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IDENTIFICATION OF DANISH NORTH SEA TRAWL FLEETS AND FISHERIES

BY

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ABSTRACT

Many North Sea fisheries are mixed-species fisheries, which make management of technical interactions problems important. This kind of management requires that the main fisheries are identified and described with respect to species composition and spatial and temporal distribution of landings. Furthermore, appropriate identification of main fisheries and the corresponding catch and effort data may lead to more useful estimates of catchability for tuning of Virtual Population Analysis (VPA) or integrated stochastic models.

Cluster analysis and principal component analysis have been used as a general method of classification. Two different approaches have been taken. Firstly, classification of individual trips gives an overall description of the Danish trawl fishery and may lead to more accurate catchability estimates due to the close connection of effort and target species. Secondly, classification of annual landings by vessel results in manageable subfleet divisions by metiers.

Introduction

Overfishing of some demersal North Sea stocks is one of the reasons for the increased need for more refined and detailed management measures. Most North Sea stocks are presently regulated using TAC's, minimum mesh size and minimum landings size as the dominating management instruments. However, as many roundfish fisheries have been mixed fisheries, these instruments seem to insufficient. In this connection management consideration taking technical interaction into account has become urgent.

Dealing with technical interactions requires, contrary to Total Allowable Catch (TAC), that total catch should be divided into fleets (e.g. by gear and nation) for which the species compositions are known. Multi fleet prediction models taking technical interactions into account are in principle models for which partial fishery mortality rate by species and fleet are treated separately for each fleet but simultaneously for all species. This type of age structured models are used in many areas, for example the STCF model considering the North Sea (Anon, 1991 a), The Celtic Sea treated by (Anon, 1991 b) and (Laurec et al 1991) and the Gulf of Maine by (Murawski et al 1991). Other models perform both age and length structured multi-fleet and multi-species predictions (Mesnil and Shepherd 1990).

When performing multi fleet predictions using above mentioned type of models it is implicitly assumed, that the species composition of a fleet remains constant for the prediction period. However, if managers want to change the rate of exploitation of specified target species/fisheries or if multi-species TAC's should incorporate the effect of technical interactions, then a division into fleets is not sufficient for evaluation of such changes. To do that it is necessary to identify "metiers" or main fisheries by fleet and obtain estimates of the corresponding effort and species composition of the catch.

Identification of main fisheries may be trivial if all species are caught in well separated "clean" fisheries. This is not the case for many North Sea fisheries, where many species are caught in the same areas at the same time. This applies especially to the roundfish species, cod, haddock, whiting and saithe, and to some extent to some flatfish species as well.

Identification of main fisheries in the North Sea has until yet not been carried out on a scientific basis and generally only rather limited work has been done in this area. As far as we can see only the Americans and the French have previously dealt with this question. Main fisheries may be defined and identified in several ways. (Murawski et al. 1983) analyses the otter-trawl fisheries off the northeast coast of United States and define fisheries by grouping categories of areas, depth zones and time periods. They used cluster analysis technique as an objective method of fisheries identification. Besides of management of individual fisheries this kind of definition is especially suitable for management measures as box closures in time and space.

(Biseau and Gondeaux 1988) and (Laurec et al. 1990) defines "metiers" of French Celtic fleets as a combination of gear, target species and area using principal component analysis.

This paper present analyses of Danish North Sea trawl fisheries, which includes small mesh fisheries for industrial purposes and human consumption fisheries. As some fisheries very often are mixed-species fisheries because of spatial co-occurrence of the species it is in this cases not a satisfactory solution to define main fisheries on an area basis as above. Instead main fisheries are defined as objective classifications of the observed species composition (target species) of the landings, where any relevant time scale could be considered.

Such classifications may be useful for management of individual species involved in mixed-species fisheries e. g. when identifying fleets fishing for cod, which has earlier been tried. If the spatial distribution of the landings or the fisheries are known the effects of box closures in time and space may be evaluated as well.

Identification of fleet fisheries may be carried out in several ways depending on the purpose of the analyses. Two purposes are considered:

A. To obtain main fisheries, based on as disaggregated catch information as possible, for which the corresponding effort is closely related to the catch of specified target species.

B. To identify operational sub-fleets homogenous with respect to species composition of catch. These sub-fleets grouped by metiers could be the basis for management of mixed-species fisheries taking technical interactions into account.

The first purpose could in principle include catch analyses by each haul. However, as catch information by vessel trip is the most detailed level of aggregation available, this will form the basis of the analysis. This may lead to improved estimates of catchability by species for tuning of VPAs or integrated stochastic methods.

This analysis of the North Sea trips is not a classification of the vessels because each vessel may contained in all or many of the trip classifications.

Therefore, the second purpose deals with an operational classification of the vessels, which could be used for management purposes. This could be achieved applying monthly or annual landings of the vessels.

Data material

The present analyses are based on a comprehensive database for 1988 describing the Danish North Sea fishery by each individual trip. Data stem from four main sources: Sales slip, a vessel register, log books and biological data. The database contains the following information by each vessel trip:

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

654 trawlers greater than 10 GT and their 12892 trips were considered. The Trawl landings formed the main part of total North Sea landings and accounted for 90 and 60 percent of total Danish North Sea landings in weight and value respectively.

Methodology

Cluster analysis was used as a general tool for classification of landings into groups homogeneous with respect to the species compositions. Only the relative distributions were considered. The species composition was calculated on basis of the **value** of the species landed in order to ensure that a relative small quantity of valuable species corresponds to a non-negligible proportion of total value. Furthermore, as the resulting classifications may be used for analyses of effort allocation/reallocation problems, the value of the catches is a more relevant measure than the quantity.

Fishing ground, time of landings, vessel size and other factors are not included in the first classification, but may be incorporated at later stage in the analysis for a final definition of the classification.

Hierarchical cluster analysis was applied, which means that the clusters are disjoint and that one cluster may be entirely contained within another cluster, but no other overlap between clusters is allowed.

Input data to the cluster analysis are vectors containing the species composition of the landings in percent:

$$\underline{X_j}=(X_{1,j},X_{2,j}, \ldots)$$

where

$$x_{i,j} = \frac{Landings_{i,j}}{\sum_{i} Landings_{i,j}} * 100$$

and

$x_{i,j}$ *Indicates percentage in the landings of* $species_i$ *for* $unit_j$

All species landed are included in the total sum but only the dominating species for a fleet are included in the cluster analysis.

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

The distance between two clusters can be defined either directly or combinatorial, that is, by an equation for updating a distance matrix when two clusters are joined.

The direct distance between two clusters is defined as

$$D_{KL} = \| \overline{x}_K - \overline{x}_L \|^2$$

Where

$\overline{x}_k$ *Indicates mean vector for cluster* C_K

D_{KL} *Indicates distance measure between cluster* C_K *and* C_L

The distance is the Euclidian distance

The combinatorial distance is

$$D_{JM} = \frac{(N_K D_{JK} + N_L D_{JL})}{N_M} - \frac{N_K N_L D_{KL}}{N_M^2}$$

Where

N_M *Indicates number of observation in Cluster M*

For the method used the distance between two clusters is defined as the (squared) Euclidian distance between their centroids or means. The formula for the combinatorial distance assumes that clusters C_K and cluster C_L are merged to form C_M and the formula gives the distance between the new cluster C_M and any other cluster C_J.

Estimation of the number of clusters or main fisheries is a delicate matter, which may depend on purpose of the analysis. For the present analysis four objective criteria were applied for this estimation by using plots of the number of clusters versus pseudo F statistic, pseudo t^2 statistic, cubic clustering criteria and the correlation (Sarle 1983, Mulligan and Cooper 1983). The number of clusters may be identified by looking for consensus among local peaks for the cubic clustering criteria, the pseudo F statistic and the R^2 values combined with a small value of the pseudo t^2 statistic and a larger pseudo t^2 for the next cluster fusion. The assumptions behind these tests may be or are often violated. However, if all four methods indicate the same number of clusters, this value probably is applicable and will be selected.

Principal component analysis was used as a dimension-reduction technique for discriminating among the clusters. A scatterplot of the cluster canonical variables visualizes the separation of the clusters.

The SAS centroid cluster procedure was used for the calculations.

Results

Firstly, the 5470 species compositions of all **human consumption vessel trips** in the North Sea were classified into groups defined as main fisheries using the cluster analysis technique described above. 9 species accounting for about 90 percent of total value were included in the analysis.

The number of clusters were estimated using the four clustering criteria described above. The plots of the four criteria vs number of clusters are shown in figure 1. All of the four clustering criteria indicated a number of 9 clusters or main fisheries.

The average species compositions in the resulting 9 clusters are given in table 1. The clusters are named according to the dominant species (the target species) in the cluster. A cluster with a species composition of e.g. 75 percent cod, 20 percent haddock and 5 percent other species will be named a "Cod - Haddock" fishery. Except for the haddock, monk and the mixed main fisheries the remaining fisheries were in general rather clean fisheries, as the average percentage of the target species amounted to more than 60 percent of the value.

Table 1. Species composition of landings in value by main fishery of the Danish North Sea human consumption trawlers 1988.

CLUSTER/ MAIN FISHERY		NO OF TRIPS	SPECIES									VALUE
			LOBSTER	PANDALUS	MONK	HADDOCK	SAITHE	PLAICE	HERRING	COD	OTHER	%
1	PANDALUS	851	8.3	66.4	12.5	0.7	1.2	0.5	0.0	5.4	5.0	18.3
2	PLAICE	1039	0.6	0.0	0.4	0.4	0.0	74.8	0.0	4.5	19.4	10.7
3	HERRING	348	0.0	0.0	0.0	0.1	0.7	0.0	94.8	0.2	4.1	10.2
4	LOBSTER	147	86.6	0.5	0.6	0.1	0.2	5.1	0.0	0.7	6.2	2.9
5	MIXED	486	10.9	0.0	4.0	1.8	0.5	16.6	0.2	7.5	58.5	4.4
6	COD	1206	0.0	0.0	0.3	8.6	0.8	2.8	0.0	80.8	6.6	16.7
7	HADDOCK	878	0.1	0.0	1.2	49.4	8.6	0.7	0.0	29.3	10.7	21.7
8	SAITHE	205	0.6	0.4	5.0	7.8	60.4	0.2	0.0	13.4	12.2	4.8
9	MONK	310	2.8	0.2	48.8	2.3	6.0	0.7	0.0	22.9	16.4	10.4
	SUM											100

*Note. In the calculation of the mean relative value per species, each trip has been weighted by the total value of the trip.

The haddock, shrimps and cod fisheries were the most important fisheries representing about 22, 18 and 17 percent of the total value of the human consumption trawl landings in the North Sea in 1988 respectively. The haddock fishery was a combined fishery of haddock and cod as the cod proportion was about 29 percent of the value.

Each of the fisheries for plaice, herring and monk amounted to about 10 percent of total value.

The canonical discriminant analysis is illustrated in figure 2, where the values of the first two canonical variables, explaining about 55 percent of total variation, are plotted against each other for each trip. The figures plotted indicate the numbers assigned to the fisheries or clusters in table 1. Cluster 3, which was well separated from the other fisheries, was excluded from the plot due to scaling problems.

Figure 2 indicates that it may be difficult to separate the cod and haddock fisheries, and the haddock and saithe fisheries, while the other main fisheries were well separated and therefore easy to identify.

The 9 main fisheries may be described in detail with respect to information on bycatches, when and where the fishery took place and vessel characteristics. This is done in (Lewy and Vinther 1992).

Two examples of the spatial distribution of the cod and haddock fisheries are shown in fig. 3 and 4.

The descriptions of the main fisheries are summarised in the table 2.

Table 2. Features of the main fisheries of the human consumption trawl trips in the north sea 1988.

FISHERY	VALUE IN PERCENT OF TOTAL	BYCATCH	VESSEL SIZE (GT)	HOME DISTRICT	PERIOD	FISHING GROUND
HADDOCK	22	COD, SAITHE	40-250	RINGKØBING, THISTED, LEMVIG	WHOLE YEAR PEAK AUGUST	THYBORØN TO WEST OF STAVANGER
COD	17	HADDOCK	10-70	RINGKØBING, LEMVIG, THISTED	WHOLE YEAR PEAK JUNE	EAST OF 6° TO W.COAST OF JUTLAND
SAITHE	5	COD, HADDOCK	40-250	THISTED RINGKØBING HIRTSHALS	APRIL/MAY	THYBORØN TO STAVANGER
SHRIMPS	18	MONK	10-250	SKAGEN THISTED ESBJERG HIRTSHALS	JAN.- SEPT. PEAK MARCH	NORWEGIAN DEEP FLADEN
PLAICE	11	-	10-70	ESBJERG RINGKØBING	WHOLE YEAR PEAKS APR.,OCT.	EAST OF 4° TO W.COAST OF JUTLAND
MONK	10	COD	90-250	HIRTSHALS THISTED	JAN. TO SEPT.	FLADEN SHETLAND ISLANDS
HERRING	10	-	100-700	SKAGEN	JUNE- AUGUST	THYBORØN TO BERGEN
LOBSTER	3	-	10-500	ALL WEST COAST HARBOURS	AUGUST- SEPTEMBER	CLEAVER BANK
MIXED	4	-	10-250	ALL	WHOLE YEAR	-

In order to obtain a manageable division of the Danish North Sea trawl fleet with respect to metiers the annual species composition by vessel including both human consumption and industrial landings were analyzed and grouped into sub-fleets applying cluster analysis.

The four clustering criteria determining the number of clusters indicate that there were 9 clusters. Four of these were mixed fisheries of limited economical importance. These clusters are further combined to one fishery called "other". The resulting 5 sub-fleets and their species composition are shown in table 4.

Table 4. Species composition of landings in value by sub-fleet. The Danish North Sea trawl fleet, 1988.

Sub-fleet by target species	NO OF VES-SELS	LOB-STER	PAN-DALUS	MONK	HAD-DOCK	SAIT-HE	PLAI-CE	HER-RING	COD	IND-STRI-AL	OTHER	TOTAL %	% of value
Cod, haddock	143	1.6	4.1	9.6	20.2	8.2	2.8	0.2	34.8	5.7	12.8	100	16.4
Plaice, ind. l.	42	0.5	0.3	0.3	0.3	0.0	61.9	0.0	5.4	13.0	18.1	100	2.4
Herring,ind. l.	40	0.3	0.6	1.5	0.8	1.7	0.0	65.6	1.0	20.8	7.8	100	4.0
Pandalus	68	11.5	61.5	8.9	1.1	1.9	1.4	0.0	4.7	1.4	7.5	100	3.8
Industrial	254	0.4	0.9	1.2	1.3	1.1	1.4	1.1	3.0	80.5	9.3	100	71.9
Other	91	29.3	1.0	3.1	0.2	1.8	4.4	0.9	4.0	37.6	17.7	100	1.6

Table 4 indicates that the vessels only targeting for industrial purposes were the far most important one accounting for about 72 percent of total value of the trawl landings. The second most category was the human consumption trawlers targeting mainly for the roundfish species (about 16 percent of total value). The rest of the vessels participated in mixed industrial and human consumption fisheries of plaice, herring and pandalus taking about 12 percent of total value.

The descriptions of the sub-fleets by metiers are summarized in the table 5.

Table 5. Features of the main trawl sub-fleets by metiers in the north sea 1988

METIERS	VALUE IN PERCENT OF TOTAL	OTHER SPECIES	VESSEL SIZE GT	HOME DISTRICT	PERIOD
INDUSTRIAL LANDINGS	72	COD, PLAICE	100-700	ESBJERG, LEMVIG, RINGKØBING	APRIL-NOVEMBER PEAK: MAY
COD, HADDOCK	16	MONK, SAITHE PLAICE	ALL	RINGKØBING THISTED HIRTSHALS	ALL MONTH
PANDALUS	4	LOBSTER MONK COD	10- 20 30- 80 90-150	SKAGEN THISTED HIRTSHALS	FEBRUARY-JUNE
HERRING, INDUSTRIAL LANDINGS	4	OTHER SPECIES	100-500	SKAGEN FREDERIKSH RØNNE	MAY-DECEMBER
PLAICE, INDUSTRIAL LANDINGS	2	COD, OTHER SPECIES	10- 70	ESBJERG HELSINGØR RINGKØBING	MARCH-NOVEMBER
OTHER	2	LOBSTER IND.HERRING OTHER SP.	ALL	LEMVIG FREDERIKSH SKAGEN	AUGUST-JANUARY

Discussion

The cluster analysis technique used for classification is an objective method providing results with respect to identification of main fisheries and "metiers" which seems to be in general agreement with our knowledge of the fishery.

The method seems to be reliable for identification of groups for which there are many observations and for which the target species amount a high proportion of total catch.

Mixed fishery groups characterized by many species of equal value are more difficult to identify because the resulting clusters in these cases are sensible to variations of the species compositions and the selection of both the number of clusters and the measure of distance between clusters used in the analysis. The only solution to this is a detailed knowledge of the fishery, which can serve as guideline for the definition of main fisheries or metiers.

Management considerations requires that the fleets should be divided into operational units, the sub-fleets by metiers. It should be noted that the purpose of the management may affect the definition of these units. For instance regional conditions may require that the fleet is considered by port and more detailed local metiers than defined above have to be identified.

The above metiers classifications of the fleet are based on the annual species compositions of the vessels. It would an improvement if the seasonal variation of the vessels could be included in definition of the metiers. This has been tried by considering both monthly and quarterly species compositions of the landings. However, the change of seasonal target fisheries for the Danish trawlers seem to so complicated that it has not been possible to obtain an operational fleet division.

The classification of individual trips is not such an operational division. Instead, this classification may be considered as a general description of existing fisheries. Besides the corresponding catch and effort data may lead to better estimates of catchability of the target species compared to standard estimates in the ICES area. The reason for that is that the latter estimates usually include effort, which is not relevant for the species in question. However, improved estimates of catchability do not necessarily lead to better estimates of terminal fishing mortality rate when tuning VPA's. This is due to that fleet catchability and the more accurate estimates may be subject to considerable fluctuations in time, which do not result in better estimates of terminal F for most tuning methods. Anyway, it is worthwhile for a range of year to try estimating catchability by target species from main fisheries identified as described above.

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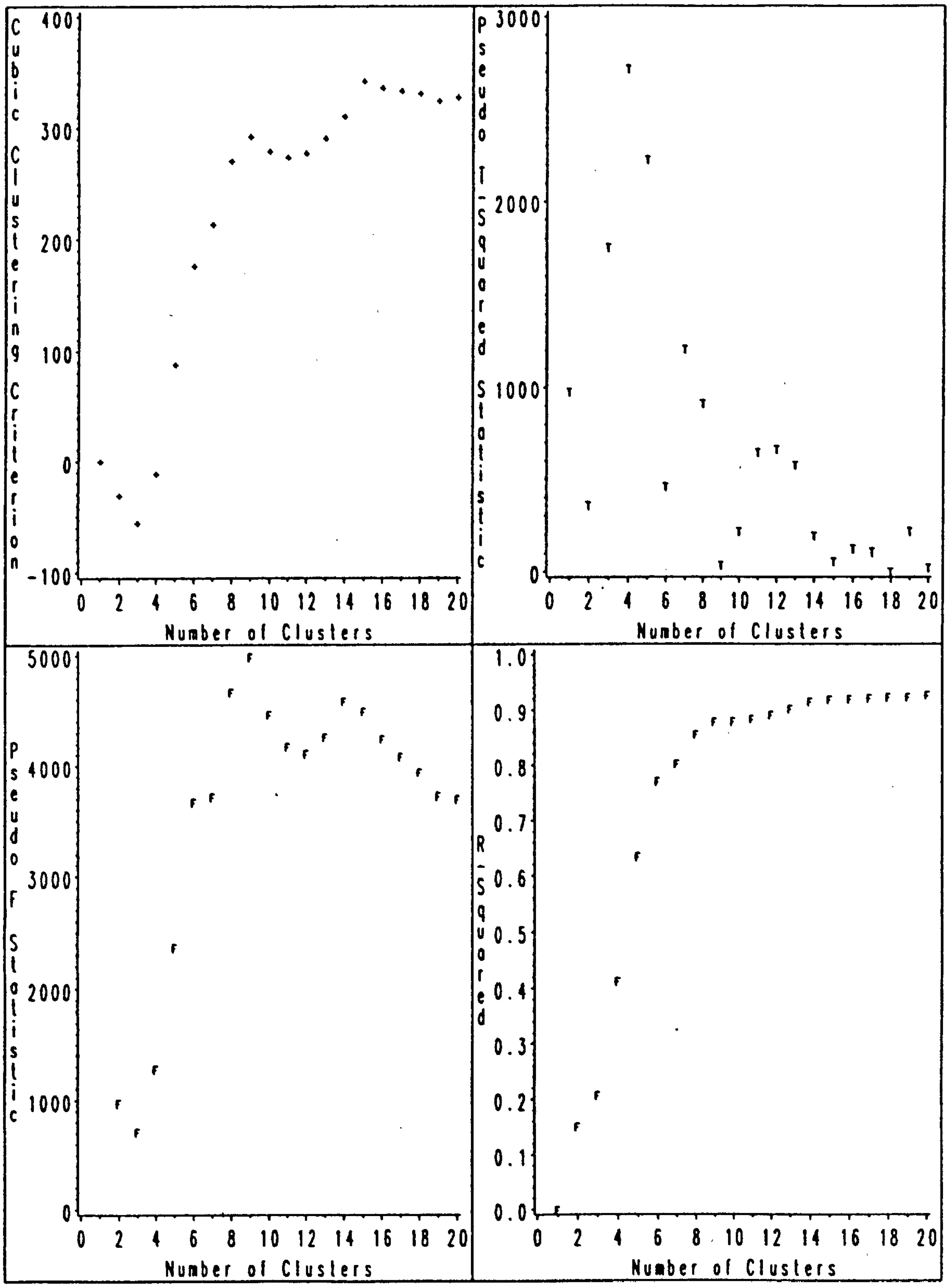

Figure 1. Plots of four clustering criteria vs the number of clusters for the Danish human consumption trips.

Plot of CAN2*CAN1. Symbol is value of CLUSTER.

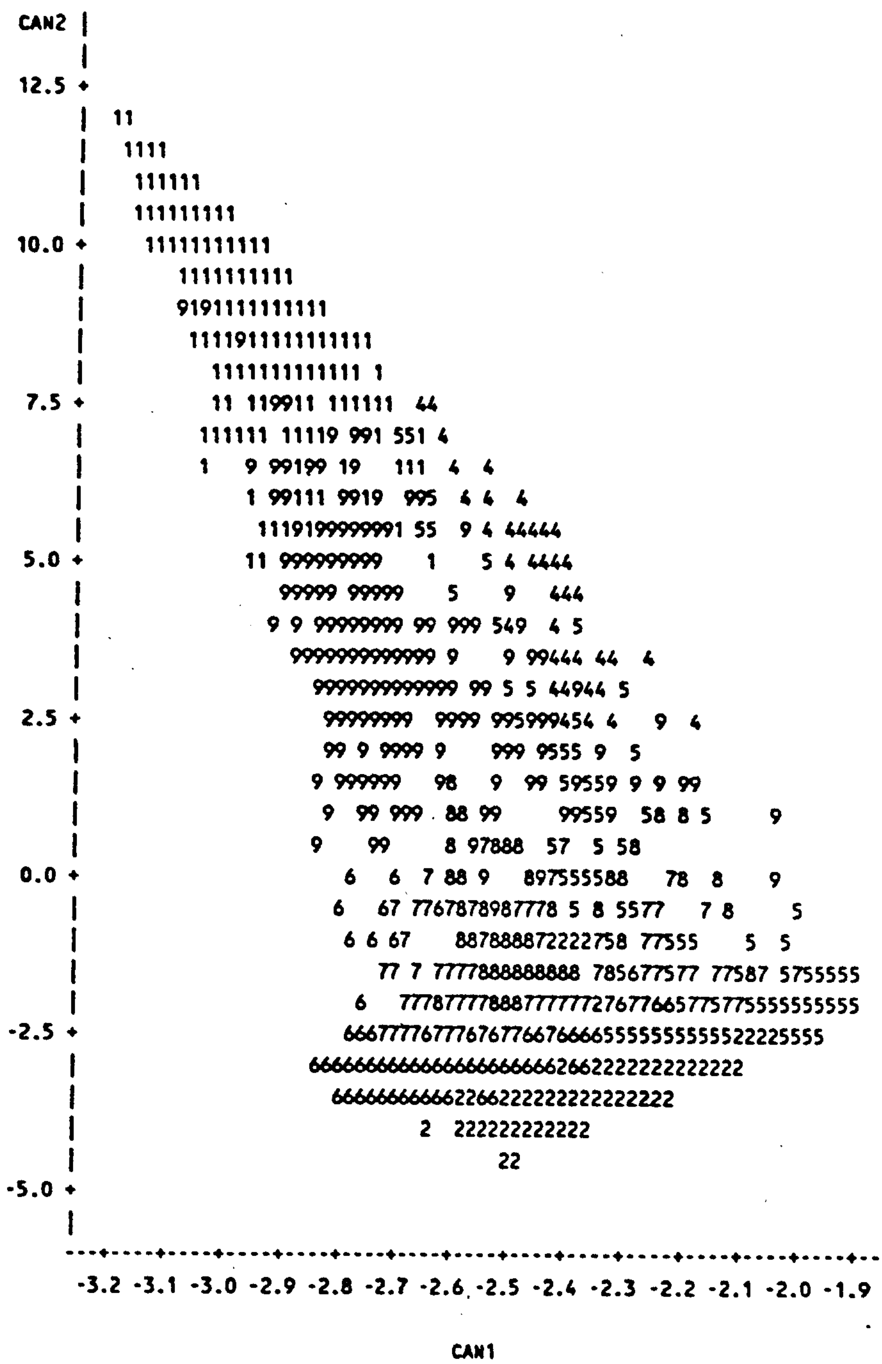

Figure 2. Principal component analysis of the Danish human consumption trawl North Sea fishery. Main fishery, indicated by the numbers 1-9, plotted for the first and second canonical variable.

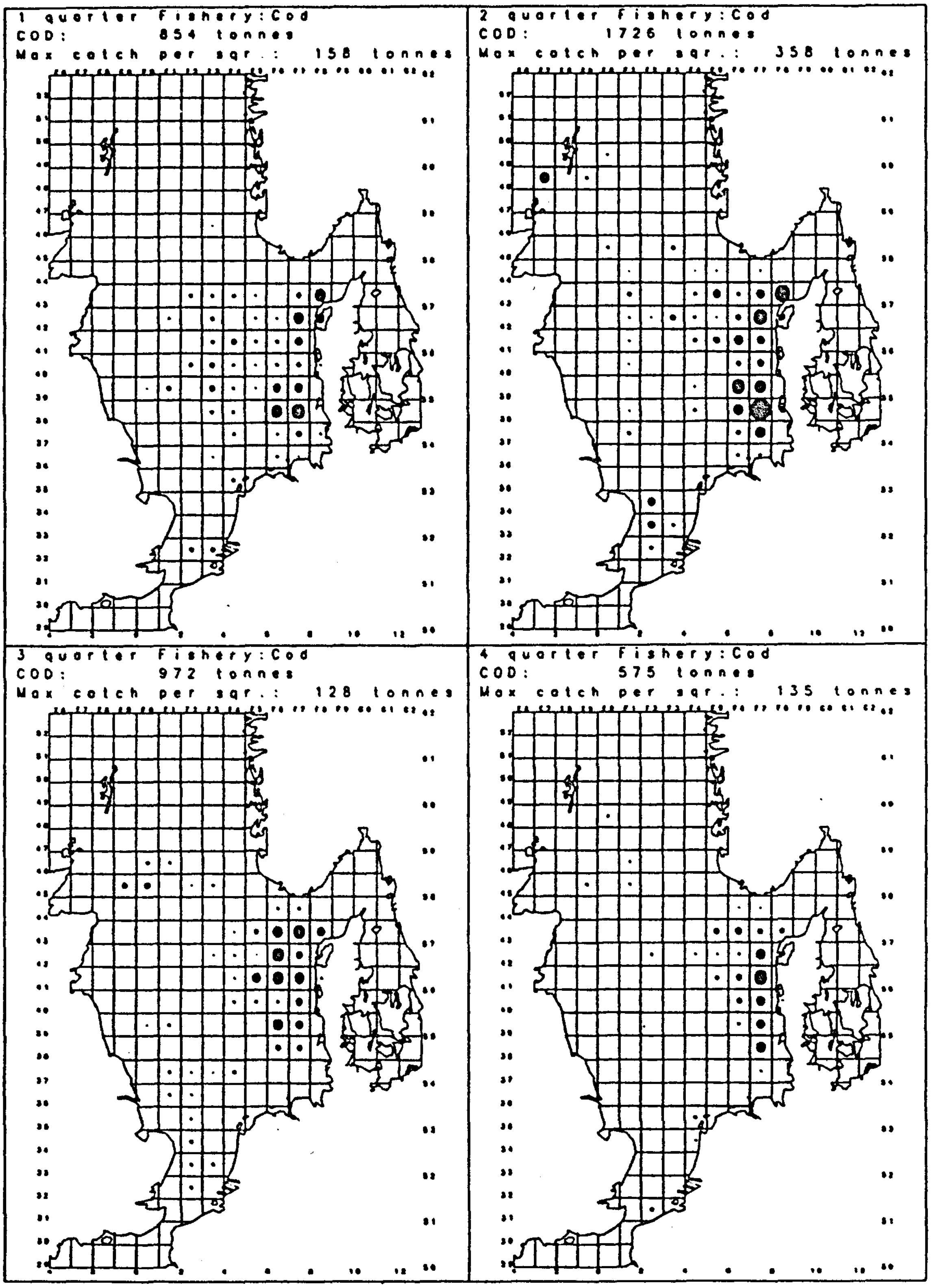

Figure 3. The Danish North Sea human consumption trawl cod fishery distributed by statistical rectangle and quarter.

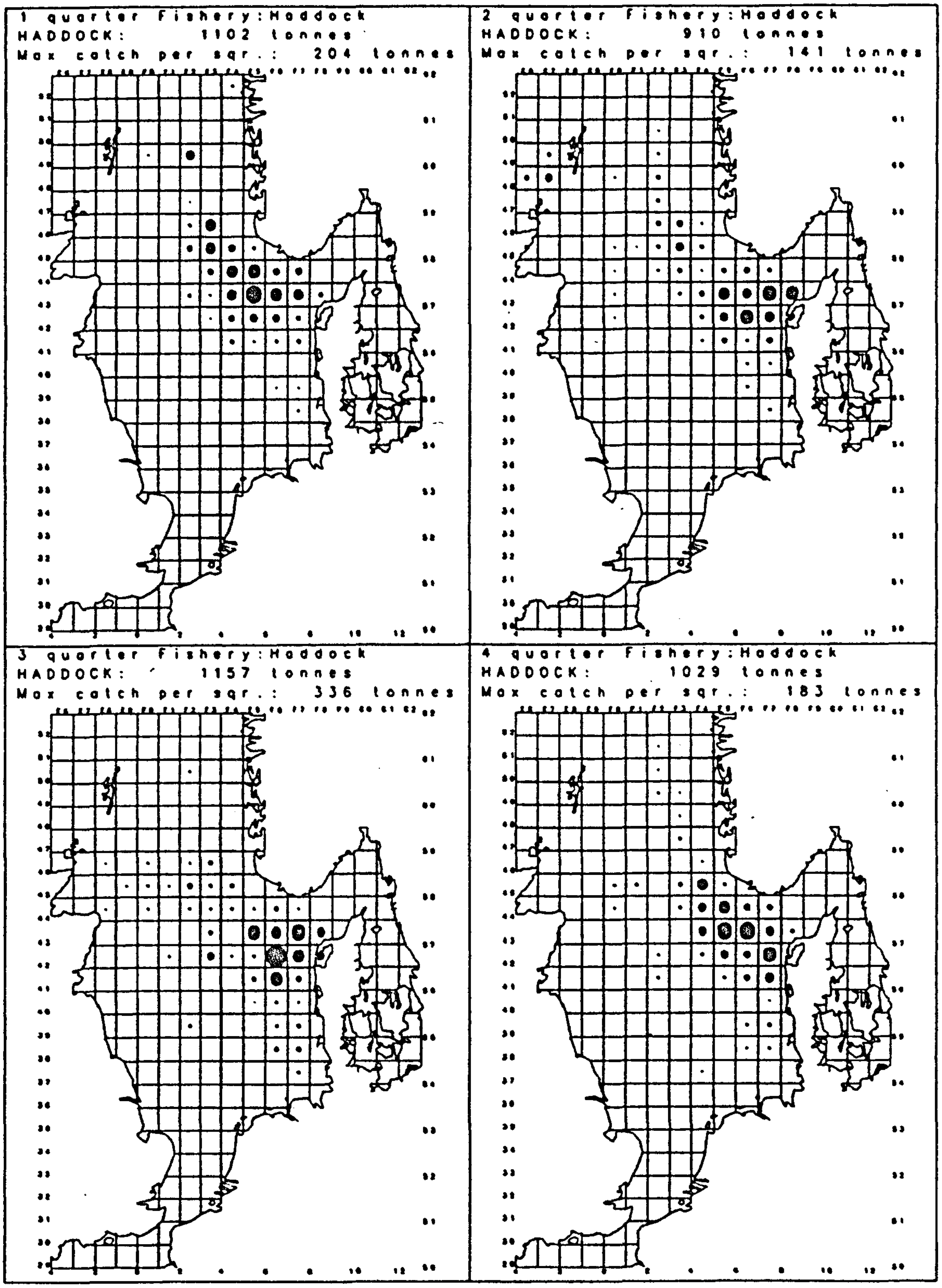

Figure 4. The Danish North Sea human consumption trawl haddock fishery distributed by statistical rectangle and quarter.