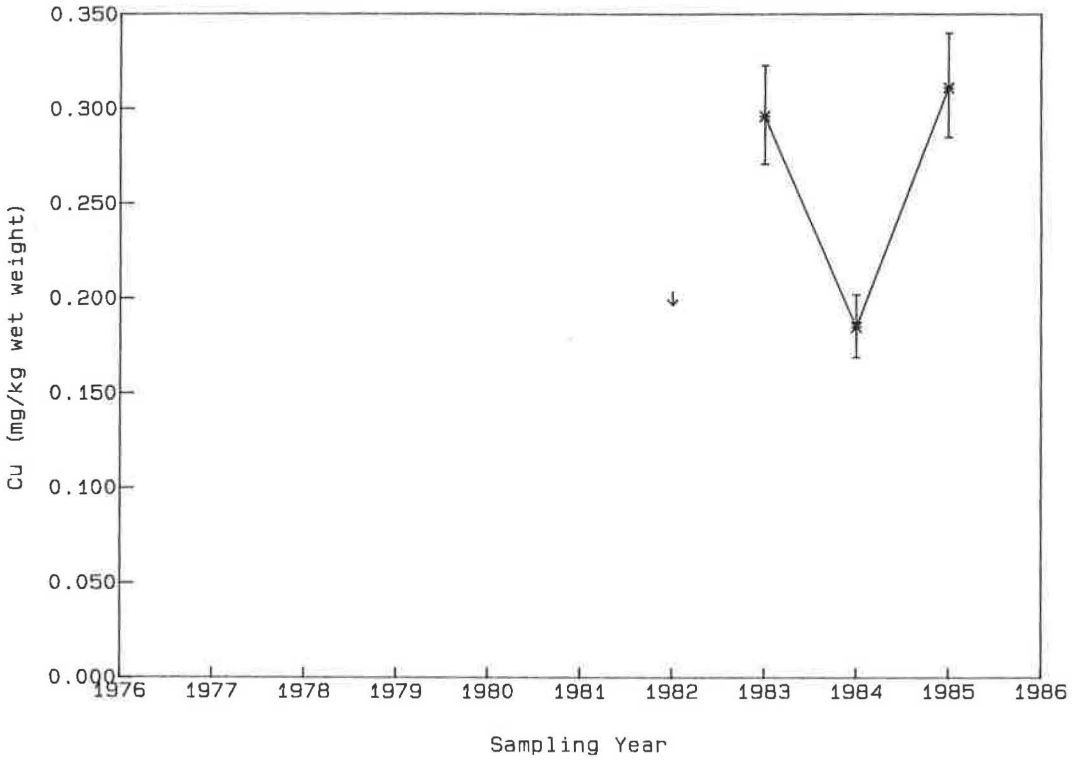

(LA) Estimates of Hg in whiting muscle - whiting in 35E6
Hg (mg/kg wet weight)
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Hg versus length by year - whiting in 35E6
Ln-conc. Hg (mg/kg wet weight)
0.00
-1.00
-2.00
-3.00
-4.00
120
140
160
180
200
220
240
260
280
300
320
340
360
Length (mm)
Year : slope
1978 :
1979 :
1980 :
1981 :
1982 : 0.005712
1983 : 0.008851
1984 : 0.005555
1985 : 0.006089

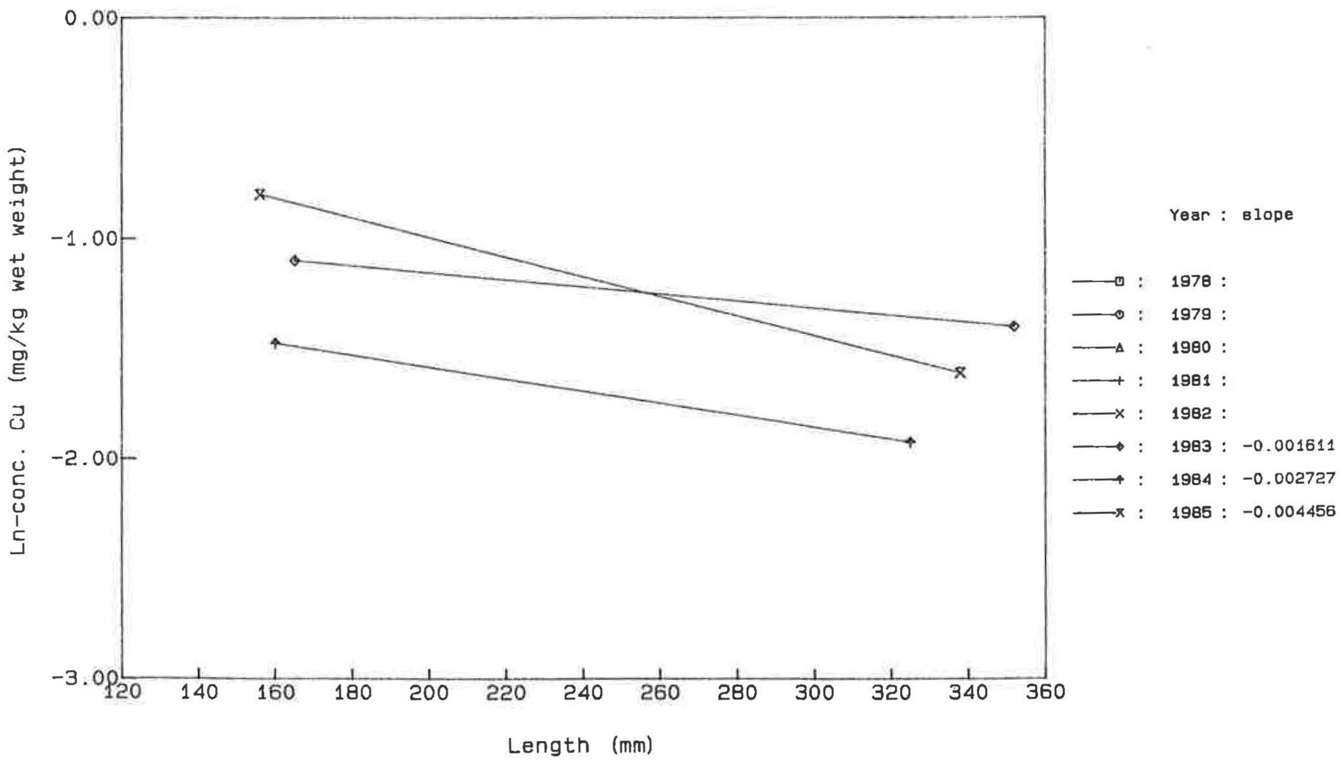

(LA) Estimates of Zn in whiting muscle - whiting in 35E6
Zn (mg/kg wet weight)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Zn versus length by year - whiting in 35E6
Ln-conc. Zn (mg/kg wet weight)
3.00
2.00
1.00
0.00
120
140
160
180
200
220
240
260
280
300
320
340
360
Length (mm)
Year : slope
: 1978 :
: 1979 :
: 1980 :
: 1981 :
: 1982 : -0.001869
: 1983 : -0.000528
: 1984 : -0.000967
: 1985 : -0.002312

(GM) Estimates of Cu in whiting muscle - whiting in 35E6



Regression of Ln-conc. Cu versus length by year - whiting in 35E6



SPECIES: Herring (CLUP HAR) TISSUE : muscle					NOMINAL AREA: 40G5 COUNTRY : Sweden			
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length		o	o	o	o	o	o	o
Weight		o	o	o	o	o	o	o
Age			o	2-3	o	2-3	2-3	o
Sex		o	o	F	F	F	F	F
Tissue wt.								
Fat %		o	o	o	o	o	o	o
Dry %						o	o	o
CONTAMINANTS								
Hg			o	o	o	o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB		o	o	o	o	o	o	o
SAMPLING								
sampling periods		Oct	Nov	Nov	Oct	Oct	Oct	Nov
sampling locations		40G5	40G5	40G5	40G5	40G5	40G5	40G5
number of specimens		20	20+20[1]	20	20	20	20	20

Commentary:

Since 1981 samples have included only female fish.

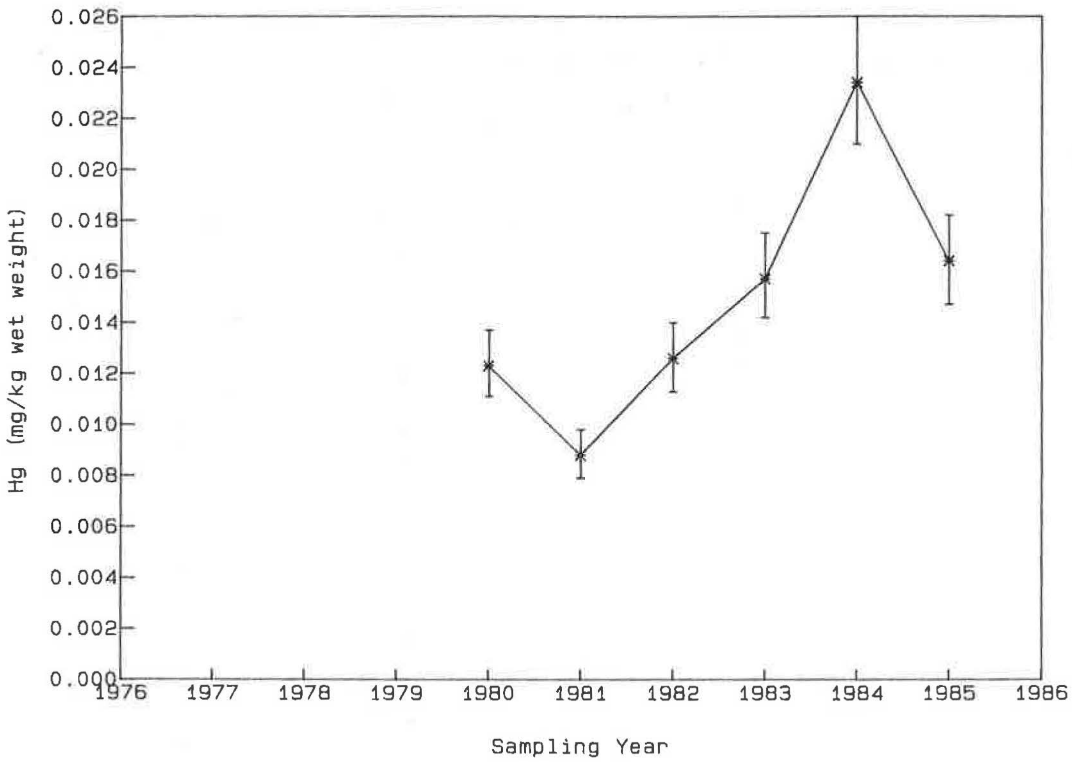
[1] In 1980, 40 specimens were sampled; 20 were analyzed for Hg and 20 for PCB.

Results of analyses:

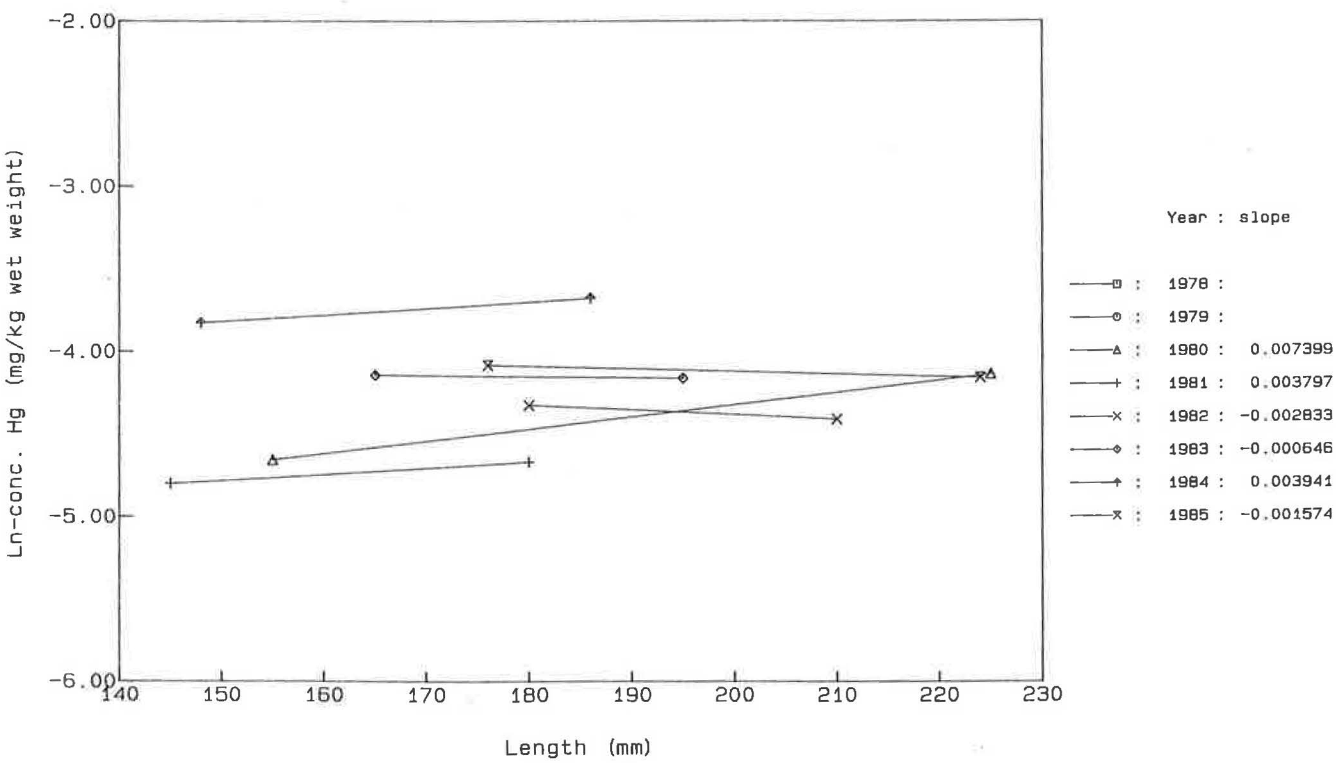
Mercury; PCB;

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

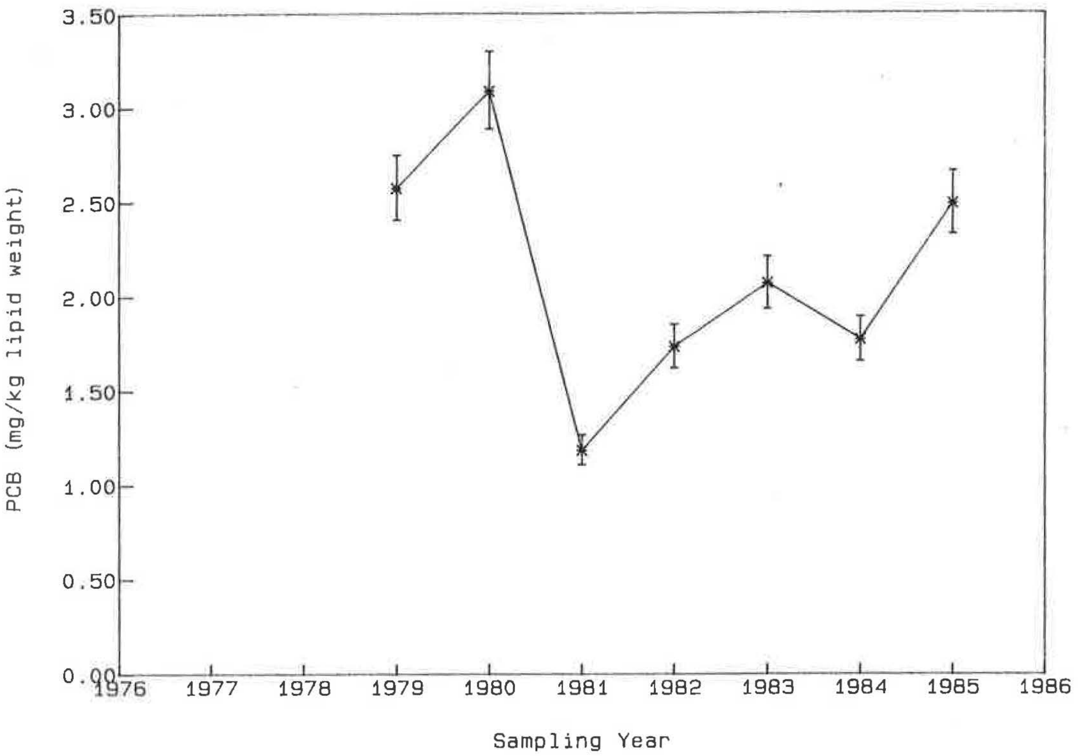
(GM) Estimates of Hg in herring muscle - herring in 40G5



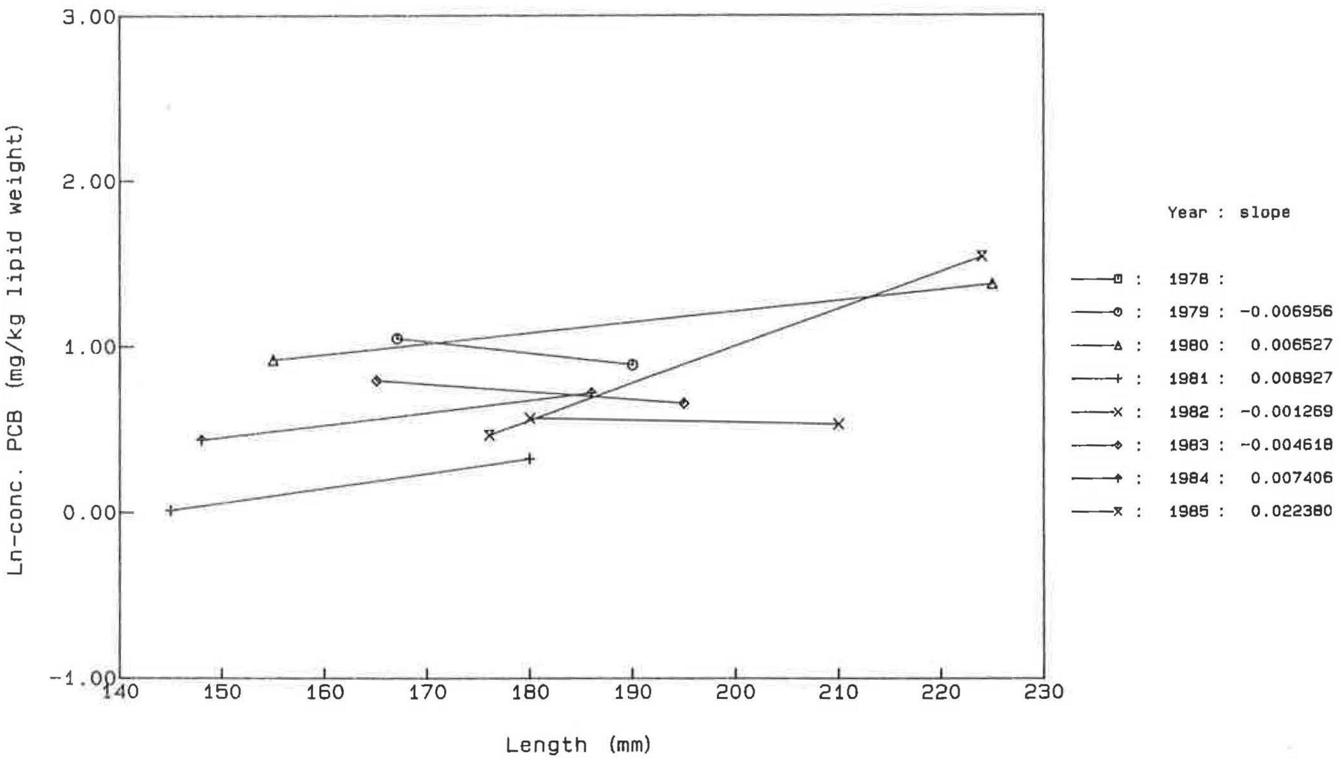
Regression of Ln-conc. Hg versus length by year - herring in 40G5



(GM) Estimates of PCB in herring muscle - herring in 40G5



Regression of Ln-conc. PCB versus length by year - herring in 40G5



SPECIES: Herring (CLUP HAR) TISSUE : muscle	NOMINAL AREA: 43G1 COUNTRY : Sweden

DATA CHARACTERISTICS

BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length			o	o	o	o	o	o
Weight			o	o	o	o	o	o
Age			●	2	2	2	2-3	2
Sex			o	o	F	F	F	F
Tissue wt.								
Fat %			o	o	o	o	o	o
Dry %						o	o	o
CONTAMINANTS								
Hg			o	o	o	o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB			o	o	o	o	o	o
SAMPLING								
sampling periods			Sept	Sept	Aug	Sept	Aug	Aug
sampling locations			43G1	43G1	43G1	43G1	43G1	43G1
number of specimens			20	20	20	25	25	25

Commentary:

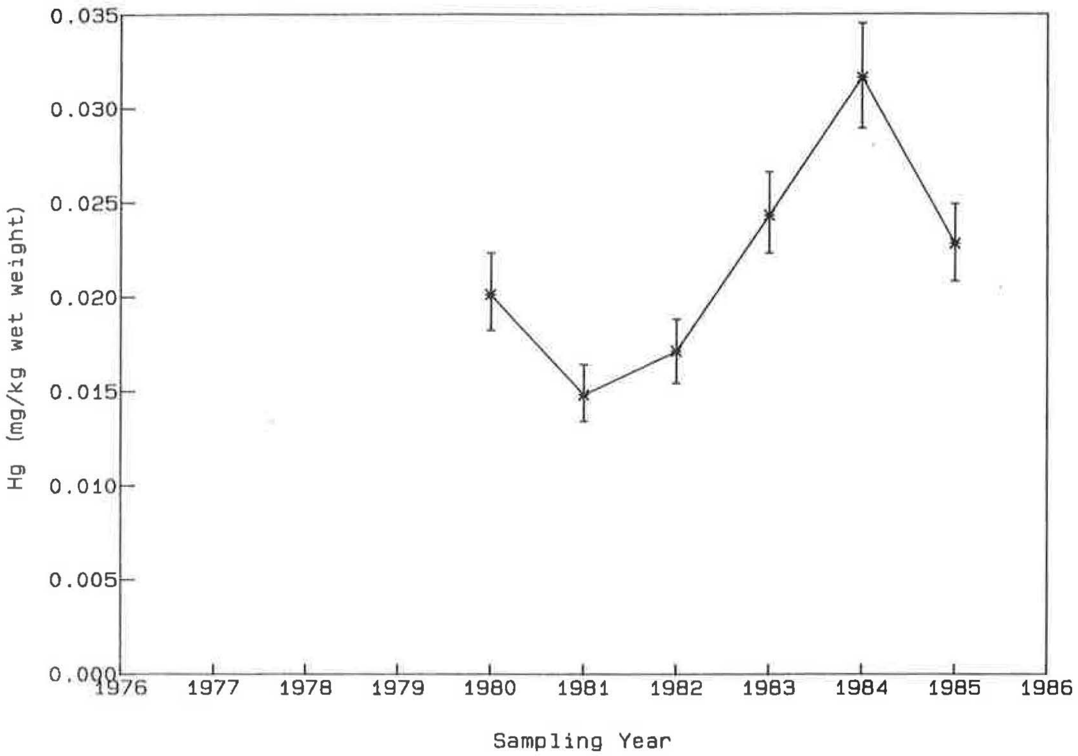
Since 1981 samples have included mainly 2-3 year-old female fish.

Results of analyses:

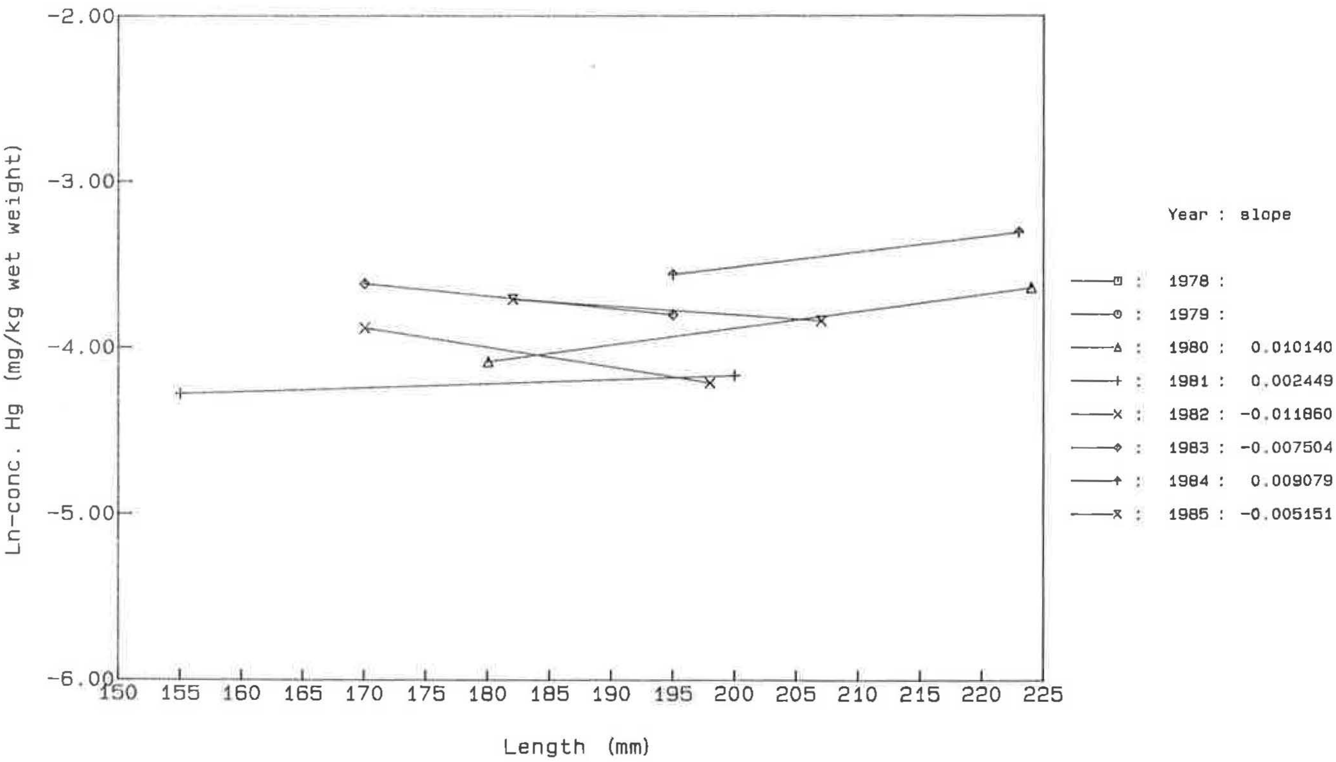
Mercury; PCB;

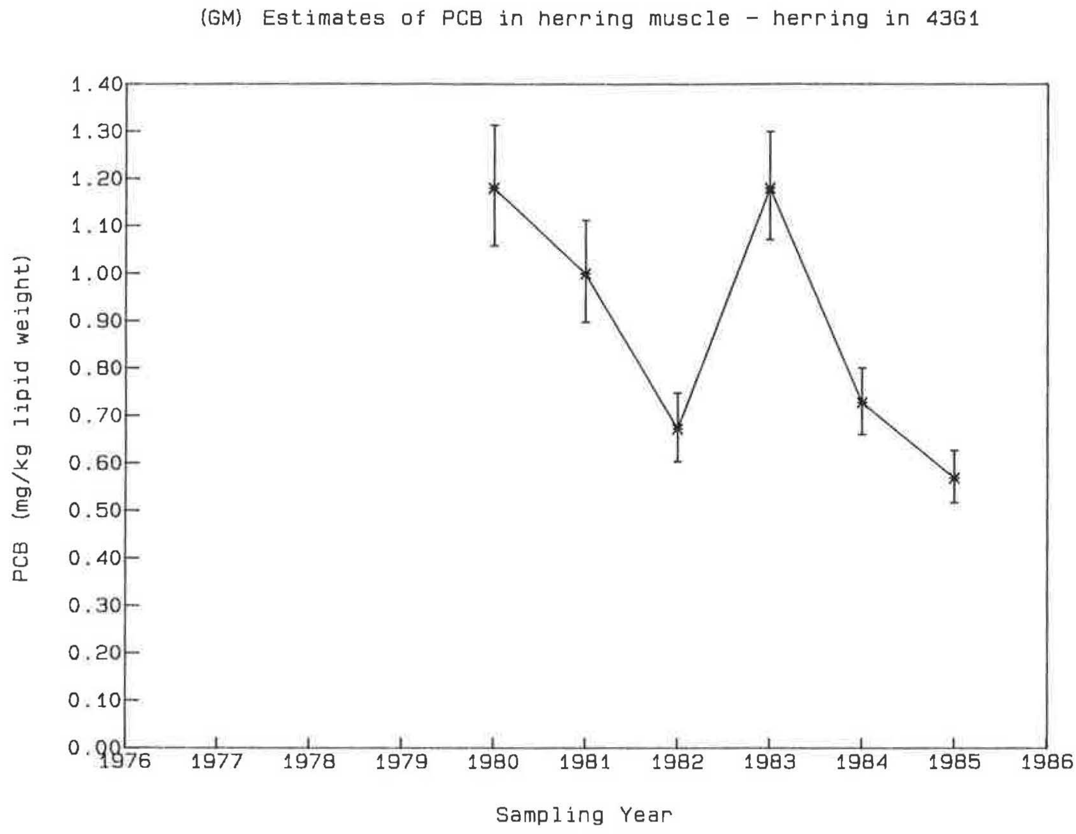
- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

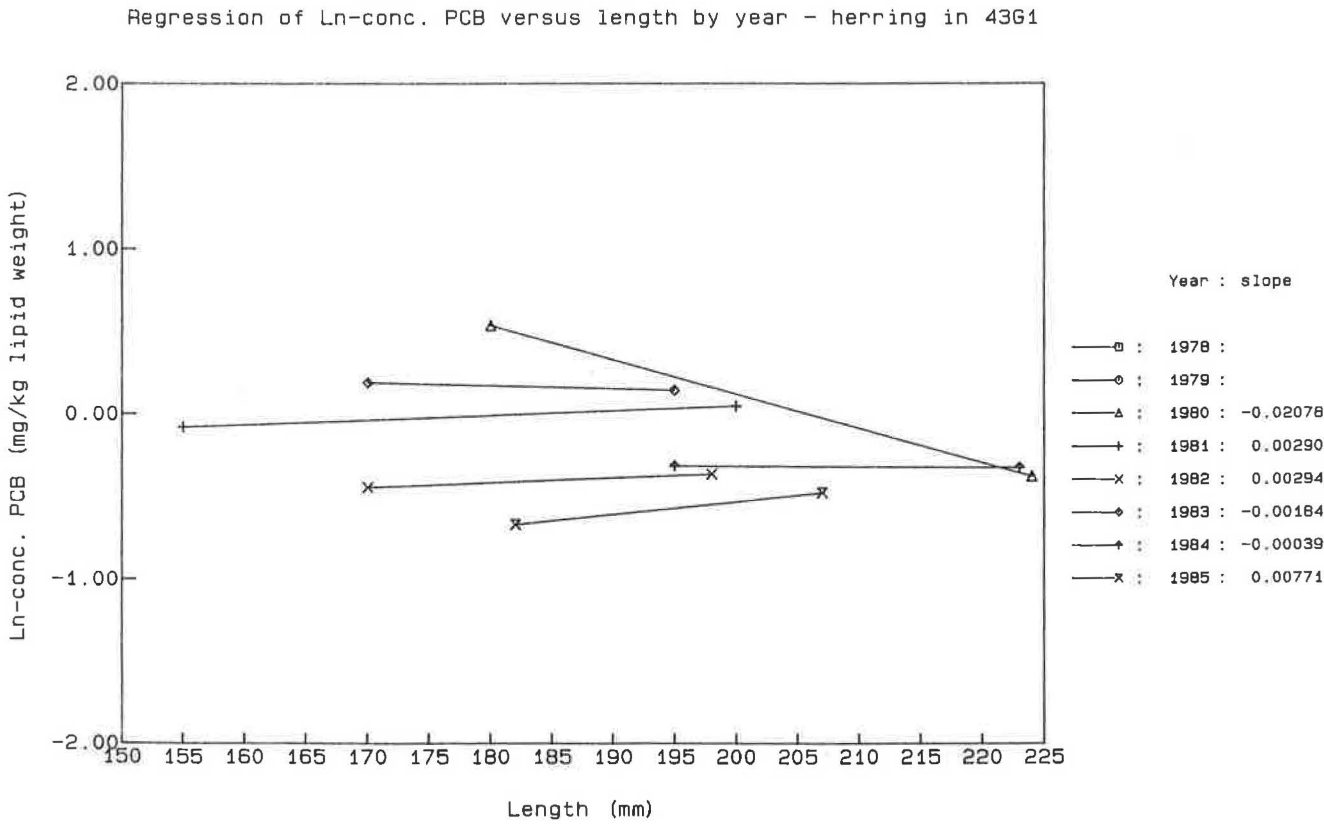
(GM) Estimates of Hg in herring muscle - herring in 43G1



Regression of Ln-conc. Hg versus length by year - herring in 43G1




(GM) Estimates of PCB in herring muscle - herring in 43G1
PCB (mg/kg lipid weight)
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
Sampling Year


Regression of Ln-conc. PCB versus length by year - herring in 43G1
Ln-conc. PCB (mg/kg lipid weight)
2.00
1.00
0.00
-1.00
-2.00
150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225
Length (mm)
Year : slope
1978 :
1979 :
1980 : -0.02078
1981 : 0.00290
1982 : 0.00294
1983 : -0.00184
1984 : -0.00039
1985 : 0.00771

SPECIES: Herring (CLUP HAR) TISSUE : muscle			NOMINAL AREA: 46G7 COUNTRY : Sweden					
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length	o		●	o	o	o	o	o
Weight	o		o	o	o	o	o	o
Age	3		●	o	o	o	o	o
Sex	o		o	F	F●	F	F	F
Tissue wt.								
Fat %	o		o	o	o	o	o	o
Dry %						o	o	o
CONTAMINANTS								
Hg			o	o	o	o	o	●
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB	o		o	o	o	o	o	o
SAMPLING								
sampling periods	Sep		Oct	Nov	Oct	Nov	Nov	Oct
sampling locations	46G7		46G7	46G7	46G7	46G7	46G7	46G7
number of specimens	20		20+20[1]	20	20	20	20	20

Commentary:

Since 1981 samples have included only female fish.

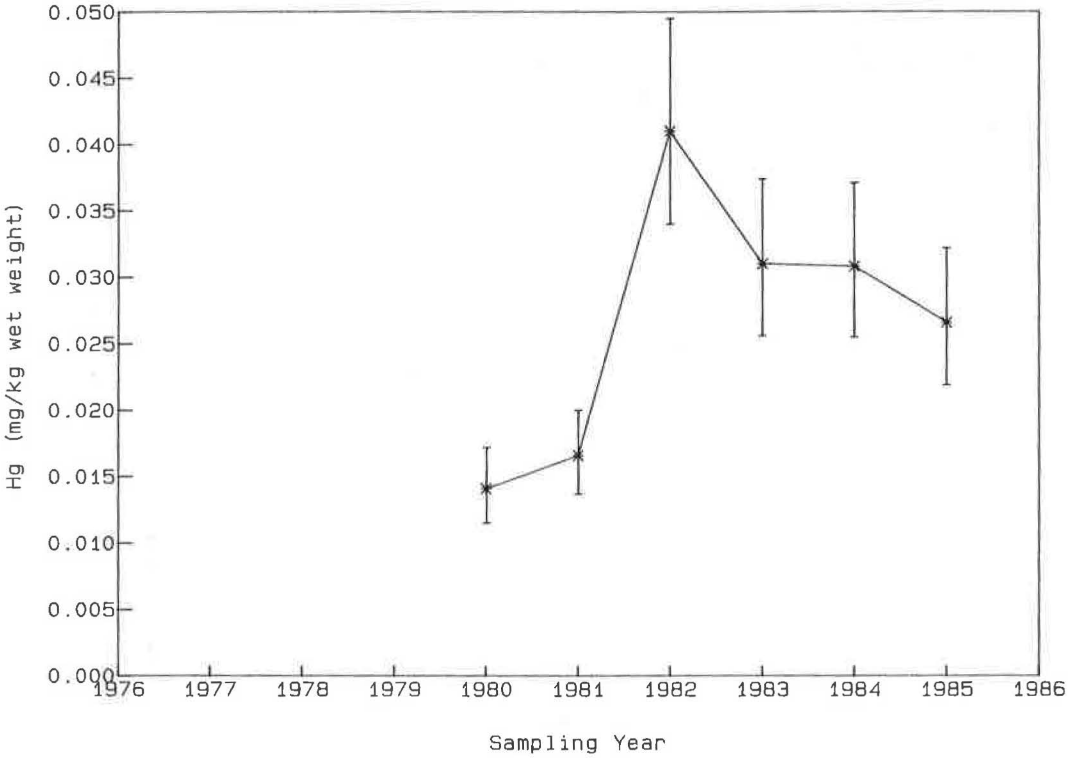
[1]In 1980, 40 specimens were sampled; 20 were analyzed for Hg and 20 for PCB.

Results of analyses:

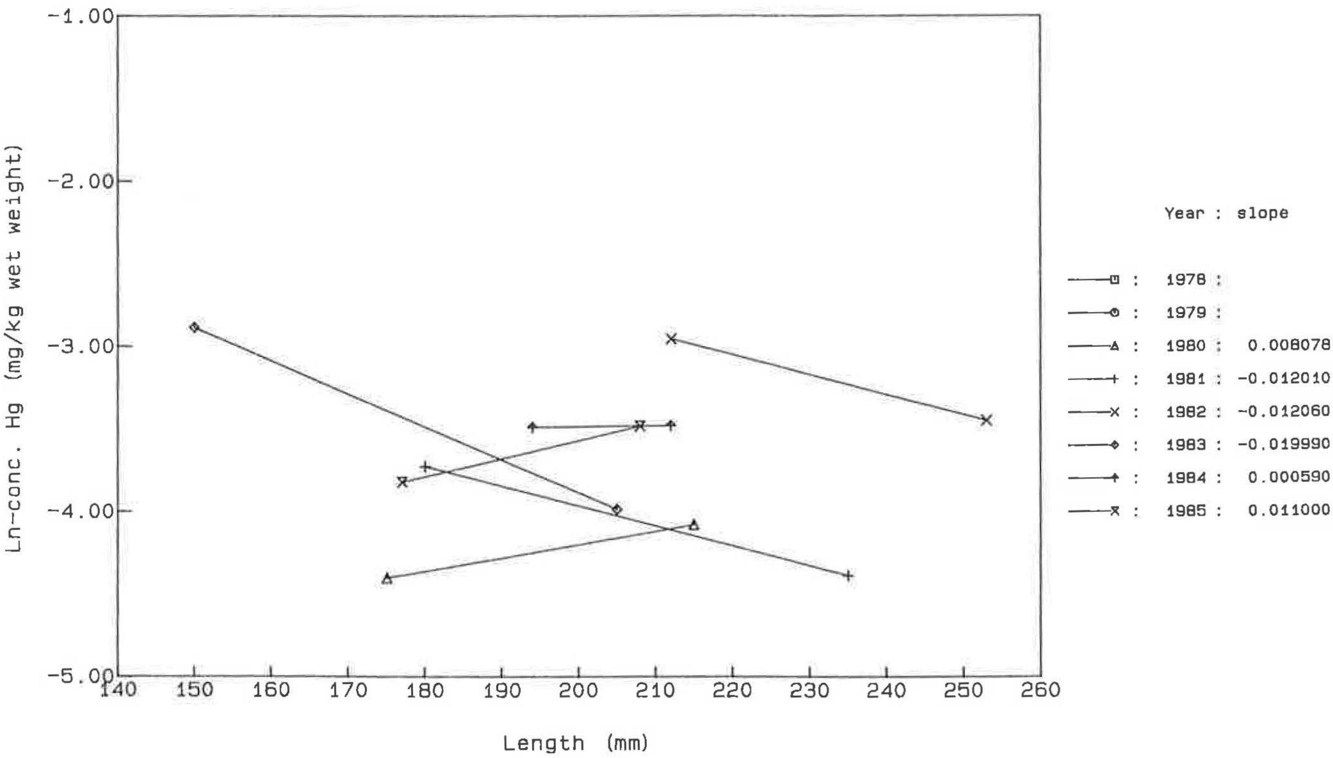
Mercury; PCB;

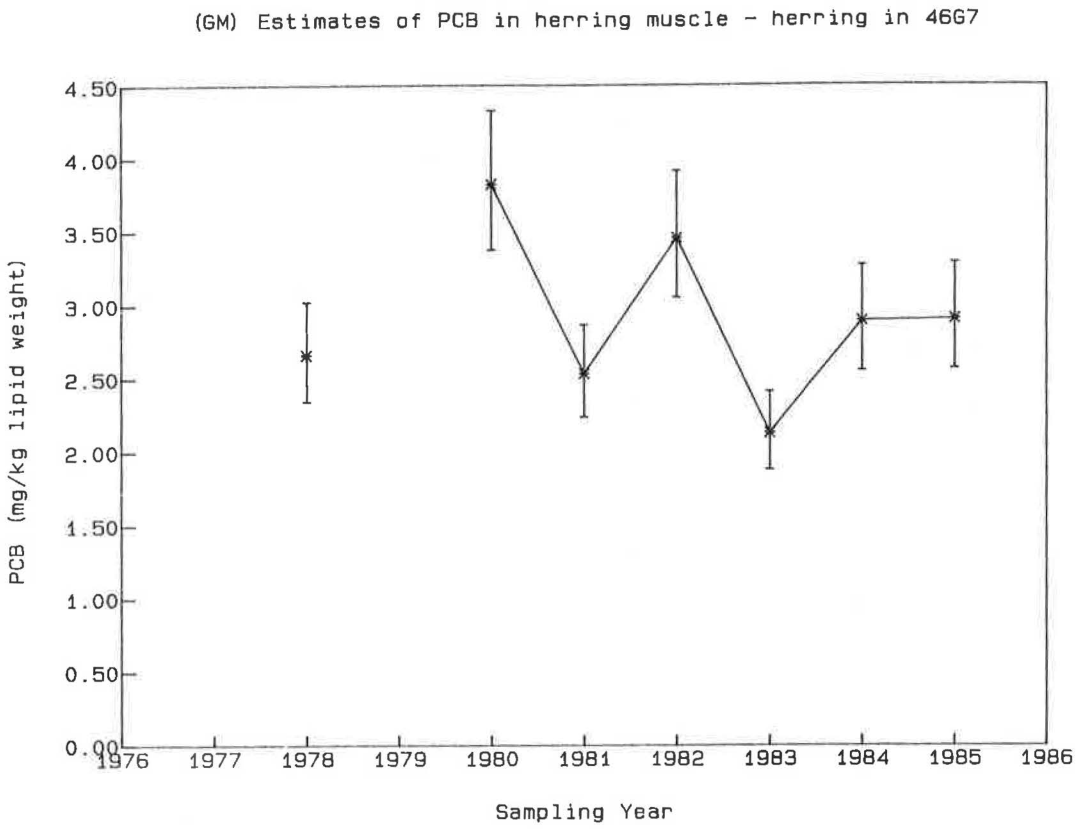
- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

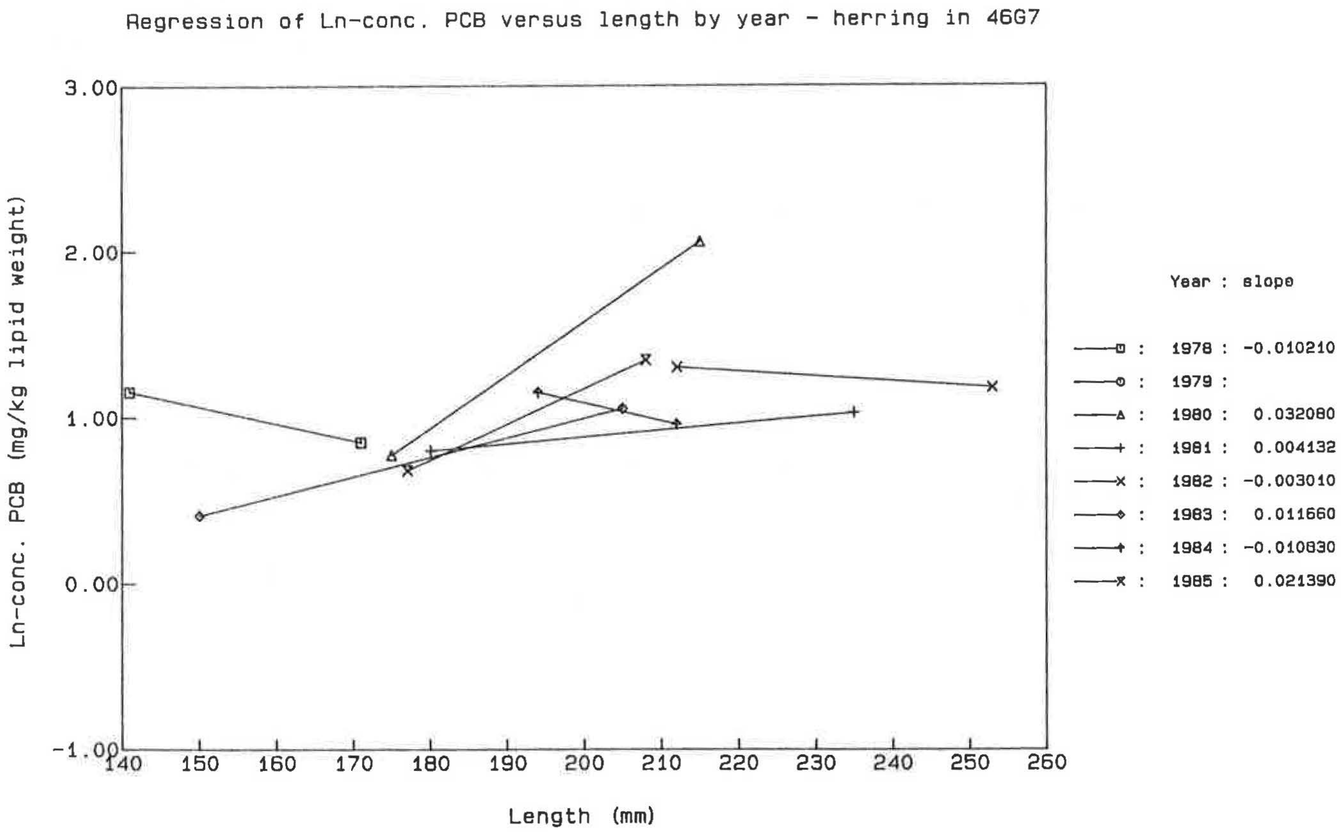
(GM) Estimates of Hg in herring muscle - herring in 46G7



Regression of Ln-conc. Hg versus length by year - herring in 46G7




(GM) Estimates of PCB in herring muscle - herring in 46G7
PCB (mg/kg lipid weight)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. PCB versus length by year - herring in 46G7
Ln-conc. PCB (mg/kg lipid weight)
3.00
2.00
1.00
0.00
-1.00
140
150
160
170
180
190
200
210
220
230
240
250
260
Length (mm)
Year : slope
1978 : -0.010210
1979 :
1980 : 0.032080
1981 : 0.004132
1982 : -0.003010
1983 : 0.011660
1984 : -0.010830
1985 : 0.021390

SPECIES: Herring (CLUP HAR) TISSUE : muscle	NOMINAL AREA: 50G8 COUNTRY : Sweden							
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length	o	o	o	o	o	o	o	o
Weight	o	25	o	o	o	o	o	o
Age	o		o	5	o	o	o	3-4
Sex		o	o	F	F	F	F	F
Tissue wt.								
Fat %	o	o	o	o	o	o	o	o
Dry %						o	o	o
CONTAMINANTS								
Hg			o	o	o	o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB	o	o	o	o	o	o	o	o
SAMPLING								
sampling periods	Sept	Nov	Oct	Sept	Oct	Sept	Oct	Oct
sampling locations	50G8	50G8	50G8	50G8	50G8	50G8	50G8	50G8
number of specimens	20	20	20	20	20	20	20	20

Commentary:

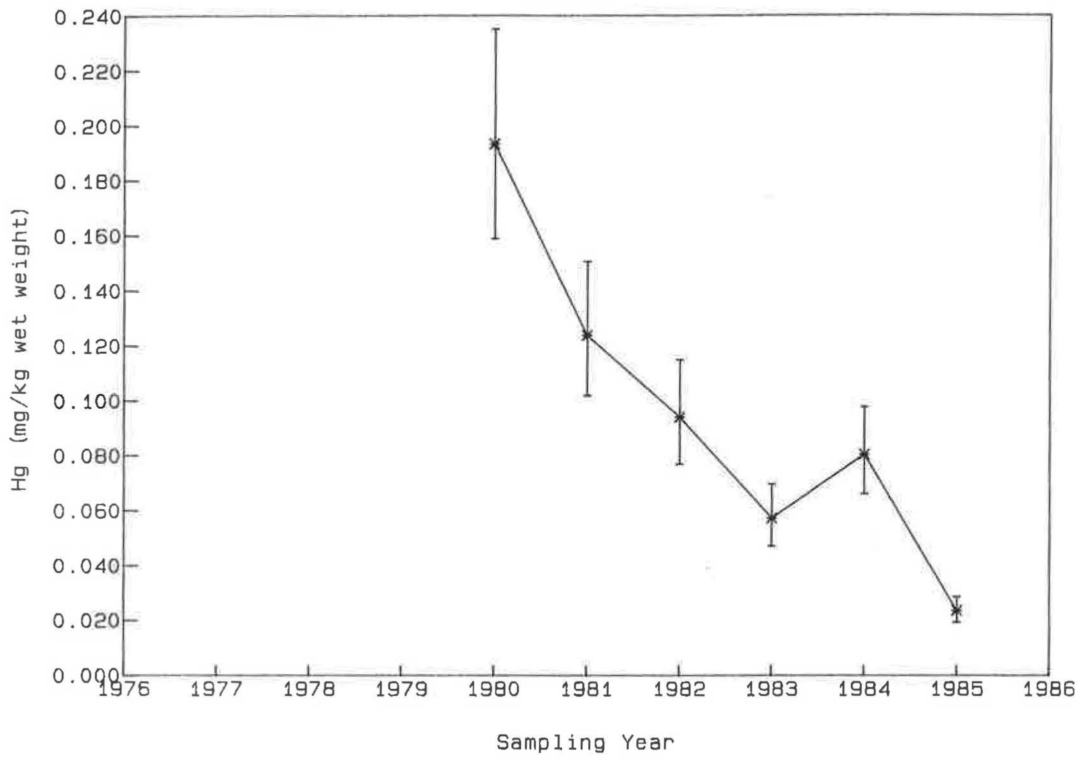
Since 1981 samples have included only female fish.

Results of analyses:

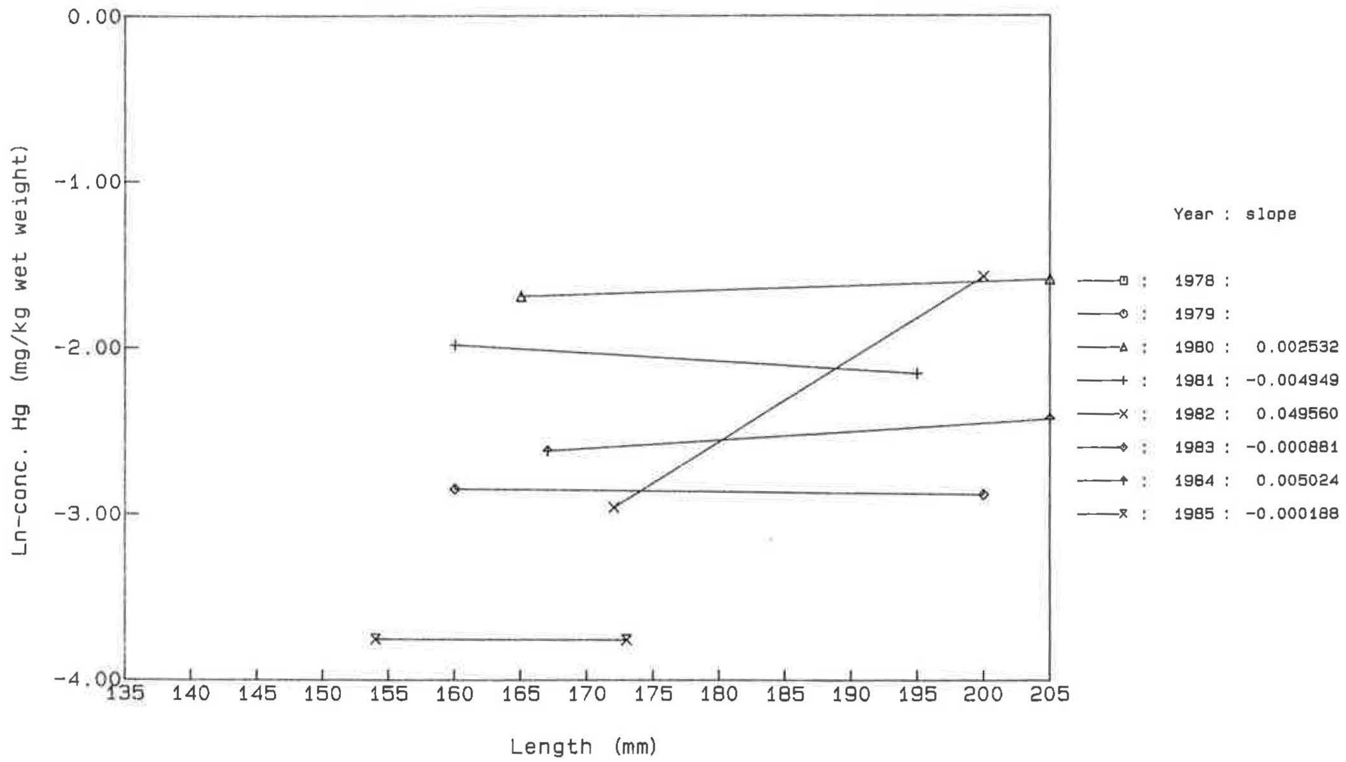
Mercury; PCB;

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

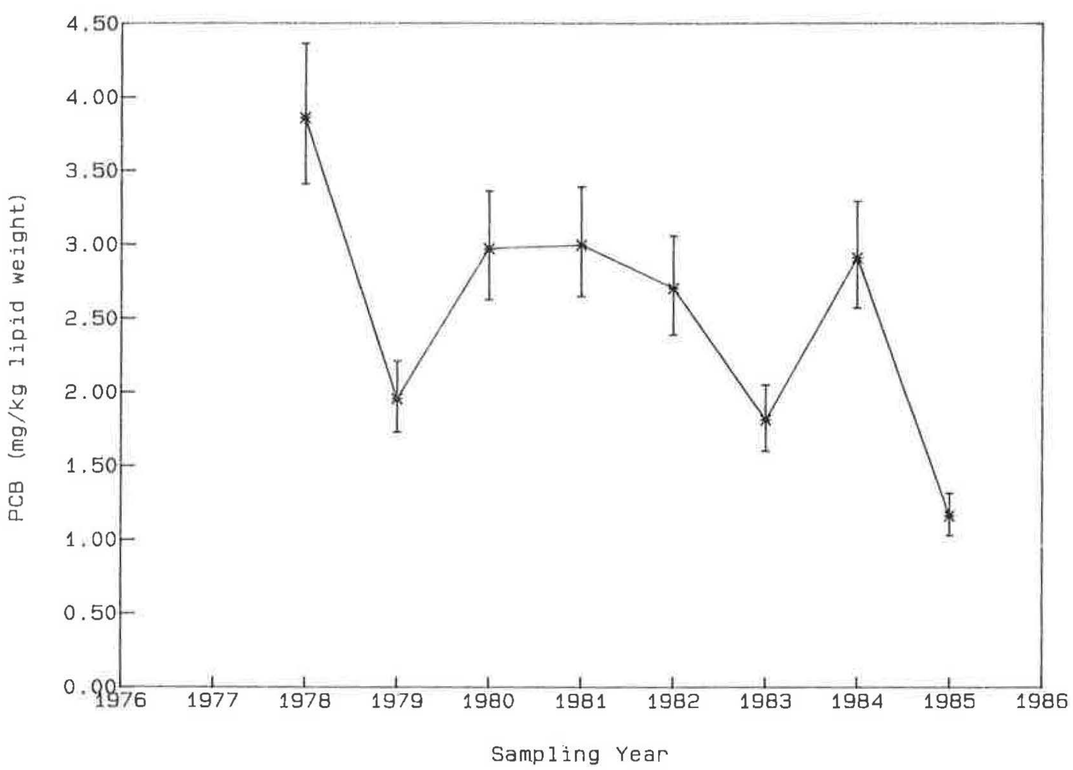
(GM) Estimates of Hg in herring muscle - herring in 50G8



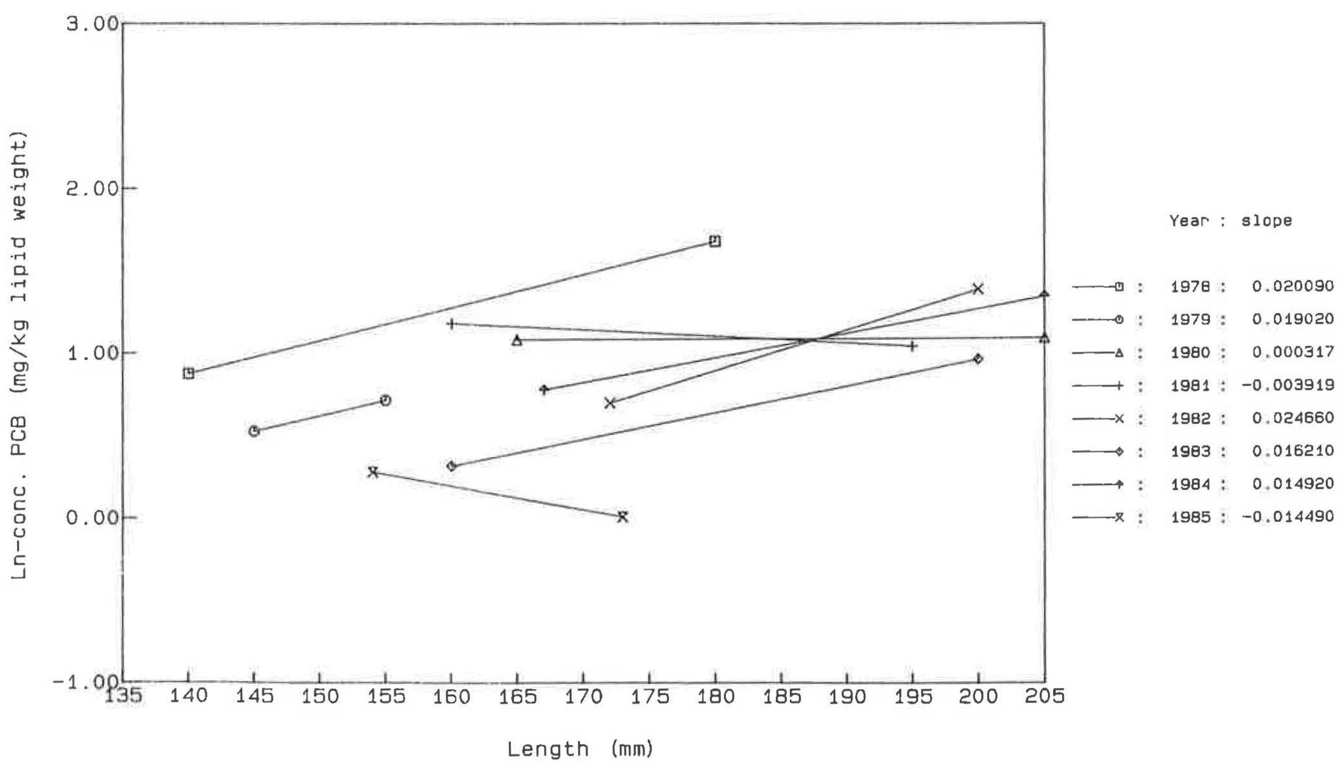
Regression of Ln-conc. Hg versus length by year - herring in 50G8



(GM) Estimates of PCB in herring muscle - herring in 50G8



Regression of Ln-conc. PCB versus length by year - herring in 50G8



SPECIES: Herring (CLUP HAR) TISSUE : muscle	NOMINAL AREA: 60H2 COUNTRY : Sweden							
DATA CHARACTERISTICS								
BIOLOGY	1978	1979	1980	1981	1982	1983	1984	1985
Length	o	o	o	o	o	o	o	o
Weight	o	o	o	o	o	o	o	o
Age	o		o	3	3-4	o	3	4
Sex			o	F	F	F	F	F
Tissue wt.								
Fat %	o	o	o	o	o	o	o	o
Dry %						o	o	o
CONTAMINANTS								
Hg			●	o	o	o	o	o
Cd								
Cu								
Pb								
Zn								
Cr								
Ni								
PCB	o	o	o	o	o	o	o	o
SAMPLING								
sampling periods	Oct	Oct	Oct	Sept	Oct	Oct	Sept	Oct
sampling locations	60H2	60H2	60H2	60H2	60H2	60H2	60H2	60H2
number of specimens	20	20	20	20	20	20	20	20

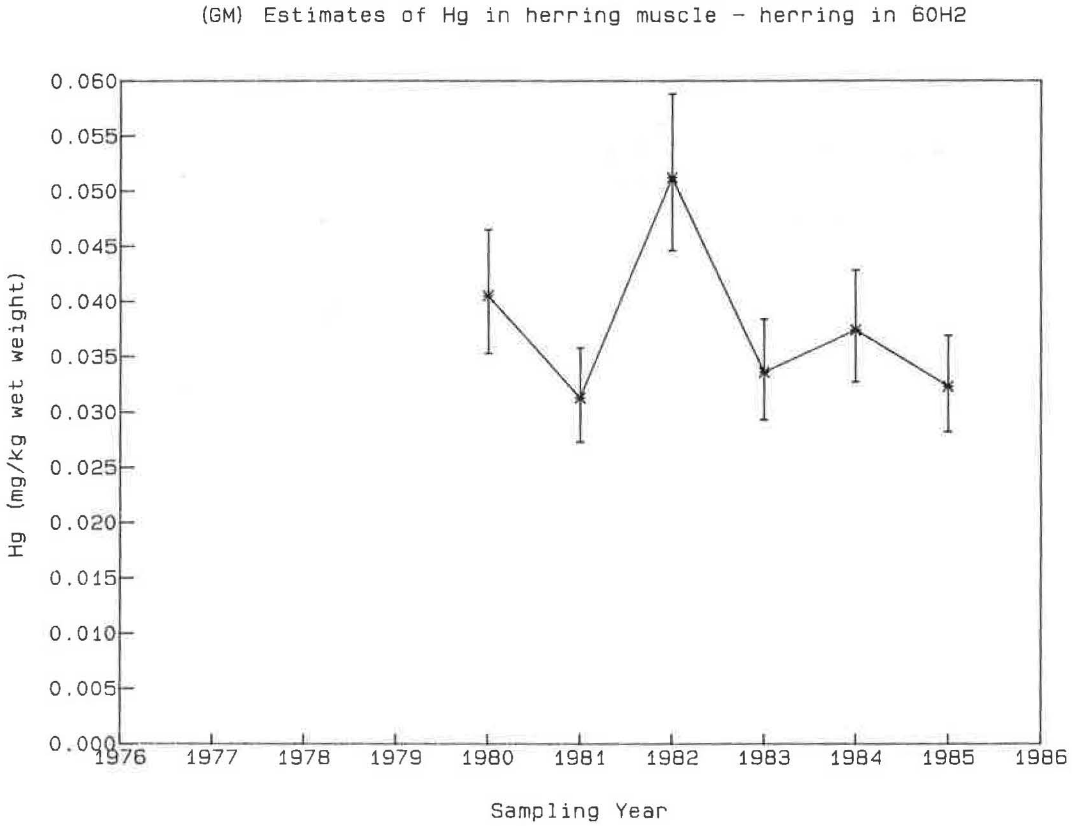
Commentary:

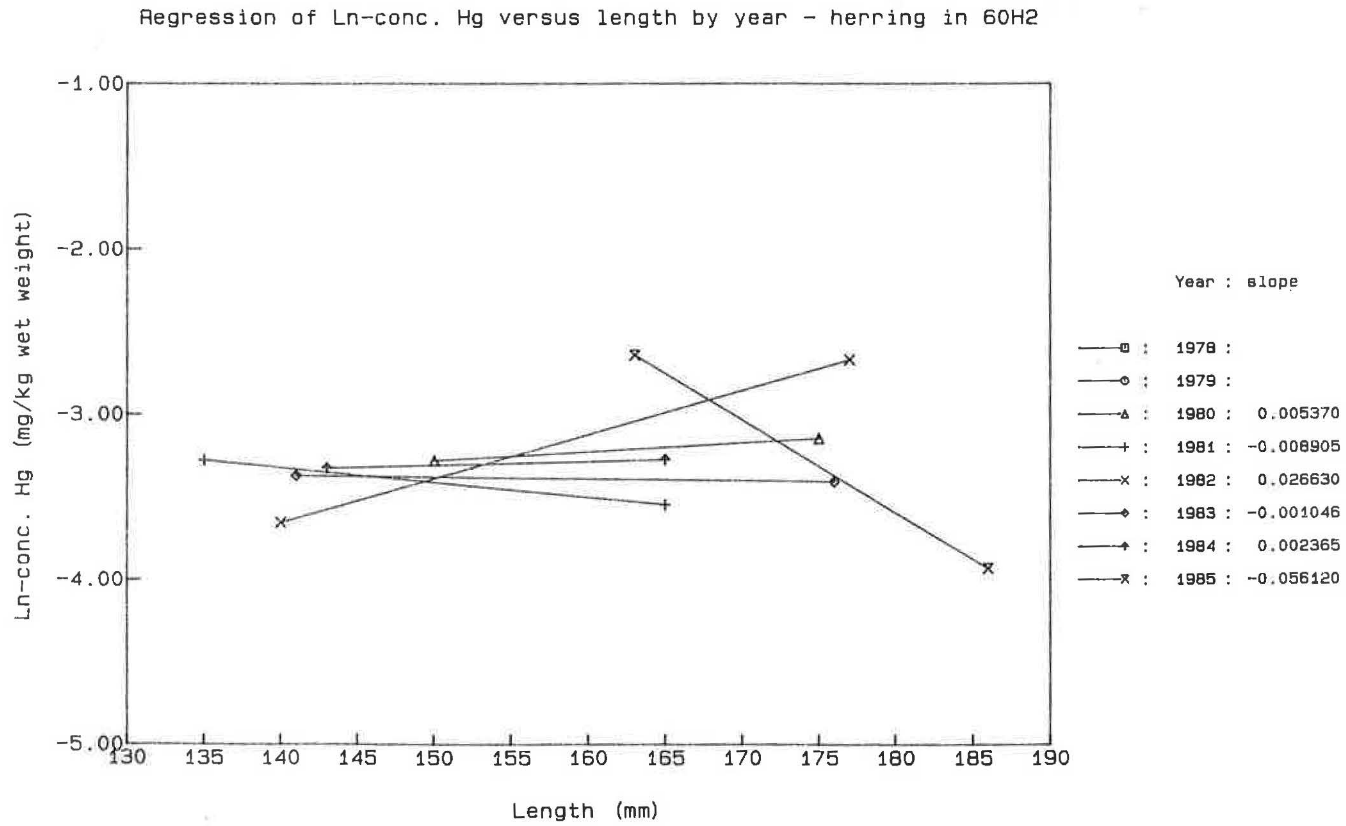
Since 1981 samples have included only female fish.

Results of analyses:

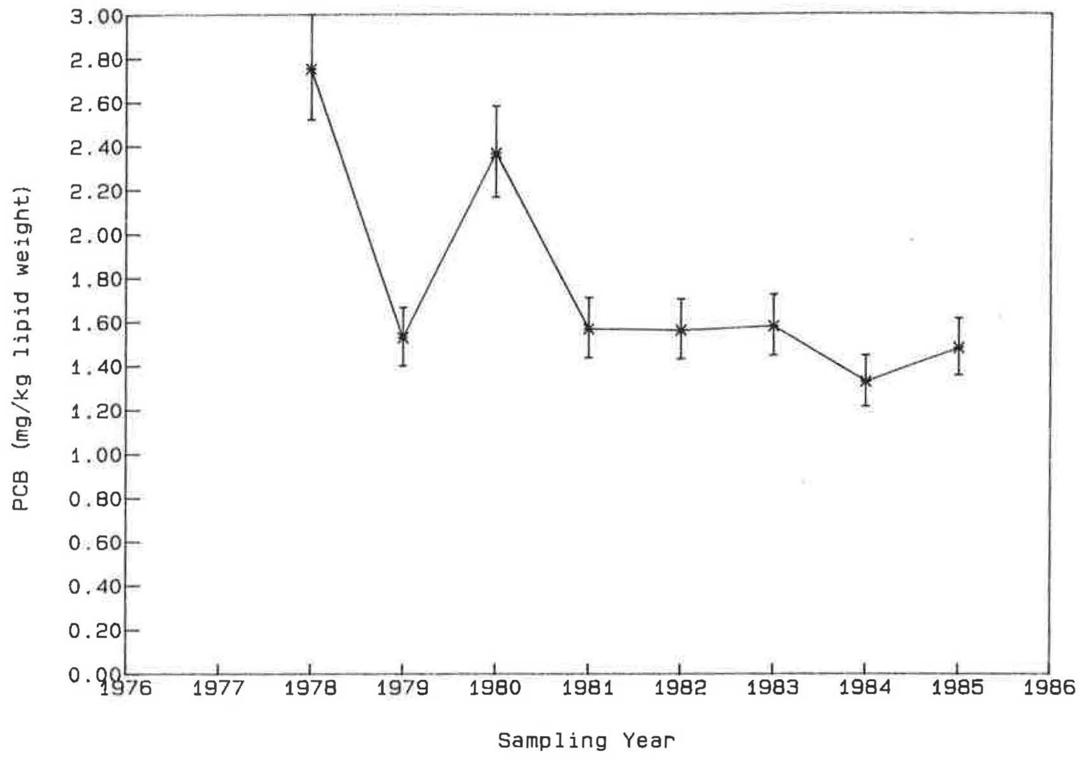
Mercury; PCB;

- Analyses are based upon yearly geometric mean contaminant levels (see graphical presentation of results).

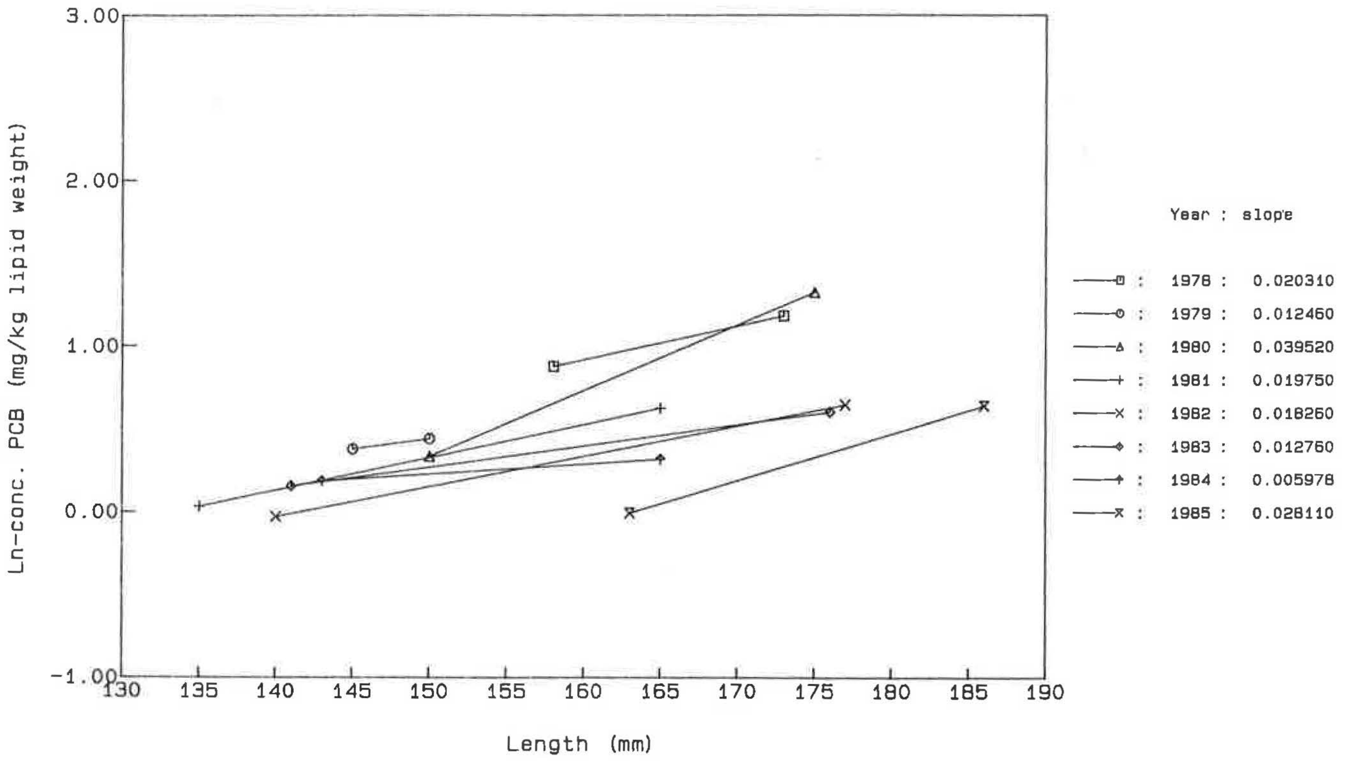

(GM) Estimates of Hg in herring muscle - herring in 60H2
Hg (mg/kg wet weight)
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
Sampling Year


Regression of Ln-conc. Hg versus length by year - herring in 60H2
Ln-conc. Hg (mg/kg wet weight)
-1.00
-2.00
-3.00
-4.00
-5.00
130
135
140
145
150
155
160
165
170
175
180
185
190
Length (mm)
Year : slope
1978 :
1979 :
1980 : 0.005370
1981 : -0.008905
1982 : 0.026630
1983 : -0.001046
1984 : 0.002365
1985 : -0.056120

(GM) Estimates of PCB in herring muscle - herring in 60H2



Regression of Ln-conc. PCB versus length by year - herring in 60H2



5 CONCLUSIONS

As stated in the introductory remarks, this report presents only the results of a statistical analysis of data collected for the purpose of monitoring temporal trends in contaminant levels in selected areas. In this context, the results presented in Section 4 of this report represent the conclusions of this analysis. It should be recognized that the data analyzed concern only one tissue (fish muscle) of certain fish species, and this may not be the optimal matrix for monitoring for all the contaminants considered. What has not been attempted here is to extend the conclusions to an interpretation of these statistical results in relation to the trends in environmental contaminant levels in a given area. The reasons for this are given in the following paragraphs.

5.1 Statistical Results in the Context of Environmental Information

When using biota in monitoring programmes aimed at establishing temporal trends in environmental contaminant levels, it must be recognized that reliable conclusions with respect to the latter cannot be achieved on the basis of information provided by a single component (e.g., a purely statistical analysis of contaminant levels in one tissue of a single biological species) alone. The results of this type of study must be viewed in the general context of a range of relevant information which can provide a broad basis for a reliable interpretation process.

For any particular area, the assessment of temporal trends in contaminant levels should include information relating to known inputs of contaminants to the area and to any control measures that have been applied to reduce these inputs.

Furthermore, because the mechanisms of transport, accumulation, dispersal and removal of contaminants within the marine environment are not generally well defined, a comparison of the results from temporal trend studies using biota with the results of similar studies using other media and compartments of the marine environment could be useful.

5.2 Statistical Results in the Context of Biological Information

Wherever possible, the question should be posed of whether a given statistical relationship makes sense in relation to the known physiological or biochemical processes affecting the uptake of contaminants, their subsequent assimilation into a given tissue or organ, and their possible metabolism or excretion, for a given species.

Frequently, the information required to answer such questions is lacking, but if it is available, it should be used to complement the statistical analysis in allowing an assessment of whether the results suggested are reasonable, and the proposed relationships between the contaminant levels and a given biological variable sensible in relation to the biology of the organism used in the trend monitoring programme.

In the absence of this type of information during the interpretive stage, it can be difficult to resolve possibly conflicting results of statistical analyses, for example, if opposite trends are observed for a contaminant between predator and prey species in the same area.

5.3 Further Interpretation

In general, the compilation and evaluation of the types of information described above, which are required for a detailed interpretation of trends in environmental contaminant levels, was not considered an objective of the analyses reported here. It is, therefore, envisaged that this report on the statistical analysis of the data will constitute one component of the total amount of information that will need to be considered as the basis for a comprehensive assessment of temporal trends in environmental contaminant levels in a given area.

Several of the originators of the data used in this study have provided some of the above-mentioned information in the form of commentary or published scientific papers, internal reports, etc. Where appropriate, this has been incorporated in the information supplied in earlier sections of this report, for example, information relating to the conduct of the monitoring, sampling and analytical considerations, etc. For completeness, the list on the following page is included as a reference to the information made available, which may provide appropriate sources for some of the material required during further consideration of the results of the statistical analyses reported here.

Belgium

De Clerck, R., Guns, M., Vyncke, W. and Van Hoeyweghen P. 1984. La teneur en métaux lourds dans le cabillaud, le flet et la crevette des eaux côtières belges. Revue de l'Agriculture 37(4): 1079-1086.

De Clerck, R., Guns, M., Vyncke, W. and Van Hoeyweghen P. 1988. Métaux lourds dans les organismes marins de la mer d'Irlande. Revue de l'Agriculture 41(1): 213-220.

Guns, M., De Clerk, R., Vyncke W. and Van Hoeyweghen, P. 1984. Poursuite de l'étude de la teneur en métaux lourds dans les organismes marins de la Mer du Nord. Revue de l'Agriculture 37(2): 311-318.

Guns, M., Vyncke, W., De Clerk, R. and Moermans R. 1985. Teneurs en mercure des roussettes et des aiguillats provenant des lieux de capture de la pêche maritime belge. Revue de l'Agriculture 38(2): 253-259.

Vanderstappen, R., De Clerck, R., Vyncke, W. and Moermans R. 1978. Les teneurs en mercure, zinc, cuivre, plomb et cadmium dans le hareng. Revue de l'Agriculture 31(2): 332-336.

Vyncke, W., Vanderstappen, R., De Clerck, R. Moermans, R. and Van Hoeyweghen, P. 1979. L'évolution de la teneur en mercure dans les soles pêchées en mer du Nord et en mer d'Irlande. Revue de l'Agriculture 32(4): 955-964.

Vyncke, W., Guns, M., De Clerck, R. and Van Hoeyweghen, P. 1984. La teneur en métaux lourds dans les soles pêchées en Mer du Nord et en Mer d'Irlande: 10 années de recherches (1973-1982). Revue de l'Agriculture 37(5): 1179-1184.

Vyncke, W., Guns, M, Baeteman, M. and Van Hoeyweghen, P. 1988. La teneur en métaux lourds et en PCB (polychlorobiphenyls) des moules de la côte belge (1982-1986). Revue de l'Agriculture 41(3): 721-727.

Denmark

Jensen, A. and Cheng, Z. 1987. Statistical Analysis of Trend Monitoring Data of Heavy Metals in Flounder (Platichthys flesus). Marine Pollution Bulletin 18(5): 230-238.

Federal Republic of Germany

Luckas, B. and Harms, U. 1987. Characteristic Levels of Chlorinated Hydrocarbons and Trace Metals in Fish from Coastal Waters of North and Baltic Sea. Intern. J. Environ. Anal. Chem., 29: 215-225.

Köhler, A., Harms, U. and Luckas, B. 1986. Accumulation of organochlorines and mercury in flounder - an approach to pollution assessments. Helgoländer Meeresuntersuchungen, 40: 431-440.

Sweden

Odsjö, T. and Olsson, M. 1986. Rapport från verksamheten 1986. Övervakning av Miljögifter i Levande Organismer. Naturvårdsverket Rapport 3346.

Odsjö, T. and Olsson, M. Verksamhetsberättelse 1987. Miljögiftsgruppen PMK. 1988-03-29 (draft report).

Olsson, M. and Reutergårdh, L. 1986. DDT and PCB Pollution Trends in the Swedish Aquatic Environment. AMBIO, 15(2): 103-109.

ANNEX 1

HISTORICAL REVIEW

In 1972, ICES conducted a Baseline Survey of Contaminant Concentrations in Fish and Shellfish of the North Sea (Coop. Res. Rep. No. 39) and subsequently, in 1974, commenced a Coordinated Monitoring Programme (CMP) on contaminants in fish and shellfish in the North Sea. In 1976, the geographical area was extended to the North Atlantic (ICES, Doc. C.M.1976/E:4) and by 1980 all areas of the North Sea and the North Atlantic were included within the CMP.

Following discussions in 1976 within the Working Group on Pollution Baseline and Monitoring Studies in the Oslo Commission and ICNAF Areas (subsequently renamed Working Group on Marine Pollution Baseline and Monitoring Studies in the North Atlantic (WGMPNA)), a small sub-group recommended at the 1977 Working Group meeting that there was a need to establish whether or not contaminant levels in fish were changing with time (ICES, Doc. C.M.1977/E:10). Accordingly, the Working Group recommended that member countries consider a proposal for temporal trend monitoring based on length-stratified sampling and analysis of individual fish. Each fish was to be weighed and its age and length determined. Multiple linear regression of log transformed contaminant concentrations on age, log length, and log weight was to be used to determine trends.

In 1978, the WGMPNA considered national reports (Belgium, Canada, Scotland, and England/Wales) on the results of investigations into the effects of a number of biological variables, such as length, weight, and age, on contaminant concentrations in liver and muscle tissue (ICES, Doc. C.M.1978/E:6). The results identified different variables as important for different contaminants and species. The Working Group concluded that, "in the light of the work completed so far, it is not possible to make generalisations as to what physiological factors are important or unimportant in affecting the concentration of any particular contaminant in any particular species or area." The Group concluded that each contaminant and species or stock will require separate analysis until the importance of each variable has been established.

Temporal trend analysis was discussed by the Marine Chemistry Working Group (MCWG) at its first meeting in 1979. The MCWG noted that statisticians involved in trend studies had different views on how the data should be evaluated and on the type of data which needed to be collected (ICES, Doc. C.M.1979/C:1). The MCWG recommended that statisticians consult with each other with a view to reaching agreement and developing recommendations on appropriate sampling protocols, statistical analysis, and presentation to provide the best answers using biota for monitoring contaminants in the marine environment. The WGMPNA agreed with this recommendation (ICES, Doc. C.M.1979/E:36). As attempts to reach agreement among statisticians by correspondence were not particularly successful, the MCWG recommended to the WGMPNA in 1980 that a meeting of statisticians should be held, that should include all persons who were interested in the question of time trend analysis of contaminants in marine biota. The MCWG further recommended that each statistician should receive a set of raw data and be requested to consider the following questions:

1) What method should be used to determine changes in time in contaminant levels within a population within a discrete geographical area?

2) What is the best way to determine relationships between a population and a contaminant level?

3) What are the significant factors which control the levels of a contaminant within a population?

The MCWG further stated that trend analysis is more relevant to the programme of WGMPNA and asked that Group to take over the work on developing appropriate methods to monitor trends in contaminant levels in biota. The WGMPNA agreed to this (ICES, Doc. C.M.1980/E:4) and made the following statement on the issue, "Recognizing that we are making a basic assumption that the concentrations of contaminants in [marine] biota reflect the absolute level of these contaminants in the environment and, therefore, inter alia, the input of these contaminants to the environment, our question is how we can screen out the influence of the various biological variables relevant to the accumulation of contaminants in biota. This presumably means identifying which variable(s) are the most significant. Having done this, perhaps with the aid of biochemists and statisticians, we then want advice from the statisticians on how we should construct our samples. Also, how do we analyze them (singly, in batches or bulked) so as to show the changes in either space or time of a contaminant level and hence the impact of that contaminant? We must specify what size change we wish to see and, for each contaminant, the analytical variance." At the 1980 ICES Statutory Meeting, the Council approved the WGMPNA recommendation for a meeting of an ad hoc Group of Statisticians (C.Res.1980/2:14) which was to be held immediately prior to the 1981 WGMPNA meeting (ICES, Doc. C.M.1981/E:33).

The ad hoc Group recommended to WGMPNA that: (a) a sample of fish should consist of at least 25 individuals and preferably 60 or more, and (b) the sample of fish should be stratified according to length, with the fish spanning as wide a range as possible. A recommendation that all data collected as a part of the CMP should be stored in a centralized (ICES) computerized data bank and made available for exchange was also accepted by WGMPNA (ICES, Doc. C.M.1981/E:33). Unfortunately, the group was unable to agree on a simple, most useful statistical analysis for trend data, i.e., the forms of the relationships between contaminant levels and time. The distribution of the dependent variable (contaminant) was questionable and, as will be seen later, the appropriate statistical analysis (multiple linear regression (MLR) or analysis of variance (ANOVA)) was also questioned, although it was agreed that the various techniques all identified the important independent variables. By the time of the 1982 meeting of WGMPNA, the ad hoc Group of Statisticians had shown that, for some metals, the length of the fish was very important and, thus, the samples for trend analysis should be composed by length stratification based on a log-linear relationship, with a minimum sample number of 25 fish spread evenly across a minimum of 5 strata (ICES, Doc. C.M. 1982/E:3). However, it was noted that the group had shown that the software in different computer packages could give different results. Further possible complications in the use of biota as monitors of temporal trends in contaminants were also described in a series of papers presented at the 1982 ICES Statutory Meeting (ICES, Docs. C.M.1982/E:25, E:26, E:27). Not only could contaminant levels in one species of brown algae not be used to compute levels in another species of brown algae from the same sampling area, but different species might even demonstrate opposite trends. Analysis of variance of trace metal concentrations in blue mussels showed a significant relationship between locality and the size of the mussel, regardless of whether size was expressed as shell length or freeze-dried weight of soft tissue.

In addition to the analysis of contaminants in individual fish, the ad hoc group recommended that a minimum list of biological variables be determined on each fish, namely, total weight, total length, liver weight, sex, age, and percent fat in each tissue analyzed. The importance of ensuring sampling consistency between years was stressed.

In a study of trace metals in Greenland biota (blue mussels and three species of seaweed) reported to the 1983 meeting of the WGMPNA, Munk Hansen presented results showing that different species indicated different trends in contaminant concentrations (ICES, Doc. C.M.1983/E:3). It was also reported that the between-year variability could be very large, resulting in a marked decrease in the utility of organisms as trend monitors. However, a further meeting of the statisticians' group recognized that the time span for which data were available was quite short and that certain data sets did not yield consistent trends. The group encouraged further work to extend the time frame of the data base. A further complicating factor was that significant deviations from a linear trend were apparent in certain data sets.

The facts were noted that certain tissues may act as repositories for certain contaminants and that fish are dynamic interactors with their environment, not merely passive accumulators of contaminants. Trend monitoring, i.e., modelling for statistical analysis, will be assisted by understanding the dynamics of contaminants within an animal under natural conditions, but such studies are, as yet, far from complete. A suggestion was made that studies needed to be carried out to aid selection of the most suitable organ for trend analysis. The importance of accurately estimating the noise or unexplained variation (random fluctuations plus unaccounted-for fluctuations) in the system was stressed along with the importance of minimizing the noise levels.

Trend monitoring problems were further considered at an ad hoc meeting of statisticians in early 1984 (ICES, Doc. C.M.1984/E:46). Past trend analysis studies were based on either MLR (e.g., Scott et al. in ICES, Doc. C.M. 1983/E:3) or ANOVA (e.g., Lassen in ICES Doc. C.M.1983/E:26). The group pointed out that certain factors in the data sets (higher order interactions, spurious and real interactions (multicolinearity) and sampling inconsistencies) could drastically affect the power of the test and no complete statistical analysis had been carried out in a manner to compensate for such effects. In a series of papers (ICES, Docs. C.M.1985/E:34, E:35 and E:36), Misra showed the similarities and differences in the statistical methods employed to date, namely MLR and ANOVA (ICES, Doc. C.M.1985/E:34), and developed six MLR models for intensive analysis of the Canadian cod data studied by Scott et al. (1983). He further discussed the importance of, and methods for, identifying outliers and the need to eliminate them from data sets. He also pointed out that (a) MLR and ANOVA are only parts of a more general multivariate linear (MANCOVA) model, and (b) the multivariate model will yield more extensive information than MLR or ANOVA. Much discussion was generated by these papers during the 1985 meeting of the Working Group on the Statistical Aspects of Trend Monitoring (WGSATM) (ICES Doc. C.M.1985/E:10). Concern about the identification of proper models for MANCOVA was expressed as well as the need for very good, long-term data sets and for physiological information to select certain groupings of contaminant-tissue pairs to use in the MANCOVA. The analysis of trends in the data submitted for the CMP was considered and the group recommended that a structured analytical approach to time-trend determinations based upon the analysis of covariance be used until the results of research, required to model the system better, were available. The recommended procedure was:

1) Fit a linear model relating levels of the contaminant to biological variables, with all of the coefficients estimated separately in each year. The residuals from the fitted model must be examined to show that the model and the data agree. If they do, attempt Step 2.

2) Fit a simpler model in which the regression coefficients are the same in every year. The intercepts are still estimated separately for each year. If the residual variability of this simpler model is not significantly increased above that observed at step 1, accept that the relationship between contaminant levels and biological variables (covariates) is the same for these years. If the residual variability is increased, the biological relationships are different in each year and interpreting the results is more difficult.

3) If the biological relationships are constant, the next step is to test for differences between years in the average contaminant levels adjusted for the biological variables. Fit a model with a common intercept for all years and compare the residual variability with that obtained at Step 2. If there is a significant increase, then there are differences between years which can be interpreted.

An attempt was made to apply this procedure to the CMP trend monitoring data during 1985. However, problems were discovered within the data sets which confused and complicated the analyses. These problems were of two types: (1) sampling inconsistencies among years, e.g., different size ranges of fish, and (2) reporting inconsistencies, e.g., sex determined only on certain samples, pooling of small fish. Of the 44 cases examined, 27 showed no significant differences in the effect of biological variables on contaminant concentrations between years, while 15 showed that contaminant levels (adjusted for biological variables) differed between years (ICES, Doc. C.M.1986/E:39). It was, therefore, decided that a single robust model could be more readily adapted to the analysis of CMP data rather than attempting to develop a number of different optimum models. Since animal size (e.g., length) had been identified as a major covariable in terms of contaminant levels, length was chosen as the primary independent variable within the approach described above. Additional features were included to test the basic assumptions and to measure the consequences of omitting the remaining biological variables. The procedure is described in detail in Annex 3 to this report and has been used to analyze CMP data on contaminants in fish muscle for temporal trends, the results of which are the topic of this report.

ANNEX 2

GUIDELINES FOR THE CONDUCT OF MONITORING WITHIN THE CONTEXT OF THE ICES COOPERATIVE MONITORING STUDIES PROGRAMME (CMP)

Monitoring of Contaminants in Fish and Shellfish for the Purpose of Determining Temporal Trends

SAMPLING

(Samples to be collected every year starting in 1982)

a) A sample of fish should consist of at least 25 individuals, and preferably more individuals. The sample should be collected in a length-stratified manner, i.e., the sizes of the fish should span as wide a length range as possible and there should be an equal number of individuals in each length grouping.

   The stratification should be based upon an equidistant logged length interval, i.e., the log (upper bound) minus log (lower bound) should be equal for each length interval. The length range of the entire sample should be selected so that the individuals in the lower bound yield sufficient tissue for the chemical analyses, while the upper bound should be selected such that at least 5 fish can readily be found in the sampled catch. The length range should be divided into 5 (or more) length intervals of equal size (after log transformation). (See notes on length stratification at end of the Annex for an example.) Once the length stratification for a particular species and area has been agreed, this stratification should be strictly adhered to for a number of years. No length interval should be less than 2-3 cm. If the length range is smaller than 2-3 cm, the species is not ideally suited for the proposed analysis.

b) A sample of mussels should span as wide a size range as possible and should consist of sufficient individuals to provide material for analysis in groups of the different sizes. The number of individuals in each length range should be recorded for each site and this distribution should thereafter be used for that site each year.

c) Sampling should be conducted annually from the same areas and from the same stock and at the same time each year; mussel samples should be collected at the same position in relation to tidal height each year.

d) Samples should be collected in such a way that at least the following areas are adequately covered: the estuaries of the Forth, Thames, Rhine, Scheldt and Clyde, the Skagerrak, Kattegat and Oslo Fjord, the Irish Sea, German Bight and Southern Bight of the North Sea, certain parts of the Gulf of St Lawrence, the US middle Atlantic Bight, and the area off Portugal.

e) The species of interest can only be selected in the light of information on fish stock composition and history and the known or perceived problems which define national priorities. It is preferable to use a fish species which continues to grow throughout its life. Species which are of particular interest in an ICES context are:

Cod or Hake
Plaice
Flounder
Mackerel (Scomber scombrus)
Mussels
Shrimps

but data relating to other species are also required.

STORAGE AND PRETREATMENT OF SAMPLES PRIOR TO ANALYSIS

General

a) Fish samples should be collected ungutted and preserved (deep frozen) as soon as practicable after collection; length and weight should be determined before freezing.

b) Mussels should be held live in clean (settled) sea water from the area of collection for 12-24 hours to allow discharge of pseudo-faeces. The length of each individual, even if used as part of a composite, should be measured as a maximum value regardless of direction of orientation.

c) After cleaning and measuring the mussels, the individual animals should be carefully freed from their shells by cutting the adductor muscle. The shell cavity liquor can then be drained and discarded by placing the opened shells vertically in a filter funnel for 5 minutes. The remaining shell contents may then be preserved either individually or as pooled samples.

For samples taken in connection with monitoring of temporal trends

a) Each fish should be analysed individually and the following biological variables should always be recorded when sampling for time trend analysis purposes:

Age

Total weight

Total length

Liver weight - when contaminants in liver are determined. (If another fatty organ is used, the weight should be recorded.)

Sex (where applicable)

Degree of sexual maturation (where applicable)

b) Mussels may be pooled in small groups to provide enough tissue for analysis, but different size groups should be analysed separately.

REPORTING OF RESULTS

General

a) Results should be reported on a wet weight basis along with details of the size range of the sample and details of site, date and method of collection, preservation details (if appropriate) and brief details of the methods of analysis used; if PCBs were analysed for, these details should include the formulation or chlorobiphenyls and the method of quantitation used.

In addition, results of analyses of mussels for metals should also be reported on a dry weight basis. All results of analyses for organochlorine compounds must be reported also on an extracted fat weight basis or as a minimum be accompanied by a fat weight determination result.

b) Dry weight determinations should be carried out in duplicate by air-drying to constant weight at 105^{0}C of sub-samples of the material analysed for the contaminants.

c) Fat weight should be determined on a sub-sample of the extract used for the organochlorine compound analyses. The results should be accompanied by a brief description of the method used for extraction.

For samples taken in connection with monitoring of temporal trends

a) The individual analysis figures should be given together with full details of the size, age, weight, sex, etc., of the individual fish analysed.

b) In reporting these data to ICES, the ICES Reporting Format for Contaminants in Fish and Shellfish must be used for such data so as to allow machine handling and statistical analysis of the data.

Results should be submitted to the ICES Environment Officer not later than 30 June of the calendar year following collection of the sample. These results should be accompanied by the name of the contributing laboratory(s) and the name of an individual contact in the event of queries. The contributors should specify the most recent ICES intercalibration exercise in which they took part. A brief commentary on the data is also required.

Notes on Length stratification

The main finding from the statistical analyses of data on contaminants in fish tissue is the gain in precision which can be obtained from stratification using biological variables. Although several biological parameters have been shown to be significant as stratification variables in different materials, length appears to be the only parameter which is simple to apply at sea and which shows up as being significant in most analyses.

Much discussion has been devoted to whether simple linear or log-linear (multiplicative) models give the better fit. General experience with other fish and other types of data indicate preference for the log-normal model at least for the present. As the length dependence of the contaminant level is not well understood, sampling should keep the length-contaminant relationship under constant surveillance, i.e., the entire length range should be covered evenly. The length range should be defined from practical considerations, the lower bound ensuring that enough tissue is available for chemical analysis and the upper bound such that at least 5 fish in the largest length interval can readily be found. The length stratification should be determined in such a way that it can be maintained over many years. The length interval should be at least 2-3 cm in size.

It is suggested that the length range be split into 5 length intervals which are of equal size after log transformation. For example, if the length range is 20 - 70 cm, then the interval boundaries could be (rounded to 0.5 cm) as follows:

cm	No. of fish	Log upper - Log lower
20.0 - 25.5	5	0.243
25.5 - 33.0	5	0.258
33.0 - 42.5	5	0.253
42.5 - 54.5	5	0.249
54.5 - 70.0	5	0.250
Total	25	

Care should be taken that samples are not unduly clustered within each stratum (length interval). More length intervals could be used and the test of the hypothesized contaminant-length relationship becomes stronger if the lengths are evenly distributed. But the item of major importance is to keep the length stratification identical from one year to the next.

ANNEX 3

GUIDELINES FOR TEMPORAL TREND ANALYSIS OF DATA ON CONTAMINANTS IN FISH

These statistical guidelines have been developed to fulfill the need for routine reporting of contaminant concentrations in fish tissue for temporal trend monitoring purposes. Because of the large number of CMP/JMP data sets, the analysis must satisfy two conflicting objectives: it must proceed quickly with little human intervention, and yet must have the facility to draw attention to anomalies/irregularities in the data/analysis.

The principle of the analysis is that concentration is related to one or more covariables. Before measuring trends or comparing contaminant levels in different areas, concentrations are adjusted for the effect of the covariables, and expressed relative to selected values of the covariables which are the same for all time periods, areas, etc. (cf. C.M.1985/E:10, Annex 4).

In practice, the experience of members of the ad Hoc Group of Statisticians assisting WGMPNA on Trend Monitoring Issues has been that when the covariables are mutually correlated (e.g., as with length, weight, age), a single covariable may be essentially as effective as all of the covariables acting together. For concentrations of metals in muscle, length has usually been found to be the most effective single variable. Also, experience has indicated that the relationship between log concentration (y) and length (x_1) is linear, and that the resulting error structure is Normal with constant variance. This proposed analysis provides a check that these assumptions are met.

The method of analysis follows the guidelines given in Annex 4 to C.M.1985/E:10. The series of models are as follows:

$$\text{Model 1:} \quad E[y] = \mu_t + b_t x_1$$

which has a different intercept and different regression coefficient in each year t.

$$\text{Model 2:} \quad E[y] = \mu_t + b x_1$$

which has a different intercept in each year, but the same regression coefficient.

$$\text{Model 3:} \quad E[y] = \mu + b x_1$$

which has the same intercept and regression coefficient in each year.

$$\text{Model 4:} \quad E[y] = a_0 + a_1 t + b x_1$$

which has the same regression coefficient in each year, and a linear trend in the intercepts. This series of models are compared using the principle of reduction in the residual sum of squares, i.e., as the number of parameters in the model decreases, the residual sum of squares (RSS) will increase. The simpler model is rejected in favor of the more complex model if the increase is significantly large. For example, to compare model 1 (complex) with model 2 (simple), calculate

$$\frac{[(RSS_2 - RSS_1)/(df_2 - df_1)]}{[RSS_1/df_1]}$$

and accept model 1 if this is significantly large compared to an F distribution with $(df_2 - df_1)$ and df_1 degrees of freedom.

The analysis is designed in the expectation that model 2 will be appropriate. The output from the analysis includes the adjusted mean log concentrations calculated at a selected value of x_1.

An equation of the same form can be applied for the other model comparisons by inserting the appropriate RSS's and df's, except in the case of the test for a linear trend, where model 3 is tested against model 2 and model 4 as follows:

$$\frac{[(RSS_3 - RSS_4)/(df_3 - df_4)]}{[RSS_2/df_2]}$$

which has an F-distribution with $(df_3 - df_4)$ and (df_2) degrees of freedom.

The rest of the analysis has been designed to ensure

a) that there are no problems within the data, and

b) that model 2 is, in fact, appropriate.

To satisfy criterion (b), model 2 is compared with two additional models:

$$\text{Model 5: } E[y] = \mu_t + b_{t1}x_1 + b_{t2}x_2 + \ldots + b_{tp}x_p$$

which has different intercepts and regression coefficients in each year, and all available covariates included.

$$\text{Model 6: } E[y] = \mu_t$$

which has year effects, but no covariates (i.e., the mean log concentration in each year).

A test of model 2 against model 5 establishes whether there is significant information in the additional (p-1) covariates which has not been exploited. A test of model 2 against model 6 establishes whether x_1 itself contains no useful information. In either case, the output from model 2 would usually be reported, but qualified by an appropriate comment.

Analysis

The analysis has been built around procedures in the statistical package SPSS-X. (SPSS Inc., Suite 3300, 444 N. Michigan Ave., Chicago, Illinois 60611, USA.)

The first stage is to fit model 1 and for each year to look closely at the residuals (the difference between the observed and predicted values of y). This stage is very important. It establishes that the assumptions about linearity and about the error structure are correct, and that there are no irregularities in the data. The residuals are plotted first against x_1 and secondly against a coded sex variable.

Figures 1 and 2 show satisfactory plots. In Figure 1, the residuals are spread evenly about zero, and there is no discernable dependence of the residuals on length. For Figure 2, the residuals for each sex code are spread around zero, and are not displaced relative to each other.

Figures 3 to 7 show examples of residual plots which suggest that there are problems with either the data or the model.

In Figure 3, the spread of residuals increases with increasing length. This suggests that some transformation other than logarithmic might be appropriate. If no changes are made, the estimated adjusted log concentrations are all right, but the analysis of variance will only provide approximate guidelines as to which model should be chosen. The results should be qualified to the effect that the variance and mean value are related.

In Figure 4, the residuals for each sex code are displaced, implying that sex may need to be included in the model. If this plot is seen for other years, then model 1 needs to be re-run with sex included as a factor. If the residual sum of squares is significantly reduced, then sex should be included in all subsequent models.

In Figure 5, there is evidence that the linear relationship between y and x_1 is not appropriate. The data for this year may include some very large or very small fish which are outside the range for which the model has previously been found to be linear. If this is the case, or if there is evidence of non-linearity in other plots, the analysis should be discontinued. The user should obtain help, or simply report that the model is not linear.

The plot in Figure 6 suggests some outlying points, i.e., points which do not seem to belong to the rest of the data. The data source should then be checked and, if found wrong, the corrections should be made and the model re-run. If the data are correct and the "outliers" are less than 2.5 standard deviations away from zero, they should be left in. If they are more than 2.5 standard deviations away, they should be excluded and a comment made to that effect in the report.

In Figure 7 there is evidence of a more extreme form of outlier. Its residual is not large, but it is clearly not in agreement with the rest of the data. Again, the data source should be checked and, if correct, the model should be re-run with the point excluded to determine how much the fitted line changes. The fitted line should be checked against those from the other years. If all the evidence is against the validity of this point, it should be excluded and a comment made in the report to that effect.

If the residual plots are satisfactory, the analysis should be continued. If the residual sum of squares for model 2 is significantly greater than that for model 1, the data should be examined more closely. It may be that an outlier as in Figure 7 is present, or there may be imbalance in the distribution of x_1 from year to year. If the latter is the case, the analysis should be continued using model 2, but an appropriate comment should be made in the report.

If there is no imbalance in the data, model 1 should be used and the analysis should continue as shown in Example 2 in Doc. C.M. 1985/E:10, Annex 4.

Also, the residual standard deviations in each year should be checked. They should be similar. If they are not, a check for outliers should again be made. If the residual sum of squares for model 2 is not significantly greater than that for model 1, the adjusted mean log concentrations can be reported together with 95% pair-wise significance bands (Nicholson, 1985). These have an advantage over standard errors and 95% confidence limits in that they can be used for testing between the adjusted means: if the bands overlap, then the means are not pair-wise significantly different. If they do not overlap, then the means will necessarily be significantly different only if the numbers of observations in those means are equal. This simple graphical display is only an <u>aid</u> to interpretation. The results of the tests of model 2 against model 3 and the tests for linear trend should also be reported.

Finally, the results of the tests of model 2 against the new models 5 and 6 should be checked. If the residual sum of squares for model 2 is significantly greater than that for model 5, then a comment to that effect should be made. Also, the percentage increase in the residual standard deviation, which may be small, should be quoted. However, it may be necessary that an alternative model be developed. If the residual sum of squares for model 2 is <u>not</u> significantly greater than that for model 6, then a comment to this effect should be made. In both cases, the results from model 2 should be reported.

Reference

Nicholson, M.D. 1985. The treatment of time-effects in the statistical analysis of contaminant monitoring data. Doc. ICES C.M. 1985/E:31.

```
STANDARDIZED SCATTERPLOT
ACROSS - LENGTH     DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                     +   SYMBOLS:
    I                                     I
    I                                     I      MAX N
  2 +                                     +
    I                                     I   *      1.0
    I                                     I   2      2.0
  1 +       *      **                     +
    I              *   2                  I
    I              * *   **      *        I
  0 +                * *          *       +
    I            *                    *   I
    I                                     I
 -1 +              **     * *             +
    I                  **                 I
    I                                     I
 -2 +                                     +
    I                                     I
    I                                     I
 -3 +                                     +
OUT ++-----+-----+-----+-----+-----+-----++
    -3    -2    -1     0     1     2     3 OUT
```

Figure 1. ================================

```
STANDARDIZED SCATTERPLOT
ACROSS - SEX        DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                     +   SYMBOLS:
    I                                     I
    I                                     I      MAX N
  2 +                                     +
    I                                     I   *      1.0
    I                                     I   2      2.0
  1 +           2           *             +   3      3.0
    I                       3             I
    I           2           3             I
  0 +           2           *             +
    I                       2             I
    I                                     I
 -1 +           2           2             +
    I           2                         I
    I                                     I
 -2 +                                     +
    I                                     I
    I                                     I
 -3 +                                     +
OUT ++-----+-----+-----+-----+-----+-----++
    -3    -2    -1     0     1     2     3 OUT
```

Figure 2. ================================

```
STANDARDIZED SCATTERPLOT
ACROSS - LENGTH     DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                     +   SYMBOLS:
    I                                     I
    I                                     I      MAX N
  2 +                                     +
    I                         *     *     I   *      1.0
    I                       *             I   2      2.0
  1 +                    *     *          +
    I                 * * *       *       I
    I              *  *      *            I
  0 +          2   2  ** *                +
    I            * * *                    I
    I                  * 2    *           I
 -1 +                      *        *     +
    I                         *           I
    I                                     I
 -2 +                                  *  +
    I                                     I
    I                                     I
 -3 +                                     +
OUT ++-----+-----+-----+-----+-----+-----++
    -3    -2    -1     0     1     2     3 OUT
```

Figure 3. ================================

```
STANDARDIZED SCATTERPLOT
ACROSS - SEX        DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                     +   SYMBOLS:
    I                                     I
    I                                     I      MAX N
  2 +                                     +
    I                                     I   *      1.0
    I                       4             I   2      2.0
  1 +                       4             +   4      4.0
    I                       4             I
    I                       2             I
  0 +                                     +
    I                                     I
    I           4           2             I
 -1 +           4                         +
    I           4                         I
    I                                     I
 -2 +                                     +
    I                                     I
    I                                     I
 -3 +                                     +
OUT ++-----+-----+-----+-----+-----+-----++
    -3    -2    -1     0     1     2     3 OUT
```

Figure 4. ================================

```
STANDARDIZED SCATTERPLOT
ACROSS - LENGTH     DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                     +   SYMBOLS:
    I                                     I
    I                                     I      MAX N
  2 +                                     +
    I                                     I   *      1.0
    I                  *                  I   2      2.0
  1 +              *                      +
    I              *     2 *              I
    I            * **   *     *           I
  0 +         *       *                   +
    I           *               *         I
    I           *             *           I
 -1 +        2                     *      +
    I     *                     *         I
    I                               *     I
 -2 +                                     +
    I                                     I
    I                                     I
 -3 +                                     +
OUT ++-----+-----+-----+-----+-----+-----++
    -3    -2    -1     0     1     2     3 OUT
```

Figure 5. ================================

```
STANDARDIZED SCATTERPLOT
ACROSS - LENGTH     DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                     +   SYMBOLS:
    I                                     I
    I                       *             I      MAX N
  2 +                                     +
    I               *                     I   *      1.0
    I                                     I   2      2.0
  1 +                                     +
    I                                     I
    I                                     I
  0 +              ***                    +
    I            *    *     *             I
    I              2**  *  *              I
 -1 +                     *               +
    I                                     I
    I                                     I
 -2 +                                     +
    I                                     I
    I                                     I
 -3 +                                     +
OUT ++-----+-----+-----+-----+-----+-----++
    -3    -2    -1     0     1     2     3 OUT
```

Figure 6. ================================

```
STANDARDIZED SCATTERPLOT
ACROSS - LENGTH     DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                     +   SYMBOLS:
    I                                     I
    I                     *               I      MAX N
  2 +                                     +
    I                  *                  I   *      1.0
    I                                     I   2      2.0
  1 +                 **                  +
    I                                     I
    I             * * 2                   I
  0 +                                     +
    I           *  *                      I
    I              *                      I
 -1 +           **                     *  +
    I      *    *                         I
    I         *                           I
 -2 +     *                               +
    I                                     I
    I                                     I
 -3 +                                     +
OUT ++-----+-----+-----+-----+-----+-----++
    -3    -2    -1     0     1     2     3 OUT
```

Figure 7. ==================================

ANNEX 4

DATA CHARACTERISTICS

Table I - Summary table over the data, indicating inconsistencies in months and locations of sampling.

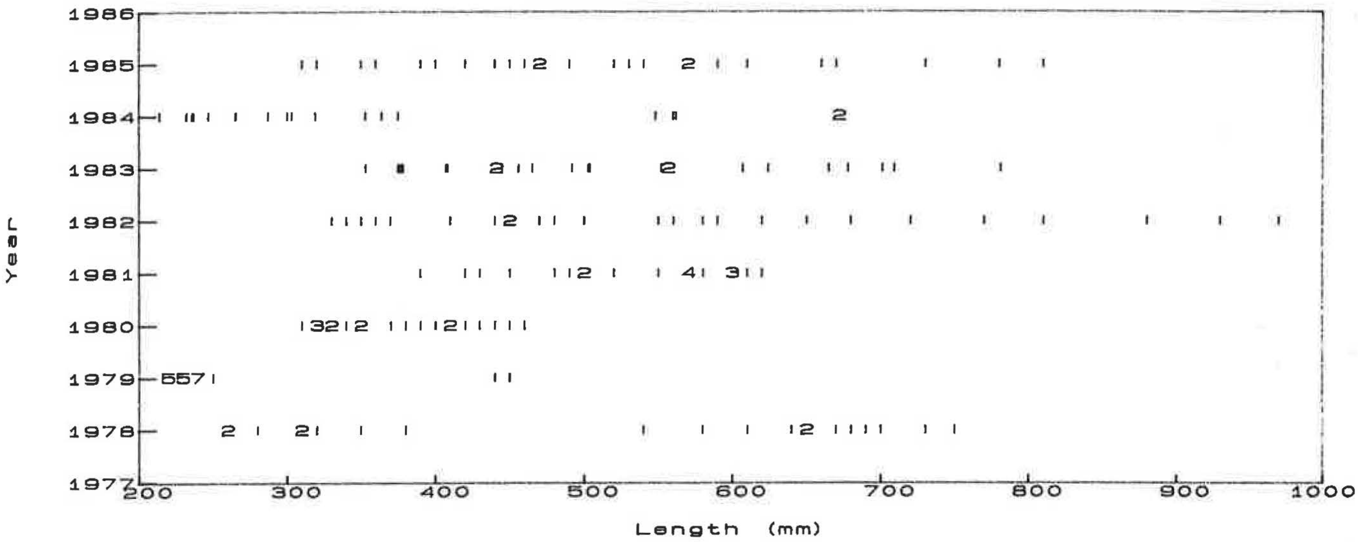
Figures - Length distributions of samples by year.

Table I Summary table over the data, indicating inconsistencies in months* and locations of sampling; table split by country.

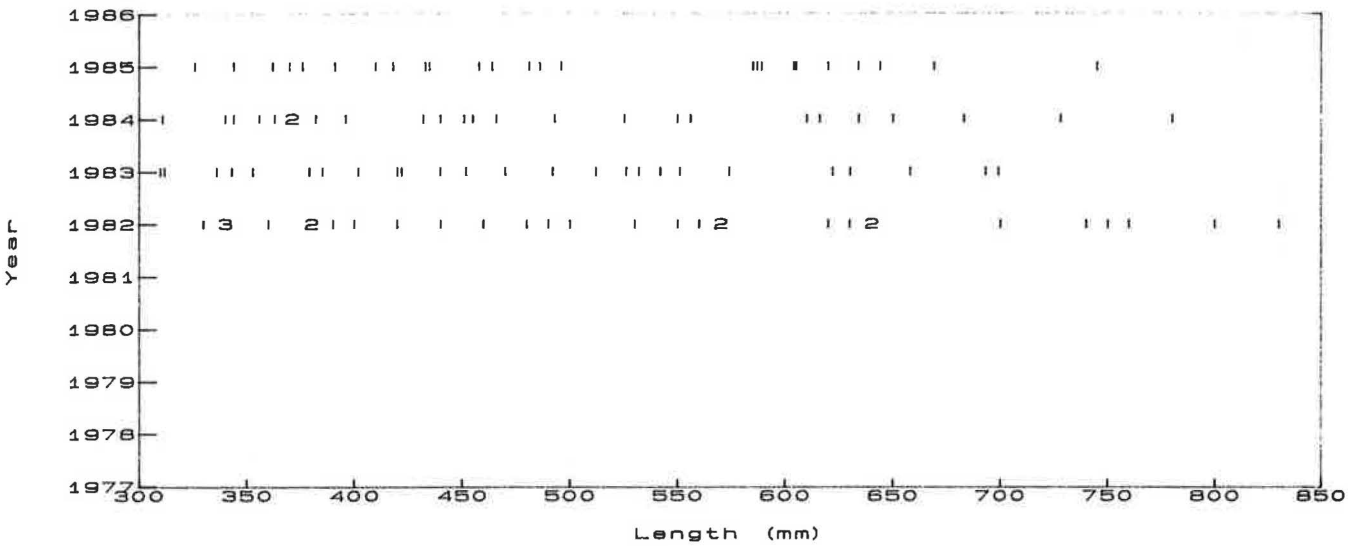
Species	Area	Number of years of data							Comments
		Cr	Cu	Hg	Ni	Pb	Zn	PCB	
Cod	31F2	7	8	8	6	6	8	3	Months : Nov 79,81; Sep 80; Dec 78,82,83,85; Apr 84
Flounder	31F2	6	8	8	7	7	8	3	Months : Apr 81,83-85; Jun 79; Sep 80; Oct 82; Dec 78
Sole	31F2	4	5	5	5	3	5		Months : Apr 79,83; May 81; Jun 80; Jan 82 Areas : 32F1 79,80; 32F2 81
Sole	36E5	4	5	5	5	5	5		Months : Dec 79; Jan 80; Feb 82; Mar 81; Apr 83
Plaice	40F7			3					Months : Aug 81; Apr and Oct 82; May 83
Plaice	41F7			5					Months : Aug 81; Oct 82,85; Dec 84; May 83
Plaice	43F8			5					Months : Aug 79,81; Sep 85; Nov 84; May 83
Plaice	44F9			5					Months : Aug 79,81; Sep 85; Oct 82,84
Flounder	36F8			3					Area : 37F8 85.
Cod	47G0			5					Months : Dec 81,83,84,85; Feb/Mar 83 Age data: missing 85
Cod	48G0			4					Area : Outer Oslofjord 81-82; Inner Oslofjord 84-85.
Flounder	48G0			3					Area : Outer Oslofjord 81; Inner Oslofjord 83,85 Age data: missing 85
Herring	40G5			6				7	Age data: missing 79
Cod	42G8			5					Months : Sep 82-85; Aug 78; Dec 79; Oct 81
Cod	43G1			6					Months : Sep 80-83; Nov 79; Oct 84; Dec 85
Dab	43G1			5				5	
Herring	43G1			6				6	
Flounder	46G1			6				6	Months : Sep/Oct 80-83,85; Aug 84
Herring	46G7			6				7	Months : Oct/Nov 80-85; Sep 78
Herring	50G8			6				8	Months : Sep/Oct 78,80-85; Nov 79 Age data: missing 79
Herring	60H2			6				8	Age data: missing 79
Cod	34F2		3	4			4		Months : Jul 82,83; Aug 85; Sep 84 Area : 37F2 84; 35F2 85
Plaice	34F2		3	4			4		Area : 33F2 83
Whiting	35E6		3	4			4		
Plaice	35E6		3	4			4		

* if samples are taken in the same one- or two-month period in every year then no sampling month discrepancy is inferred.

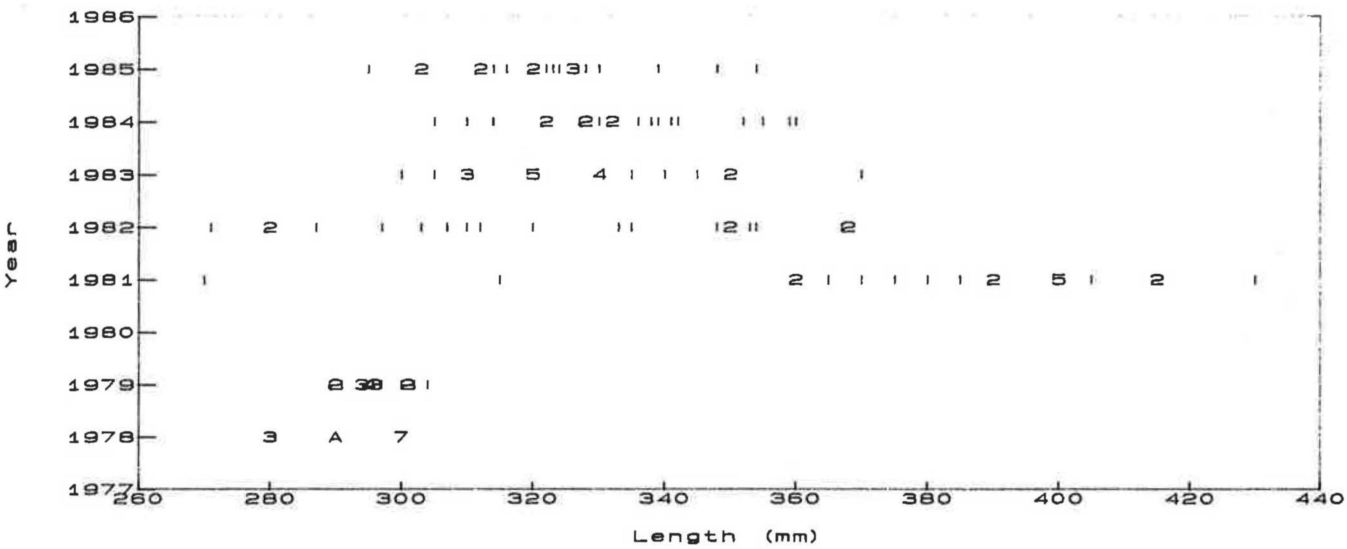
Length distributions of samples by year - cod in 31F2



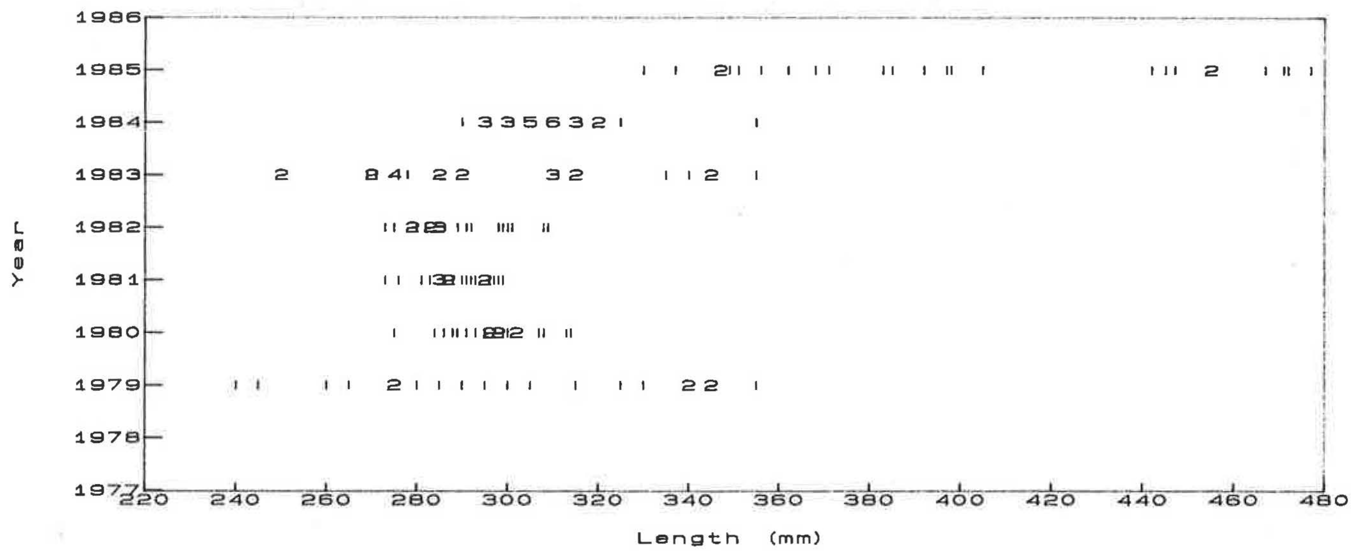
Length distributions of samples by year - cod in 34F2



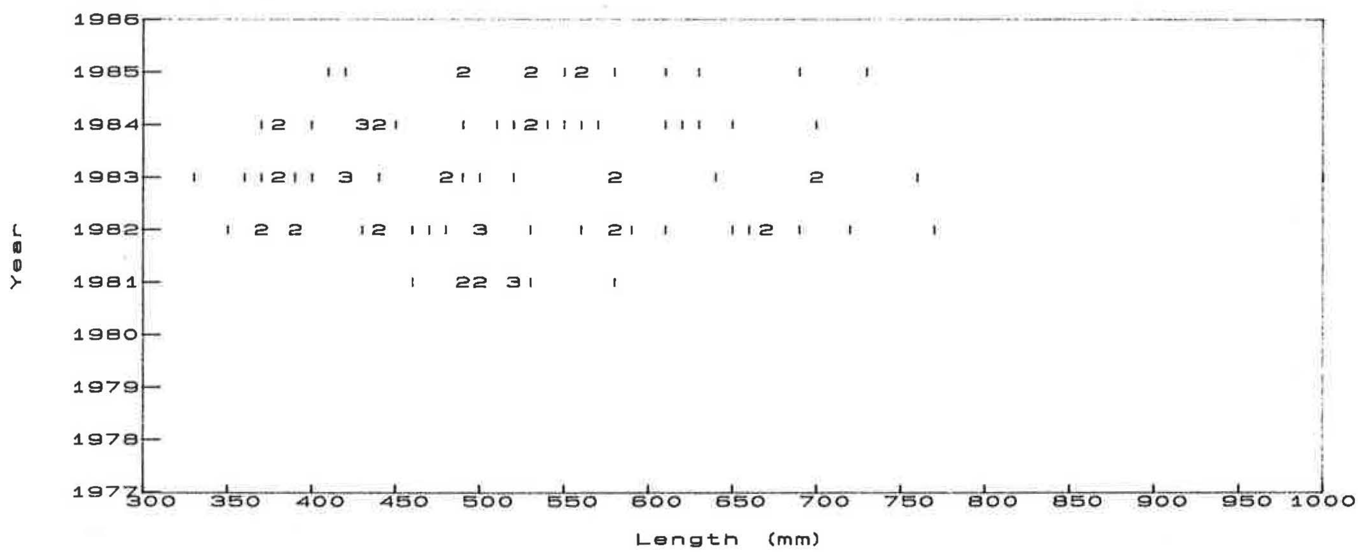
Length distributions of samples by year - cod in 42G8



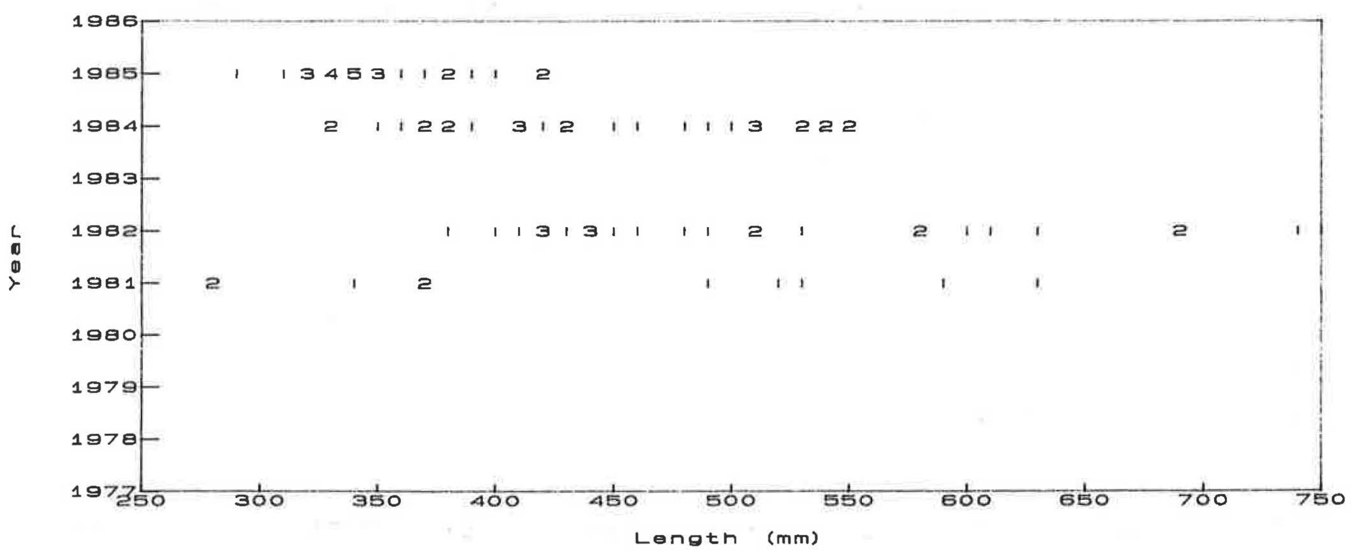
Length distributions of samples by year - cod in 43G1

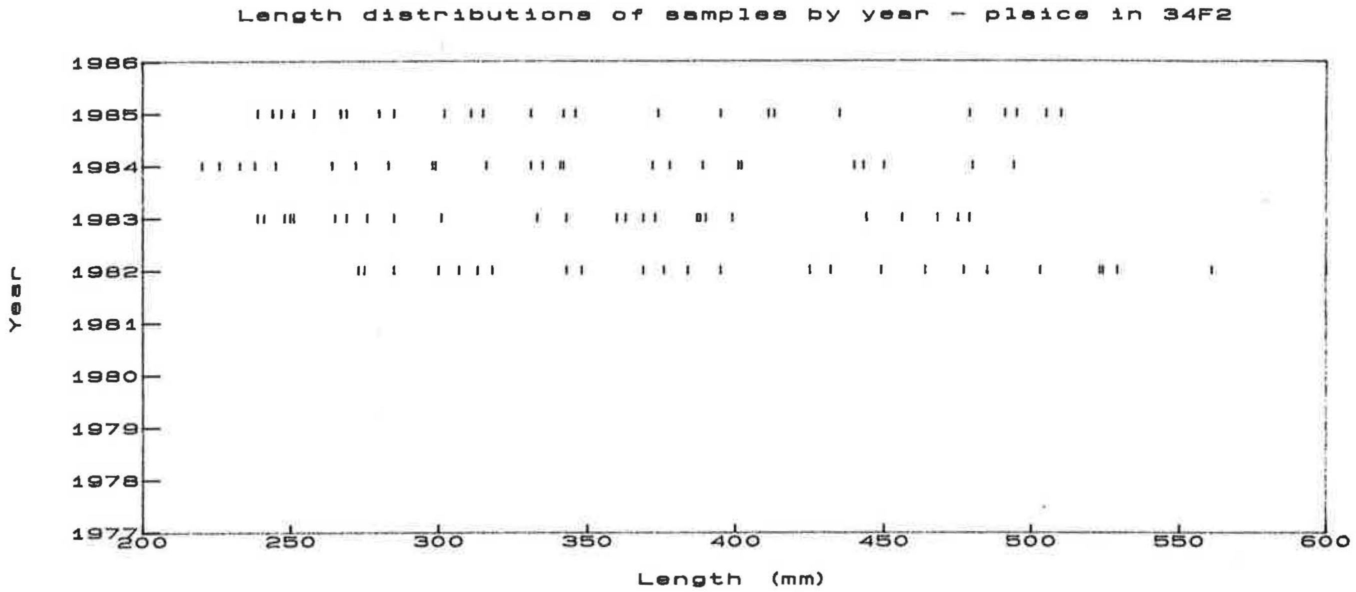


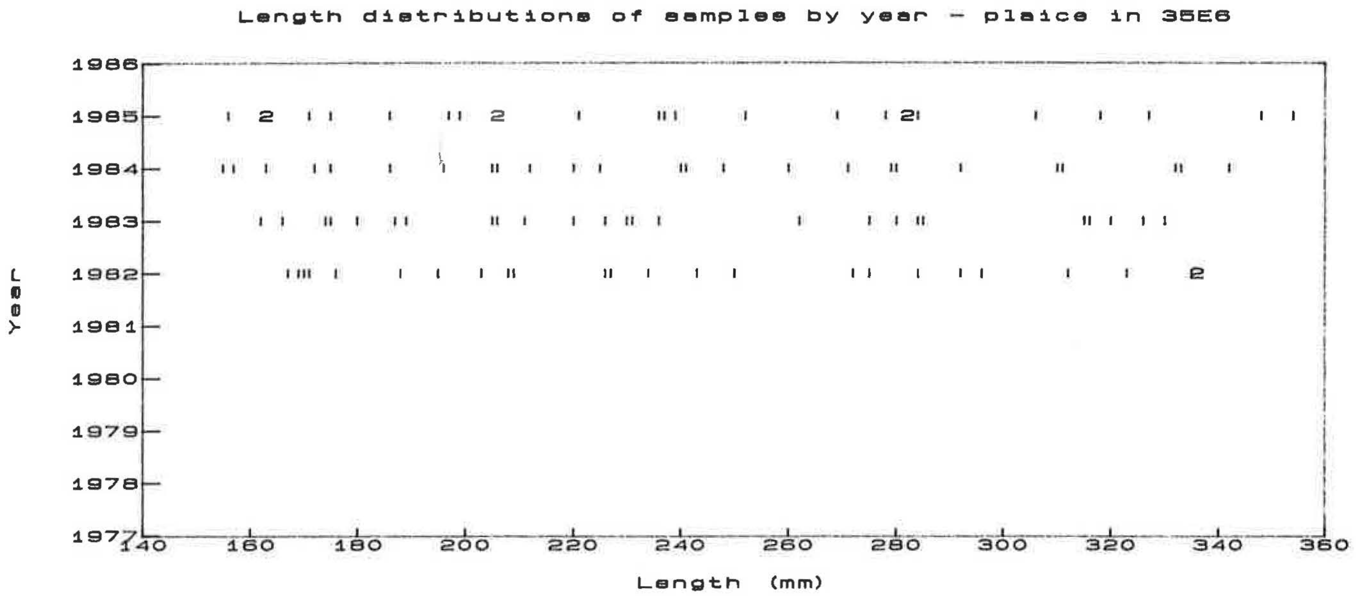
Length distributions of samples by year - cod in 47G0

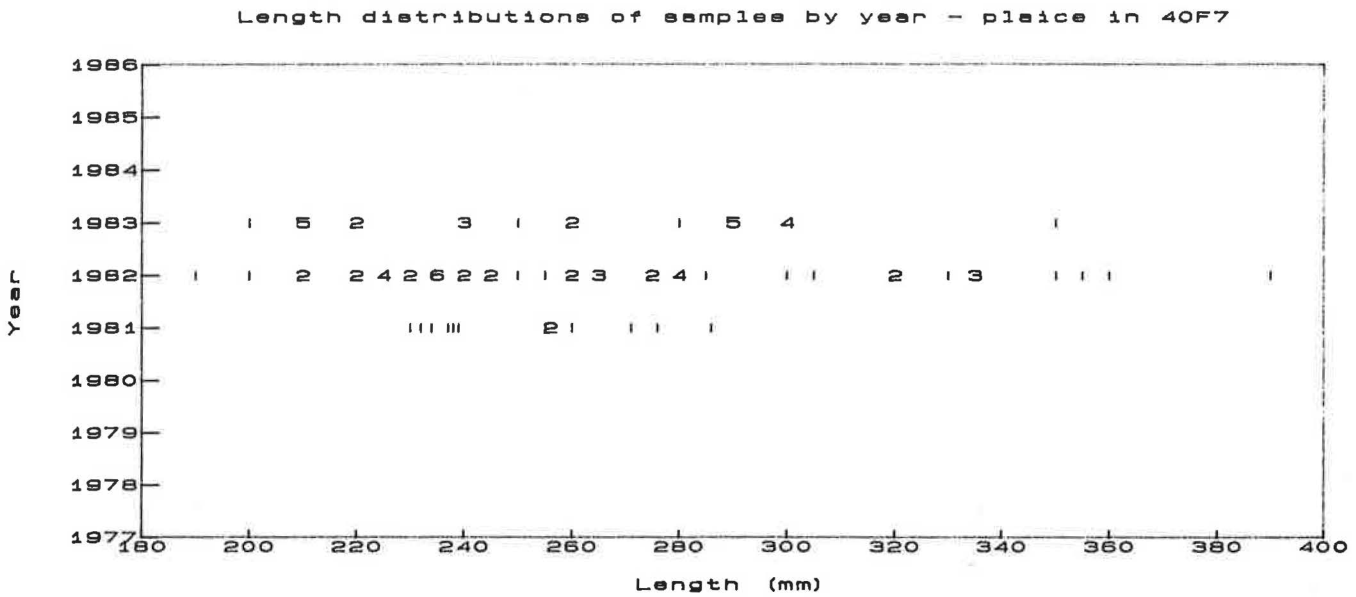


Length distributions of samples by year - cod in 48G0

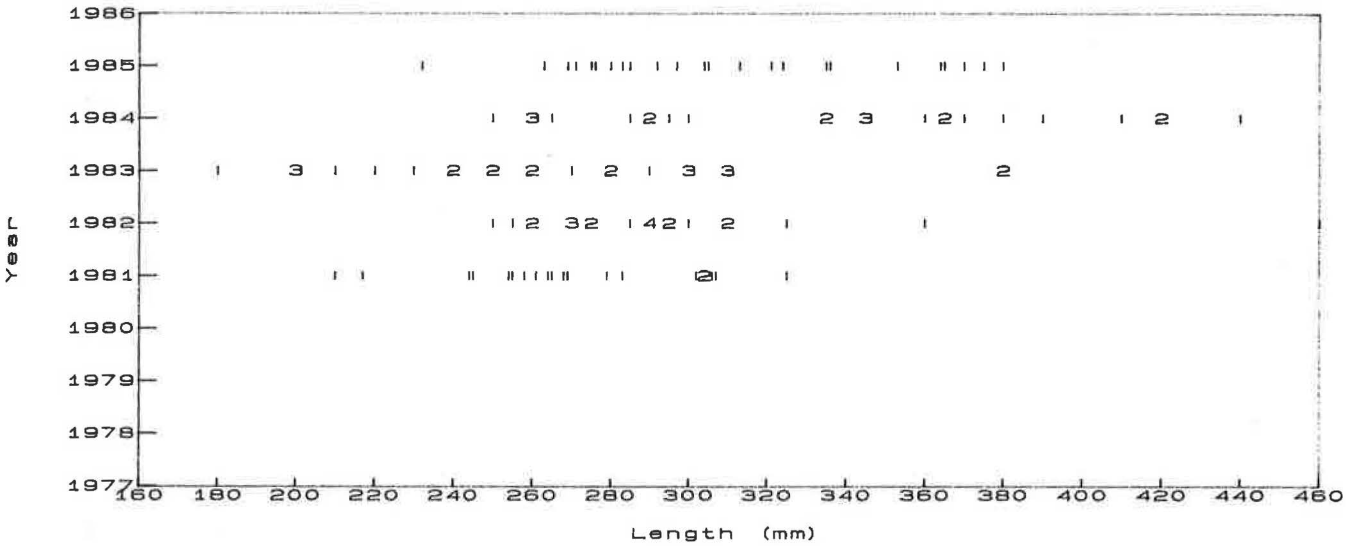



Length distributions of samples by year - plaice in 34F2
Year
Length (mm)

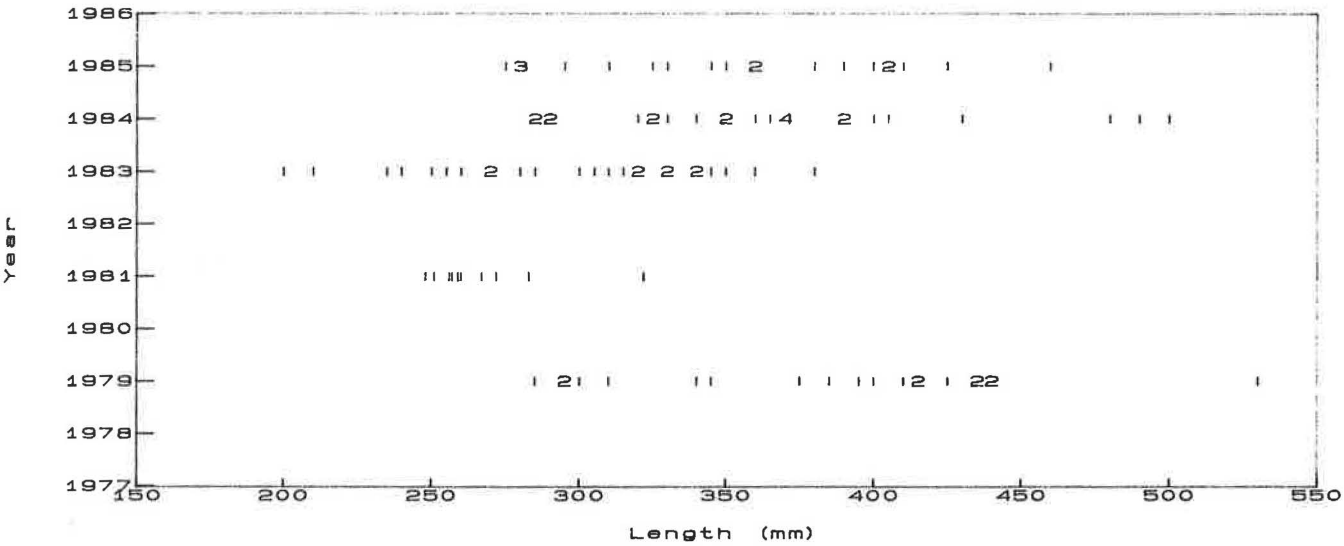

Length distributions of samples by year - plaice in 35E6
Year
Length (mm)


Length distributions of samples by year - plaice in 40F7
Year
Length (mm)

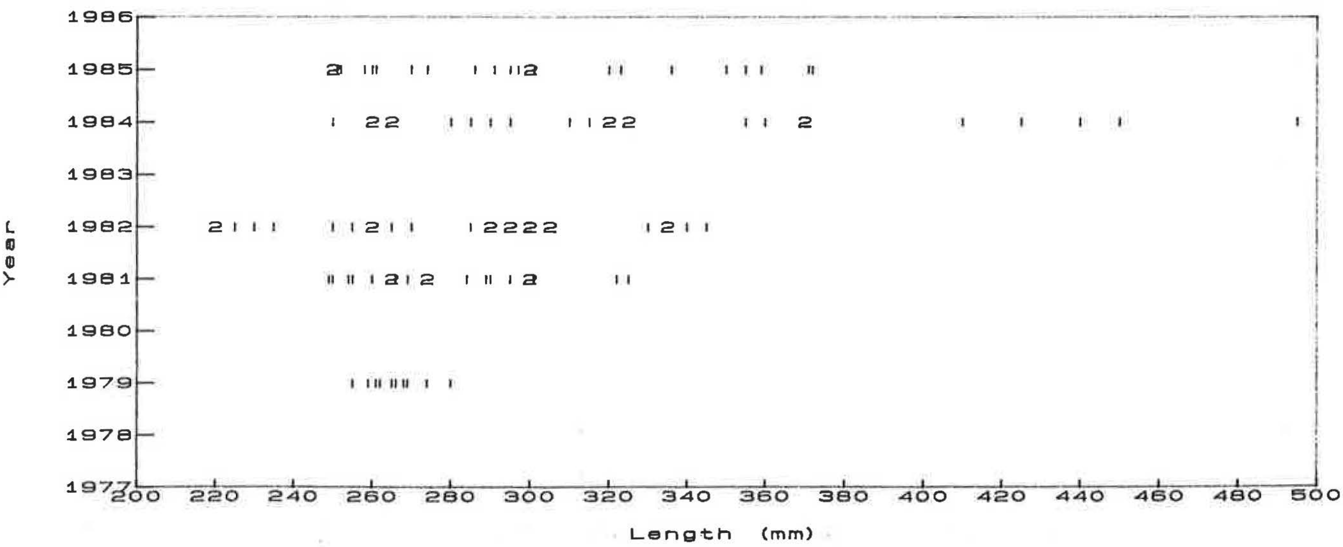
Length distributions of samples by year - plaice in 41F7



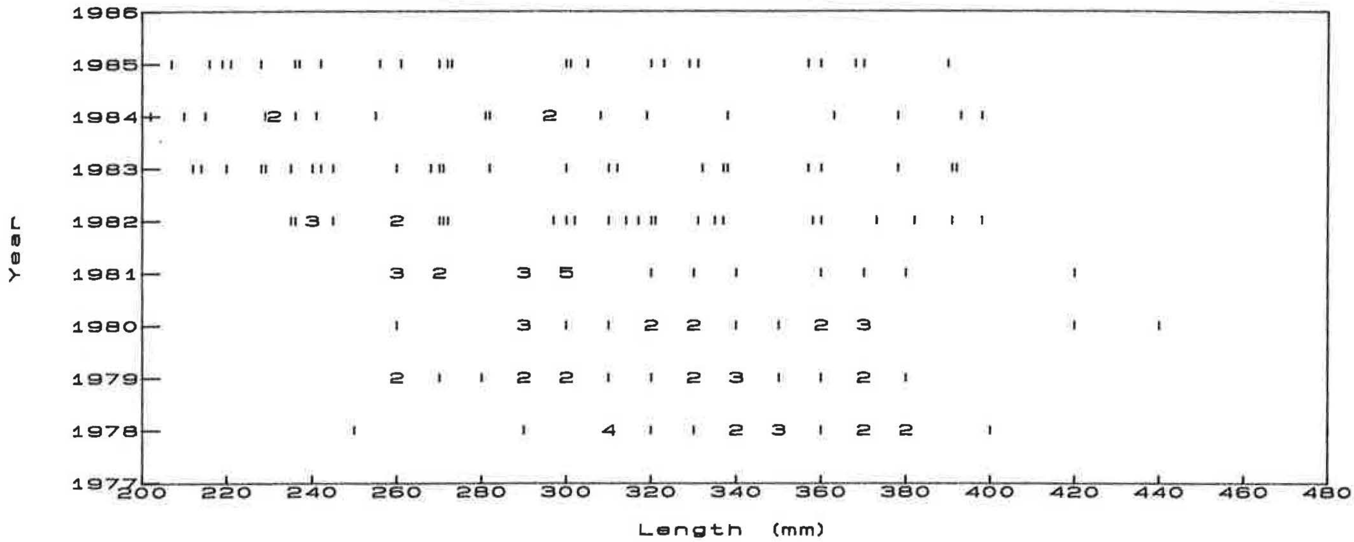
Length distributions of samples by year - plaice in 43F8



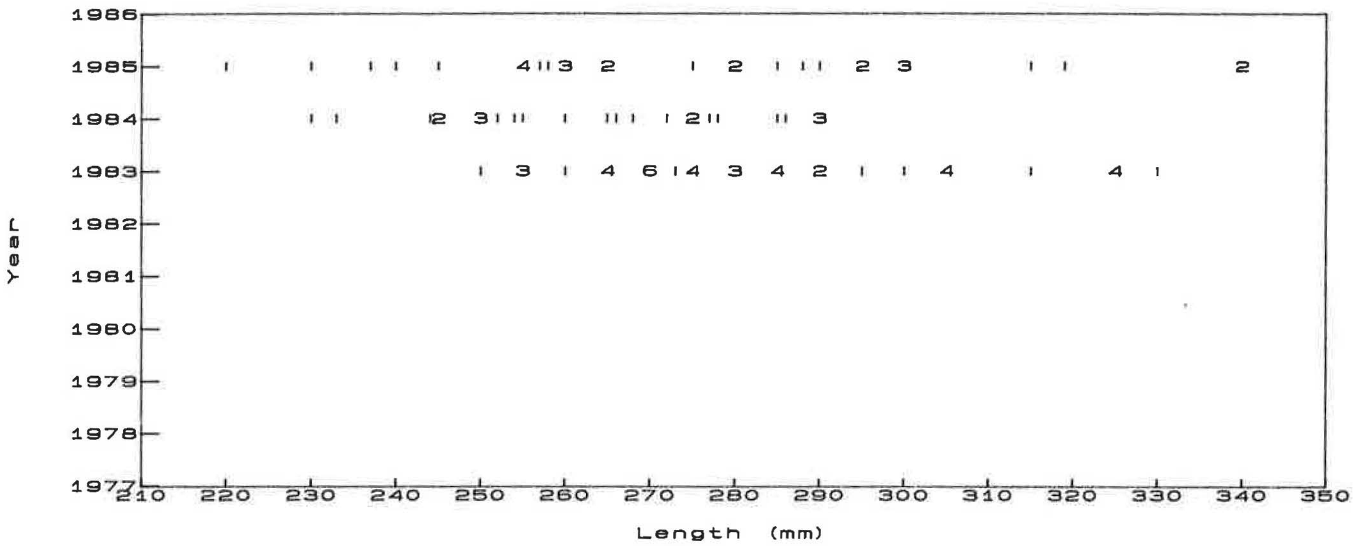
Length distributions of samples by year - plaice in 44F9



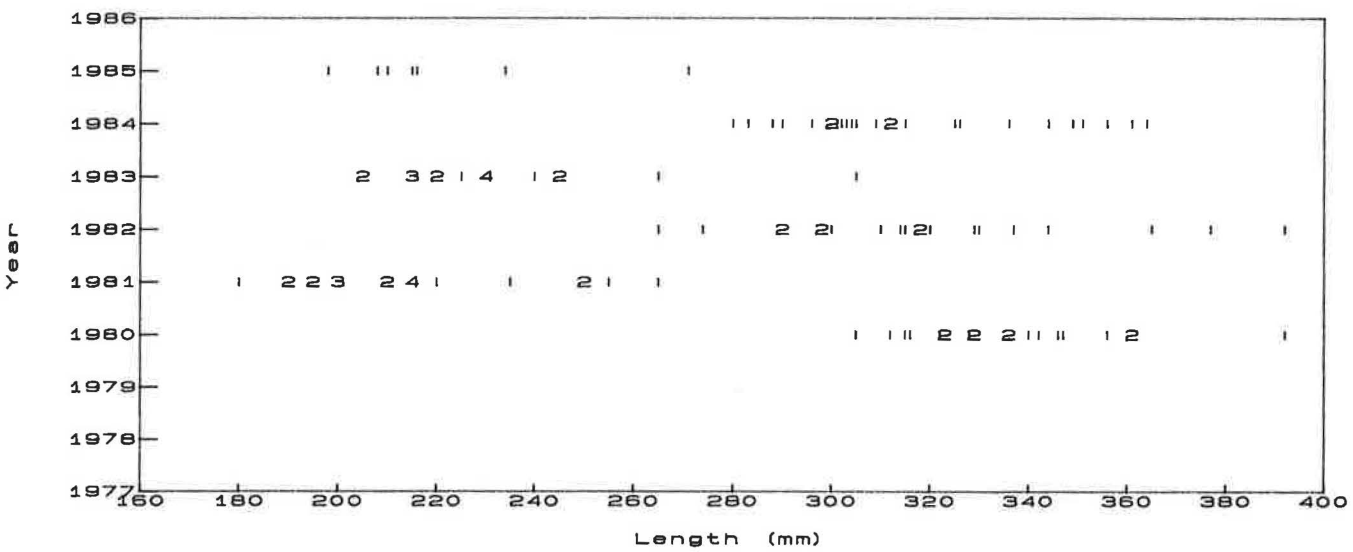
Length distributions of samples by year - flounder in 31F2

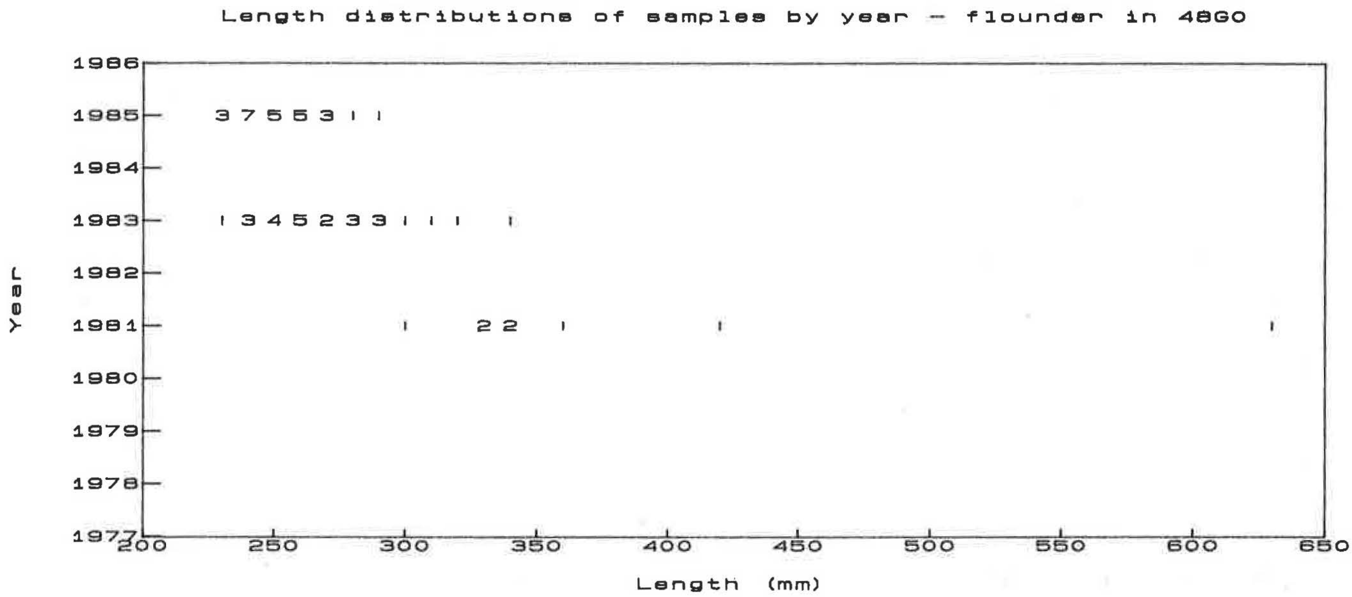


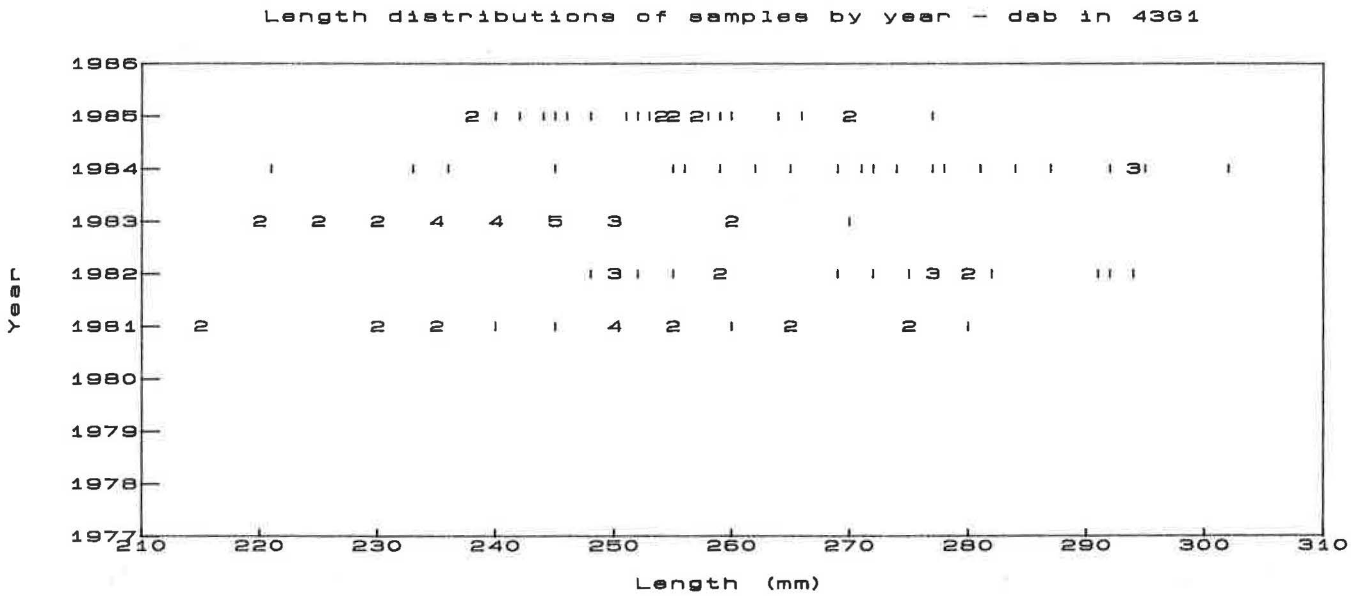
Length distributions of samples by year - flounder in 36F8



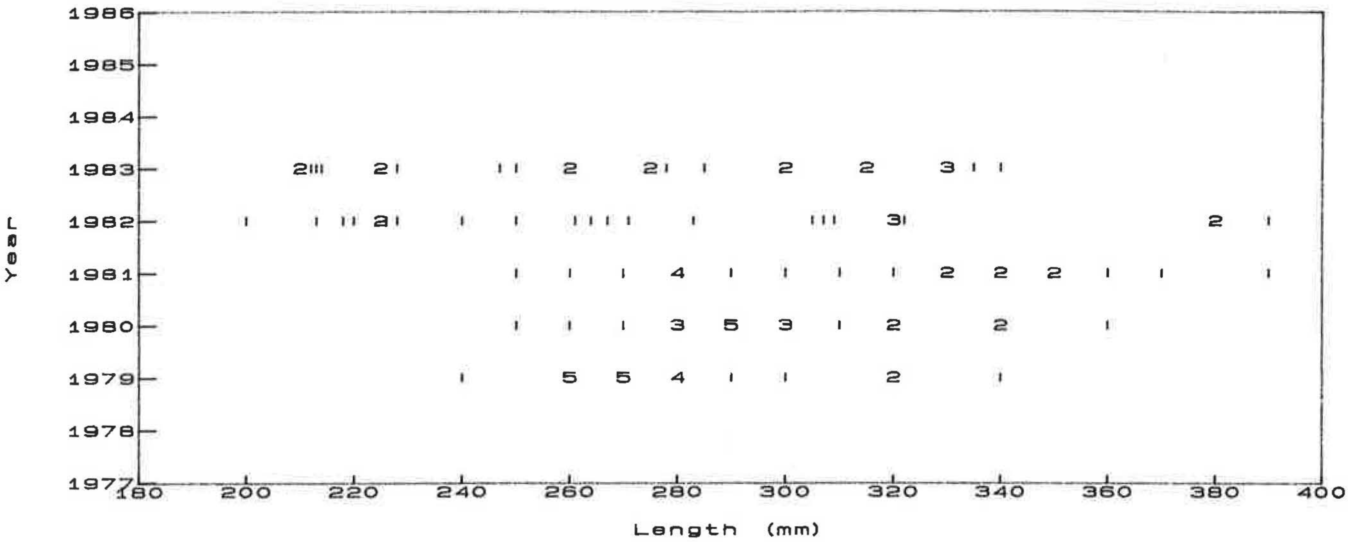
Length distributions of samples by year - flounder in 46G1



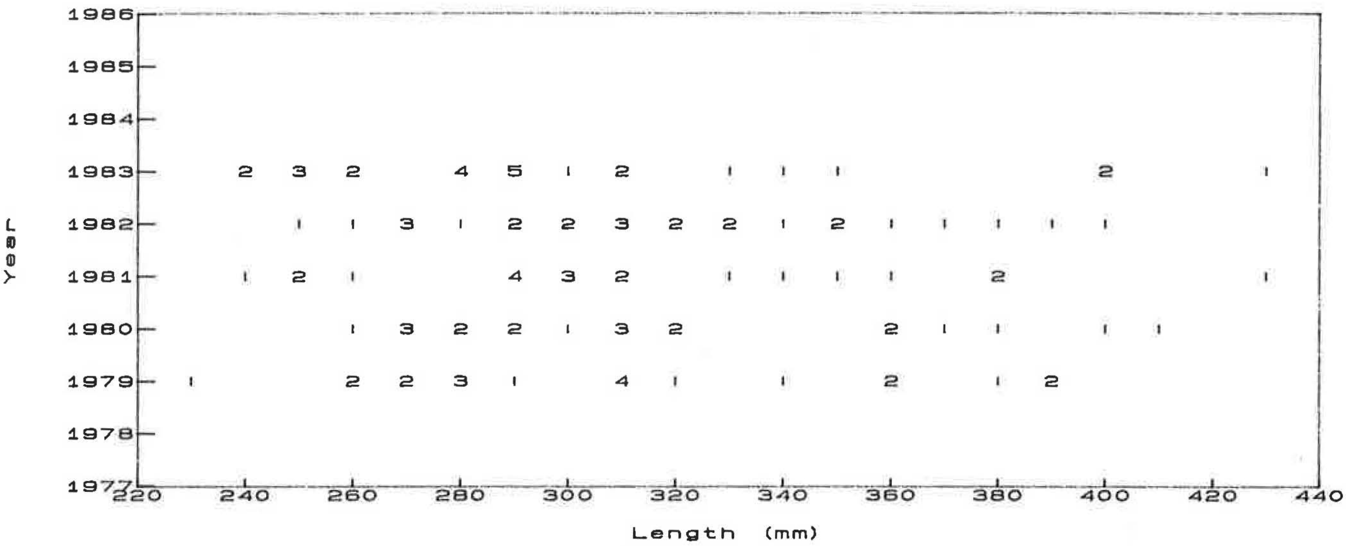

Length distributions of samples by year – flounder in 48G0
Year
Length (mm)


Length distributions of samples by year – dab in 43G1
Year
Length (mm)

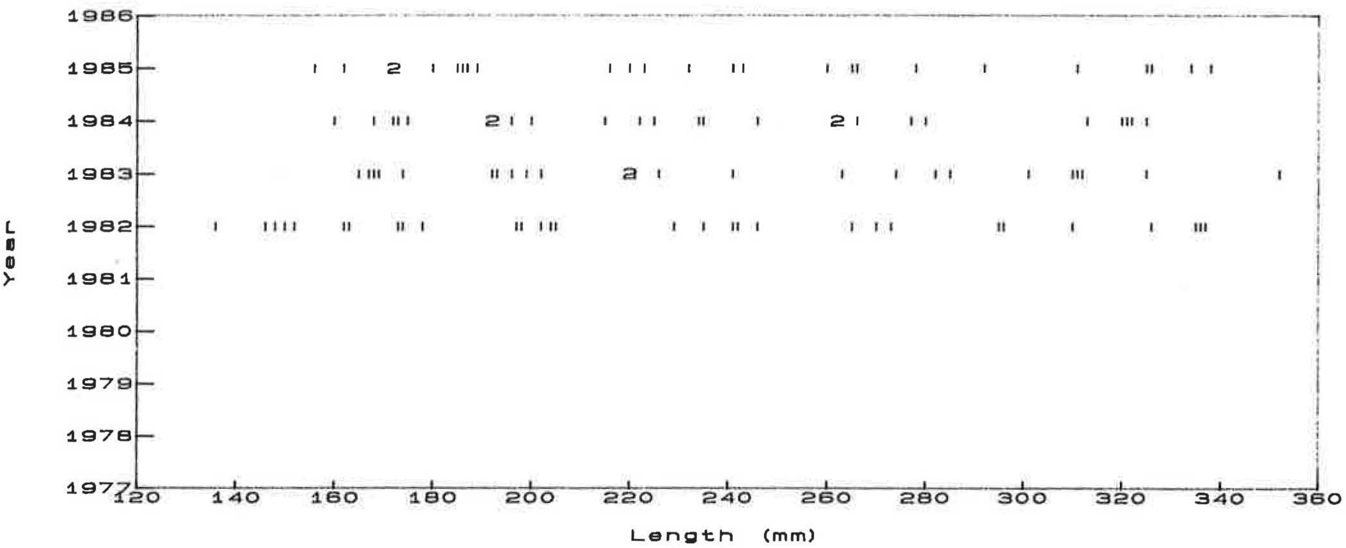
Length distributions of samples by year - sole in 31F2

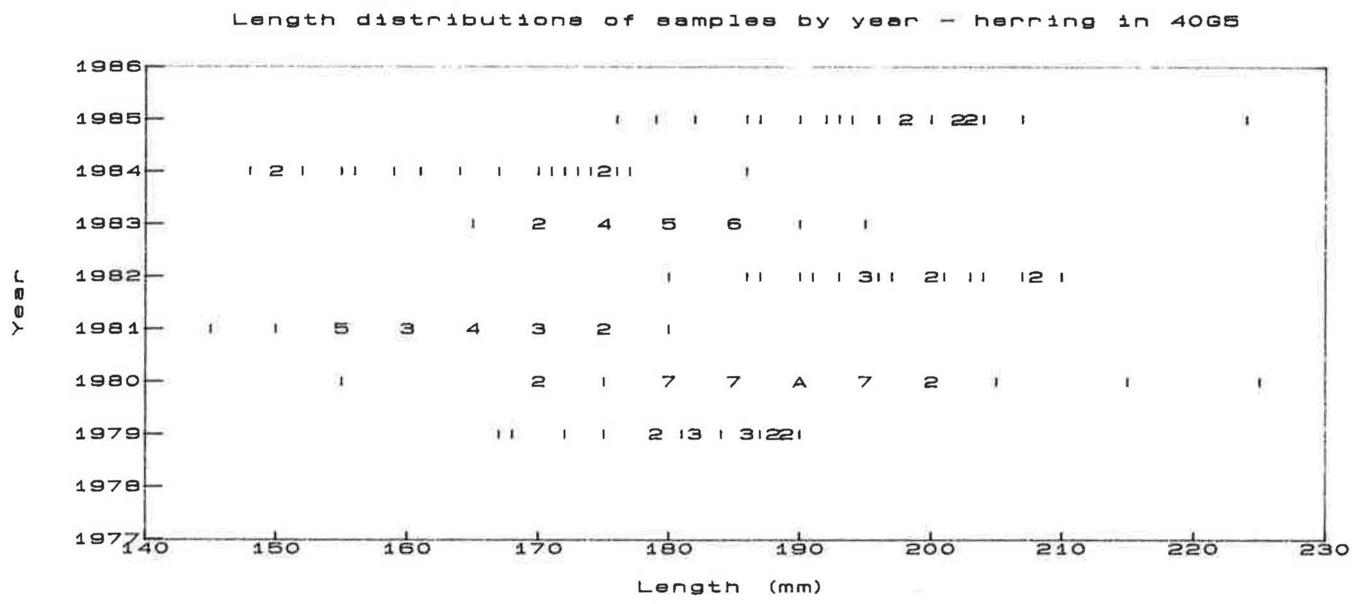


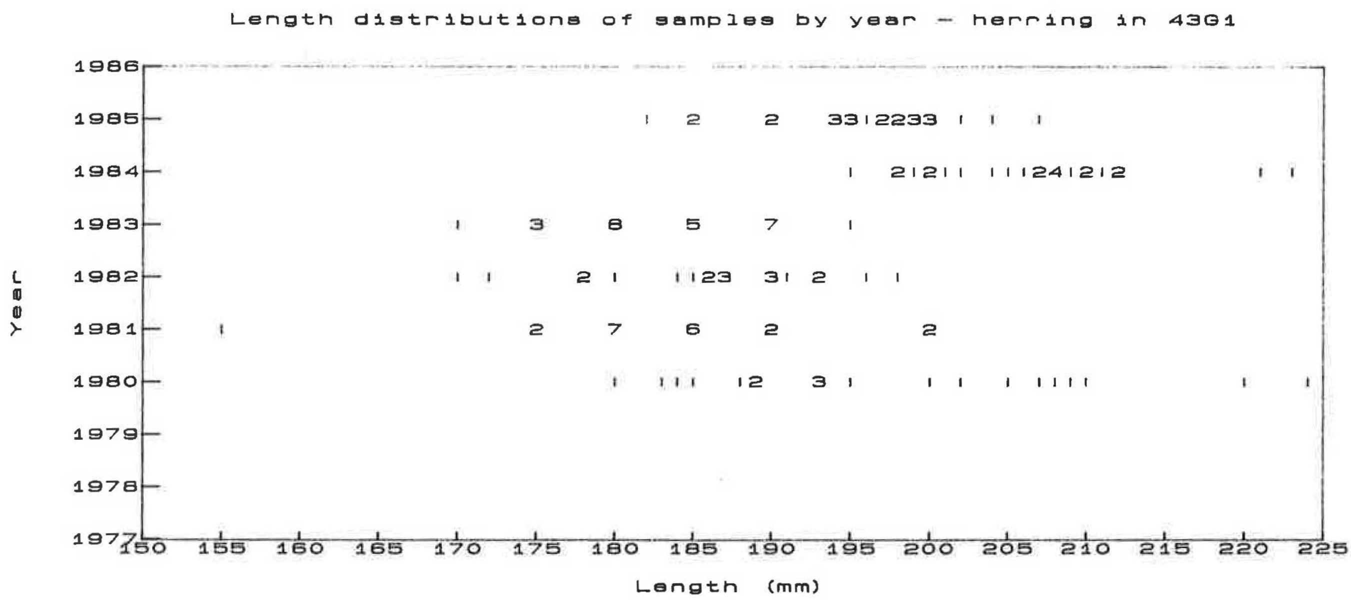
Length distributions of samples by year - sole in 36E5

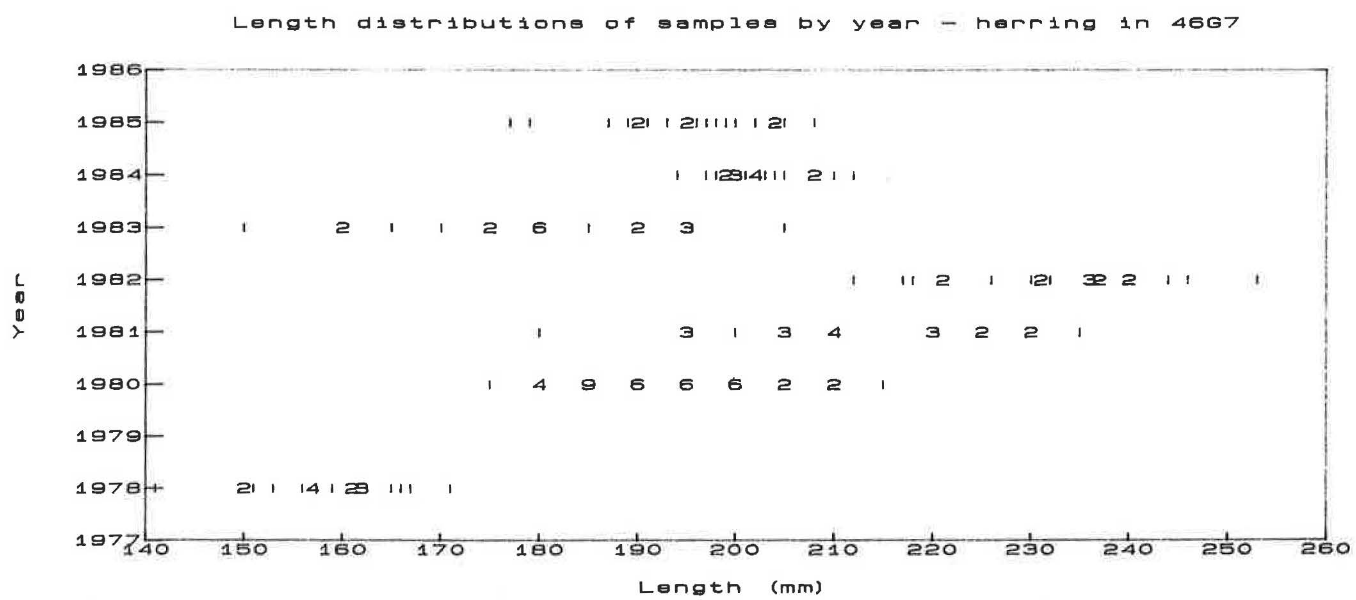


Length distributions of samples by year - whiting in 35E6

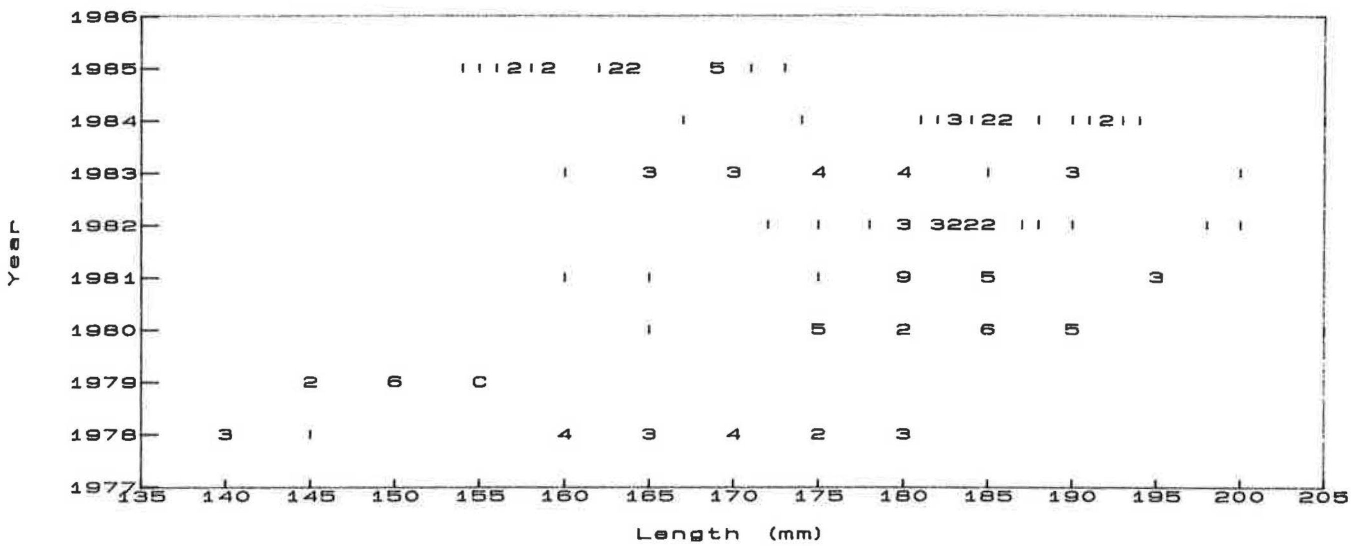



Length distributions of samples by year - herring in 40G5
Year
Length (mm)

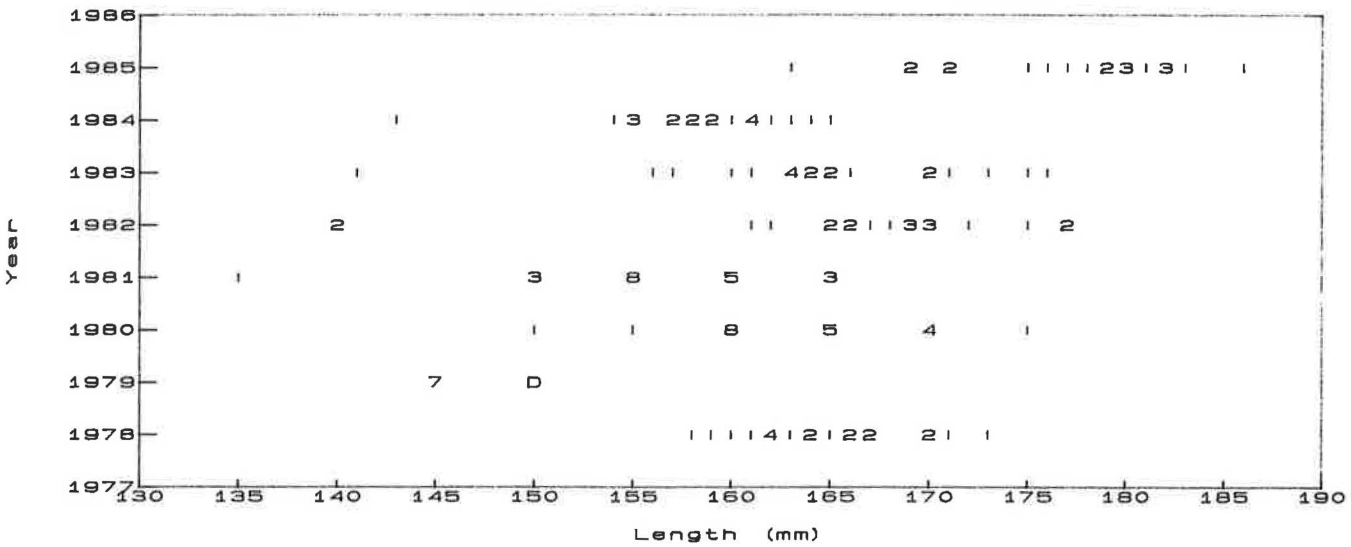

Length distributions of samples by year - herring in 43G1
Year
Length (mm)


Length distributions of samples by year - herring in 46G7
Year
Length (mm)

Length distributions of samples by year – herring in 50G8



Length distributions of samples by year – herring in 60H2



Indication of spine colours

Reports of the Advisory Committee on Fishery Management	Red
Reports of the Advisory Committee on Marine Pollution	Yellow
Fish Assessment Reports	Grey
Pollution Studies	Green
Others	Black

-o-o-o-