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Dynamics of fisheries, and the flexibility of vessel activity in Denmark between 1989 and 2001

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Danish fishing vessels can be characterized by their diversity of fishing practice in terms of fishing gear and target species, and by their operational flexibility in respect of these fishing practices throughout the year. We describe the temporal fluctuations in this flexibility by following the activity of individual fishing vessels between 1989 and 2001. Initially, a typology of fisheries (classification of fishing trips) and vessel groups (classification of fishing vessels) was established through multivariate analyses of catch and effort data for 1999. In all, 54 fisheries and 25 vessel groups were identified. These typologies were then applied to all data for the whole time period, and the dynamics of fisheries and vessel groups investigated. The dynamics of vessels groups are studied both within groups (main and secondary fisheries, changes in activity patterns) and between groups (tracking of vessels shifting between groups). Results show average stability of vessel activity in terms of the main fishery, along with a great diversity of secondary fisheries and some possibilities for shifting between gears and areas. We conclude that the level of technical interactions is high, and that separation into distinct management units is difficult.

Keywords: Denmark, dynamics, fisheries, flexibility, multivariate, technical interactions.

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Introduction

With many fish resources in rapid decline, questions are being asked about the reasons for the failure of fisheries management, as well as about improvements that could be implemented. Specifically, the concept of fleet dynamics is receiving increased attention within European fisheries research and management bodies. The concept synthesizes the general idea that the species are not exploited independently, but are considered simultaneously because of the technical interactions between fishing practices and that the fishing practices themselves cannot easily be summarized as an F-multiplier in assessment and prediction, because fishing vessels can easily modify their activity.

The importance of this for fisheries management has long been realized (Mesnil and Shepherd, 1990; Laurec *et al.*, 1991; Pope, 1991; ICES, 1992a, b), but practical progress towards integrating the issues into the processes of stock assessment and management has been slow. Notwithstanding, some analyses have started the move from single-species-based to fisheries-based advice (STECF, 2002; ICES, 2003). In particular, a major focus has been to better understand the behaviour of fishers so as to appreciate the decisions made by fishers on the grounds, and therefore, how their distribution of effort changes along with external stimuli (changes in resource availability, market price, or management).

In the case of complex fisheries, where different species can be exploited in several areas by differing gears, analysis of fishing vessel activity has been undertaken through defining the types of activities. The aim of this step is to reduce the description of the variety of fishing trips to a single categorical variable that summarizes its main characteristics (e.g. gear used, fishing ground, target species). This variable has mostly been referred to as either *métier* (Biseau and Gondeaux, 1988; Mesnil and Shepherd, 1990; Laurec *et al.*, 1991; Tétard *et al.*, 1995; Marchal and Horwood, 1996; Biseau, 1998; Ulrich *et al.*, 2001), *fishery* (Murawski *et al.*, 1983; Lewy and Vinther, 1994), or *fishing tactic* (Laloë and Samba, 1991; Pelletier and Ferraris, 2000; Pech *et al.*, 2001). Two approaches have been used for this purpose. The first is quantitative analysis of catch or landing composition, with or without effort information (gear, season, location). Several methods, based on multivariate procedures, have been applied: Principal Component Analysis (PCA; Biseau and Gondeaux, 1988; Laurec *et al.*, 1991; Jabeur *et al.*, 2000), Multiple Correspondence Analysis (MCA; Pelletier and Ferraris, 2000), and cluster analysis (Lewy and Vinther, 1994). The second approach is based on *a priori* qualitative knowledge of the fisheries. Allocation of each fishing trip to a fishery relies on a process of trial and error, by deriving discriminating thresholds based either on landings (weight or value), or mesh size (Tétard *et al.*, 1995; Biseau, 1998; Ulrich *et al.*, 2001). Such typologies are used extensively by scientists designing sampling programmes (ICES, 2003), for example.

The next step following fisheries characterization is to identify groups of fishing vessels sharing similar activity patterns, i.e. participating in the same fisheries. Such groups of vessels have been referred to as *fleets* (Laurec *et al.*, 1991; Lewy and Vinther, 1994; Ulrich *et al.*, 2001), or *strategies* (Laloë and Samba, 1991; Pech *et al.*, 2001). Here, we use the term *vessel groups*. A given vessel can belong to just one vessel group during a given period of time, but it can participate in different fisheries during the same period. Hereafter, we use the terminology *-ing* to describe a fishery (reference to the fishing trip, e.g. Baltic longlining), and the terminology *-ers* to describe a vessel group named after its main fishery (e.g. Baltic longliners, group of vessels operating mainly in Baltic longlining).

Danish fishing practices are diverse in terms of target species, fishing grounds, and gears. Except for some offshore and industrial fisheries, most fishing activities by Denmark are conducted with relatively old, medium-sized vessels, where the skipper is the owner, and where the trips usually last one or a few days. They are able to target different species with several gears at different times of the year, and to steam to many areas. The consequences of this are that Danish fishing vessels are generally difficult to classify into simple fleets for management purposes, and that the consequences of any management regulation are difficult to assess, because fishers will adapt their activity to other species or fishing grounds in a manner that is still poorly understood.

A number of studies have defined Danish fisheries, using different methods and criteria, and different results have been obtained. Lewy and Vinther (1994) defined trawl fisheries in the North Sea with clustering methods based on the 1988 value of landings. Hovgaard *et al.* (2000) and Nielsen (2000) empirically aggregated the fishing trips from 1987 to 1998 in the Kattegat and Eastern Baltic into a few groups by gear, based on the frequency distribution of the mesh sizes and the main target species. Both these studies investigated the relationships between fisheries through the annual activity pattern of individual vessels, but neither reached firm conclusions on vessel groups or flexibility. Finally, since 1995, an *ad hoc* classification, covering all Danish waters and established in collaboration with the fishing industry, has been used for discard sampling purposes (DIFRES, unpublished data). This approach by gear and main area defined 48 fisheries based on heterogeneous criteria: gear only (Danish seine, fixed ground nets, and linefisheries), mesh size (demersal trawl fisheries), landing value by species (gillnet fisheries), and mesh size together with landing volume by species (industrial and purse-seine fisheries). The advantages of this last classification are its complete coverage of all Danish trips over all years, and its current application to sampling programmes. Its disadvantages are its lack of statistical rigour, the heterogeneity of classification criteria, and the relatively high level of aggregation in some cases. Further, mesh size is often not included, which makes it difficult to match the new data requirements from the European Commission for standardized sampling programmes.

The current analysis represents the first step of a study aimed at modelling the behaviour of fishers, and in particular their reactions to technical management measures. The study is to be integrated into a framework to improve the advice on management through the dynamic simulation of fisheries systems in Denmark, including more comprehensive fleet dynamics than used until now (e.g. Ulrich *et al.*, 2002). The purpose here was twofold. First, we identified the fisheries and vessel groups present in Danish waters in 1999 (chosen as a reference year), performed a multivariate analysis of effort and landing data, and compared the results with the classifications existing previously. This led to a final definition (so-called typology) of fisheries, which would satisfy the need for quantitative data analysis, an *ad hoc* view from the fishing industry, and European Commission's requests; not differ too much from the sampling programme currently in use; and be usable for further bioeconomic modelling.

For our second purpose, we applied the typologies obtained to data in all years between 1989 and 2001 to describe the dynamics of the fisheries and the vessel groups through temporal trends and interrelationships between vessel groups. The reasons for the dynamics observed, and in particular the role of both resource availability and management, were not investigated. They will be analysed later.

Material and methods

Data

Analyses were based on logbooks and sale slips provided by Danish commercial fishers. The data contained information per vessel at a trip level, including landing weights and values by species (except for the industrial species – sandeel, Norway pout, blue whiting, and sprat – which are aggregated under the "ind" label), gear and mesh size, and fishing location (ICES rectangle).

Before analyses were performed, trips with missing information, out of range data, unknown identification numbers, or mismatched data were removed from the data set. The final data set contained around 1.3 million valid fishing trips, undertaken by 3093 fishing vessels during the period 1989–2001. However, owing to the large size of the data set, the identification of fisheries and vessel groups was restricted to the 1999 data, which was chosen as reference year. Analyses were performed with SAS (SAS Institute Inc., 1999) and SPAD.N (CISIA, 1999) software.

Identification and description of fisheries and vessel groups

Typology of fisheries

The analysis was conducted separately for each gear (gillnet, [pair] trawl, Danish seine, beam trawl, purse-seine, longline) and each main area (Figure 1), i.e. North Sea, Skagerrak, Kattegat, Western Baltic (ICES rectangles 22−24), Eastern Baltic (rectangles 25−32). Separation by area was decided on by the presence of different stocks of the same species, and the differences in regulations across areas. Only a few specific offshore fisheries, where trips generally cover more than one area, were considered on a wider spatial scale (e.g. North Sea + Skagerrak). The framework used for identifying the fisheries followed three steps, as proposed by ICES (2003): (1) identification of the different types of species composition of the landings (landings profile) from the catch data, (2) analysis of the relationships between the features of each trip (effort data) and their outcome in terms of landings profile, and (3) aggregation of the results of step 2 to define fisheries that are considered sensible in relation to the field knowledge and expertise.

The methodology for steps 1 and 2 was that used and detailed by Pelletier and Ferraris (2000). Step 1 was based on the percentage of the value of each species in the landings. All species with a total value >10 000 DKK (Danish kroner) were retained for analysis separately, the others were aggregated into the category "other". A normalized PCA was run to explore the relative distribution of the species. A Hierarchical Agglomerative Cluster (HAC) based on the minimum variance criterion of Ward (1963) was applied to all factorial coordinates from the PCA and led to partition into a given number of clusters. The criterion used for estimating the appropriate number of clusters was the percentage of the variance explained (Lebart *et al.*, 1995). The final number was chosen from those in which the increase in variance explained levelled off, based on the relevance of cluster interpretation. Each cluster corresponded to one type of landings profile, which was then considered as a categorical variable named "landings profile" in the subsequent output data set.

In step 2, we examined how effort variables such as mesh size, season (month), and fishing location were related to the observed landings profiles, and how all data could be combined for identifying trip clusters. A Multiple Correspondence Analysis (MCA) was applied to the data matrix, built with fishing trips as individuals, and the effort and landings profile as categorical variables. Finally, an HAC analysis with the same criteria as for step 1 was applied on all the factorial coordinates from the MCA. This led to a given number of clusters (called "combinations") combining area, effort data, and landings profile.

In step 3, the final definition of fisheries was set. This was done by arbitrarily pooling some of the clusters obtained in step 2. The aim of this procedure was to decrease the number of combinations without losing meaningful information on the structure of the data set. Various criteria were considered, including cluster size, similarity with other clusters, seasonal patterns, difference in current management practices, and consistency with the *ad hoc* classification used by DIFRES.

Typology of vessel groups

Describing the fisheries was not deemed sufficient to understand the mechanisms involved in the dynamics of fishing

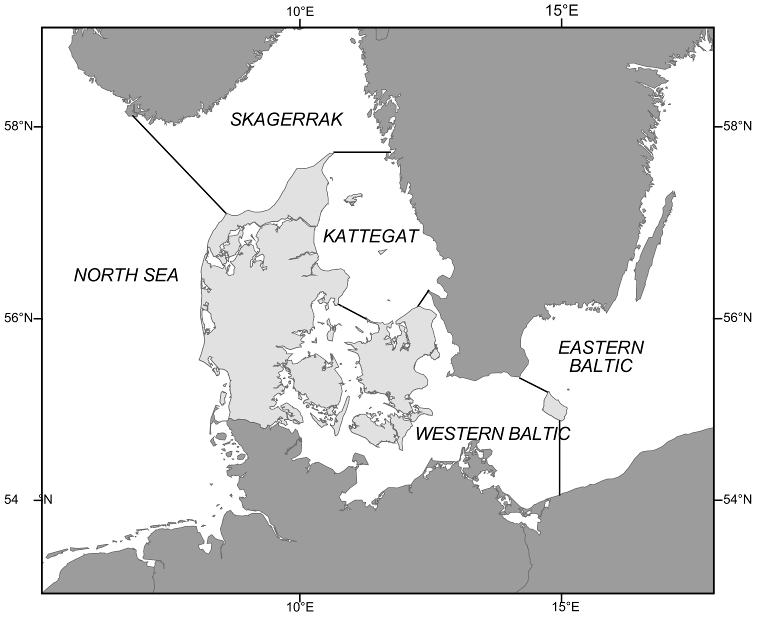

Figure 1. Danish waters.

activity. That required also analysis at the scale of the fishing vessel, not just at the trip level. We therefore constructed groups of fishing vessels that had similar activities, regardless of their physical characteristics and home port.

Vessel groups were identified using the same multivariate procedure as used for the identification of landings profiles (step 1). A normalized PCA was applied to the data matrix, built with vessels as individuals, and the percentage of trips spent in each fishery as variables. An HAC was then applied to all factorial coordinates from the PCA. The identified clusters (vessel groups) were named after the fishery with the highest percentage of trips within the cluster. That fishery was referred to as the main fishery of a given vessel group.

Description of vessel group flexibility

The flexibility of vessel groups is a generic term underlining the fact that fishing vessels are able to switch between fisheries at a trip level, i.e. without modifying their physical characteristics. This flexibility was quantified by two indices: polyvalence, and seasonality.

The index of polyvalence, H, reflects the relative importance of the main fishery to the other fisheries. We used an index similar to that developed by Shannon (1948) for measuring biodiversity:

$$H_{vg,y} = \sum_{i=1}^{F} p_{i,vg,y} \times \log p_{i,vg,y}$$

where $p_{i,vg,y}$ is the proportion of trips spent by vessel group vg in fishery i during year y, and F is the total number of fisheries. A high index indicates that the activity of that vessel group is spread over several fisheries of importance. Such vessel groups are referred to as polyvalent. A low index indicates a vessel group operating in few fisheries, with strong preference for the main fishery. Such vessel groups are referred to as specialized.

The index of seasonality IS, by year y and vessel group vg, reflects the seasonal pattern of the main fishery. It is expressed as the maximum number of consecutive months during which the main fishery of the vessel group (which was identified at the year level) was also the main fishery in terms of number of trips over the period analysed. An index close to 12 indicates that vessels operated in their main fishery throughout the year, whereas one closer to 1 indicates that vessel activity was more seasonal, with the main fishery being operated during a limited period, and secondary fisheries being operated during the balance of the year.

Dynamics of fisheries and vessel groups

Temporal trends

The typologies of fisheries and vessel groups identified for the year 1999 were translated into discriminating allocation rules, based on area, gear, mesh size, and/or dominant species for fisheries, and on the main fishery (for vessel groups). These rules were subsequently applied to trip data for the period 1989–2001. Each trip was allocated to just one fishery, and each vessel was allocated to only one vessel group per year. The use of fixed rules allowed comparison of the dynamics of the various fisheries and vessel groups independently from the natural fluctuations in species assemblages.

Temporal trends for fisheries were described in terms of number of trips per year. For vessel groups, they were described in terms of number of vessels, average number of trips, average percentage of trips spent in the main fishery, and index of polyvalence.

Shifts between vessel groups

For any two consecutive years, we calculated transition matrices that described shifts between vessel groups. These matrices represented the number and percentage of vessels in vessel group i in year y and in vessel group j in year y + 1. Vessels entering or leaving the fishery were also included. This allowed measuring the extent to which vessels tended to stay within the same vessel group throughout the study period, i.e. did not broadly change their activity by modifying their main fishery. The median value of the percentage of vessels staying in the same vessel group i between two consecutive years was referred to as the index of stability S_i.

Results

Identification of fisheries and vessel groups

Typology of fisheries

Multivariate analyses (steps 1 and 2) were performed on 20 cases of area × gear (Table 1). Only the case of Kattegat longlines, from which landings were exclusively cod, was not analysed but introduced directly as a fishery in step 3. Analysis of the landings profile by PCA and HAC led to the identification of 2–13 clusters per case, which explained 16–97% of the variance. In all cases, one or two species were highly characteristic of each cluster, which was then named after them. Choice of the number of clusters was made on the basis of the thresholds of variance explained, and on the relevance of clusters, in particular of the dominant species. For example, other levels were possible for Danish seiners in the Skagerrak (e.g. 4, 13, or 15 clusters explained, respectively, 19, 47, and 51% of the variance), but the clusters obtained all had the same dominant species (cod or plaice) as in the classification with three clusters, and were therefore no indication of changes in target species. In all analyses, many clusters were also small (<5% of the number of trips per case). Among them, only those considered to be indicators of real target species (e.g. herring and *Pandalus* for Kattegat otter trawl trips) were retained as active landings profiles in step 2.

Various preliminary trials were run during step 2 to decide which effort data should be retained among mesh size, month, and ICES rectangle. Given that the analyses

Table 1. Three-step approach for identifying Danish fisheries by area and gear during 1999. Areas are displayed in geographical order. The number in parenthesis is the number of clusters including <5% of the number of trips. MVA, multivariate analysis; SS, single-species; LP, landings profile; MS, mesh size class; E + W, eastern and western.

				Step 1 LP		Step 2 Combinations LP + MS			Step 3 Fisheries
Area	Gear	No. of trips	Method	No. of clusters	% of variance	No. of MS	No. of clusters	% of variance	No. of fisheries
Baltic E + W	Danish seine	850	MVA	2 (0)	24.7	1	–	–	1
Baltic E + W	Longlines	584	MVA	3 (1)	97.4	–	–	–	1
Baltic East	Otter trawl	6 231	MVA	5 (3)	44.4	2	2 (0)	92.0	2*
Baltic East	Gillnet	1 793	MVA	4 (3)	62.9	2	2 (1)	91.6	2
Baltic West	Demersal trawl	16 609	MVA	5 (3)	25.6	3	3 (1)	67.0	2*
Baltic West	Gillnet	6 883	MVA	9 (6)	56.0	4	5 (0)	89.4	3
Kattegat	Longlines	8	SS	–	–	–	–	–	1
Kattegat	Otter trawl	10 551	MVA	13 (8)	49	5	11 (5)	94.9	6
Kattegat	Danish seine	1 287	MVA	5 (2)	41.8	1	–	–	1
Kattegat	Gillnet	2 714	MVA	8 (3)	60.2	5	6 (1)	72.4	4
Skagerrak	Otter trawl	12 812	MVA	7 (3)	29.3	5	12 (6)	96.0	5
Skagerrak	Danish seine	2 550	MVA	3 (1)	16.0	1	–	–	1
Skagerrak	Gillnet	4 238	MVA	9 (4)	50.2	5	8 (1)	88.0	3
Skagerrak	Longlines	76	MVA	2 (0)	29.4	–	–	–	1
North Sea	Otter trawl	13 587	MVA	9 (3)	41.6	5	11 (5)	96.3	6**
North Sea	Danish seine	2 147	MVA	5 (3)	25.1	1	–	–	1
North Sea	Gillnet	8 464	MVA	7 (4)	45.1	5	9 (3)	93.3	5
North sea	Longlines	238	MVA	3 (0)	40.0	–	–	–	1
North Sea + Skagerrak	Beam trawl	2 132	MVA	2 (0)	33.9	2	2 (0)	98.8	2
North Sea + Skagerrak	Purse-seine	196	MVA	2 (0)	100	1	–	–	2

*The Eastern and the Western Baltic herring and industrial midwater trawl fisheries were pooled.

**The North Sea and Skagerrak herring midwater trawl fisheries were pooled.

were already performed by area, the fishing location expressed by ICES rectangle was not relevant for describing fisheries, especially in the smaller areas such as the Skagerrak, the Kattegat, and the Western Baltic. Final runs were performed with mesh size (aggregated into a limited number of classes) and landings profiles as active variables. The cases where a single mesh size class was identified (Danish and purse-seine cases) were not analysed in this step, but were introduced directly as fisheries in step 3. The MCA and HAC procedures led to the identification of 2–11 clusters per case, explaining 67–99% of the variance (Table 1). These high levels of explained variance indicated that species assemblages, and in particular dominant species, were strongly related to the mesh size used. Some combinations showed redundancy between variables (i.e. a given mesh size class was related to just one landings profile, and vice versa, e.g. the industrial species caught by otter trawls with mesh size <30 mm). However, the landings profile was also necessary to discriminate between combinations using the same gear and mesh size class, specifically when the technical characteristics of the gear were not available in the data set (e.g. most gillnet combinations). A total of 71 combinations (area × gear × mesh size class × landings profile) was identified from these 20 cases, among which 23 contained $<5\%$ of the number of trips per case. They represented the highest level of disaggregation obtained when selecting combinations that could be interpreted.

Finally, some of the combinations were pooled in step 3. The resulting pools were considered as relevant fisheries. In total, 1–6 fisheries per case were retained, the largest numbers for otter trawl cases. In all, 40 such fisheries were so defined from step 2, and a further ten fisheries were introduced directly from step 1 and from the single-species case (8% of all trips in 1999). Finally, one miscellaneous fishery per area was assigned to gather all trips not included in the other fisheries. This led to a total of 54 fisheries for the whole Danish fleet (Table 2).

The importance of these fisheries in terms of number of trips differed widely. The smallest was Kattegat longlining (eight trips in 1999), and the largest was groundfish trawling in the Western Baltic (16 609 trips). Of the total number of trips, 55% were within just eight fisheries (Eastern and Western Baltic groundfish trawling, North Sea industrial midwater trawling, North Sea cod gillnetting, Western Baltic groundfish gillnetting, Skagerrak mixed trawling, and Kattegat and Skagerrak *Nephrops* trawling). The average value of the dominant species was $>45\%$ for all fisheries ("others" not considered in this calculation), except for some of the mixed and groundfish trawling and Danish seining fisheries.

Typology and description of vessel groups

The PCA–HAC analysis of fishing vessels in terms of the percentage of trips spent in each fishery led to the identification of 31 clusters, explaining 61.2% of the variance. For each cluster, one fishery was highly characteristic and referred to as the main fishery. Six clusters had fewer than five vessels, and showed strong similarities with some other clusters regarding the main fishery. They were arbitrarily pooled. This led to a total of 25 clusters, referred to as vessel groups (Table 3). Vessel groups contained between 2 (Skagerrak longliners) and 139 (North Sea gillnetters) fishing vessels. Few vessel groups were characterized by operating in a single fishery (e.g. *Crangon* beam trawling, Baltic longlining); most operated in three or more different fisheries in 1999. The index of polyvalence H reflected this diversification of activity. Vessel groups whose index was <1 (ten vessel groups) were highly specialized, spending at least 70% of their trips in their main fishery (with the exception of the North Sea/Skagerrak purse-seiners, which shared their trips equally between just two fisheries). Conversely, the most polyvalent vessel groups (highest H values) spent $<50\%$ of their trips in their main fishery, the minimum being observed for the Kattegat gillnetters (29%). It is remarkable that gillnetters in each area, and Danish seiners off eastern Denmark (Skagerrak to the Baltic Sea), were not statistically split into several vessel groups. This indicated a high level of complementarity between the fisheries.

Comparing secondary fisheries with the main fishery within each vessel group indicated whether this polyvalence was in terms of gear, mesh size, target species, and/or fishing area. The Danish seiners (10% of all vessels) were typically highly specialized in terms of gear, but often switched between fishing areas, even remote ones (North Sea Danish seiners sometimes fished in the Baltic Sea). Conversely, gillnetters (30% of all vessels) always remained in the same area, but had different nets which they set for different target species throughout the year. *Nephrops* trawlers (19% of all vessels) operated with different mesh sizes within the same area, but also visited adjacent areas. Midwater trawlers (11% of all vessels) and demersal trawlers (23% of all vessels) were more difficult to describe; their activity changed throughout the year in many combinations of area, gear, and mesh size.

Half the vessel groups showed no seasonal pattern, operating in their main fishery throughout the year (Table 3). Seven vessel groups had a long season in their main fishery ($6 \leq \text{IS} \leq 9$). These were essentially the Danish seiner and *Nephrops* trawler vessel groups. Finally, six vessel groups had a short season in their main fishery ($\text{IS} < 6$). They were those with a discontinuous activity (North Sea/Skagerrak purse-seiners, Skagerrak longliners), and vessel groups demonstrating a strong seasonality in the various fisheries (Kattegat gillnetters).

Temporal trends by fisheries and vessel group

Fisheries

The number of trips by fishery varied greatly for all areas (Figure 2). The average number of trips, along with the

Table 2. Typology of Danish fisheries in 1999. Area, descriptive name, with the type of gear used, mesh size range, main species and average percentage value, total number of trips. Emboldening indicates the parameters used for allocation rules.

Code	Area	Name	Mesh size (mm)	Species 1	Species 2	Species 3	No. of trips
BA3.1	Baltic E + W	Industrial midwater trawling	**<30**	**ind (79)**	cod (15)		2 225
BA3.2	Baltic E + W	Herring midwater trawling	**30−<90**	**herring (81)**	ind (9)	sprat (5)	982
BA4.1	Baltic E + W	Danish seining	100−120	cod (64)	flounder (12)	plaice (11)	850
BA7.1	Baltic E + W	Longlining		cod (65)	salmon (29)	eel (4)	584
BA8.1	Baltic E + W	Others		cod (61)	eel (14)		787
EB1.1	Baltic East	Groundfish trawling	**>=90**	cod (95)			6 111
EB5.1	Baltic East	Cod gillnetting	**<160**	cod (97)			1 734
EB5.2	Baltic East	Salmon gillnetting	**>=160**	salmon (87)			59
WB1.1	Baltic West	Groundfish trawling	**>=90**	cod (74)	plaice (11)	witch (6)	16 609
WB5.1	Baltic West	Cod gillnetting	**<120**	cod (88)	sole (3)		1 118
WB5.2	Baltic West	Groundfish gillnetting	**120−<220**	cod (69)	plaice (15)	witch (8)	5 640
WB5.3	Baltic West	Turbot gillnetting	**>=220**	turbot (54)	cod (20)	lump (10)	125
KA1.1	Kattegat	*Pandalus* trawling	**30−<70**	**pandalus (48)**	cod (23)	nephrops (13)	89
KA1.2	Kattegat	*Nephrops* trawling	**70−<90**	nephrops (82)	cod (5)	sole (5)	4 640
KA1.3	Kattegat	Mixed trawling	**90−<105**	nephrops (46)	cod (24)	sole (12)	3 365
KA1.4	Kattegat	Groundfish trawling	**>=105**	cod (53)	plaice (15)	nephrops (12)	1 228
KA3.1	Kattegat	Industrial midwater trawling	**<30**	**ind (93)**			946
KA3.2	Kattegat	Herring midwater trawling	**30−<70**	**herring (97)**			283
KA4.1	Kattegat	Danish seining	100−120	plaice (53)	cod (24)	dab (9)	1 287
KA5.1	Kattegat	Sole gillnetting	**<120**	sole (82)	plaice (6)	cod (5)	811
KA5.2	Kattegat	Flatfish gillnetting	**120−<220**	**plaice (42)**	sole (30)	lemon sole (5)	942
KA5.3	Kattegat	Roundfish gillnetting	**120−<220**	**cod (83)**	plaice (6)		433
KA5.4	Kattegat	Lump gillnetting	**>=220**	lump (45)	turbot (22)	cod (18)	463
KA7.1	Kattegat	Longlining		cod (100)			8
KA8.1	Kattegat	Others					305
SK1.1	Skagerrak	*Pandalus* trawling	**30−<70**	**pandalus (70)**	nephrops (9)	cod (9)	460
SK1.2	Skagerrak	*Nephrops* trawling	**70−<90**	nephrops (71)	cod (10)	witch (6)	5 143
SK1.3	Skagerrak	Mixed trawling	**90−<105**	nephrops (34)	cod (24)	plaice (13)	5 163
SK1.4	Skagerrak	Groundfish trawling	**>=105**	cod (45)	plaice (26)	lemon sole (9)	1 086
SK3.1	Skagerrak	Industrial midwater trawling	**<30**	ind (81)	cod (7)		960
SK4.1	Skagerrak	Danish seining	100−120	plaice (61)	cod (22)	witch (5)	2 550
SK5.1	Skagerrak	Sole gillnetting	**<120**	sole (69)	cod (14)	plaice (11)	157
SK5.2	Skagerrak	Flatfish gillnetting	**>=120**	**plaice (64)**	sole (12)	cod (11)	1 269
SK5.3	Skagerrak	Roundfish gillnetting	**>=120**	**cod (85)**	pollack (4)		2 678
SK7.1	Skagerrak	Longlining		cod (63)	mackerel (26)		76
SK8.1	Skagerrak	Others		monkfish (29)			285
NO1.1	North Sea	*Pandalus* trawling	**30−<70**	pandalus (64)	nephrops (12)	monkfish (9)	625
NO1.2	North Sea	*Nephrops* trawling	**70−<100**	nephrops (66)	monkfish (8)	plaice (7)	544
NO1.3	North Sea	Mixed trawling	**100−<105**	cod (23)	nephrops (22)	monkfish (15)	3 405
NO1.4	North Sea	Groundfish trawling	**>=105**	plaice (38)	cod (26)	turbot (6)	2 767
NO3.1	North Sea	Industrial midwater trawling	**<30**	**ind (97)**			6 246
NO4.1	North Sea	Danish seining	100−120	plaice (42)	cod (37)	lemon sole (8)	2 147
NO5.1	North Sea	Hake gillnetting	120−<220	**hake (65)**	cod (23)	sole (3)	202
NO5.2	North Sea	Turbot gillnetting	>=120	**turbot (74)**	brill (6)	cod (6)	175
NO5.3	North Sea	Plaice gillnetting	120−<220	**plaice (61)**	cod (16)	sole (7)	1 047
NO5.4	North Sea	Sole gillnetting	<140	**sole (87)**	plaice (4)		1 624
NO5.5	North Sea	Cod gillnetting	120−<220	**cod (88)**	plaice (3)		5 416
NO7.1	North Sea	Longlining		cod (70)	haddock (7)		238
NO8.1	North Sea	Others		mussels (24)			797
NS2.1	NS/Skagerrak	Flatfish beam trawling	**>=80**	plaice (67)	turbot (7)	cod (7)	610
NS2.2	NS/Skagerrak	*Crangon* beam trawling	**<80**	**crangon (99)**			1 522
NS3.2	NS/Skagerrak	Herring midwater trawling	**30−<70**	**herring (69)**	mackerel (18)		668
NS6.1	NS/Skagerrak	Mackerel purse-seining	30−40	**mackerel (100)**			91
NS6.2	NS/Skagerrak	Herring purse-seining	30−40	**herring (100)**			105

coefficient of variation and slope of the linear regression over the time period of all fisheries, are displayed in Table 4. Some fisheries were more active during the early 1990s (Kattegat and Skagerrak *Nephrops* trawling), others were more active during the mid-1990s, when the number of trips was greatest (Baltic longlining, Western Baltic gillnetting, Kattegat sole and plaice gillnetting, North Sea cod gillnetting). Overall, the number of trips increased in 23 fisheries (positive slope), but often with large variations between years. Four fisheries showed no trends in number

Table 3. Typology of Danish vessel groups in 1999. Main fishing area, name describing the type of main activity, number of vessels and average number of trips, main and secondary fishery with percentage of trips, polyvalence and seasonality indices.

Code	Main area	Name	No. of vessels	Average no. of trips	Main fishery	Secondary fishery	H	IS
BA_Lg	Baltic E + W	Longliners	4	56	BA7.1 (92)	EB5.1 (5)	0.51	11
EB_Gn	Baltic East	Gillnetters	10	146	EB5.1 (86)	BA7.1 (5)	0.47	12
EB_Ot	Baltic East	Demersal trawlers	52	100	EB1.1 (77)	WB1.1 (12)	0.78	12
WB_Gn	Baltic West	Gillnetters	84	81	WB5.2 (66)	WB5.1 (12)	1.26	12
WB_Ot	Baltic West	Demersal trawlers	134	106	WB1.1 (78)	NO1.4 (4)	0.99	12
KA_Gn	Kattegat	Gillnetters	36	60	KA5.2 (29)	KA5.1 (22)	2.19	3
KA_Ne	Kattegat	*Nephrops* trawlers	77	84	KA1.2 (47)	KA1.3 (29)	1.50	9
KA_Ot	Kattegat	Demersal trawlers	12	53	KA1.4 (69)	KA1.3 (9)	1.52	12
KB_He	Kattegat + Baltic	Herring midwater trawlers	10	88	BA3.2 (51)	KA3.2 (15)	1.59	5
KB_In	Kattegat + Baltic	Industrial midwater trawlers	12	133	BA3.1 (33)	KA3.1 (26)	1.95	4
KS_Ds	Kattegat + Skagerrak + Baltic	Danish seiners	52	88	SK4.1 (56)	KA4.1 (21)	1.44	8
SK_Gn	Skagerrak	Gillnetters	48	79	SK5.3 (46)	SK5.2 (26)	1.64	9
SK_Lg	Skagerrak	Longliners	2	5	SK7.1 (68)	SK5.3 (23)	0.85	3
SK_Ne	Skagerrak	*Nephrops* trawlers	84	103	SK1.2 (40)	SK1.3 (35)	1.66	8
NO_Ds	North Sea	Danish seiners	51	46	NO4.1 (83)	BA4.1 (11)	0.75	9
NO_Gn	North Sea	Gillnetters	139	52	NO5.5 (66)	NO5.4 (14)	1.35	11
NO_Lg	North Sea	Longliners	8	38	NO7.1 (66)	NO5.5 (9)	1.45	7
NO_Ms	North Sea	Mussels dredgers	15	28	NO8.1 (84)	NO7.1 (5)	0.97	9
NO_Ne	North Sea	*Nephrops* trawlers	37	84	NO1.3 (63)	NO1.2 (11)	1.40	12
NS_Bt	North Sea + Skagerrak	Flatfish beam trawlers	3	78	NS2.1 (79)	NO1.3 (10)	0.80	11
NS_Cr	North Sea + Skagerrak	*Crangon* beam trawlers	22	65	NS2.2 (98)		0.16	12
NS_In	North Sea + Skagerrak	Industrial midwater trawlers	103	65	NO3.1 (71)	NS3.2 (10)	1.16	11
NS_Ot	North Sea + Skagerrak	Demersal trawlers	48	72	NO1.4 (46)	SK1.4 (21)	1.87	12
NS_Pa	North Sea + Skagerrak	*Pandalus* trawlers	14	68	NO1.1 (44)	SK1.1 (39)	1.35	4
NS_Ps	North Sea + Skagerrak	Purse-seiners	6	18	NS6.2 (50)	NS6.1 (49)	0.79	4

of trips (Eastern Baltic cod gillnetting, North Sea plaice gillnetting, North Sea/Skagerrak flatfish beam trawling, and Skagerrak groundfish trawling), and the number of trips decreased in another 27 fisheries (negative slope). Fisheries with increasing trends included all fisheries in the Western Baltic, and most fisheries with fixed gears. Other fisheries with towed gears decreased in number of trips, except for Baltic industrial midwater trawling and Danish seining, Kattegat and North Sea mixed trawling, and *Crangon* beam trawling.

Vessel groups

The temporal dynamics in the number of vessels and number of trips during the past decade differed between vessel group and between areas (Figure 3). General results were that most vessel groups decreased in terms of number of vessels, but increased in terms of number of trips per vessel (Table 5). The slope of the index of polyvalence decreased for most vessel groups, indicating that they became less polyvalent with time. However, the slope of average percentage of trips spent in their main fishery was also negative or close to zero in most cases, indicating no increasing activity in the main fishery. This means that the progressive loss of polyvalence took place rather through the loss of some secondary activities.

Only a few vessel groups failed to follow these general trends. The number of vessels increased in some small vessel groups, but also in some more important ones such as Western Baltic demersal trawlers. The index of polyvalence increased for some vessel groups (Baltic Sea longliners, and North Sea Danish seiners and demersal trawlers). The large variations in the number of vessels in the Western Baltic and Kattegat gillnetter vessel groups between 1994 and 1997 were due to changes in the regulations: to protect inshore vessel groups, small boats were allocated a fixed proportion of the cod quota in 1994. This contributed to the registration of a large number of small boats in an attempt to increase individual catch shares. The system lasted until 1996, when the Danish Fisheries Directorate decided to control the activity of registered vessels, and to suppress the fishing rights of less active ones (F. I. Hansen, DIFRES, pers. comm.).

Shifts between vessel groups

The stability over two consecutive years differed widely among vessel groups, both in median value (S_i), and in interannual fluctuations (Figure 4). The most stable vessel groups were among the specialized offshore vessel groups (North Sea/Skagerrak purse-seiners, *Crangon* beam trawlers, industrial trawlers), and some North Sea inshore vessel groups (Danish seiners, gillnetters, longliners). Danish seiners were also stable in other areas, with an index of stability $>85\%$. The least stable vessel group was the Kattegat demersal trawlers ($S_i = 38\%$). The *Nephrops* trawler vessel groups had an index of stability around 70%,

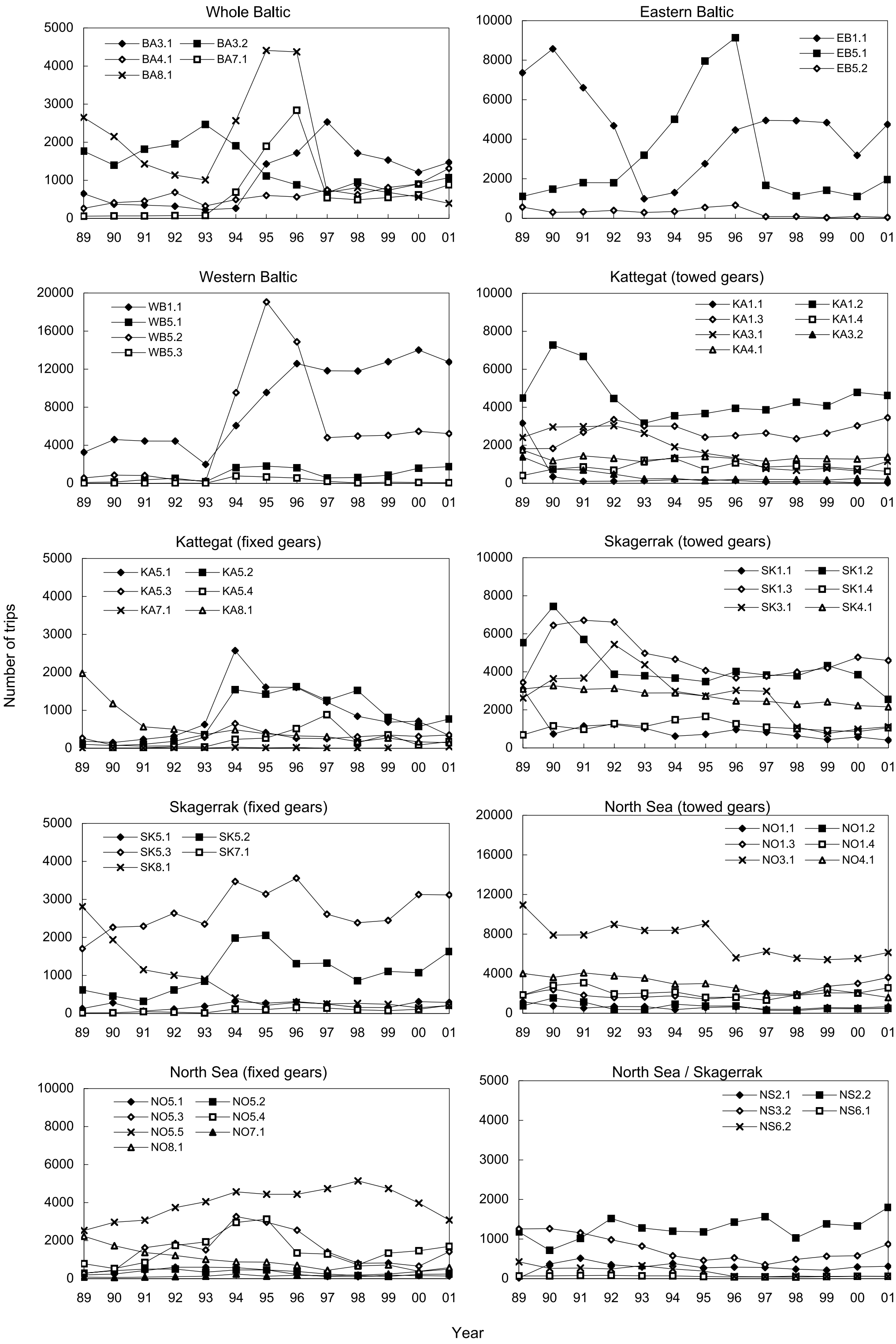

Figure 2. Dynamics of Danish fisheries between 1989 and 2001, in terms of total number of trips per year. Three different scales are used on the y-axis because of large differences in effort across fisheries. Fishery coding is defined in Table 2.

Table 4. Summary statistics for fisheries temporal trends (number of trips per year) between 1989 and 2001. Fishery coding is defined in Table 2.

Code	Mean	CV (%)	Slope (%)
BA3.1	1 060	70	12
BA3.2	1 357	42	−8
BA4.1	631	44	9
BA7.1	680	121	11
BA8.1	1 758	79	−8
EB1.1	4 569	48	−5
EB5.1	2 980	91	0
EB5.2	291	73	−12
WB1.1	8 469	52	12
WB5.1	905	75	12
WB5.2	5 528	106	10
WB5.3	199	140	4
KA1.1	360	235	−32
KA1.2	4 527	26	−3
KA1.3	2 671	19	2
KA1.4	844	29	1
KA3.1	1 761	53	−12
KA3.2	396	91	−17
KA4.1	1 329	12	−1
KA5.1	855	84	5
KA5.2	798	77	10
KA5.3	282	56	6
KA5.4	231	112	11
KA7.1	12	103	12
KA8.1	527	97	−19
SK1.1	955	73	−13
SK1.2	4 297	29	−5
SK1.3	4 763	24	−3
SK1.4	1 119	23	0
SK3.1	2 722	52	−10
SK4.1	2 699	14	−4
SK5.1	218	40	4
SK5.2	1 092	51	7
SK5.3	2 701	20	3
SK7.1	87	71	14
SK8.1	756	107	−23
NO1.1	616	33	−4
NO1.2	660	56	−8
NO1.3	2 113	30	5
NO1.4	2 102	24	−1
NO3.1	7 388	24	−5
NO4.1	2 839	32	−8
NO5.1	309	63	−8
NO5.2	334	39	−7
NO5.3	1 509	63	0
NO5.4	1 524	52	2
NO5.5	3 960	21	3
NO7.1	190	66	14
NO8.1	986	54	−12
NS2.1	295	38	0
NS2.2	1 279	22	3
NS3.2	762	42	−8
NS6.1	61	23	−4
NS6.2	176	72	−17

but most gillnetter vessel groups had one closer to 60%. Other than that, no general pattern could be observed in terms of stability by area or type of gear. The interannual fluctuations were obviously larger for the small vessel groups (e.g. longliners), but there were also large fluctuations in the larger vessel groups (e.g. Western Baltic gillnetters).

The average value of the percentage of shifts among vessel groups over the 12 years is shown in Table 6. Following the rows of this table indicates which vessel groups lost vessels most often, and how. Following the columns shows which vessel groups attracted most vessels from other vessel groups. Vessel shifts were often small ($<10\%$), but they do reflect repeated shifts from one vessel group to another during the decade. The vessel groups that decreased through vessels leaving the fishery (by decommissioning or another means of stopping operation) were mostly the gillnetters from eastern areas (Kattegat and Baltic), plus Kattegat demersal trawlers, and North Sea mussel dredgers. There were few reciprocal shifts of equal intensity. This indicated that such vessel groups were regularly exchanging vessels, i.e. that some vessels were able to shift between vessel groups from one year to the next, by altering their main fishery. This applied mainly to vessels near the boundary between two areas, which clearly decided to operate some years mainly in one area, and in some years mainly in another, likely depending on differences in resource availability and management measures between areas. Examples were between Skagerrak and Kattegat gillnetters (3−4% by year on average) and *Nephrops* trawlers (7−9%), and between Danish seiners in the North Sea and in other areas (4−5%).

Finally, there were more-systematic trends. Some vessel groups decreased continually during the period, to the benefit of other vessel groups, without reciprocity. This reflected some important changes in the strategy of fishing vessels, which clearly changed from one main fishery to another, the latter presumably more profitable. This situation was particularly evident for Kattegat vessel groups, whose main fishing activity shifted from the Kattegat to the Western Baltic (on average, 23% by year for the demersal trawlers, and 14% by year for the gillnetters). Such a change was also observed for Kattegat/Baltic Sea industrial trawlers, whose activity was displaced into the North Sea and Skagerrak (12%). Other such major shifts in main activity resulted from changes in the main gear within the same area, as for North Sea/Skagerrak demersal trawlers, which shifted to industrial midwater trawlers (12% by year on average), or for Kattegat/Baltic Sea midwater trawlers: herring trawlers became demersal trawlers in the Eastern (9%) and Western Baltic (6%), whereas the industrial trawlers became Kattegat *Nephrops* trawlers (8%), and Western Baltic trawlers (7%).

Discussion

A number of comments need to be made about this analysis. First, we found that the multivariate descriptive methods were a valuable tool for identifying fisheries and

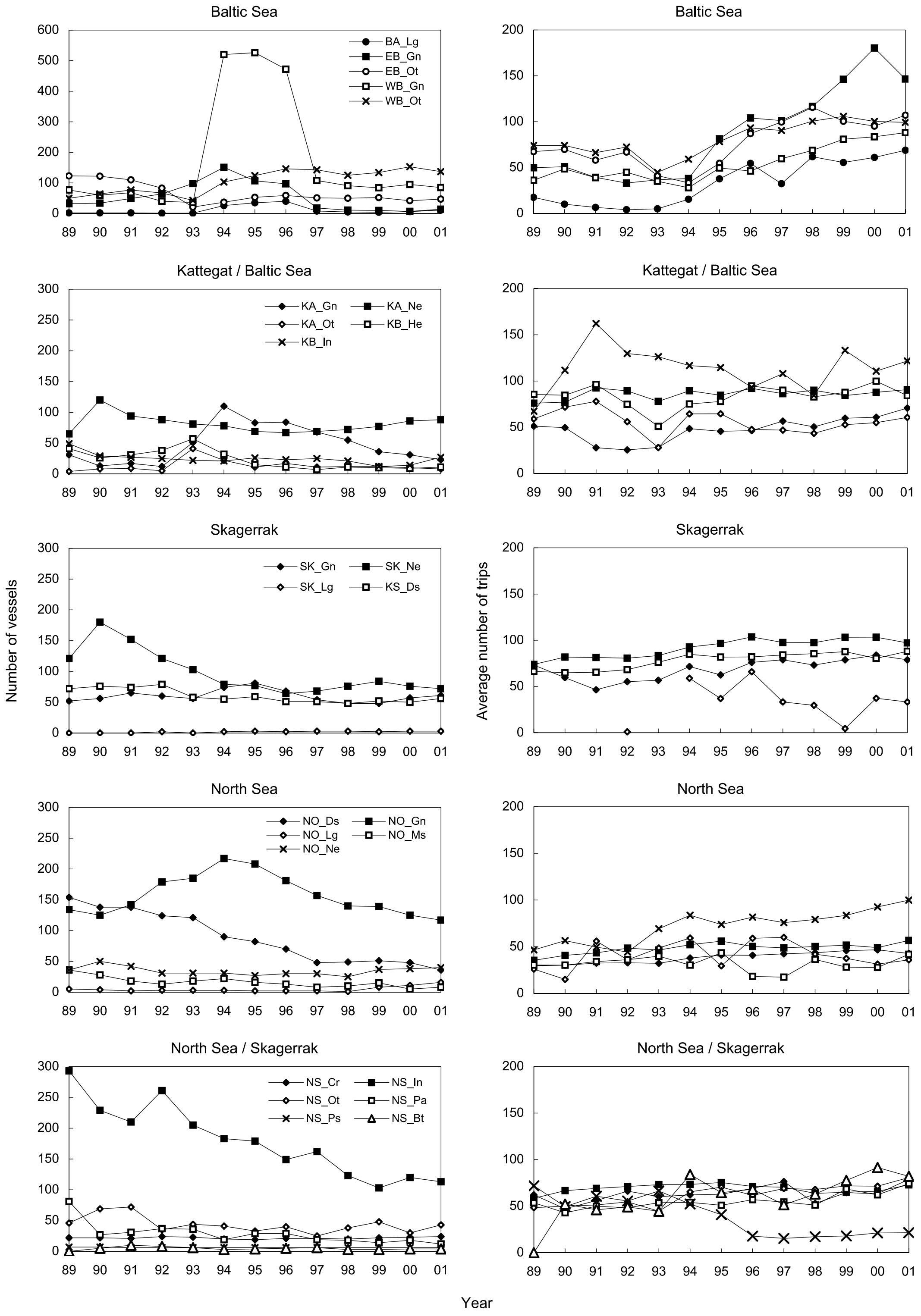

Figure 3. Dynamics of Danish vessel groups between 1989 and 2001, in terms of number of vessels, and average number of trips. Two different scales are used on the y-axis for the number of vessels. Vessel group coding is defined in Table 3.

Table 5. Summary statistics for vessel group temporal trends between 1989 and 2001. Vessel group coding is defined in Table 3.

	Number of vessels			Number of trips			Index of polyvalence			% of trips in the main fishery		
Code	Mean	CV (%)	Slope (%)	Mean	CV (%)	Slope (%)	Mean	CV (%)	Slope (%)	Mean	CV (%)	Slope (%)
BA_Lg	11	123	6	41	100	15	0.9	43	2	77	28	1
DK_Ms	6	202	−25	79	52	−8	1.3	40	−4	57	32	−3
EB_Gn	53	87	−8	63	96	17	0.8	38	−8	86	20	−5
EB_Ot	65	51	−9	75	55	5	1.2	21	−3	72	30	−9
WB_Gn	174	110	2	48	100	11	1.5	23	−5	83	25	3
WB_Ot	105	38	8	87	51	4	1.2	21	−4	76	28	12
KA_Gn	47	66	3	48	78	5	2.1	9	0	61	37	2
KA_Ne	81	18	−1	86	42	1	1.5	11	−1	64	33	−2
KA_Ot	13	74	0	50	73	0	1.5	14	−2	65	35	0
KB_He	23	68	−13	78	52	0	1.8	12	−2	59	32	−5
KB_In	25	36	−6	110	50	1	1.8	15	2	57	34	−3
KS_Ds	60	18	−4	77	56	3	1.4	7	−1	74	27	−3
SK_Gn	60	16	−1	68	64	3	1.7	15	−3	61	34	0
SK_Lg	3	21	4	34	75	0	0.7	45	7	78	23	0
SK_Ne	98	37	−7	89	42	3	1.7	10	−2	60	33	−12
NO_Ds	88	47	−12	36	52	4	0.7	12	1	85	20	−12
NO_Gn	158	21	−1	49	47	2	1.7	14	−2	58	33	−3
NO_Lg	5	92	13	37	68	1	1.0	38	0	72	27	1
NO_Ms	16	53	−11	32	81	0	1.0	60	−12	78	32	−2
NO_Ne	34	20	−1	71	45	6	1.5	16	−4	64	32	−1
NS_Bt	5	42	−7	60	47	6	0.7	46	−5	82	24	0
NS_Cr	22	7	0	63	31	2	0.4	53	−9	91	15	0
NS_In	179	33	−8	69	50	1	1.6	14	−3	73	29	−19
NS_Ot	43	32	−4	60	56	4	1.7	11	2	66	32	−3
NS_Pa	28	62	−12	54	41	2	1.6	21	−5	63	34	−5
NS_Ps	6	6	−1	40	56	−12	0.7	25	4	68	20	0

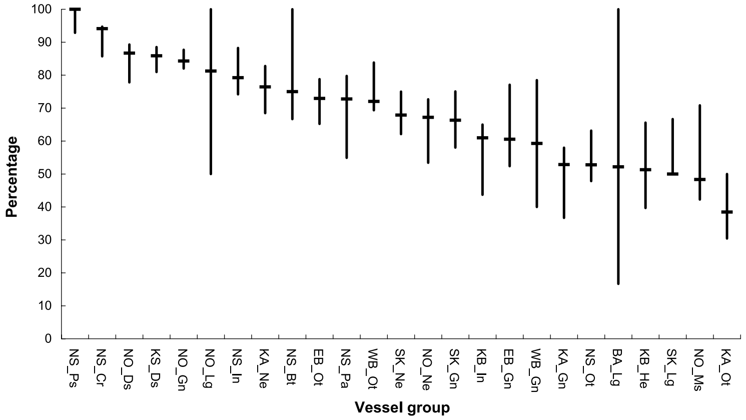

Figure 4. Stability of Danish vessel groups between 1989 and 2001. Median, 25th, and 75th quartiles of the percentage of vessels staying within the same vessel group during two consecutive years. Vessel group coding is defined in Table 3.

vessel groups. However, as observed in other case studies (e.g. Biseau and Gondeaux, 1988; Laurec *et al.*, 1991; Lewy and Vinther, 1994; Jabeur *et al.*, 2000, Pelletier and Ferraris, 2000), and as acknowledged by ICES (2003), the typologies could not be determined exclusively by statistical criteria. These had to be supplemented by a number of arbitrary choices, e.g. for selecting the number of clusters. Further, preliminary runs showed that the results could differ widely through the use of various aggregation methods (e.g. Ward method vs. centroid method). This highlighted the fact that such analyses require *a priori* knowledge of the fisheries, and an iterative approach through a process of trial and error. We were supported in our analyses by the results of the *ad hoc* DIFRES classification, and our results were fairly consistent with those (29 fisheries were common to both typologies).

Second, we worked here at a national level, with the purpose of discriminating activities with meaningful differences in exploitation pattern. This led to the identification of many fisheries and vessel groups. This is neither surprising nor problematic, when considering the diversity of fishing gears used and target species sought by the Danish fleets, and the large spatial scale of the analysis. Similar studies on other complex mixed fisheries came to similar conclusions (Laloë and Samba, 1991; Pelletier and Ferraris, 2000; Ulrich *et al.*, 2001). The advantages are that homogeneous groups are identified, and that these are then used for descriptive purposes: all the information on a trip and a vessel, which generally requires several rows and columns in a catch and effort database, can be summarized by a single categorical variable with obvious meaning. However, such a level of precision cannot be handled internationally, when dealing with the management of international stocks (ICES, 2003). Fisheries and vessel groups need to be defined in a manner that can subsequently be aggregated at a level compatible with an international framework. In particular, vessel groups can be aggregated according to their physical characteristics, leading to fewer, but larger, fleets. Such fleets would be more stable in terms of number of vessels (vessels would not shift between fleets as they shifted between vessel groups), but they would also be more heterogeneous in terms of behaviour and activity.

Third, we made the choice here to use the gear description (including mesh size) as the primary descriptor of each fishery, deciding that the landings profile may well not reflect the choice of fishers. Two comments are necessary. First, description of the gear alone was sometimes not sufficient to discriminate among different fisheries, and we had to use the landings profile as a second criterion. This problem was particularly relevant for the gillnet fisheries, for two reasons: (1) the mesh size indicated on logbooks is often not reliable, because fishers generally utilize a range of nets with different mesh sizes laced together; (2) the material and the rigging of a gillnet, not mentioned in the logbooks, play as important a role in selectivity as does the mesh size. For example, cod and plaice were always caught by the same mesh size, but by different fishing vessels. The gear used is in reality very different, but this cannot be detected from the data. The landings profile appeared thus as a necessary descriptor of the gillnet fisheries, as in other case studies (e.g. Ulrich *et al.*, 2001). Second, by doing this we were more dependent on the reliability of the data, and particularly on what fishers write in their logbooks. This is crucial for gears with specific regulations, such as *Nephrops* trawling, which is subject to strict by-catch regulation. The extent of this potential bias is difficult to assess. For Danish *Nephrops* fisheries, we believe that the problem was large in the early 1990s, but decreased over time (J. Dalskov, DIFRES, pers. comm.).

Fourth, we restricted our analysis here to vessel groups defined only through their activity (main fishery). However, it is obvious that other criteria could be accounted for when modelling vessel group dynamics, and in particular vessel size and home port.

Our results have revealed a number of characteristics of Danish fishing vessels. First, they are generally specialized

Table 6. Vessel shifts between vessel groups. Average value over the years 1989–2001 of the percentage of vessels registered in each group moving to another group during one year (in rows) and the next consecutive year (in columns). Pale grey, 1–10%; mid-grey, 11–25%; dark grey, 26–50%; black, > 50%.

	Vessel group year y+1																									
Vessel group year y	Ba_ Lg	EB_ Gn	EB_ Ot	WB_ Gn	WB_ Ot	KA_ Gn	KA_ Ne	KA_ Ot	KB_ He	KB_ In	KS_ Ds	SK_ Gn	SK_ Lg	SK_ Ne	NO_ Ds	NO_ Gn	NO_ Lg	NO_ Ms	NO_ Ne	NS_ Bt	NS_ Cr	NS_ In	NS_ Ot	NS_ Pa	NS_ Ps	Leaving
BA_Lg	35	6	6	23												5										25
EB_Gn	3	63	1	8								1				2										20
EB_Ot	1	2	69	1	7		2		4	1				1								1	2			8
WB_Gn	1	3	3	58	2	4	1		1							3										23
WB_Ot			4	1	71	1	4	3	3	1				1									2			9
KA_Gn		2		14	1	49	3	1	1	2	1	4				7	1	1								14
KA_Ne					3		76	1	1	2				9									1			7
KA_Ot					23	5	6	38						3								1	6			17
KB_He		1	9	1	6	1	2	1	53	9				1			1					6	1			7
KB_In			2	1	6		8		3	56				4					1			12	2			6
KS_Ds											85	2			5											6
SK_Gn				1		4					2	67	1	2		10								1		11
SK_Lg	6					13						17	54													10
SK_Ne			1		3		7			1				68					3			4	2	2		8
NO_Ds											5				84			1	1				1			8
NO_Gn				1		1						4				84	1									7
NO_Lg													1			13	75					2				8
NO_Ms			1	1	1	1					1	2			5	6	1	58	1	1	1	2	1	2		15
NO_Ne			1		1		1		1					7				1	63			6	3	5		9
NS_Bt																		2		77	4	1	8			8
NS_Cr																		1		1	92		1			5
NS_In			1		1				1	2				3					1			82	3	1		6
NS_Ot			1		6			1	1	1				3		2			4		1	12	55	1		10
NS_Pa							1							10					4			4	1	65		13
NS_Ps																									96	4

into a single type of gear, and multi-gear vessels are limited to few beam trawlers/trawlers and longliners/gillnetters. Most are also primarily specialized into one main type of fishery using this gear (in annual percentage of trips). Almost all vessels combined different riggings during the year (various types of gillnets, various trawl mesh sizes, combination of demersal and midwater trawls). Only Danish seiners, purse-seiners, and *Crangon* beam trawlers showed a strong specialization into a unique rigging. Second, the spatial mobility of Danish vessels is generally high, and they fish in different areas during the year (with the exception of gillnetters). In most cases, spatial mobility was restricted to adjacent waters, but there was also greater mobility to more remote fishing sites. This indicated that, given the relatively small size of the country, Danish waters should be considered more as one large integrated area than as a mosaic of independent fishing regions. Most Danish vessels can easily steam elsewhere, even medium-sized ones (10–20 m long). Third, vessel strategy changed during the 1990s. Many vessels changed significantly during the decade, with temporary or definitive allocation of their main activity into other areas or the utilization of other gears.

This analysis reflects a rather complicated description of the fishing activities of Danish fishing vessels, with a great flexibility of fishing vessel groups. The level of technical interactions is high in all Danish waters. Fishing grounds, species, and fishing practices are sufficiently diverse to permit major diversification of fishing vessel activities. The various fisheries are strongly linked, because of the ability of fishers to switch between them. This precludes classification of fishing vessels into fixed categories for monitoring and management. Regrettably, it is not possible now to predict the consequences of changes in resource availability or in regulation, at least until we better understand the incentives underlying such changes. However, the fact that changes in fishing strategy during the study period were shown makes future changes in strategy likely if the regulations change. This highlights the necessity of integrating these scenarios when the expected consequences of a management measure are evaluated.

In conclusion, we need to place this study in its broader framework. We stated that this descriptive analysis of the dynamics of fisheries and vessel groups in Denmark was the first step in a bigger process of comprehending and modelling fishers' reaction to external factors, including management. The results show that fishers are offered a wide range of choices on how and where to allocate their effort, but we cannot yet explain why they do what they do. It requires a thorough analysis to understand their decision-making (e.g. Gillis *et al.*, 1993; Campbell and Hand, 1999;

Holland and Sutinen, 1999; Wilen *et al.*, 2002). Further work has been started in this direction, and we hope that the progress made in this analysis will help in formulating more accurate advice in the management process, with a broader overview of the potential externalities introduced into the system by fishing vessel flexibility.

Acknowledgements

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