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The ICES Stomach Sampling Project in 1981: Aims, Outline and Some Results

by

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1. INTRODUCTION.

Within ICES interest in multispecies assessment has been aroused primarily by ANDERSEN & URSIN (1977) in developing their North Sea ecosystem model as an extension of the BEVERTON & HOLT (1957) theory of exploited fish population dynamics. Essentially the model maintains a mass balance, which results in a redistribution of the available food through competition and predation whenever changes in the commercial fish fauna take place due to exploitation.

The model has been run in various versions for specific purposes (e.g. ANDERSEN & URSIN, 1978; URSIN & ANDERSEN, 1978), but the main conclusion has been that, after the collapse of the North Sea herring and mackerel stocks as a consequence of overexploitation, repartitioning of the zooplankton food resource among the other components could have supported the observed increased abundance of demersal and industrial fish species. Clearly, the virtue of a model of that level of complexity, which includes a large number of hardly testable assumptions, lies less in the actual proof that the real world behaves like the model system and that the natural processes are realistically described than in the observation that certain trends can be mimicked on the basis of our integrated knowledge about fish stocks.

From a different starting point, an analysis of the consumption and production of the North Sea cod stock (DAAN, 1973; 1975) showed that this predator species consumed considerable numbers of recruits of other commercially important species as well as of its own offspring, the implication being that managing the cod stock on the basis of optimizing yield per recruit might result in unwanted effects on other fish stocks. SPARRE (1979) further evaluated the inconsistencies from single species assessment if natural mortality rates are kept constant over wide ranges of exploitation levels.

Despite the available evidence that interspecific relations between stocks should not be ignored in stock assessment, it has not yet been possible to break through the tradition of single species assessment. A main reason for this is that the ANDERSEN & URSIN (1977) model cannot be used reliably in a quantitative sense to prepare advice on fish stock management, because in practice many of the underlying assumptions have remained untestable and also many parameter values have to be guessed. Since various components of the model are not strictly relevant in respect of fish stock assessment, several authors have tried to develop simpler multispecies assessment models, which only reflect the essential interactions (POPE,1979; HELGASON & GISLASON, 1979; SPARRE, 1980). The essentially similar approach adopted by these authors was to develop algorithms for the simultaneous solution of VPA's for more than one fish stock, the important feature being that natural mortality is at least partially modulated by inter- and intraspecific predation among the species included in the data set. The major differences between the various approaches are related to how predation is formulated and how 'other food', that is the food resource not explicitly defined by the species to be included in multispecies virtual population analysis (MSVPA), is treated. Apparently, the theory had advanced to a stage where species interaction could be effectively incorporated in routine fish stock assessment. However, before being applicable the MSVPA requires reliable information on food composition of and consumption by the different species by age groups. Despite the long tradition of food research, the type of data required for the specific purpose of testing the underlying assumptions of these models and for estimating actual parameter values appeared to be not generally available.

With the progress in the theoretical field this lack of basic information was identified as the primary impediment to practical application and in 1980 an ad hoc Working Group on Multispecies Assessment Model Testing was convened in Copenhagen (ANONYMUS,1980) in order to identify the kind of information most urgently required for testing the assumptions and to design an international sampling scheme to obtain this information. This has resulted in an international Stomach Sampling Project being carried out in 1981 under the auspices of ICES.

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This paper presents an overview of the various aspects of the project. Although it is still too early to present a complete account of the results, it is tantalizing to look into the future on the basis of preliminary results available sofar.

2. THE STOMACH SAMPLING PROJECT 1981

2.1. Aims

The primary aim of the project is to provide the essential input data for MSVPA, which can be summarized as

1. an annual estimate for a reference year of food composition by prey species and age group thereof for each predator age group;
2. an average annual rate of food intake for each predator age group.

Obviously only species included in the exploited species complex, both in respect of prey and predator, are of ultimate interest for the exersize, but since the various models assume preference functions the prey should be investigated in rather greater detail in order to be able to test the various assumptions. Generally, preference can be split into two aspects (ANDERSEN & URSIN,1977): an ecological vulnerability of a prey species for the predator and a size suitability of an organism as prey for a predator. In other words a particular species may be more or less vulnerable depending on its way of life in relation to the habits of the predator and therefore may more or less frequently occur in predator stomachs. Within a species characterized by a specific ecological vulnerability the various specimens may be more or less suited as food for a predator depending on their relative sizes (URSIN,1973). Since size preference models can be readily tested on the basis of stomach content data if size spectra of prey are recorded (URSIN, 1973; ANDERSEN, 1982; ARNTZ & URSIN, 1981a,b), this aspect formed an important feature of the project.

Food composition and food intake are known to vary considerably from one area to another, from season to season and also individually. In MSVPA one deals with annual populations and it is essential that estimates of average food composition represent the total annual population. This could be achieved by planning surveys in each quarter and to take into account in the analysis both spatial and seasonal distribution of the species sampled.

In taking stomach samples at sea the age of the fish sampled cannot be taken into account dircetly. In view of the fact that per predator species an estimated 6000 stomachs were required in order to obtain reliable population estimates, it appeared impractical to store and analyse all stomachs individually and therefore it was decided to group stomachs from individual hauls by predefined predator size classes, which at a later stage in the analysis could be translated into age groups by appropriate otolith sampling. Since weights and numbers of prey were required by species size classes, the analysis could be accelerated considerably by working up grouped samples instead of individual stomachs within a sample. The resulting loss in information on individual variation was considered to be more than compensated by the larger number of samples that could be processed.

Stomach content analysis yields direct information on food composition and average weight of food in a stomach. The latter parameter should be some function of food intake, but the consumption rate cannot be estimated without independent information on digestion rates. Although the need has been stressed for more information on digestion rates of natural food particles (e.g. ANONYMUS, 1980), the coordination of the experimental work involved fell beyond the scope of this project.

The five predator species selected for stomach investigations (COD, WHITING, SAITHE, MACKEREL and HADDOCK) represented the most important fish consumers among the eleven exploited species which, on the basis of the availability of detailed catch data, might ultimately be incorporated in multispecies assessment (COD, HADDOCK, WHITING, SAITHE, PLAICE, SOLE, HERRING, MACKEREL, NORWAY POUT, SPRAT, SANDEELS).

2.2. Outline

The Stomach Sampling Project planned for 1981 required extensive sampling during each quarter over a wide area and, since a limited amount of research vessel time could be allocated specifically to this project, sampling was associated as far as possible with routine surveys programmed by the various countries. The available additional effort was used to fill gaps in the coverage and in some instances sampling has been extended on board of commercial vessels. Nine countries (BELGIUM, DENMARK, ENGLAND, FRANCE, FEDERAL REPUBLIC OF GERMANY, THE NETHERLANDS, NORWAY, SCOTLAND, USSR) participated in sampling at sea.

The basic stratum for stomach sampling was defined as the statistical rectangle and up to 10 stomachs per size class (25 for less abundant size classes whenever possible) were collected from each haul for each of the five predator species studied. Specimens in the size range below 10 cm were generally excluded. Per rectangle samples from individual hauls were combined and the average number per size class caught was reported with the

For the total project a coordinator was assigned to ensure that sampling and recording by individual countries followed the same procedures and to take care of the logistics involved in a speedy exchange of the samples collected. The analysis of the samples was centralized in so far that for each species a coordinator was assigned in order to obtain complete homogeneity at least within species. In a joint meeting the coordinators defined the general rules of procedure in sampling and analysis which have been laid down in a project manual (ANONYMUS, 1981).

Fig 1 presents a flow chart of the operations necessary to achieve the final aim of multispecies assessment and some less immediate objectives are also indicated. The project proper deals only with the box in the top lefthand corner, because these actions reflect the phase of responsibilty of each of the species coordinators. The results should be made available to a broader scientific community before the stomach content data can be translated into estimates of consumption, which would ultimately enter the MSVPA.

Although stomach sampling has been restricted to the five species mentioned, length compositions of the catches and otolith samples by area of all 11 species to be incorporated in the MSVPA were requested in order to allow transformation from the prey size classes encountered in stomachs to age distributions of prey.

In sampling stomachs at sea the problems of regurgitation due to the catching process and of fish swallowing prey within the codend got special attention in order to avoid bias in the proportion of fish estimated to be feeding (ANONYMUS, 1981).

In exchanging the samples care was taken that each sample was properly labelled. Extensive arrangements had to be made to facilitate redistribution of the samples collected by the various countries among the responsible species coordinators. The essential format for recording sample information and stomach content data is given in fig 2. Coding of prey followed essentially the 10-digit NODC system (NOAA, 1978), which has been gradually extended to cover all North Sea species as they were identified in stomachs.

The size classes distinguished followed approximately an exponentially increasing scale (table I). The same classification was applied to both predators and prey.

Since different gears have been used during the various national surveys, there have been some difficulties in comparing catch rates, which were required for weighting samples according to the spatial distribution of the predator. However, any resultant error was considered to be small enough not to affect the results too dramatically in view of the rather high degree of variation inherent to stomach content data.

The statistical rectangle presented the primary stratum for further analysis of the stomach contents. In addition the standard roundfish areas were defined as a secondary stratum for transformation from size classes to age groups.

Since the coordinators were distributed among various countries the primary data have been stored within national computer systems for primary analysis, but it is intended to exchange the complete data base and put a copy at ICES headquarters at a later stage.

2.3. Sampling intensity achieved

Preliminary details on the temporal and spatial intensity of sampling have been are given in ANONYMUS (1982). Updated information based on DAAN (1983), HISLOP et al (1983) and MEHL & WESTGARD (1983) is summarized here to give a global indication of the sampling intensity achieved.

Table II provides the numbers of stomachs collected by species, size class and quarter and in fig 3 totals over the year by species by statistical rectangle are given. In case of mackerel, samples taken in 1982 have been included in fig 3d. Haddock data were not available.

The target of 1500 stomachs per quarter, which had been considered as the minimum required for a reliable estimate of food composition (ANONYMUS, 1980), has been exceeded for cod and whiting and,although final figures are not yet available, this probably applies to haddock as well. For mackerel and saithe the number collected has remained well below the target in all quarters. Survey gears used appear to have been highly inadequate for catching mackerel, whereas the main distribution of saithe is restricted to the border of the continental shelf and sampling of this species has suffered from lack of attention to these areas. In order to make up for these sampling deficiencies countries have been asked to continue sampling for these species. In 1982 an additional 1868 mackerel stomachs have thus been collected (MEHL & WESTGARD, 1983).

The distribution of stomachs by size class indicates that sampling for cod and whiting has been poor for the largest size class, whereas there is an almost complete lack of information on small saithe and mackerel. All these sampling deficiencies result from the difficulty of catching sufficient numbers of these species and sizes in general purpose trawling surveys and the sampling problems could only have been resolved by designing specific sampling programmes dedicated to these fish.

From the spatial distribution of the stomachs collected for cod and whiting (fig 3), it can be concluded that on an annual basis the entire North Sea has been effectively covered by the surveys. Within individual quarters some gaps can be observed (ANONYMUS, 1982; HISLOP et al, 1983), but there appear to have been no systematic sampling errors on an area basis. Of the 3674 mackerel stomachs sampled in 1981 and 1982, 2056 were collected during the third quarter and only 81 stem from the first quarter, the remainder being almost equally split

2.4. Selected results

Because of the rather variable sampling intensities among the various species requiring different approaches in the analysis and because the primary analysis of the samples for the different species had proceeded at rather different speeds, the group of coordinators decided (ANONYMUS,1982) to submit individual species reports to the forthcoming Council Meeting in Gothenburg and that an integrated analysis of all species should be delayed to a later stage. For the purpose of this overview I have had access to some of these forthcoming reports, but my account cannot give full credit to all species.

Since the main emphasis of the project lies on exploited fish species eating exploited fish species, the results presented here are mainly restricted to this topic, but some information is added on the analysis of size preference because of its bearing on the various MSVPA models.

2.4.1. Consumption of exploited fish species by exploited fish species.

COD.

A full account of the summarized data presented here and of the estimation procedures involved can be found in DAAN (1983).

Tables III-A/D provide summary tables of the results of the stomach analysis by size class of cod by quarter of the year. General information is provided at the top of the tables and food compositions are given in weight percentages by major taxa and for the various commercially important species individually. In obtaining these estimates of average stomach contents for the total North Sea population, the samples from individual rectangles have been weighted by the estimated abundance by size class according to the catch rates. However, since trawl catches are rather variable, the square root of N per hour has been applied as a weighting factor rather than the actual N per hour in order not to put too much weight on accidentally high catches.

The considerable differences in food composition between quarters probably reflect to a large extent changes in the availability of the various prey. Still some consistent patterns are revealed; more than 80% of the total food consisted of crustaceans and fish in all size groups and quarters and there is a clear increasing contribution of fish prey with predator size and a corresponding decrease in the crustaceans. Also it is quite evident that, even if the actual composition of the fish prey changes over the year, a very high proportion consists of commercially important species in all seasons.

The seasonal stomach content data by size class of predator have been transformed in estimates by age group by applying appropriate age size keys. The quarterly food compositions by age group have been averaged in table IV to provide a mean weight percentage of food for the 11 MSVPA species. Only saithe has not been observed in cod stomachs and the total exploited species complex contributes to the food of cod from 30% in I-group to approximately 50% in adult cod. The contribution of haddock and whiting is particularly worth noting, but except for the flatfish species, saithe and mackerel all species have been found in significant amounts.

For the three major gadoid species in the North Sea (cod, haddock and whiting) the average number of specimens present per stomach by prey size group have been further analysed by applying appropriate age size keys, which yields an array of age groups of prey versus age group of predator (table V). Apparently, the predation of North Sea cod is mainly directed towards I-group fish, but it should be observed that 0-group fish have only been found during the second half of the year and thus yield reduced values on a total year average. With increasing age of prey their numbers rapidly diminish although predation mortalities will affect even adult haddock and whiting. Up to 3 year old cod may suffer from cannibalism.

Table V represents in fact the final stage of analsyis of the data collected during the Stomach Sampling Project and if one wishes to proceed with estimating consumption rates one has to rely upon additional information. Based on a model presented earlier (DAAN, 1973), in which digestion rate is assumed to be a function of size of prey and, because prey size is a function of predator size (URSIN, 1973; DAAN, 1973; DEKKER, 1983), thus of predator size, some preliminary estimates have been made of the number of these prey species by age group consumed by the average cod stock in 1981 according to VPA estimates (table VI ; for details see DAAN, 1983). These numbers have been compared with the VPA estimates of numbers of each age group in the sea according to the assessments of the North Sea Roundfish Working Group (ANONYMUS, 1983a).

All these assessments are based on the assumption of constant natural mortality (M = .2) for all age groups. This exersize shows that,if the assessments were correct, the cod stock would have eaten more I-group fish of all three species than there were in the sea at the beginning of 1981. Thus a severe inconsistency is observed, which could only be resolved by a considerable increase in the natural mortality in the younger age groups. Alternatively, a very much higher exploitation rate on the cod stock, resulting in smaller stock sizes and correspondingly lower consumption figures, might reduce the discrepancy.

The quantitative implications of cod predation on other exploited fish species has not yet been investigated.

Apart from this main line of analysis various other interesting results can be derived from the data collected. As an example the estimated regressions of total weight of the stomach contents against mean length of cod for various data sets are provided in table VII. Despite considerable differences in spatial coverage of the North Sea, the differences between years are not statistically significant. Assuming that the model w = phi . L^3 (DAAN, 1973) fits all sets, the resultant values for the feeding coefficient phi are very similar indeed, which suggests that in cod total food intake is rather constant from year to year.

WHITING

A comprehensive account of the whiting results of the Stomach Sampling Project has been given by HISLOP et al (1983) and the authors' permission to use their information for this review is gratefully acknowledged.

As in cod, there is again considerable variation if food composition by seasons and areas, but for details reference is made to the original paper. However, even more so as the cod the whiting appears to represent an almost exclusive fish feeder. From 34% of the food by weight in 0-group to 85% in adult whiting constitutes of fish, the major proportion of which is accounted for by the eleven exploited species (table VIII), particularly gadoids, clupeoids and sandeels.

The methods of calculation applied by HISLOP et al (1983) in estimating average food composition and food intake of whiting are slightly different from those applied for cod, but essentially the same digestion model (DAAN, 1973) has been applied, be it that digestion rate has been taken as a constant throughout the size range on the basis of experimental evidence. The authors argue that in comparison with other existing models the approach followed here yields conservative estimates of food consumption.

Estimated numbers by age group of exploited fish species consumed by each age group of whiting are given in table IX. Clearly, in numbers consumed the 0-group of the various prey species forms by far the most important component of the food of whiting. (It should be noted that this table cannot be compared directly with the cod table V, because the latter gives the average number present per 1000 stomachs at any point in time whereas the former gives the number consumed annually per 1000 whiting.)

In table X the numbers consumed quarterly by the whiting population have been estimated for six species on the basis of the recent whiting assessment (ANONYMUS, 1983), assuming that fishery mortality is constant over the year. The consumption by 0-group whiting has been excluded, because of possible bias due to the fact that only larger fish in this age group (>= 10 cm) have been sampled and because the assessments do not pretend to yield a reliable estimate of 0-group abundance anyway.

In table XI the annual consumption figures are compared with stock size estimates from VPA. For the three roundfish species a very similar picture arises as for cod (table VII). The number of I-group haddock and whiting consumed by the whiting stock are in the same order of magnitude as the estimated number in the sea at the beginning of 1981. Combining predation rates by cod and whiting yields the impression that natural mortality on I-group fish would be in the order of at least 1.0 rather than 0.2. Older haddock and whiting and also I-group cod are consumed in rather lower quantities by the whiting stock than by the cod stock. On the other hand the estimated impact of whiting on 0-group fish is two times higher than for cod.

The figures for herring indicate that also for this species the natural mortality coefficient applied in routine stock assessment (0.1; ANONYMUS, 1983b) is inconsistent with the estimated predation rates by the whiting stock. For Norway pout and sprat rather higher natural mortality rates are applied (1.0 and 1.1 respectively; ANONYMUS, 1983c). The predation mortality by whiting on I-group Norway pout of 20% remains well below the total natural mortality of 63% assumed, but for sprat there would be no room for other predators.

SAITHE

Table XII presents information on the weight percentage composition of the stomach contents of saithe according to the preliminary data presented in ANONYMUS (1982). In view of the limited amount of sampling in 1981, samples collected in 1980 and 1982 have been included. Euphausids and fish account for more than 95% of the total food, the latter becoming increasingly more important with increasing predator size. A high proportion of the fish is accounted for by exploited species, particularly sandeels in small saithe and Norway pout in larger saithe.

The results on fish consumption by saithe presented by GISLASON (1983) did not become available in time for incorporation in this review.

MACKEREL

MEHL & WESTGARD (1983) report extensively on the results of the stomach analyses for mackerel and the authors' permission to use their results in this review is gratefully acknowledged.

The situation with the mackerel samples is rather different from the one for cod and whiting in that the surveys not only yielded a limited number of stomachs but also inadequate data about the distribution of the mackerel over the North Sea to use directly in estimating food composition of the stock. Thus sampling has been extended to cover commercial catches taken by different gears and also sampling has continued in 1982. The analysis presented here is based on the average of the two years. Instead of weighting the samples by the catch rate in the corresponding rectangles the authors have chosen to divide the North Sea in a small number of regions, where consumption is supposed to be more or less homogeneous, and to calculate unweighted means for each of these areas and for each quarter..

Table XIII provides information on the average amount of food present by area, quarter and size class.There is a clear seasonal trend, high values being reached in spring after extremely low winter values. Although sampling in the first quarter has been rather limited, these data suggest that food intake during this time of year is negligible. Apparently the food intake varies also considerably by area and the picture is further complicated by the fact that samples taken from pelagic gears yielded rather different results from bottom trawl catches. In the absence of detailed information on horizontal and vertical distribution of the mackerel stock, it has not been possible to provide a straightforward estimate of the average food composition for the total population and the data presented in table XIV, based on an unweighted total North Sea average for 1981, can only give a rough indication of the relative contribution of the various components.

Still, MEHL & WESTGARD (1983) have made a tentative assessment of the spatial distribution of the stock and, on the basis of detailed information on the food composition by area and quarter and of an exponential digestion model involving ambient temperatures, they have estimated the total consumption in 1981 for selected prey categories (table XV). Norway pout and sandeels account each for approximately 10% of the total food in weight, whereas other exploited fish species appear to be insignificant. According to the prey size distribution (fish predominantly <10 cm) mackerel consumption would mainly affect 0-group fish and to a much lesser extent I-group, which would show up even more strongly when prey biomasses are transformed to numbers of prey comsumed.

The authors stress that their estimates are very preliminary, because of a large number of uncertainties in their estimation procedure and it would seem premature to extend this analysis any further at this stage.

HADDOCK

Data on haddock have not yet become available.

2.4.2. Size preference.

Fig. 4a/d provide plots of observed prey size distributions in relation to predator size for the various species. Although the general trend of increasing size of prey with increasing size of predator is obvious for all species, the results appear to vary considerably with prey type. This need not point to a difference in size preference, but may be entirely due to differences in the availability of prey sizes. Because the prey size distribution in stomachs is a function of both the preference of the predator and the relative abundance of the various prey sizes in the environment, the preferred size can not be determined without making some assumption about the abundance..

ANDERSEN (1982) has proposed a model which allows the preference function to be estimated from stomach content data (ARNTZ & URSIN, 1981a,b), making some general assumption about the nature of the size distribution of prey in the sea but allowing its parameters to be estimated from the total set of stomach content data. DEKKER (1983) has investigated the various problems in using this model on real data exemplified by the cod data set and some of his findings are reported here.

Firstly, some severe limitations of the data base became apparent, because the model, and size preference in general (URSIN, 1973), is based on relative prey to predator weights, whereas the information reported from the stomach analysis refers to size classes based on some measure of length. Since growth is generally isometric any measure of length is probably an adequate index of weight within species, but problems arise when different species are combined. In that case the 'condition factors', that is the parameter defining the average length weight relationship, become essential pieces of information. At present these are not readily available for a majority of the prey species.

Fig 6 shows as an example the relationship between the observed prey length in stomachs and predator length and the estimated preference function for fish prey only. It should be noted that in calculating the latter the larger size classes get more weight, because they eat more fish. Apparently the fish found in stomachs are in fact larger than the preferred size, which suggests that small fish are less available to the cod stock than the larger sizes. Still, the general validity of a linear approximation of the size preference function is clearly illustrated.

In table XVI the estimated parameter values obtained by applying the model to selected prey categories are reproduced from DEKKER (1983). It can be seen that if the condition factor is assumed to be .01 (the average value for cod), the estimated preferred log weight ratio eta is rather variable. This is also true for the standard deviation sigma of the log weight ratio distribution, although if inaccurate estimates are excluded the range of values is narrowed down considerably. Only for all prey combined a high value for sigma is found, but the c-values (representing the coefficient of the negative exponential function of prey number) are very different for invertebrates and fish. It may well be that the combined prey size distribution would be bimodal (cf fig 4), in which case the basic assumption of log normality of the distribution function is not fulfilled.

In the table also estimates of the condition factors are reported, which would be required to adjust the preferred log weight ratio of all prey categories to the value estimated for cod eating cod. Apparently, these estimated condition factors are in a number of cases where information is available (e.g. Norway pout,whiting) quite beyond the possible range. It must be concluded that preferred prey size may not be constant among various organisms. This would in fact not seem unlikely, because for instance the selection mechanism for slowly moving animals (e.g. Aphrodite) should be different from the one for swimming organisms, of which swimming speed itself, and thus possible escape from the predator, is a function of size.

It should be noted that in applying the model frequently situations occur where no mathematical solution can be found for various reasons (e.g. outlying data poimts, data set limitations). A particular problem may result from the width of the size classes distinguished. If the real standard deviation of the preferred log weight ratio would be smaller than the log of the weight class width, characterizing a highly size selective predator, this might result in instability of the analyses. Moreover, since the estimated sigma's vary around a value of 1.0 whereas the average log of the weight class width is .86, the values given in table XX might be biassed, because the size class definition sets an underlimit to the estimated values of sigma (DEKKER, personal communication). To solve this problem the prey and predator size classes should be further refined.

Another approach followed by DEKKER (1983) has been to estimate prey size preference parameters for a specific prey category (cod eating Gadidae) from various subsets of the total data base in order to study variation due to years, seasons and areas (table XVII). Again it was not possible to arrive at a solution in all cases. Compared to the variation in eta and sigma observed between various prey, the variation within a prey category due to spatial and seasonal effects appears to be relatively small. Fig 6 compares the estimated relative prey length distributions as preferred by cod and as found in stomachs for two different quarters. Although the difference is estimated to be statistically significant, the absolute difference in preference is probably small enough to be considered negligible for any practical applications.

For further details the reader is referred to the original paper (DEKKER, 1983). It would be worthwhile to extent such analyses to other predator species, although even more difficulties with the estimations procedure are envisaged because of the reduced number of predator size classes available.

3. THE FOLLOW UP

According to the time schedule planned it was hoped that the data could be worked up by May 1982, but this has proved to have been far too optimistic. Progress reports with preliminary results have been submitted to ICES in 1981 and 1982 (DAAN, 1981; ANONYMUS,1982) and only in 1983 comprehensive species reports have become available (DAAN, 1983; DEKKER, 1983; GISLASON,1983; HISLOP et al,1983; MEHL & WESTGARD, 1983). Primary analysis and computer processing have taken much more time than originally envisaged.

One conclusion that can be drawn from the preliminary results presented here is that the consumption by at least some of the species studied, particularly cod and whiting, adds a significant mortality factor to the younger age groups of a variety of species among the exploited species complex and that major changes in the estimated natural mortality rate in these age groups as compared to the traditional values used in single species assessment must be envisaged. Since the predator stocks as well as the prey stocks vary from year to year, the predation mortalities exersized will vary correspondingly.

Firstly, this can be expected to severely reduce the usefullness of the yield per recruit concept. Clearly, predation affects mainly young fish and assessments of the adult stocks may hardly be affected. However, in giving advice on total allowable catches it still is a general rule in ICES that these are based on yield per recruit considerations. Since recruitment is taken at age 1, this means that the yield per recruit is affected by at least one year of high and variable natural mortality depending on the predator stocks that happen to be around. Since the effect of the predator stocks on the various prey stocks will be different, it will be virtually impossible to control predation mortality in individual prey species, and thus yield per recruit, by appropriate management of the predator stocks. Therefore, it seems unlikely that, if multispecies assessment is to be generally accepted, yield per recruit considerations in the traditional sense will continue form a sound basis for the advice on fish stock management. New criteria have to be found for managing the total fish stock assemblage.

Secondly, the estimated impact of discarding of small fish by human consumption fleets and the effect of industrial fisheries exploiting juveniles of human consumption species as by-catch will necessarily become reduced compared to former assessments for various species, if the higher natural mortalities are implemented. In the North Sea, where industrial fisheries account for a major part of the total fish landings, this will strongly affect any further development in management strategies.

Thirdly, an analysis during a recent meeting on estimated year class strength from research vessel surveys (ANONYMUS, 1983d) revealed that recruitment indices from various independent surveys were consistently more highly correlated than any of these survey indices with VPA estimates of recruitment. This would seem to imply that research vessel surveys give an adequate measure of the number of young fish in the sea, whereas the traditional VPA doesnt, at least for the younger age groups. The incorporation of variable predation mortalities in the MSVPA might well result in a better alignment of the survey indices and the estimated recruitment values. At present this is still wishful thinking but any improvement in the correlations obtained might be interpreted as a validation of the MSVPA.

From these considerations it appears to be a matter of great urgency to proceed with trial runs of the MSVPA, the essential data now being available, and to study the integrated impact of the estimated consumption rates on the population dynamics of the various fish stocks. Also new management objectives have to be found and it is my personal conviction that the biology is not going to give us adequate answers. More than before it will depend largely on the economists to find the goal function of fisheries.

The Stomach Sampling Project yielding its final results, one may wonder if all essential questions have been adequately resolved by this unique exersize. The project has been concerned with obtaining a reliable estimate of food composition for just one reference year (1981) and this will allow tuning of the predation rate in that year to the estimated stock sizes within the MSVPA. However, the relative preference has to be assumed constant in order to allow extrapolation to other years, where other predator/prey aggregates prevail. The only way of testing that preference does not change is to repeat the exersize once more. The decision on a follow up will greatly depend on the balance of the costs and of value of the results. The project has undoubtedly been expensive but even so it represents only a minor entry in the total costs of providing the best possible advice on North Sea fish stock assessment. It appears to me that, if measured by the progress that can now be made in providing better advice, the exersize has certainly been cost effective and a follow up would seem appropriate.

Acknowledgements.

The ICES Stomach Sampling Project has involved a large number of people taking up the additional working load of sampling stomachs at sea during already heavily loaded research vessel cruises. Also some laboratories have literally become buried under boxes of samples and sorting through these samples amidst the smells from partly digested material and formalin has not been a very appealing task. It is impossible to acknowledge all these people, but it should be remembered, that results of the quality reported here could only have become available through the positive interest and the international cooperation through ICES of a very large number of people.

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4. REFERENCES

ANDERSEN, K.P., 1982 - An interpretation of the stomach contents of fish in relation to prey abundance. Dana 2: 1-50

ANDERSEN, K.P., & E.URSIN, 1978 - A multispecies analysis of the effects of variations of effort upon stock composition of eleven North Sea fish species. Rapp. P.-v. Reun. Cons. int. Explor. Mer, 172 : 5-9

ANDERSEN, K.P., & E.URSIN, 1977 - A multispecies extension to the Beverton and Holt theory of fishing, with accounts of phosphorous circulation and primary production. Meddr Danm. Fisk.- og Havunders., N.S. 7 : 319-435

ANONYMUS, 1980 - Report of the ad hoc Working Group on Multispecies Assessment Model Testing. ICES C.M. 1980/G:2

ANONYMUS, 1981 - Draft Manual for the Stomach Sampling Project. (Report available from the Netherlands Institute for Fishery Investigations)

ANONYMUS, 1982 - Report of the meeting of the coordinators of the North Sea Stomach Sampling Project 1981. ICES C.M. 1982/G:33

ANONYMUS, 1983a - Report of the North Sea Roundfish Working Group. ICES C.M. 1983/Assess:18

ANONYMUS, 1983b - Herring Assessment Working Group for the area south of 62 N. ICES C.M. 1983/Assess:9

ANONYMUS, 1983c - Industrial Fisheries Working Group. ICES C.M. 1983/Assess:7

ANONYMUS, 1983d - Report of the International Gadoid Survey Working Group. ICES C.M. 1983/G:62

ARNTZ, W.E. & E.URSIN, 1981a - On the estimation of food preference parameters when food concentrations are not known. ICES C.M. 1981/L:40

ARNZT, W.E. & E.URSIN, 1981b - Estimates of food consumption parameters for dab (Limanda limanda) utilizing information on food concentrations. ICES C.M. 1981/L:41

BEVERTON, R.J.H. & S.J.HOLT, 1957 - On the dynamics of exploited fish populations. Fishery Invest., Lond.(2) 19 : 1-533

DAAN, N., 1973 - A quantitative analysis of the food intake of North Sea cod, Gadus morhua. Neth. J. Sea Res. 8 (1) : 27-48

DAAN, N., 1975 - Consumption and production in North Sea cod, Gadus morhua: an assessment of the ecological status of the stock. Neth. J. Sea Res. 9 (1) : 24-55

DAAN, N., 1983 - Analysis of the cod data collected during the 1981 Stomach Sampling Project. ICES C.M. 1983/G:61

DEKKER, W., 1983 - An application of the Andersen Consumption model in estimating prey size preference of North Sea cod. ICES C.M. 1983/G:63

GISLASON, H., 1983 - A preliminary estimate of the yearly intake of fish by Saithe in the North Sea. ICES C.M. 1983/G:52

HELGASON, T., & H.GISLASON, 1979 - VPA-analysis with species interaction due to predation. ICES C.M. 1979/G:52

HISLOP, J.R.G., A.P.ROBB, M.A.BROWN & D.W.ARMSTRONG, 1983 - A preliminary report on the analysis of the whiting stomachs collected during the 1981 North Sea stomach sampling project. ICES C.M. 1983/G:59

MEHL, S. & T.WESTGARD, 1983 - The diet and consumption of mackerel in the North Sea. ICES C.M. 1983/H:34

NOAA, 1978 - NODC Taxonomic Code. Second edition. National Oceanographic Data Center, Washington, DC.

POPE, J.G., 1979 - A modified Cohort Analysis in which constant natural mortality is replaced by estimates of predation levels. ICES C.M. 1979/H:16

SPARRE, P., 1979 - Some rematks on the application of yield/recruit curves in estimation of maximum sustainable yield. ICES C.M. 1979/G:41

SPARRE, P., 1980 - A goal function of fisheries (Legion analysis). ICES C.M. 1980/G:40

URSIN, E., 1973 - On the prey size preference of cod and dab. Meddr Danm. Fisk.- og Havunders., N.S. 7 : 85-98

URSIN, E. & K.P.ANDERSEN, 1978 - A method of predicting the biological effects of eutrophication in the North Sea. Rapp. P.-v. Reun. Cons. int. Explor. Mer, 172 : 366-377

Fig. 1
Flow chart of operations necessary to achieve the aim of using stomach content data as input for multispecies assessment.

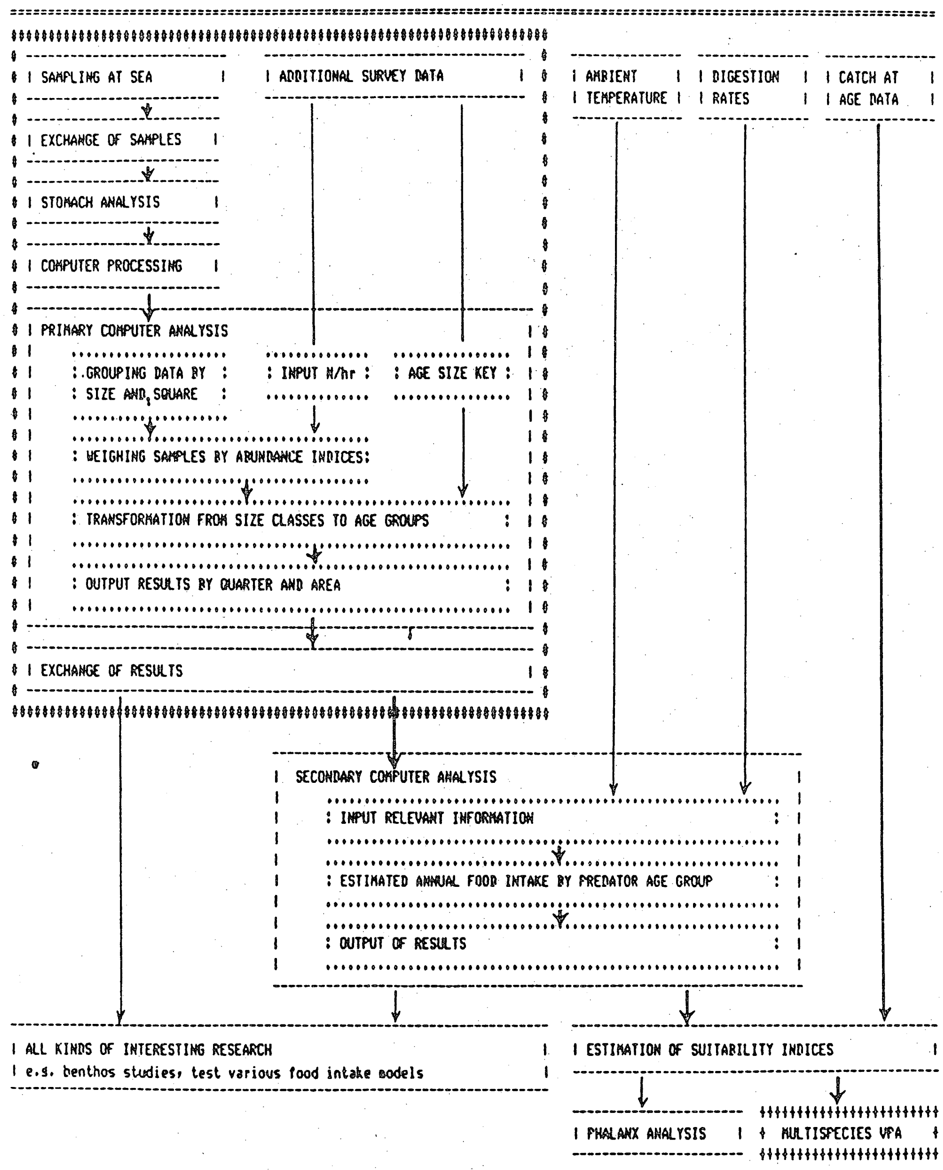


Fig. 2
Format for recording sample information and stomach content data (.... : mandatory computer input; ----- : optional information).

ICES STOMACH SAMPLING PROJECT

A. sample information

PREDATOR CODE	....	Ship	------------
SIZE CODE	....	Date	------------
YEAR	....	Haul	------------
QUARTER	.	Time	------------
COUNTRY	....	Depth	------------
SQUARE	....		
N-food	...		
N-regurgitated	...		
N-empty	...		
N-sample	...		

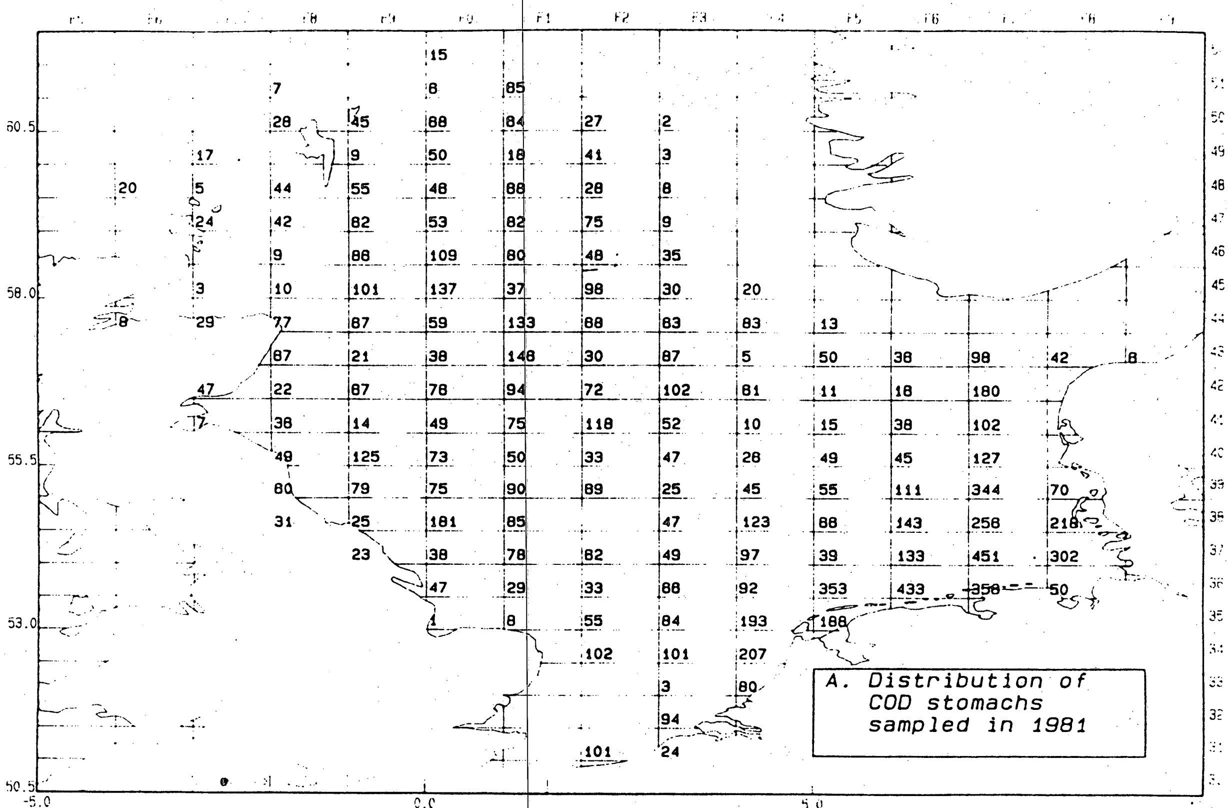
B. stomach contents

	Taxonomic unit	PREY CODE	SIZE CODE	WEIGHT(g)	NUMBER	Additional information
1	-------------	....	....	......	......	--------------------
2	-------------	....	....	......	......	--------------------

etcetera

Fig. 3

Spatial distribution of sampling intensity for COD (A), WHITING (B), SAITHE (C) and MACKEREL (D).



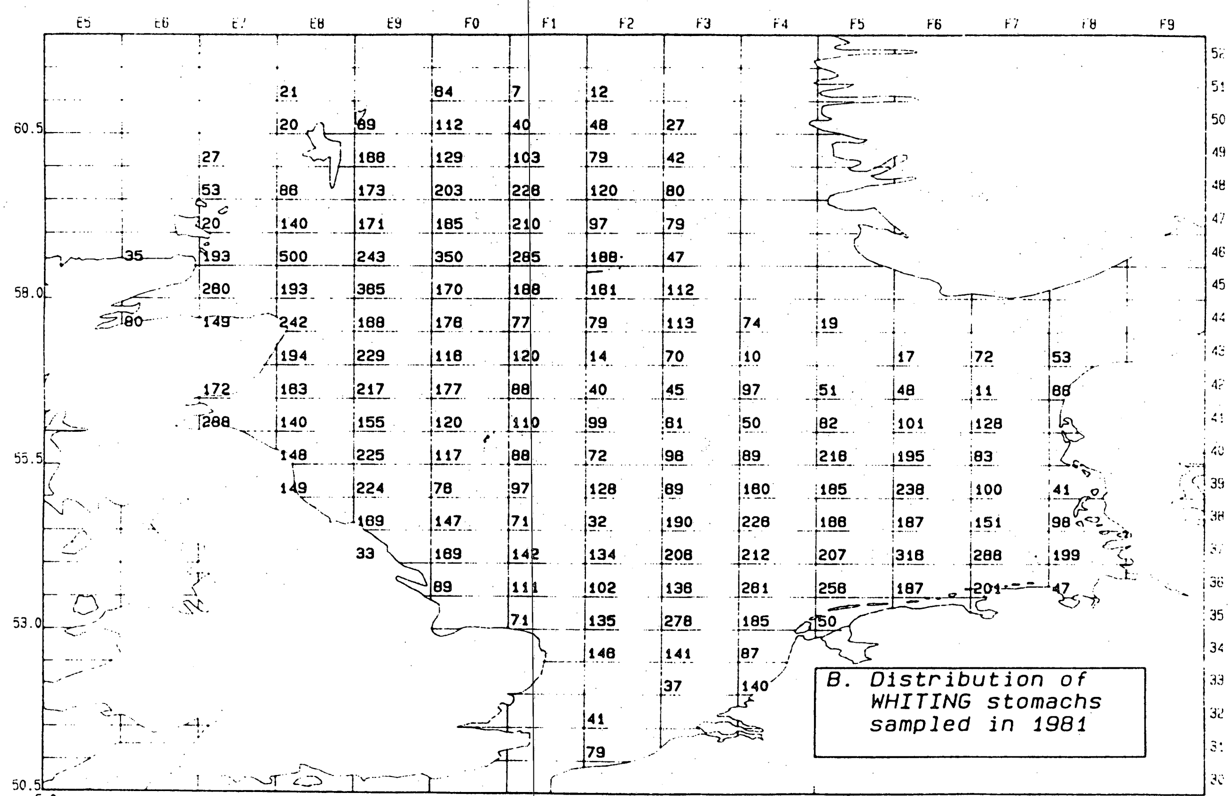
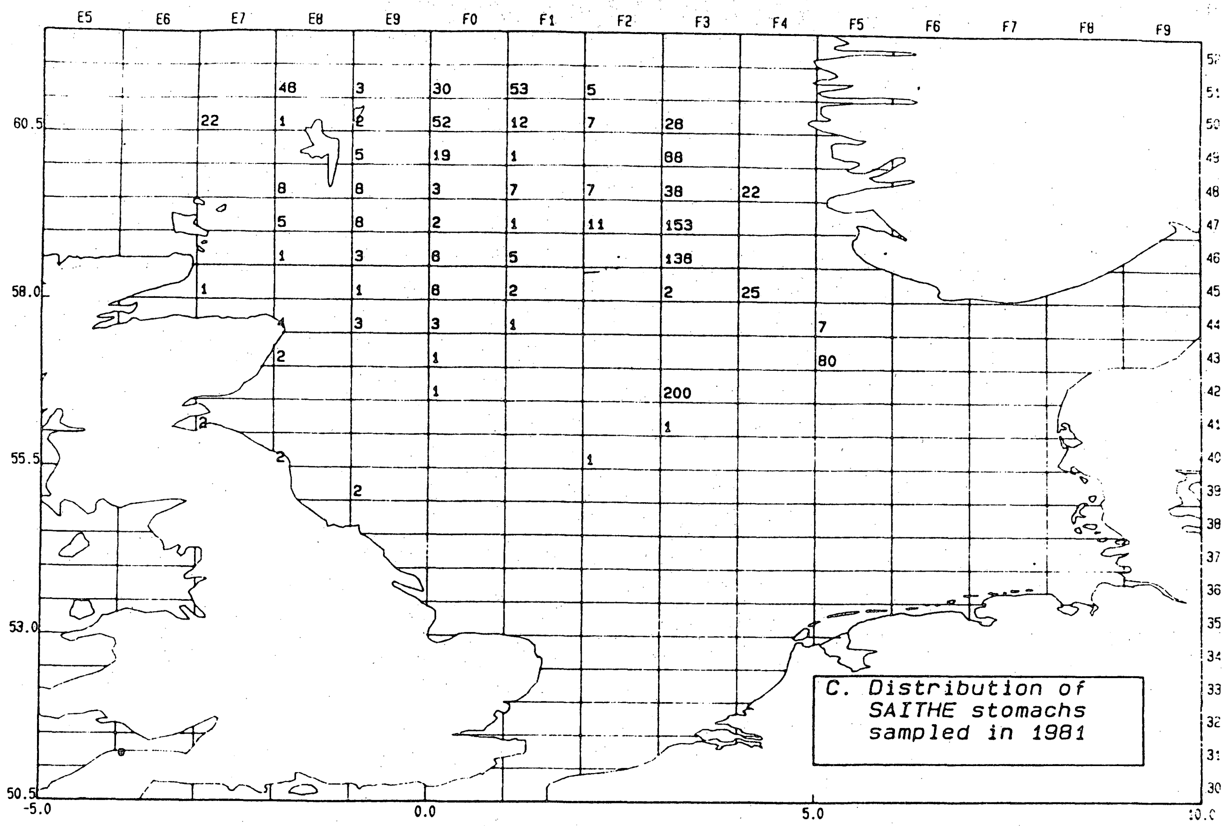
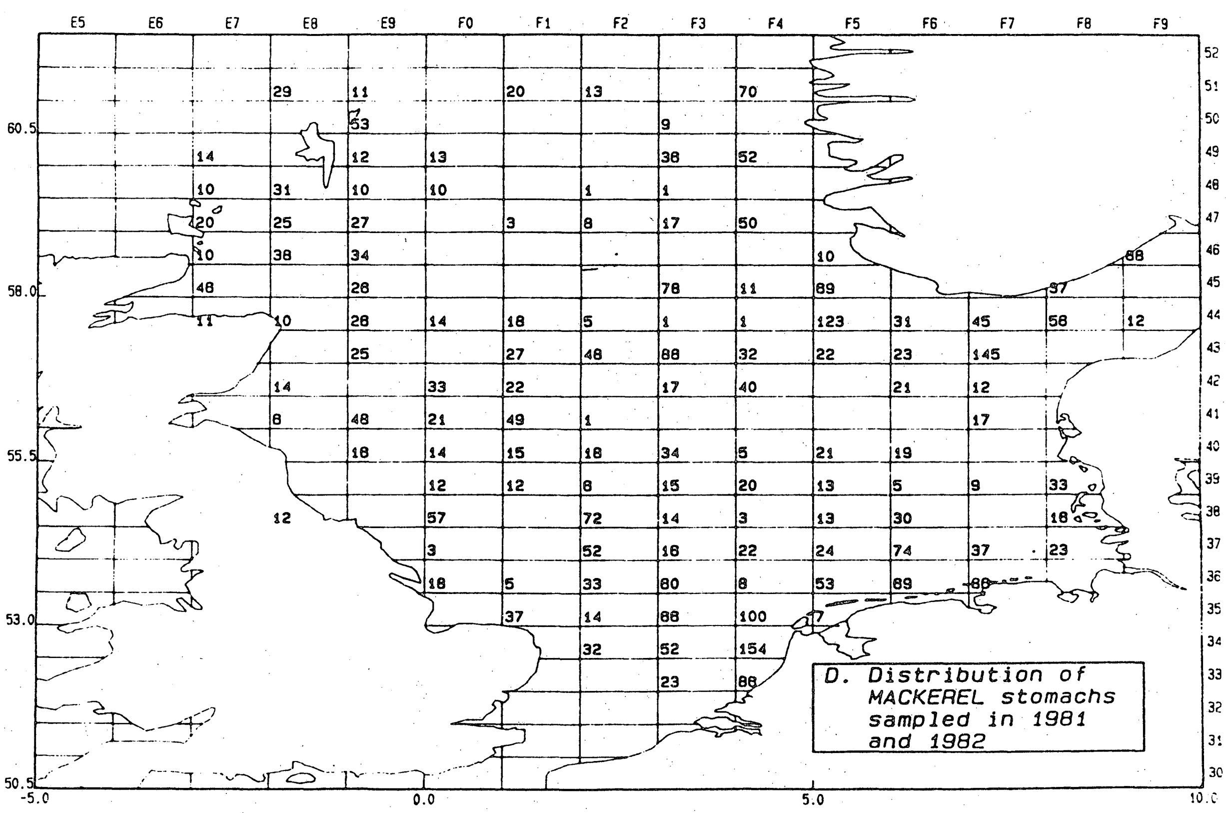


Fig. 3 (ctd)



C. Distribution of SAITHE stomachs sampled in 1981



D. Distribution of MACKEREL stomachs sampled in 1981 and 1982

Fig. 4
Prey size distribution by predator size in number percentages for COD (A) and in weight percentages for WHITING (B), SAITHE (C) and MACKEREL (D).

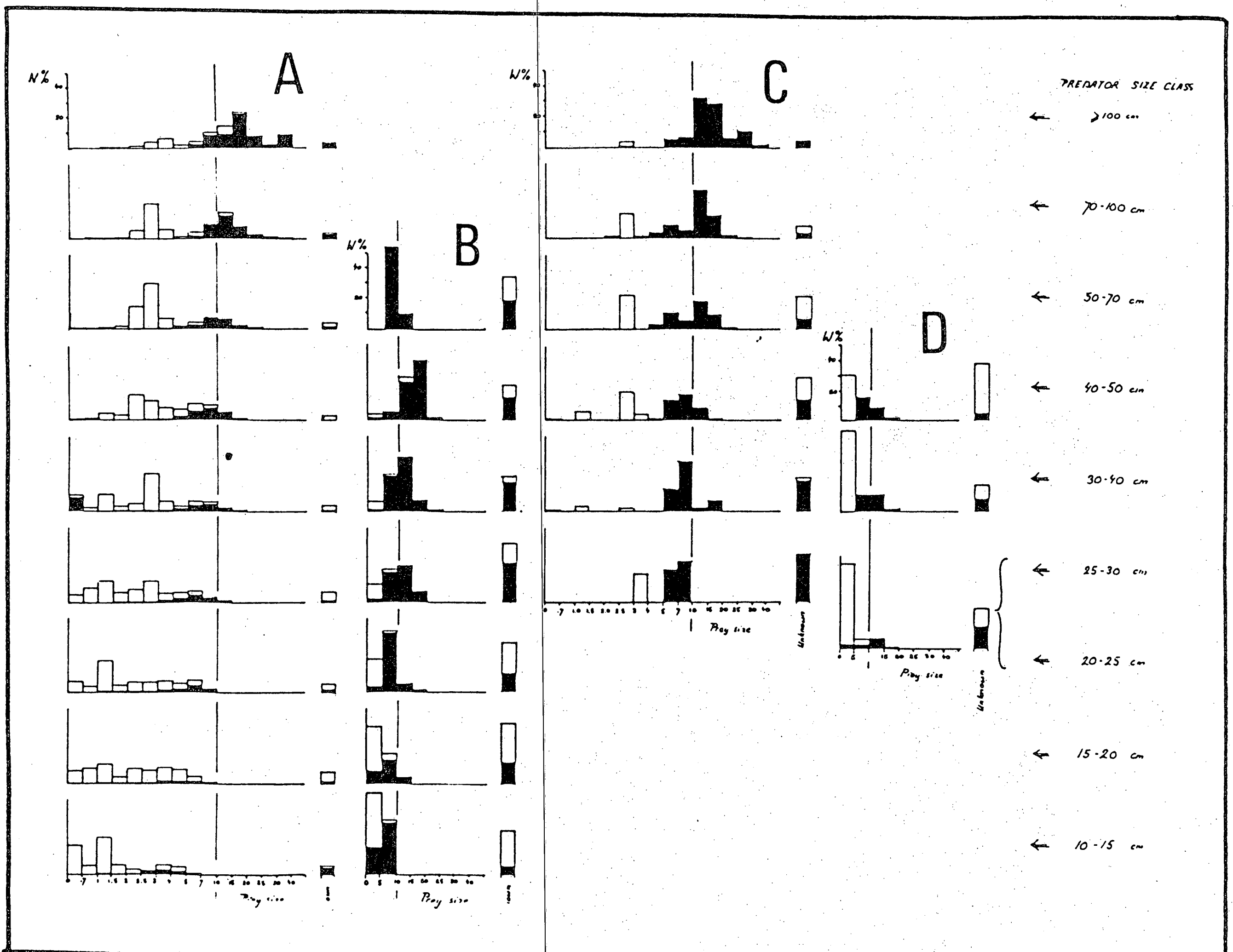


Fig. 5
Observed mean prey length (thin line) plus/minus standard deviations (dotted vertical lines) in stomachs against predator length and the estimated preference function for the whole predator size range (thick line) with standard deviations (heavy dotted lines) for 'COD EATING GADIDAE'.

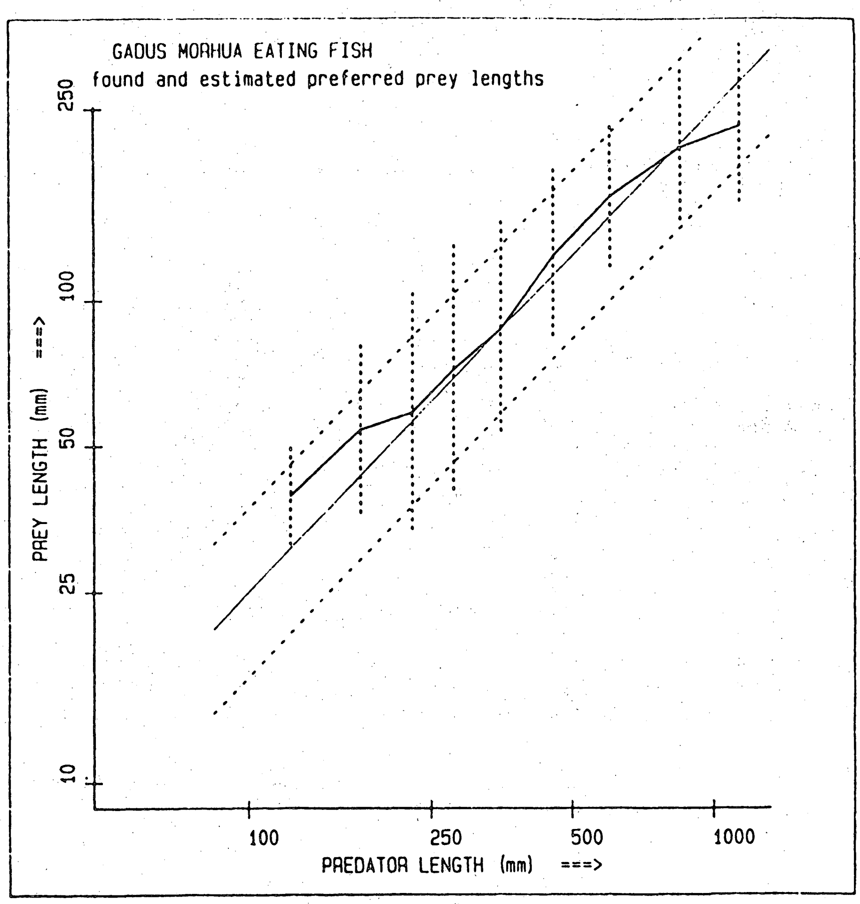


Fig. 6
Relative prey length distribution as prefeered (———) and as found in cod stomachs (—.—.—) for two different quarters.

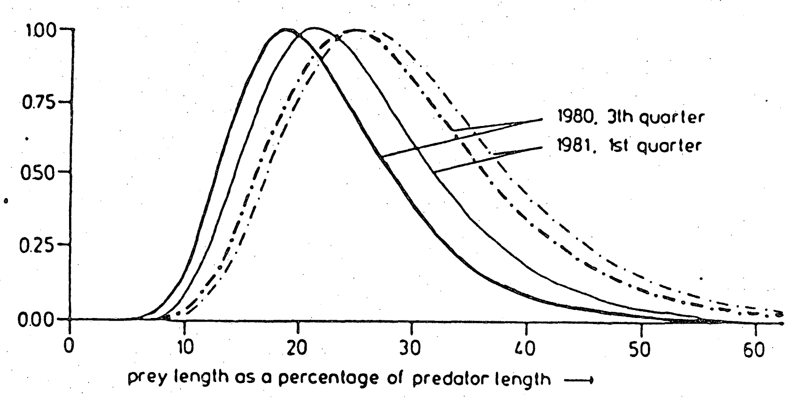


TABLE I

Definition of size class codes, applying to both predator and prey.

SIZE CLASS	CODE	SIZE CLASS	CODE	SIZE CLASS	CODE
eggs	0				
1.0 - 1.5 mm	1	1.0 - 1.5 cm	10	10 - 15 cm	100
1.5 - 2.0 mm	1.5	1.5 - 2.0 cm	15	15 - 20 cm	150
2.0 - 2.5 mm	2	2.0 - 2.5 cm	20	20 - 25 cm	200
2.5 - 3.0 mm	2.5	2.5 - 3.0 cm	25	25 - 30 cm	250
3.0 - 4.0 mm	3	3.0 - 4.0 cm	30	30 - 40 cm	300
4.0 - 5.0 mm	4	4.0 - 5.0 cm	40	40 - 50 cm	400
5.0 - 7.0 mm	5	5.0 - 7.0 cm	50	50 - 70 cm	500
7.0 - 10.0 mm	7	5.0 - 10.0 cm	70	70 - 100 cm	700
				100 - 150 cm	1000
				No information	9999

NB: The size class of an organism is in principle defined by its largest measure excluding appendages, but the following guidelines were used:

- Fish - length from snout to tip of tail.
- Crabs - maximum carapace width or total body length, whichever is the larger measure.
- Shrimps and Nephrops - total body length excluding claws (Standard carapace length to be reported under 'additional information').
- Cephalopods - length from mouth to end of body (Standard mantle length to be reported under 'additional information').
- Starfish - distance from the edge of disc to the tip of opposite arm.
- Brittle stars - disc diameter.
- Polychaetes - except for obvious exceptions (e.g. Aphrodite) code 9999 should be assigned, because length of these creatures is a highly inadequate measure of weight.

TABLE II

Number of stomachs sampled in 1981 by size group, species and quarter and totals (approximate estimates in brackets).

Quarter	Species	Size class 7-10	10-15	15-20	20-25	25-30	30-40	40-50	50-70	70-100	>=100	Total Nr of stomachs
1	Cod	1	113	253	532	610	854	460	557	683	117	4180
	Whiting		1525	1638	1623	1616	1250	176	4			7832
	Saithe							(3	109	208	16	336)
	Mackerel			(3	13	10)						28
	Haddock	not available										(4862)
2	Cod		37	180	330	370	538	391	374	180	19	2419
	Whiting		428	756	889	1161	924	53				4211
	Saithe						(14	6	42	105	3	170)
	Mackerel			(3	23	49	252	217)				556
	Haddock	not available										(1997)
3	Cod	90	355	232	87	186	372	347	367	260	49	2345
	Whiting		231	321	843	1131	1032	163	6			3727
	Saithe						(39	48	60	53	4	204)
	Mackerel				(33	275	550	209)				1008
	Haddock	not available										(702)
4	Cod	1	177	199	198	223	384	334	358	300	53	2227
	Whiting		524	519	729	821	740	110	4			3447
	Saithe							(46	82	78	166	407)
	Mackerel					(33	213	58)				214
	Haddock	not available										(857)

TABLE III

Average quarterly stomach content data for COD by size class .

A.

Year: 1981 Quarter: 1

Area: TOTAL NORTH SEA

SIZECLASS	7-10	10-15	15-20	20-25	25-30	30-40	40-50	50-70	70-100	>100
SAMPLING INFORMATION										
Nr SQUARES sampled	1	26	48	69	76	96	69	90	94	40
Nr STOMACHS sampled	1	113	253	532	610	854	460	557	683	117
Nr of Stomachs with FOOD		96	211	437	502	691	368	423	518	98
Nr of REGURGITATED Stom.		3	14	35	35	80	45	36	61	
Nr of EMPTY Stomachs	1	14	28	60	73	83	47	98	104	19
GENERAL RESULTS										
% EMPTY	100.000	15.107	14.619	12.063	13.355	12.196	13.571	16.080	14.049	15.569
Mean W Stomach Contents		.401	.657	1.114	2.018	5.196	14.048	37.147	86.146	164.911
Mean NR of Prey Items		2.444	2.694	2.819	4.303	4.842	4.954	5.495	5.915	7.194
AVERAGE W per PREY ITEM		.164	.244	.395	.469	1.073	2.835	6.761	14.563	22.924
Food Composition in WEIGHT % by Major Taxa										
PHAEOPHYTA								.02	.00	
CNIDARIA		1.47		.12	.02	.24	.06	.12	.09	
RHYNCHOCOELA					.01					
ANNELLIDA		14.39	9.90	7.70	11.06	11.32	7.13	4.52	2.34	1.00
GASTROPODA		7.82	3.98	2.92	2.86	3.03	.54	.49	.31	.28
BIVALVIA		5.33	2.30	9.81	5.40	8.40	2.86	.42	.16	.07
SCAPHOPODA						.00		.00		
CEPHALOPODA				2.79	5.28	2.49	.53	.70	.35	.24
PYCNOGONIDA				.72	.61					
CRUSTACEA		36.98	61.10	45.12	42.52	31.64	32.48	14.33	8.20	5.34
SIPUNCULA				.15					.00	
ECHIURA					.84	.57	1.16	.34	.02	
PRIAPULIDA				.06		.08	.04			
ECHINODERMATA			.11	.15	.17	.19	1.22	.85	.19	.05
CHAETOGNATHA					.11	.06				
UROCHORDATA						.04			.00	
CEPHALOCHORDATA				.00		.05	.11	.00		
AGNATHA					.06					
GNATHOSTOMATA		34.00	22.60	30.42	31.04	41.84	49.66	72.96	88.30	93.02
UNKNOWN				.01					.02	
WEIGHT % Commercial Species										
GADUS MORHUA						.86	1.47	1.33	10.16	8.98
MELANOGRAMMUS AEGLEFINUS				.70	2.09	2.95	4.45	9.15	19.78	1.65
MERLANGIUS MERLANGUS		1.11		.02	.27	6.73	6.62	19.60	33.24	28.61
TRISOPTERUS ESMARKI				5.16	6.86	4.24	2.89	5.63	3.49	.55
CLUPEA HARENGUS					.90	1.86	3.03	6.53	2.26	2.89
CLUPEA SPRATTUS		7.13	4.06	12.14	5.93	11.34	7.52	4.87	2.79	2.79
AMMODYTIDAE		.60	.44	1.49	.62	4.64	13.20	14.84	.32	.03
PLEURONECTES PLATESSA									1.05	5.06
SOLEA SOLEA						.13	.07	.00	.49	
SCOMBER SCOMBLR										
NEPHROPS NORVEGICUS				1.29	.28	.14	.85	1.78	3.54	1.24
CRANGON CRANGON		25.14	32.06	15.06	4.10	2.12	1.12	.51	.21	.01

TABLE III(ctd)

Average quarterly stomach content data for COD by size class .

B.

Year: 1981 Quarter: 2

Area: TOTAL NORTH SEA

SIZECLASS	7-10	10-15	15-20	20-25	25-30	30-40	40-50	50-70	70-100	>100
SAMPLING INFORMATION										
Nr SQUARES sampled		7	26	44	50	74	58	64	44	13
Nr STOMACHS sampled		37	180	330	370	538	391	374	180	19
Nr of Stomachs with FOOD		33	153	276	309	406	331	276	149	17
Nr of REGURGITATED Stom.				3	20	82	23	76	29	2
Nr of EMPTY Stomachs		4	27	51	41	50	37	22	2	
GENERAL RESULTS										
% EMPTY		17.460	16.711	19.730	12.640	10.097	10.113	6.839	1.087	
Mean W Stomach Contents		.328	.793	1.304	3.044	7.927	14.920	36.300	108.504	189.010
Mean NR of Prey Items		2.599	3.783	3.953	7.338	15.752	9.351	15.396	96.116	18.071
AVERAGE W per PREY ITEM		.126	.209	.330	.415	.503	1.595	2.357	1.128	10.459
Food Composition in WEIGHT % by Major Taxa										
CNIDARIA						.48	.07	.03	.11	
ANNELLIDA		9.67	5.98	17.27	7.92	4.23	8.44	3.88	3.82	6.58
GASTROPODA			2.23	1.27	1.39	1.26	1.64	.03	.06	
BIVALVIA			3.64	5.49	1.57	1.37	.51	.13		
SCAPHOPODA								.00		
CEPHALOPODA				.70	.10	.10	.01	.01	.16	.13
CRUSTACEA		58.72	45.72	43.03	39.13	34.77	36.57	34.83	40.55	29.55
SIPUNCULA					.05					
ECHIURA		3.19	.09	.60	.42	.00				
PRIAPULIDA					.08	.05	.09	.01		
ECHINODERMATA				.41	1.55	3.75	7.45	2.47	.00	
CHAETOGNATHA			.26							
UROCHORDATA				.18		.16				
CEPHALOCHORDATA			.05				.00			
GNATHOSTOMATA		28.43	42.02	31.04	47.77	53.82	44.96	58.57	55.27	63.73
WEIGHT % Commercial Species										
GADUS MORHUA			2.41	1.03	.76	1.49	.83	1.86	6.02	
MELANOGRAMMUS AEGLEFINUS					1.15	2.58	1.66	5.76	6.43	.54
MERLANGIUS MERLANGUS						.40	1.97	5.67	9.08	19.27
TRISOPTERUS ESMARKI				2.87		2.59	1.18	4.51	4.78	.48
CLUPEA HARENGUS		4.71	.76	.07	.09	.70	1.68	1.48	4.53	1.17
CLUPEA SPRATTUS			.08	1.46	.39	4.27	4.10	2.58	.54	2.85
AMMODYTIDAE			17.90	14.23	38.44	36.48	19.15	12.93	5.92	1.54
PLEURONECTES PLATESSA				.01			.00	.16		2.11
SOLEA SOLEA						.01	.13	.06		
SCOMBER SCOMBER										
NEPHROPS NORVEGICUS						.28	.69	5.21	10.58	21.72
CRANGON CRANGON		32.11	21.23	8.00	3.81	.98	.65	.00		.02

TABLE III (ctd)

Average quarterly stomach content data for COD by size class .

C .

Year: 1981 Quarter: 3

Area: TOTAL NORTH SEA

SIZECLASS	7-10	10-15	15-20	20-25	25-30	30-40	40-50	50-70	70-100	>100
SAMPLING INFORMATION										
Nr SQUARES sampled	6	24	23	20	39	58	60	48	38	13
Nr STOMACHS sampled	90	355	232	87	186	372	347	367	260	49
Nr of Stomachs with FOOD	70	307	210	64	147	254	199	229	145	26
Nr of REGURGITATED Stom.		2		2	10	67	87	74	80	4
Nr of EMPTY Stomachs	20	46	22	21	29	51	61	64	35	19
GENERAL RESULTS										
% EMPTY	22.331	23.866	7.805	21.568	14.339	12.803	12.366	13.237	10.592	12.000
Mean W Stomach Contents	.087	.329	.919	1.467	2.306	6.410	16.906	38.980	133.370	376.461
Mean NR of Prey Items	3.925	1.620	2.650	4.554	5.287	9.772	8.702	35.790	7.787	4.180
AVERAGE W per PREY ITEM	.022	.203	.346	.322	.436	.656	1.942	1.089	17.127	90.063
Food Composition in WEIGHT % by Major Taxa										
CNIDARIA					.11			.00	.00	
ANNELLIDA	1.71	.82	2.51	5.16	8.90	4.94	6.79	4.68	11.08	.40
GASTROPODA					.66	2.26	.40	.10	.01	
BIVALVIA		7.08				.02	1.00	.60	.00	
SCAPHOPODA							.00			
CEPHALOPODA							.64		.16	.14
PYCNOGONIDA					.01					
CRUSTACEA	69.15	67.66	49.45	51.66	50.74	37.07	29.89	36.56	16.96	11.98
PRIAPULIDA			.15			.05				
ECHINODERMATA		.07	.03		.66	.14	1.07	.78	.39	.01
GNATHOSTOMATA	29.13	24.38	47.84	43.18	38.91	55.51	60.20	57.27	71.36	87.45
WEIGHT % Commercial Species										
GADUS MORHUA						12.94		.69	1.85	
MELANOGRAMMUS AEGLEFINUS					1.76	5.70	8.29	9.89	12.84	32.97
MERLANGIUS MERLANGUS			17.00	2.70	18.67	12.20	5.58	2.61	3.60	1.58
TRISOPTERUS ESMARKI					3.08	2.17	16.22	27.00	16.06	1.06
CLUPEA HARENGUS						5.52	7.40	4.21	15.68	
CLUPEA SPRATTUS						2.88	5.43	.10	.00	
AMMODYTIDAE		.00	14.41	23.24	9.08	6.86	9.25	3.36	.55	
PLEURONECTES PLATESSA						.12				14.20
SOLEA SOLEA						.13			.21	.24
SCOMBER SCOMBER									2.19	4.55
NEPHROPS NORVEGICUS				1.82	.40	.87	2.74	9.73	11.17	6.51
CRANGON CRANGON	21.37	45.06	32.99	5.60	1.86	.24	.75		.37	

TABLE III(ctd)

Average quarterly stomach content data for COD by size class .

D.

Year: 1981 Quarter: 4

Area: TOTAL NORTH SEA

SIZECLASS	7-10	10-15	15-20	20-25	25-30	30-40	40-50	50-70	70-100	>100
SAMPLING INFORMATION										
Nr SQUARES sampled	1	32	33	36	37	55	49	42	37	9
Nr STOMACHS sampled	1	177	199	198	223	384	334	358	300	53
Nr of Stomachs with FOOD	1	125	172	169	188	328	292	333	253	49
Nr of REGURGITATED Stom.		14	2	2	6	21	18	16	38	
Nr of EMPTY Stomachs		38	25	27	29	35	24	9	9	4
GENERAL RESULTS										
% EMPTY		21.291	10.421	14.733	14.430	10.651	6.374	3.488	3.519	2.797
Mean W Stomach Contents	.230	.258	.625	1.309	2.794	5.773	13.407	33.024	116.655	148.189
Mean NR of Prey Items	4.000	1.973	2.272	2.290	3.241	4.516	5.649	7.205	7.383	7.079
AVERAGE W per PREY ITEM	.057	.130	.275	.572	.862	1.278	2.373	4.583	15.800	20.934
Food Composition in WEIGHT % by Major Taxa										
PORIFERA					.03					
CNIDARIA						.04	.17	.07	.01	
ANNELLIDA		7.90	2.26	4.97	6.06	7.68	8.18	8.75	1.26	1.50
GASTROPODA			1.63		.98	1.68	.95	.36	.66	
BIVALVIA					2.94	2.09	.72	.14	.02	.01
CEPHALOPODA			.18	.71		.60	.19	.23	17.19	.51
CRUSTACEA	100.00	62.00	75.88	68.96	51.47	51.96	49.24	47.60	9.89	5.93
ECHIURA				.47	.14	.70	.21	.08		
PRIAPULIDA				.10		5.14	2.38			
ECHINODERMATA					.24	.08	.04	.09	.00	
UROCHORDATA				.35	.43					
GNATHOSTOMATA		30.09	20.02	24.41	37.70	30.04	37.89	42.66	70.95	92.04
WEIGHT % Commercial Species										
GADUS MORHUA					1.10			.31	9.25	1.57
MELANOGRAMMUS AEGLEFINUS				1.17	6.95	7.46	12.33	4.55	13.13	31.39
MERLANGIUS MERLANGUS						.33	.14	1.68	15.27	14.12
TRISOPTERUS ESMARKI		14.49			5.58	6.18	4.33	8.50	5.23	2.19
CLUPEA HARENGUS					.03		5.80	.17	.46	
CLUPEA SPRATTUS				.04	.50	.01	.97	1.34	.82	
AMMODYTIDAE			.59	3.78	9.47	5.93	3.59	.81	4.31	8.80
PLEURONECTES PLATESSA								.12		.25
SOLEA SOLEA						.11	.22	.37	.05	1.32
SCOMBER SCOMBER								15.33	1.97	
NEPHROPS NORVEGICUS						.95	4.79	1.21	.55	
CRANGON CRANGON		24.70	44.58	45.53	9.41	14.49	9.74	2.08	.05	.00

TABLE IV

Average percentage weight of exploited fish species in stomachs of COD by age group.

PREDATOR Age group		1	2	3	4	5	6+
PREY	Cod	2.57	1.43	2.81	5.99	6.67	3.91
	Haddock	4.06	5.92	8.99	12.57	13.78	17.76
	Whiting	3.47	4.35	8.95	12.78	13.62	14.64
	Norway pout	3.48	7.59	9.32	8.07	7.24	2.28
	Herring	1.76	3.03	4.50	5.78	5.50	1.71
	Sprat	3.08	3.66	1.93	1.20	1.19	1.43
	Sandeels	11.67	11.10	8.04	4.13	2.84	2.69
	Plaice	.02	.03	.03	.23	.65	4.26
	Sole	.06	.11	.08	.16	.20	.38
	Mackerel	.02	1.91	1.63	1.14	1.10	1.18
	Saithe	-	-	-	-	-	-
	TOTAL	30.19	39.13	46.28	52.05	52.79	50.24

TABLE V

Annual average nr of cod, haddock and whiting per 1000 stomachs of COD by age group.

Predator age group		1	2	3	4	5	6+
Prey : COD							
Age group:	0	15.	28.	12.	16.	18.	7.
	1	.037	1.5	11.	43.	56.	37.
	2	.0001	.007	.77	7.9	12.	13.
	3	-	.005	.028	.85	1.4	2.3
Prey : HADDOCK							
Age group :	0	19.	36.	69.	39.	15.	67.
	1	1.2	11.	34.	82.	86.	112.
	2	.038	1.3	15.	73.	85.	21.
	3	-	.009	.32	2.6	4.2	28.
	4	-	.000051	.015	.093	.22	2.6
	5	-	-	.000051	.004	.009	.065
	6+	-	-	.000051	.004	.009	.065
Prey : WHITING							
Age group :	0	20.	17.	7.	10.	10.	6.
	1	.74	12.	43.	76.	138.	135.
	2	.002	2.6	22.	76.	102.	169.
	3	-	.28	3.5	14.	20.	34.
	4	-	.052	.82	2.6	3.2	5.7
	5	-	.010	.26	.37	.41	.76
	6+	-	.003	.037	.12	.15	.27

TABLE VI

Estimated number by age group of cod, haddock and whiting consumed by the average COD stock in 1981 (P) in comparison with estimated number in the sea at the beginning of 1981 (N) from VPA (ANONYMUS,1983). Ratio: P/N. (N and P in '000 fish)

	COD			HADDOCK			WHITING		
Age group	N	P	Ratio	N	P	Ratio	N	P	Ratio
0	?	2534790	?	2278424	3768548	1.65	1603786	2078825	1.29
1	131415	151603	1.15	340792	593396	1.74	497750	650129	1.31
2	313486	17535	.056	1018240	222952	.22	892674	286494	.32
3	47499	1875	.039	255349	9715	.038	464707	46726	.10
4	16251	-	.000	33406	617	.018	147615	8898	.060
5	8987	-	.000	5211	17	.003	33086	1765	.053
[illegible]	7221	-	.000	1205	15	.012	16719	418	.025

TABLE VII

Comparison of regression parameters of mean weight stomach contents (w) against mean length (L) of North Sea COD after log transformation (Ln w = Ln a + b.Ln L) for various data sets. Feeding coefficient phi has been calculated assuming that the model w = phi . L^3 applies to all sets.

Source	Stomach Sampling Project	DAAN, 1982	DAAN, 1983
Year	1981	1980	1966-72
Area	Total North Sea	Southern North Sea	Total North Sea
Nr of stomachs	11171	8841	7430
Nr of data points	36	10	47
Correlation coeff.	.993	.992	.990
b	3.16	3.08	3.02
Sb	.063	.014	.07
95% confid.limits b	3.01-3.33	2.75-3.41	2.89-3.15
a	.000085	.000112	.000147
phi	.000151	.000147	.000158

TABLE VIII

Average percentage weight of exploited fish species in stomachs of WHITING by age group.

PREDATOR Age group	0	1	2	3	4	5	6+
PREY : Cod	.02	.06	.12	.21	.16	.16	.15
Haddock	.10	2.36	6.33	8.16	10.48	11.50	16.23
Whiting	.42	1.59	1.80	2.73	4.06	5.59	8.09
Norway pout	1.17	4.07	9.03	15.00	18.66	17.49	17.00
Herring	.71	1.46	8.62	9.88	9.31	8.62	6.47
Sprat	2.15	9.43	13.43	13.81	12.48	11.20	8.09
Sandeels	18.36	33.63	23.37	19.30	14.98	11.85	11.89
Plaice	-	-	-	-	-	-	-
Sole	.13	.02	.01	.01	.01	.01	+
Mackerel	-	-	+	.04	.11	.14	.43
Saithe	-	-	-	-	-	-	-
TOTAL	23.06	52.62	62.71	69.14	70.25	66.56	68.35
TOTAL FISH	34.02	61.36	75.10	82.59	85.95	86.65	86.28

TABLE IX

Estimated numbers of exploited fish species by age group consumed per 1000 WHITING of each age in 1981.

Predator age group		0	1	2	3	4	5	6+
Prey : COD								
Age group:	0	20.	1385.	1296.	4377.	8579.	7852.	8756.
	1	-	1.	5.	1.	-	-	-
Prey : HADDOCK								
Age group :	0	34.	1302.	7639.	9595.	23115.	30292.	48144.
	1	.23	59.	79.	451.	1060.	1151.	1478.
	2	.01	.12	5.	16.	26.	30.	38.
	3	-	-	-	.002	.002	.01	.02
	4	-	-	-	+	+	.002	.004
Prey : WHITING								
Age group :	0	182.	1837.	5901.	7183.	8097.	7876.	7636.
	1	-	1.17	48.	405.	1109.	2011.	3843.
	2	-	-	1.01	3.	16.	48.	110.
Prey : N. POUT								
Age group :	0	526.	8519.	28483.	41273.	54849.	66190.	64817.
	1	1.	309.	1305.	5071.	9205.	9767.	11514.
	2	-	2.	127.	774.	1693.	1904.	2461.
	3	-	-	1.48	15.	38.	44.	61.
Prey : HERRING								
Age group :	0	393.	2705.	8764.	16368.	20902.	23501.	19091.
	1	-	482.	3916.	6161.	7939.	8167.	8759.
	2	-	-	2.	27.	73.	80.	90.
Prey : SPRAT								
Age group :	0	593.	2728.	795.	439.	328.	299.	206.
	1	49.	4048.	7375.	12274.	14050.	16338.	14298.
	2	3.	195.	1556.	3993.	5594.	6486.	5616.
	3	-	2.4	25.	121.	219.	280.	239.
	4	-	2.2	.66	3.	7.	7.	7.
Prey : SANDEELS								
All ages		33329.	107458.	107474.	95114.	108240.	100760.	88965.

TABLE X

Estimated numbers ('000) of prey by age group consumed by the WHITING stock in 1981 by quarter.
(Based on quarterly estimates of stock size assuming constant mortality over the year and on quarterly consumption figures; personal communication Dr J.R.G.Hislop).

Quarter	Age group	Prey species COD	HADDOCK	WHITING	N. POUT	HERRING	SPRAT
1.	0	-	-	-	1596986	-	-
	1	4915	154182	263871	2884189	2384617	6914108
	2	-	2792	6792	429120	25013	1841542
	3+	-	2	-	8847	-	4826
2.	0	3569684	63356	1138	3207410	2410957	-
	1	-	173112	134019	1380285	-	1164164
	2	-	9092	12	212921	-	218994
	3+	-	-	-	3839	-	11684
3.	0	13874	5960328	5584847	14765812	5097825	-
	1	-	27467	-	25563	3021894	2893790
	2	-	-	-	-	-	852391
	3+	-	-	-	-	-	50687
4.	0	64801	2292416	416560	10891120	3193039	1151778
	1	-	9551	1297	33634	6202	923416
	2	-	434	-	-	-	135236
	3+	-	-	-	-	-	-

TABLE XI

Estimated numbers of various exploited fish species consumed by the WHITING stock in 1981 (P) in comparison with estimated number in the sea at the beginning of 1981 (N) from VPA (ANONYMUS,1983). Ratio: P/N.

(N and P in '000 fish)

	COD			HADDOCK			WHITING		
Age group	N	P	Ratio	N	P	Ratio	N	P	Ratio
0	?	3648359	?	2278424	8316100	3.65	1603786	6002545	3.74
1	131415	4975	.04	340792	364312	1.07	497750	399187	.80
2	313486	-	.000	1018240	12318	.012	892674	6804	.008
3	47499	-	.000	255349	1	.000	464707	-	.000
4	16251	-	.000	33406	+	.000	147615	-	.000
5	8987	-	.000	5211	-	.000	33086	-	.000
6+	3221	-	.000	1205	-	.000	16719	-	.000

(N and P in '000 000 fish)

	N. POUT			HERRING			SPRAT		
Age group	N	P	Ratio	N	P	Ratio	N	P	Ratio
0	232505	30461	.13	12414	10702	.86	3781	1152	.31
1	21971	4324	.20	2347	5413	2.31	21458	11895	.55
2	14634	642	.044	1496	25	.017	5176	3048	.59
3+	383	13	.034	1147	-	.000	244	67	.28

TABLE XII

Average annual stomach content composition of SAITHE by size class.
(Samples from 1980, 1981 and 1982; ANONYMUS, 1982)

Size class	25 - 30	30 - 40	40 - 50	50 - 70	70 - 100	>= 100
Nr of Stomachs	3	78	138	350	507	203
W stomach contents (g)	5.3	4.9	12.0	20.4	43.5	73.2
W per prey item	.43	.51	.45	.37	.92	4.23
Food composition in weight %						
COD	-	.9	-	.1	.1	-
HADDOCK	-	17.4	5.6	4.8	4.7	6.0
WHITING	-	-	-	.6	.2	3.0
NORWAY POUT	-	.4	10.0	19.9	37.0	37.1
HERRING	-	.4	10.4	-	.7	6.3
SPRAT	-	-	-	-	.1	-
SANDEELS	85.1	60.6	.1	.8	3.4	4.8
PLAICE	-	-	-	-	-	-
SOLE	-	-	-	-	-	-
MACKEREL	-	-	-	-	-	-
SAITHE	-	-	-	-	-	-
TOTAl	85.1	79.7	26.1	26.3	46.6	57.2
TOTAL FISH	85.1	79.7	30.9	47.4	70.9	94.1
EUPHAUSIDS	-	8.7	68.1	52.5	26.3	4.9
CEPHALOPODS	14.9	11.5	1.1	.3	2.9	.1
OTHER INVERTEBRATES	-	-	-	.1	.1	1.2

TABLE XIII

Average wet weight stomach contents (g) of MACKEREL by quarter, area and size class (Number of stomachs in brackets; NW : northwestern ; NE : northeastern ; C : central ; S : southern ; NS : total North Sea ; from MEHL & WESTGARD, 1983).

Quarter	Area	20 - 29		30 - 39		40 - 49	
1.	NW	-		2.68	(5)	.1	(2)
	NE	.12	(1)	.15	(13)	.22	(20)
	C	.11	(33)	.13	(4)	-	
	S	-		-		-	
	NS	.11	(34)	.72	(22)	.21	(78)
2.	NW	2.33	(13)	3.64	(24)	4.05	(2)
	NE	.01	(10)	6.08	(103)	8.18	(162)
	C	6.43	(15)	7.82	(120)	10.34	(111)
	S	2.58	(124)	4.81	(128)	9.82	(39)
	NS	2.76	(162)	6.05	(375)	9.12	(341)
3.	NW	3.37	(72)	5.64	(166)	4.79	(33)
	NE	1.27	(81)	2.04	(267)	3.20	(129)
	C	1.53	(193)	2.98	(357)	3.59	(126)
	S	1.31	(236)	1.89	(295)	4.60	(101)
	NS	1.63	(582)	2.86	(1085)	3.82	(389)
4.	NW	.85	(13)	3.86	(108)	4.96	(83)
	NE	-		2.76	(18)	5.03	(20)
	C	2.10	(69)	2.43	(163)	3.10	(23)
	S	.65	(38)	2.16	(127)	1.66	(21)
	NS	1.51	(120)	2.73	(416)	4.30	(147)

TABLE XIV

Food composition of MACKEREL (all size classes; 15-50 cm) in 1981 in weight percentages (from ANONYMUS, 1982).

NORWAY POUT	3.7
HERRING	3.4
SPRAT	1.6
SANDEELS	11.5
TOTAL	20.2
TOTAL FISH	34.7
COPEPODS	21.8
EUPHAUSIDS	29.3
CEPHALOPODS	.6
UROCHORDATES	4.5
OTHER INVERTEBRATES	4.2
NOT IDENTIFIED	4.9

TABLE XV

Estimated consumption in tonnes of selected prey categories by size class by the North Sea MACKEREL stock in 1981 (from MEHL & WESTGARD, 1983).

Prey size class / Prey category	Not known	0 - 5	5 - 10	10 - 15	15 - 20	TOTAL
HERRING	-	-	545	1330	78	1953
SPRAT	3444	-	331	2733	-	6507
Unspec. Clupeoids	351	-	3021	1603	-	4975
COD	-	-	25	92	-	117
HADDOCK	-	-	-	1097	-	1097
N. POUT	85	1415	98537	2900	3265	106202
Unspec. Gadoids	83	237	1783	-	-	2102
SANDEELS	9651	19007	64194	31197	3504	127552
Unspec. Teleostei	65182	1499	6741	119	-	73540
'Other'	677220	-	-	-	-	677220
TOTAL						1001265

TABLE XVI

Estimated prey size preference parameters of COD eating various prey based on an assumed condition factor of .01 for all species.
(eta: estimated preferred log weight ratio; sigma: estimated standard deviation of log weight distribution; c : estimated coefficient of negative exponential function of prey number; C : estimated condition factor assuming eta(prey) = eta(cod).
NB: non-trivial estimates could not be obtained for the following prey:
SOLE, PLAICE, FLATFISH, HERRING, HADDOCK, MACKEREL, MACROPIPUS !!!

Prey	eta	sigma	c	C
all prey	-5.58	2.24	1.080	.031
crabs	-8.92	1.94')	1.016	.88
fish	-4.20	1.20	.757	.0079
Gadidae	-4.66	1.00	.603	.012
invertebrates	-6.22	3.57')	1.448	.059
shrimps	-4.96	1.52	1.341	.017
Ammodytes	-2.24')	2.37')	.842	.0011
Aphrodite	-6.99	1.07	.839	.13
cod	-4.44	1.33	.968	.01*)
dab	-5.05	1.11	.409	.018
Norway pout	-6.02	1.71')	-.171	.049
Pagurus	-5.92	1.25	1.484	.044
sprat	-4.68	2.05')	-.001	.013
whiting	-5.57	1.47')	.024	.031

') - very inaccurate estimate (standard error _ parameter estimate)
*) - trivial value

TABLE XVII

Seasonal and spatial variation in the prey size preference parameters of "COD EATING GADIDAE". (A dot indicates all possible values of the parameter; c :estimated coefficient of negative exponential function of prey number).

Year	Quarter	Area ')	Mean log ratio of prey to predator weight and Sd: found in stomach: mu-hat	found in stomach: tau-hat	estimated preferred: eta	estimated preferred: sigma	c
.	.	.	-4.22	1.05	-4.66	1.00	.603
.	.	south			no solution		
.	.	north	-4.15	1.09	-4.58	1.05	.684
.	2+3	.	-4.16	1.03	-4.69	1.05	.600
.	1+4	.	-4.21	1.05	-4.58	.97	.634
1980	.	.	-4.28	1.10	-4.89	1.17	.662
1981	.	.	-4.20	1.03	-4.57	.94	.570
.	1	.			no solution		
.	2	.			no solution		
.	3	.	-4.13	1.04	-4.67	1.10	.642
.	4	.			no solution		
1980	1	.	-4.17	1.16	-4.46	1.24	.790
1980	2	.			no solution		
1980	3	.	-4.24	1.07	-5.02	.99	.582
1980	4	.			no solution		
1981	1	.	-4.08	1.03	-4.64	1.02	.626
1981	2	.			no solution		
1981	3	.			no solution		
1981	4	.			no solution		

') - south: south of 55 30 NB; north: north of 55 30 NB