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Identification of Danish North Sea trawl fisheries

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Many North Sea fisheries are mixed-species fisheries, which requires that management take account of technical interaction problems. Therefore, the fisheries should be identified and described with respect to species composition, spatial distribution, vessel characteristics, etc., and yield projections should be made accordingly.

Cluster analysis was used to classify the Danish trawl fisheries in the North Sea in 1988. Classification of individual trips based on the species composition in value of landings for human consumption resulted in the identification of nine directed fisheries. Some of these were mixed demersal fisheries, whereas others were relatively "clean", being comprised of only a few commercial species.

Classification of annual landings by vessel resulted in candidates for manageable units. The economically most important sub-fleet fished for industrial purposes, while the second most important fleet mainly targeted cod and haddock.

The potential applications of the concept of directed fisheries is discussed.

Key words: fisheries, Danish trawlers, North Sea, cluster analysis.

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Introduction

Most North Sea fish stocks are presently regulated using single-species management instruments such as TACs (Total Allowable Catch), minimum mesh sizes, and minimum landed sizes. However, due to spatial co-occurrence some demersal species are taken in mixed fisheries. In such cases these instruments may be insufficient in practical regulations as they do not account for technical interaction problems.

Dealing with technical interactions requires, contrary to the case of TAC management, that total catch may be divided among fleets for which the species compositions are relatively homogeneous. Fleets are most easily defined using physical characteristics like vessel size and gear used, etc. However, such fleet definitions ignore the fact that vessels in a homogeneous group often do not necessarily target the same species.

Identification of the species assemblages exploited by specific directed fisheries would be trivial if all species were caught in well-separated, "clean" one-species, fisheries. This is not the case for many North Sea fisheries, where many species are caught in the same areas at the same times. This applies especially to the roundfish species, cod (*Gadus morrhua*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), and saithe (*Pollachius virens*).

Fisheries may be defined and identified in several ways. Murawski *et al.* (1983) analysed the otter-trawl fisheries off the north-east coast of the United States and defined fisheries by grouping categories of areas, depth zones, and time periods using cluster analysis of species compositions. This kind of definition is especially suitable for management measures such as closures of specific areas or restricting fishing to specified periods of time.

Biseau and Gondeaux (1988) and Laurec *et al.* (1991) defined "métiers" of French Celtic Sea fleets as combinations of gear, target species, and area using principal components analysis.

Rogers and Pikitch (1992) applied detrended correspondence analysis in conjunction with divisive and agglomerative hierarchical cluster analysis techniques to catches and identified groups of commercial trawl fisheries off the coasts of Oregon and Washington. The resulting classifications were compared with pre-defined trawling strategies.

This paper presents the first analyses of identifying directed Danish North Sea trawl fisheries, including both small-mesh fisheries for industrial purposes and human-consumption fisheries. It is not possible to define these directed fisheries on an area basis only since the Danish roundfish fisheries are to some extent mixed-species fisheries because of spatial co-occurrence of the

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species. Instead, directed fisheries are defined by classifications of the observed species composition of the landings.

The specific objectives of this research were:

1. To classify species compositions of human-consumption landings from individual trips into homogeneous units defined as directed fisheries.
2. To partition the human-consumption trawler fleet into units characterized by the pattern of shifts between different fisheries by individual vessels over seasons.
3. To partition the total trawler fleet into sub-fleets which are homogeneous with respect to the annual species composition of the catch.

The identification of directed fisheries by trip is not a classification of the vessels because each vessel may participate in several different fisheries over the year. Therefore, the second and third purposes deal with an operational classification of the vessels, which could be used for fleet management purposes.

Materials

The analyses were based on a comprehensive database for 1988 describing the Danish North Sea fishery by individual trip. The database was established by a co-operation of the Danish Ministry of Fishery and the Danish Institute for Fisheries and Marine Research (DIFMAR). The data was obtained from three main sources: (1) sales slips for landings, providing catch data by vessel trip, marked size category, and species; (2) a vessel register containing vessel characteristics; and (3) log books recording spatial distribution of catch and effort and providing information on the gear used. These three data files were combined, producing a database containing the following information by each vessel trip:

- Vessel size category.
- Gear and mesh size.
- Date of the landing.
- Landing category (human-consumption or industrial fishery).
- Landed weight and value by species.
- Effort distributed on ICES statistical rectangles.

A total of 638 trawlers of more than 10 gross tons (GT) and their 12 892 trips were included. The landings by these trawlers accounted for about 90% of the grand total for the Danish North Sea trawler landings in 1988.

Methods

Cluster analysis was used as a general tool for classification of landings into groups with homogeneous species compositions. Only the percentage distribution of species was considered.

The species composition was calculated on basis of the value instead of weight because this ensures that an uncommon but valuable species is represented by a non-negligible proportion of the total landings.

Hierarchical agglomerative cluster analysis was applied. The SAS centroid CLUSTER procedure (Anon., 1989) was used for the calculations. The centroid method was selected because it is more robust to outliers than other hierarchical methods (Milligan, 1980). The centroid method defines the distance between two clusters as the squared Euclidian distance between their centroids or means. For agglomeration of clusters a combinatorial distance is defined by the equation below for updating a distance matrix when two clusters are joined:

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

where D_{JM} indicates the distance between clusters J and M; N_K indicates number of observations in cluster K.

In the formula it is assumed that clusters K and L are merged to form a new cluster M and the formula gives the distance between the new cluster M and any other cluster J. The pair of clusters with the shortest combinatorial distance is combined.

Estimation of the number of clusters is, however, a subjective matter, which may depend on the purpose of the analysis. In the present paper four criteria were applied for this estimation combined with the analysis of the process of aggregation of clusters visualized in the dendrogram. The four criteria used were plots of the number of clusters vs. pseudo F-statistic (Calinski and Harabasz, 1974), pseudo t^2-statistic (Duda and Hart, 1973), cubic clustering criteria (Sarle, 1983), and the correlation coefficient. The number of clusters may be determined 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. If all four methods indicate the same number of clusters, this value may be applicable and will be focused on in the analysis of the dendrogram.

The description of the seasonality of the directed fisheries of individual vessels was done by classifying the species compositions by month for each vessel using the cluster analysis described above. The result of this analysis may be combined for each vessel to a seasonality pattern, where the monthly shift in classifications defines a vector $(f_1, f_2, \ldots, f_{12})$, where f_i denotes one of the classifications for month i. The distribution of the vessels on these fishery patterns were considered.

Results

Identification of directed fisheries

Plots of the four criteria against numbers of clusters indicated the presence of nine directed fisheries (Fig. 1).

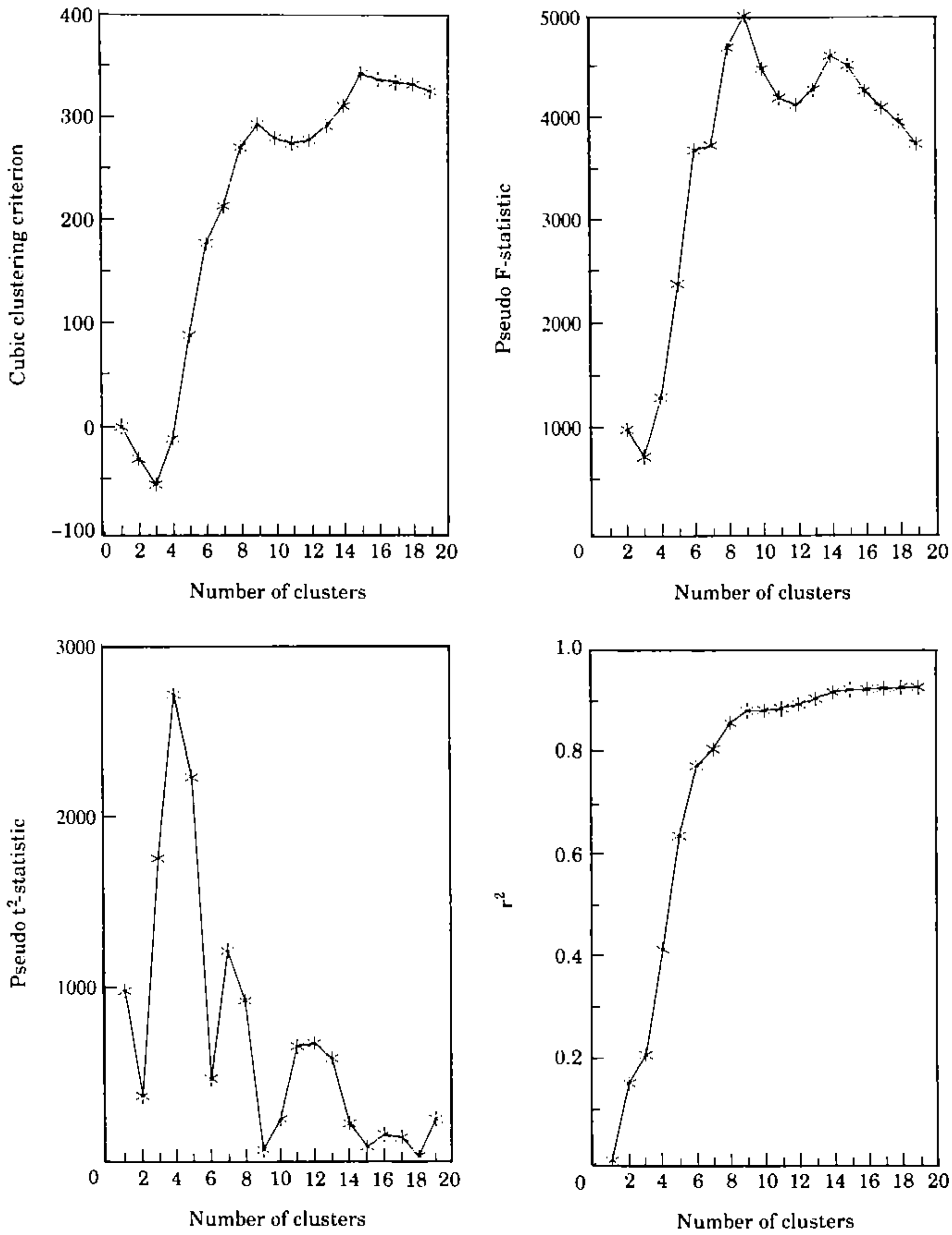

Figure 1. Plots of four clustering criteria vs. the number of clusters for the Danish human-consumption trips.

The interpretation of the dendrogram was initiated using an arbitrary, but small number of 20 clusters greater than 9 (Fig. 2). The average species composition of the 20 clusters, which corresponds to the centroids of the clusters, are given in Table 1. By increasing the distance between the clusters it is, however, possible to reduce the number of groups. The relationship between the number of clusters after aggregation and the distance between cluster centroids are shown in Table 2.

Reducing the number of clusters from 20 to 9 implies in all cases but one that new clusters are aggregated by groups having the same dominant species. E.g. the clusters numbered 3, 4, and 5 in Table 1 are aggregated to a single saithe cluster. The only exception is the combination of the clusters 10, 11, and 12. The clusters 11 and 12 are mixed fisheries dominated by lobster (40–50%) but also including important catches of plaice, monk, cod, and other species, whereas cluster 10 mainly

Table 1. Species composition (%) of landings by value for 20 clusters selected by cluster analysis for the Danish North Sea human-consumption trawlers in 1988.

Cluster number	No. of trips	Species									Total
		Lobster	Pandalus	Monk	Haddock	Saithe	Plaice	Herring	Cod	Other	
1	1098	0.0	0.0	0.3	8.8	0.8	1.7	0.0	82.1	6.2	100
2	108	0.0	0.0	0.2	3.8	0.0	27.8	0.0	52.5	15.7	100
3	161	0.3	0.0	2.3	9.6	70.1	0.1	0.0	11.1	6.5	100
4	34	1.5	1.7	14.5	3.5	33.5	0.6	0.0	11.9	32.8	100
5	10	0.0	0.6	0.5	3.2	47.7	0.0	0.0	45.6	2.4	100
6	309	0.0	0.0	0.5	68.2	2.8	0.2	0.0	20.8	7.4	100
7	500	0.2	0.0	1.7	35.8	7.6	1.2	0.0	39.3	14.2	100
8	1	0.0	0.0	0.0	38.4	0.0	34.2	0.0	24.4	3.0	100
9	68	0.2	0.0	1.5	42.3	35.4	0.1	0.0	13.8	6.8	100
10	432	0.3	0.0	1.2	2.2	0.2	16.0	0.2	7.6	72.2	100
11	26	40.9	0.0	0.8	0.3	0.1	34.6	0.0	4.2	19.1	100
12	28	47.0	0.0	25.8	0.9	2.8	1.2	0.0	10.4	11.7	100
13	279	2.7	0.1	47.0	2.4	6.2	0.7	0.0	24.0	16.8	100
14	31	3.8	1.0	75.8	0.7	2.0	0.1	0.0	5.9	10.8	100
15	1039	0.6	0.0	0.4	0.4	0.0	74.8	0.0	4.5	19.4	100
16	629	6.4	76.1	8.6	0.4	0.9	0.2	0.0	3.3	4.1	100
17	124	26.6	49.2	10.3	1.0	1.9	1.3	0.0	4.0	5.8	100
18	98	4.0	36.6	31.0	1.9	2.0	1.3	0.0	15.2	8.0	100
19	147	86.6	0.5	0.6	0.1	0.2	5.1	0.0	0.7	6.2	100
20	348	0.0	0.0	0.0	0.1	0.7	0.0	94.8	0.2	4.1	100
Total	5470										

Table 2. The relationship between the number of clusters after aggregation and the distance between cluster centroids.

Distance	Number of clusters
0–0.36	20
0.37–0.39	19
0.40–0.42	18
0.41–0.43	14
0.44–0.45	12
0.46–0.47	11
0.48–0.49	10
0.50–0.58	9
0.59–0.61	8
0.62–0.70	5
0.71–0.88	4
0.89–0.91	3
0.92–1.10	2
1.11+	1

consists of "other" species. It is thus a question whether the clusters 11 and 12 should be considered as mixed fisheries or as directed lobster fisheries. In the latter case these two clusters should be combined with the lobster cluster number 19 instead of cluster 10. We have decided to accept the results of the cluster analysis and thus combined the two clusters with cluster 10 to a new cluster, which is considered as a mixed-species cluster. It should be noticed that the size of cluster 11 and 12 is very small (less than 1% of total number of trips) and any misclassification will hence be of very limited importance.

Attempt to further reduce the number of clusters from 9 to 8 resulted in the aggregation of the mixed-species clusters (10, 11, and 12) with the monk clusters (13 and 14). A further reduction from 8 to 7 clusters led to combination of this latter cluster (other+monk) and the haddock cluster. These combinations are not reasonable, as interviews with fishermen confirmed the existence of distinct monk and haddock fisheries. The analysis of the dendrogram therefore resulted in the same number of groups of 9 as the four criteria did.

The average species compositions (by value) in these nine directed fisheries are given in Table 3. The directed fisheries are named according to their dominant species. Table 3 shows that the haddock, monk (*Lophius piscatorius*), mixed, saithe, and to some extent Pandalus fisheries were mixed fisheries with at least two species dominating in the landings, while the remaining directed fisheries were in general relatively clean fisheries, as the average percentage of the target species amounted to more than 75% of the total value.

The haddock, Pandalus, and cod fisheries were the most important, representing respectively about 22, 18, and 17% of the total value of the Danish human-consumption trawl landings from the North Sea in 1988.

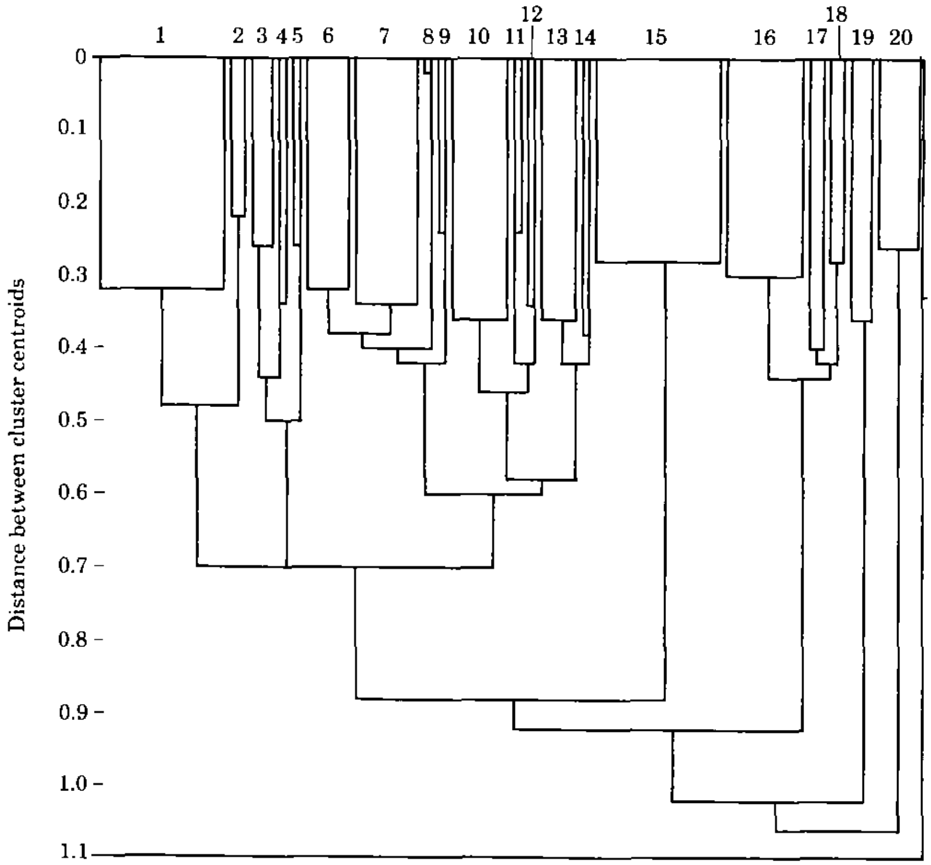

Figure 2. Cluster analysis dendrogram showing the process of agglomeration of 20 clusters. Vertical scale is the squared Euclidian distance (see text) at which groups were combined. Width of the numbered rectangles (clusters) is proportional to the number of observations in each group. Total number of observations is 5470.

Table 3. Species composition (%) of landings by value in each main fishery pursued by the Danish North Sea human-consumption trawlers in 1988.

Main fishery	No. of trips	Species									Total	Per cent of total value
		Lobster	Pandalus	Monk	Haddock	Saithe	Plaice	Herring	Cod	Other		
Haddock	878	0.1	0.0	1.2	**49.4**	8.6	0.7	0.0	**29.3**	10.7	100	21.7
Cod	1206	0.0	0.0	0.3	8.6	0.8	2.8	0.0	**80.8**	6.6	100	16.7
Saithe	205	0.6	0.4	5.0	7.8	**60.4**	0.2	0.0	**13.4**	12.2	100	4.8
Pandalus	851	8.3	**66.4**	12.5	0.7	1.2	0.5	0.0	5.4	5.0	100	18.3
Plaice	1039	0.6	0.0	0.4	0.4	0.0	**74.8**	0.0	4.5	19.4	100	10.7
Monk	310	2.8	0.2	**48.8**	2.3	6.0	0.7	0.0	**22.9**	16.4	100	10.4
Herring	348	0.0	0.0	0.0	0.1	0.7	0.0	**94.8**	0.2	4.1	100	10.2
Lobster	147	**86.6**	0.5	0.6	0.1	0.2	5.1	0.0	0.7	6.2	100	2.9
Mixed	486	10.9	0.0	4.0	1.8	0.5	16.6	0.2	7.5	58.5	100	4.4
Total	5470											100

Characteristics of the directed fisheries

The nine directed fisheries have been described with respect to area, seasonality, and vessel size and are summarized in Table 4. A more detailed description is given in Lewy and Vinther (1992).

Our analysis indicates that the directed fisheries may be divided into two groups (Table 4): the "common" fisheries, in which vessels from nearly all size groups and many home districts participated, and the "special" fisheries, in which only specific vessel groups took part.

Table 4. Features of the main fisheries of the human-consumption trawl trips in the North Sea, 1988.

Fishery	Value in per cent of total	Bycatch	Vessel size (gr. tons)	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, Thisted, Lemvig	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
Pandalus	18	Monk	10–250	Skagen, Thisted, Esbjerg	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–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	—

Table 5. The relative effort distribution (%) on fisheries by vessel size (gross tons) group for Danish North Sea human-consumption trawlers, 1988.

Fishery	Vessel size group						
	10–50 GT	50–100 GT	100–150 GT	150–250 GT	250–500 GT	500 GT	All
Pandalus	20.2	19.6	27.6	22.5	5.1	—	21.3
Plaice	28.1	20.7	5.7	5.8	1.4	—	18.8
Herring	—	—	6.3	23.2	65.3	100.0	5.0
Lobster	2.8	3.4	3.4	2.3	6.5	—	3.1
Mixed	9.9	5.6	4.6	4.3	3.0	—	6.9
Cod	20.8	15.2	3.8	9.7	1.7	—	14.3
Haddock	14.5	21.9	10.8	16.9	6.2	—	15.9
Saithe	1.6	4.6	6.0	4.0	8.2	—	3.7
Monk	2.1	9.0	31.9	11.3	2.5	—	10.9
All	100	100	100	100	100	100	100
Total effort*	10 844	7524	5420	2452	631	20	26 891

*Effort is measured as days absent from harbour.

The common fisheries consisted of the haddock, saithe, shellfish, and mixed fisheries, including vessels from all or many home districts and vessels of size 40–250 GRT. The special fisheries included the cod and plaice fisheries (pursued by small vessels located in Esbjerg and Hvide Sande), the monk fishery (vessels larger than 90 gross tons mainly from Hirtshals), and the herring fishery (the large Skagen trawlers). Each of the two groups of directed fisheries accounted for about half of total value of the landings.

The effort allocation of the trawlers is considered in Table 5, which shows the effort distribution by vessel size group. The table shows that the trawlers larger than 250 gross tons concentrated their effort on herring fishery, while the smaller trawlers spread their effort over several directed fisheries. Trawlers of less than 100 gross tons participated in haddock, saithe, plaice, and Pandalus fisheries, while the larger vessels were concentrated on one or two directed fisheries (Pandalus and monk, Pandalus and herring, or herring only).

Classification of the human-consumption trawler fleet including seasonal changes

The division into sub-fleets by monthly shift between fisheries resulted in a vessel distribution on the fishery patterns which did not contain a few "standard" patterns representing a specific group of vessels. Quarterly analyses along the same line gave similar results. The conclusion is therefore that it was not possible in this way to obtain a manageable partition of the trawlers.

The seasonal changes in the directed fisheries of the trawlers in 1988 is, however, revealed in another way: the trawlers were distributed according to the number of fisheries they were entering. This distribution by vessel size group is shown in Table 6, which shows that vessels

Table 6. The North Sea human-consumption trawlers distributed according to the number of fisheries they were entering in 1988.

Vessel size group gross tons	Number of fisheries								Number of vessels	Average number of fisheries
	1	2	3	4	5	6	7	All		
10–50	35.9	25.3	21.3	15.0	1.9	0.5	0.0	100	206	2.3
50–100	25.9	26.8	26.9	13.9	5.6	0.9	0.0	100	108	2.5
100–150	35.8	25.3	18.9	12.6	4.2	2.1	1.1	100	95	2.3
150–250	45.0	31.7	5.0	15.0	1.7	1.7	—	100	60	2.0
250–500	72.7	18.2	4.5	4.5	—	—	—	100	22	1.4
500–	100.0	—	—	—	—	—	—	100	2	1.0
Total	36.7	26.0	19.3	13.6	3.0	1.2	0.2	100	493	2.2

up to 150 gross tons participated in two or three directed fisheries, while the larger vessels pursued only one or two fisheries. This indicates that smaller vessels tend to be less specialized than larger ones.

Classification of the total trawler fleet according to annual catches

Finally, we tried to obtain a manageable division of the Danish North Sea trawlers by using the average of the annual species composition for each vessel. This analysis included both human-consumption and industrial landings.

In this case the cluster analysis indicated that there were nine clusters or sub-fleets. Four of these were, however, sub-fleets of limited economical importance and these were therefore combined to one sub-fleet called "other". The resulting sub-fleets and their species composition are shown in Table 7.

Table 7 indicates that the vessels targeting for industrial fish only were the most important sub-fleet, accounting for about 72% of total value of the trawl landings. The second most important category was the human-consumption trawlers targeting mainly the roundfish species (approximately 16% of total value). The rest of the vessels participated in mixed industrial and human-consumption fisheries of plaice, herring, and Pandalus, taking about 12% of total value.

Discussion

Identification of directed fisheries may be approached in two different ways: the first approach is by interview to investigate the behaviour of fishermen with respect to their intentions or planned target species before they go fishing. The second approach, which was used here, considers the realized catches only. The drawback of the first method is that the planned target species may not be caught, while the intentions of the fishermen are unknown in the second method. Rogers and Pikitch (1992) compared pre-defined strategies by tow based on gear used, depth fished, and species targeted with their classification of the realized catches obtained from cluster analysis and detrended correspondence analysis. They found strong agreement between many strategies and corresponding classifications, but also some differences. The degree of agreement between target and realized catches depends on many factors such as spatial co-occurrence of species in the sea, fishermen's intentions, and the gear. Generally it may be difficult to predict the realized catches for mixed-species fisheries. In the present analysis cod, haddock, and saithe often are caught at the same fishing grounds with demersal otter trawl. It therefore may be difficult to predict the catches in the corresponding fisheries, which means that these fisheries perhaps should be combined to a single roundfish directed fishery. From a management point of view it may be difficult or impossible to regulate individual stocks caught in mixed-species fisheries.

Identification of directed fisheries could also consider catch data by each haul. In principle this may lead to better definitions of directed fisheries because the catch by trip could include several fisheries. However, as landings information by vessel trip is the most detailed level of disaggregation available, this was used as basis for the analysis.

The cluster analysis technique used for classification of the catch composition by vessel trips seems to be more useful for the present analysis than the principal components analysis (PCA) applied by Laurec *et al.* (1991) and Biseau and Gondeaux (1988) for classification of the catch composition by vessel aggregated by month of the French Celtic Sea trawler fleet. The reason for that is that it was very difficult or impossible to distinguish between directed fisheries on plots of scores on principal component axes due to many overlapping observations. The PCA may be a relevant method when the number of observations is limited and when the plots of scores on the principal component axes clearly separates groups of observations. The métiers of the French Celtic Sea trawler fleet were very different from the Danish North Sea trawler fleet due to differences in the species composition in the sea. However, demersal métiers were identified for both fleets. The French métier

Table 7. Species composition of landings in value by sub-fleet. The Danish North Sea trawl fleet, 1988.

Sub-fleet by target species	No. of vessels	*Species* Lobster	Pandalus	Monk	Haddock	Saithe	Plaice	Herring	Cod	Industrial	Other	Total	Per cent of total value
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
Roundfish	143	1.6	**4.1**	9.6	**20.2**	8.2	2.8	0.2	**34.8**	5.7	12.8	100	16.4
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
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
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
Total	638												100

*Industrial species include all species landed for reduction.

consisted of cod and whiting, while the Danish consisted of cod, haddock, and saithe (Table 7). The haddock and saithe is not available in the Celtic Sea and is therefore not present in the French landings. There is no whiting in the Danish landings because they are not targeted or discarded.

Rogers and Pikitch (1992) applied two cluster analysis methods in connection with ordinated data. The ordination was used to visualize and represent catch and species relationship in a low-dimensional space. The method of selecting assemblages based on consistencies in the three types of analyses is a refined method giving the possibility to study process of agglomeration or division of clusters in detail. Among other things the maximum number of clusters may be determined in this way. In the present analysis this is replaced by plotting the four criteria mentioned above against the number of clusters, which apparently gives results in agreement with prior knowledge to the fishery practise. One advantage using the four criteria is that they are obtained quick and easy and that the maximum number is estimated in an objective way. An interesting matter which no authors have discussed yet is whether one should use raw or ordinated data when classifying catches.

Regarding classification of the trawlers including seasonal changes, it may seem strange that it was not possible to partition the vessels into a few standard patterns when, on average, each vessel entered only 2.2 directed fisheries during the year. The reason for this is partly that about 37% of the vessels entered three or more directed fisheries and partly that the vessels shifted between 2, 3, or more directed fisheries during the year following many different temporal patterns. Furthermore, many vessels fish in some periods in areas outside the North Sea or shift to small-mesh fisheries not included in the analysis. These circumstances indicate that the Danish trawlers seem to shift between directed fisheries in many different ways.

It should be emphasized that the present analyses apply to only a single year's data. Whether or not the directed fisheries identified for 1988 are persistent for a longer time period is not known. Preliminary results for 1990 and 1991 indicate the presence of the same nine directed fisheries. However, the species compositions in the fisheries have changed.

The advantage of using annual classification of directed fisheries based on species composition in landings only – compared to objective criteria independent of landings – is that the results of such methods do reflect the temporal changes in fisheries identified and their species composition. These changes depend on fluctuations in the abundance of various species, their spatial distribution and changes in gear and fishing grounds. Predictability of such changes assumes – besides biological factors – that bio-economical factors affecting fishermen's behaviour should be analysed and modelled including factors such as allocation of fleet effort and gear changes. Such analyses still need to be done.

There are three main applications of identified directed fisheries for one or several target species.

1. Management problems in relation to mixed-species fisheries. The classification of the directed Danish North Sea trawl fisheries indicates the existence of directed fisheries for specific target-species and mixed-species fisheries. The analysis revealed the existence of mixed fisheries for monkfish and the roundfish species, cod, haddock, and saithe. Based on this knowledge (and assuming that these fisheries remain stable over time), it would be possible to implement and evaluate management restrictions on one or more of these species accounting for the implications of the bycatches.
2. Improved estimates of catchability for tuning of VPA (virtual population analysis). Most effort data used for tuning of VPA consist of total effort for a specified fleet, including effort for all fisheries the fleet is entering. This implies that effort not relevant to a given species is included. If the effort distribution on fisheries for the fleet in question changes by year estimated values of catchability will change correspondingly, even if the true value remains constant. These estimates of catchability may therefore seriously affect tuning of VPA. If instead the concept of directed fishery is applied, catch and effort of a target species will be closely connected and will lead to unbiased estimates of catchability. As an example, consider the 1988 catch of cod by the Danish trawlers in the North Sea, where cod was caught in directed fisheries and as important bycatch of the haddock and monkfish fisheries (see Table 3). When catch and effort data are available for a suitable range of year it will be useful to try to identify directed cod fisheries for the whole period and use these when tuning the VPA. It could be very worthwhile to try the same with the directed haddock fishery.
3. Predictions incorporating effort reallocation effects. Most predictions automatically assume that the future fishing pattern – after correcting for eventual management measures – remains constant during the period being predicted. Implicitly, this assumes that the distribution of effort on directed fisheries remains constant as well. Of course, this is an unrealistic assumption. Many management measures and biological changes may change the spatial effort allocation of the fleets.

The dynamics of fleet effort allocation in the North Sea is not understood at present. When investigating fleet dynamics it is essential that such analyses will be based on the effort distributed on directed fisheries because the fishermen's choice of target species presumably is crucial for how they fish. Such types of fleet dynamic models are suggested for instance by Murawski and Finn (1986) and Laurec *et al.* (1991), which, respectively, consider the fleet effort allocation on fisheries and métiers.

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