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Comparative fishing experiments by research trawlers for cod and haddock in the North Sea

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For 10 days in June 1986 a comparative fishing experiment was carrried out in a small area of 240 nm^2 in the northern North Sea. Three ship-gear combinations were compared: (1) the FRV "Walther Herwig", with the French "GOV trawl (36/47 m)" but with a rubber disc groundrope; (2) the FRV "Anton Dohrn", with the "GOV trawl (36/47 m)"; and (3) FRV "Anton Dohrn", with the German "180-foot herring trawl", in each case rigged with a heavy bobbin groundgear. A significant difference in the efficiency of capture of haddock was found only with the different nets, higher values occurring with the "180-foot herring trawl" (conversion factor = 1.45). The combined vessel and groundgear effect on the haddock catches was statistically insignificant. In contrast to haddock, the capture efficiency for small cod was strongly dependent on the groundgear. Compared with the rubber disc groundrope, about 85% of cod smaller than 32 cm escaped between the heavy bobbins under the fishing line. For bigger cod (>32 cm), the capture efficiency of the "GOV trawl" is significantly higher (conversion factor = 2.4) than that of the "180-foot herring trawl".

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Introduction

Before taking the FRV "Anton Dohrn" out of commission in mid-1986, it was necessary to conduct a comparative fishing experiment together with the FRV "Walther Herwig", which was to carry on the demersal fish survey task in the North Sea. The aims were to compare the capture efficiencies of the vessels using the "GOV trawl", to investigate the effects of previous changes of survey gear, and to adapt the "GOV trawl" and its rigging to "International Young Fish Survey" standards (Wileman, 1984).

In 1985 there was a break in the time series of the national summer survey on cod in the North Sea which had been running since 1983, because of the change from the German "180-foot herring trawl" to the French "36/47 m GOV trawl", both rigged with a heavy bobbin footrope. The break expected in 1987 with the change of ships could arise from possible differences in capture efficiency between the ships with the "GOV trawl" but different groundgears, – a bobbin groundrope on "Anton Dohrn" and a rubber disc groundrope on the "Walther Herwig". Three different ship-trawl combinations were therefore compared: (1) the prospective combination of the "Walther Herwig" with the "GOV trawl", (2) the "Anton Dohrn" with the "GOV trawl", and (3) the "Anton Dohrn" with the "180-foot herring trawl", the latter two as used in previous years.

Material and method

The comparative fishing experiment was carried out for 10 days in June 1986 (14th–23rd). Instead of the conventional "paired haul" method in comparative fishing experiments, a method was used which caters for the observed high variability of catches, even in small areas of the North Sea, due to the contagious spatial pattern of the species (further comments are given in the Discussion).

A limited area of 15 by 16 nm in the northern part of the North Sea (57°43.5′N–57°58.5′N; 0°34′W–1°04′W) was selected, this being an area where high catches with relatively low variability, at least for haddock, were expected on the basis of previous surveys. Both vessels independently made two sample series of hauls, each at randomly selected stations with random towing directions (Fig. 1). To detect any influence of changes in the mean densities of the species during the period of the experiment, the "GOV trawl" and its rig were not changed during either of the "Walther Herwig" sample series, i.e. those to be used to investigate migration during the experimental period. On "Anton Dohrn"

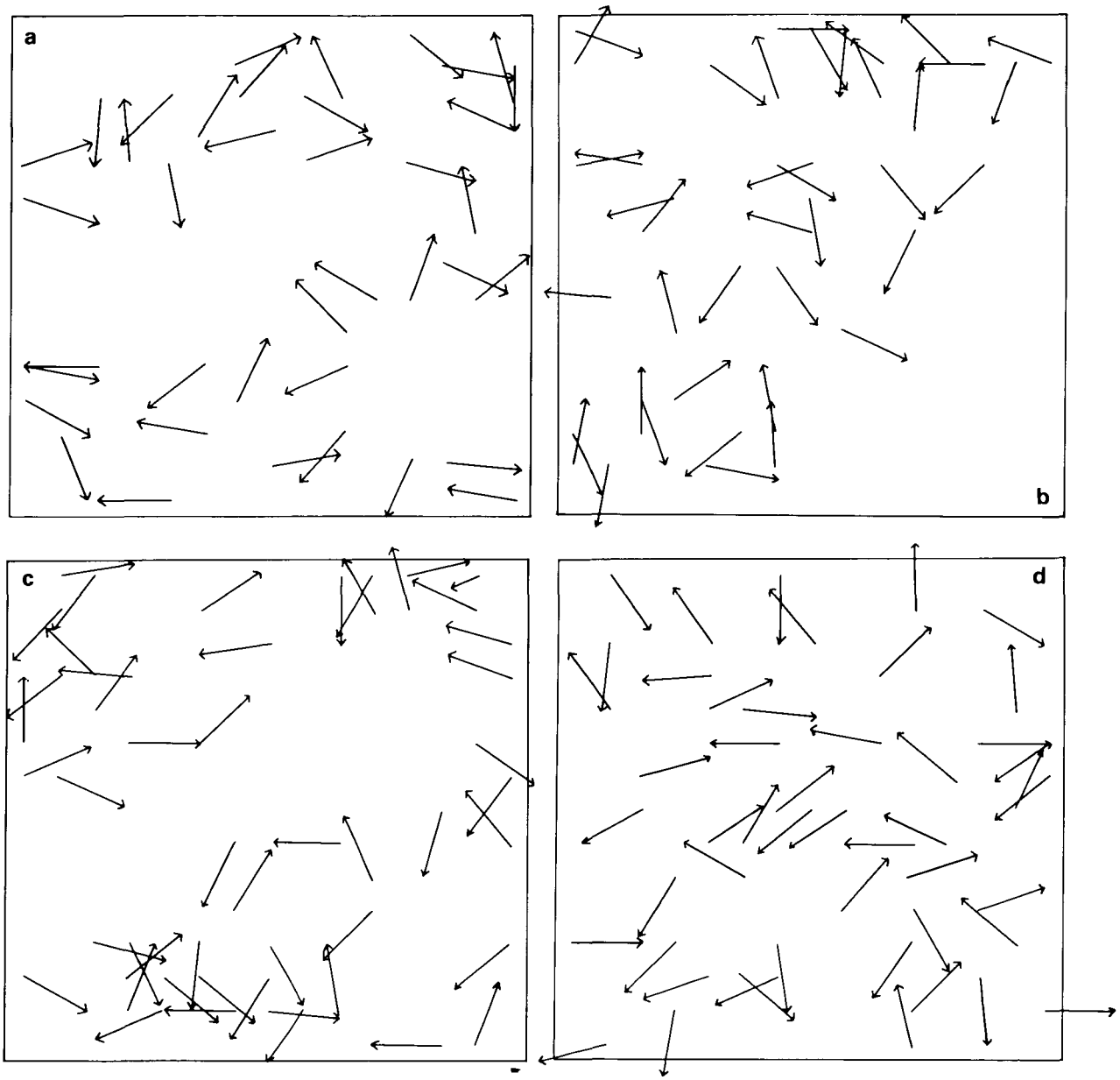


Figure 1. Distribution of hauls, the courses, and the towing distances: (a + b) "Walther Herwig" GOV. (c) "Anton Dohrn" GOV. (d) "Anton Dohrn" 180-foot herring trawl.

Table 1. Data of the vessels and the operation.

		"Anton Dohrn"	"Walther Herwig"
Type	General layout	Stern trawler with ramp	Stern trawler with ramp
Size	Length o.a.	83.3 m	77.5 m
	Displacement	1944 BRT	2250 BRT
Power	Propulsion	1471 kW	3382 kW
	Trawl winch	184 kW	440 kW
Operation	Duration of tow	30 min	30 min
	Mean towing speed	4 kn	4 kn

Table 2. Specification of the trawls.

Fishing unit	Date	Trawl rigging	Groundrope	Head line	Warp length (m)	Mean central height of the net (m)
"W. Herwig" GOV	14–17 June	$4.5\ m^2$ Polyvalent doors, 100 m sweeps, 40 m bridles	48 m length, 200 mm (bosom) and 100 mm (wings) rubber disc	Standard Exocet kite, 50 floats	400–450	5.4
"W. Herwig" GOV	18–21 June					
"A. Dohrn" GOV	14–18 June	$4.5\ m^2$ Polyvalent doors, 50 m sweeps, 50 m bridles	46 m length, Bosom: 460 mm rubber wheels, 100 mm spacers. Wings: 300–200 mm rubber and steel bobbins, 100 mm spacers	Cable net sonde, 40 floats	550	5.1
"A. Dohrn" 180' HT	19–23 June	$4.5\ m^2$ Polyvalent doors, 50 m sweeps, 50 m bridles	40 m length. Bosom: 460 mm rubber wheels, 100 mm spacers. Wings: 300–200 mm rubber and steel bobbins, 100 mm spacers	Cable net sonde, 40 floats	550	5.2

the experiment was commenced with the "GOV trawl" and a heavy bobbin footrope. After 5 days this gear was changed to the "180-foot herring trawl", also rigged with a heavy bobbin footrope.

Information on the vessels is given in Table 1. The specifications of the gears and further information on the experiment are shown in Table 2 and in Figures 2 and 3. In order to avoid any interaction between the two vessels, the area of operation was divided into four subareas and the allocation of a subarea to one vessel only was made on a daily basis. The statistical method of data analysis is species-specific and depends on the variability and the distribution curve of the catches (see below).

Results

Haddock

Although the fishing area selected had the advantage of a more uniform spatial distribution and higher abundance of haddock compared with other areas, a further prerequisite, a uniform catch probability distribution within the area, was not fulfilled; there was, in fact, a gradient in the catches, decreasing from the northwestern to the southeastern part of the area (see Fig. 4). It became necessary, therefore, to subdivide the area into two density strata (200 kg catch isoline) on the basis of the total of 178 hauls.

Normal distribution of the catch data sets, a requirement for a parametric analysis, could then be accepted and the central limit theorem was applied. Two of the eight data sets were normally distributed; the degrees of freedom were not sufficient in five cases and one fit was significantly different from normal (chi-square test).

A further requirement, confidence limits of $\pm 20\%$ of the arithmetic mean, was not met by the following subsets after the area and data splitting: (1) The second "Walther Herwig" series within the low density stratum (time-based migration check, see below). (2) The first "Anton Dohrn" series, also within the low-density stratum.

The basic requirement for the success of the experiment was that the mean densities of the target species in the area during the 10 days remained relatively constant. The time-based migration check compares both "Walther Herwig" legs, with no change of gear. For haddock, without dividing the area into two density strata, the variance of catches was very high and the time-based migration check resulted in a significant difference (see Fig. 4). After restratification of the area into two density strata (200 kg isoline) the check was only practicable with the data sets of the high density stratum (Table 3, test no. 1), these showing no statistically significant differences in the mean densities of haddock during the period. Because of the insufficient sample size, this

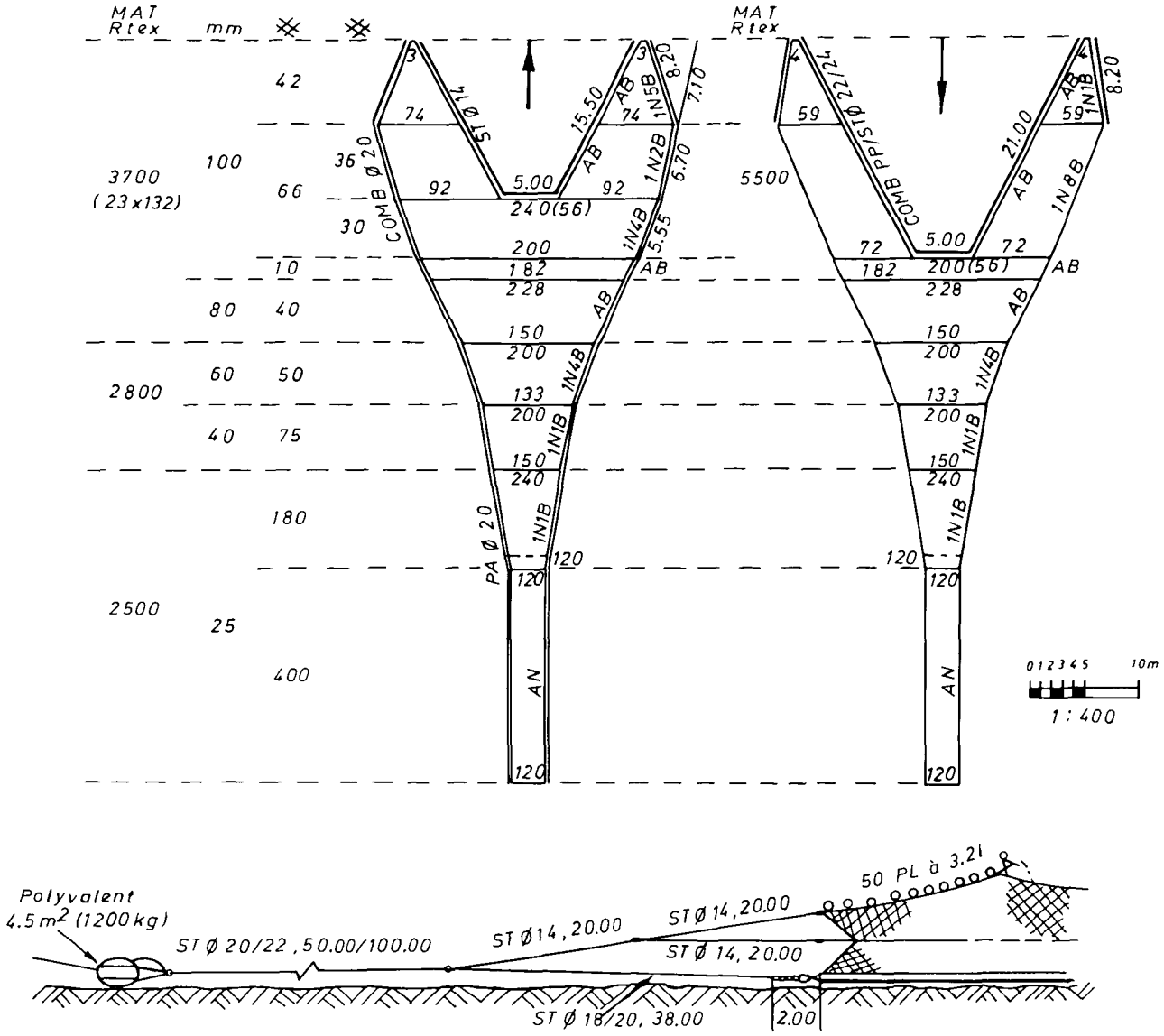


Figure 2. Construction of the nets and the riggings: (a) French "GOV trawl" (36/47 m).

result was transferred to the stratum of low density (L), now giving a statistically sufficient sample size for the calculations. These combined data subsets (WH. GOV) of both of the legs, separated into density strata, were then compared with those of the "Anton Dohrn". The results of the comparisons (t-test) between the three ship-gear combinations are given in Table 3.

No significant differences in the haddock capture efficiency were found between "Walther Herwig" and "Anton Dohrn", equipped with the same GOV-trawl but different groundgear (Table 3, test no. 2).

However, the capture efficiency of the "Walther Herwig" (GOV-trawl) in both density strata is significantly lower than that of the "Anton Dohrn" with the "180-foot herring trawl" (test nos. 3 and 4). The relationships between both combinations (ratio of the arithmetic means) were calculated for the stratum of high and of low density (1.28 and 1.38 respectively), resulting in an average conversion factor of 1.33.

Comparing the trawls used on the "Anton Dohrn", the haddock capture efficiency of the "GOV trawl" is lower than that of the "180-foot herring trawl" (the relationship being 1 to 1.45; test no. 5). The very similar length distributions of the haddock catches do not indicate a gear-specific catch preference for different length groups (Fig. 5a).

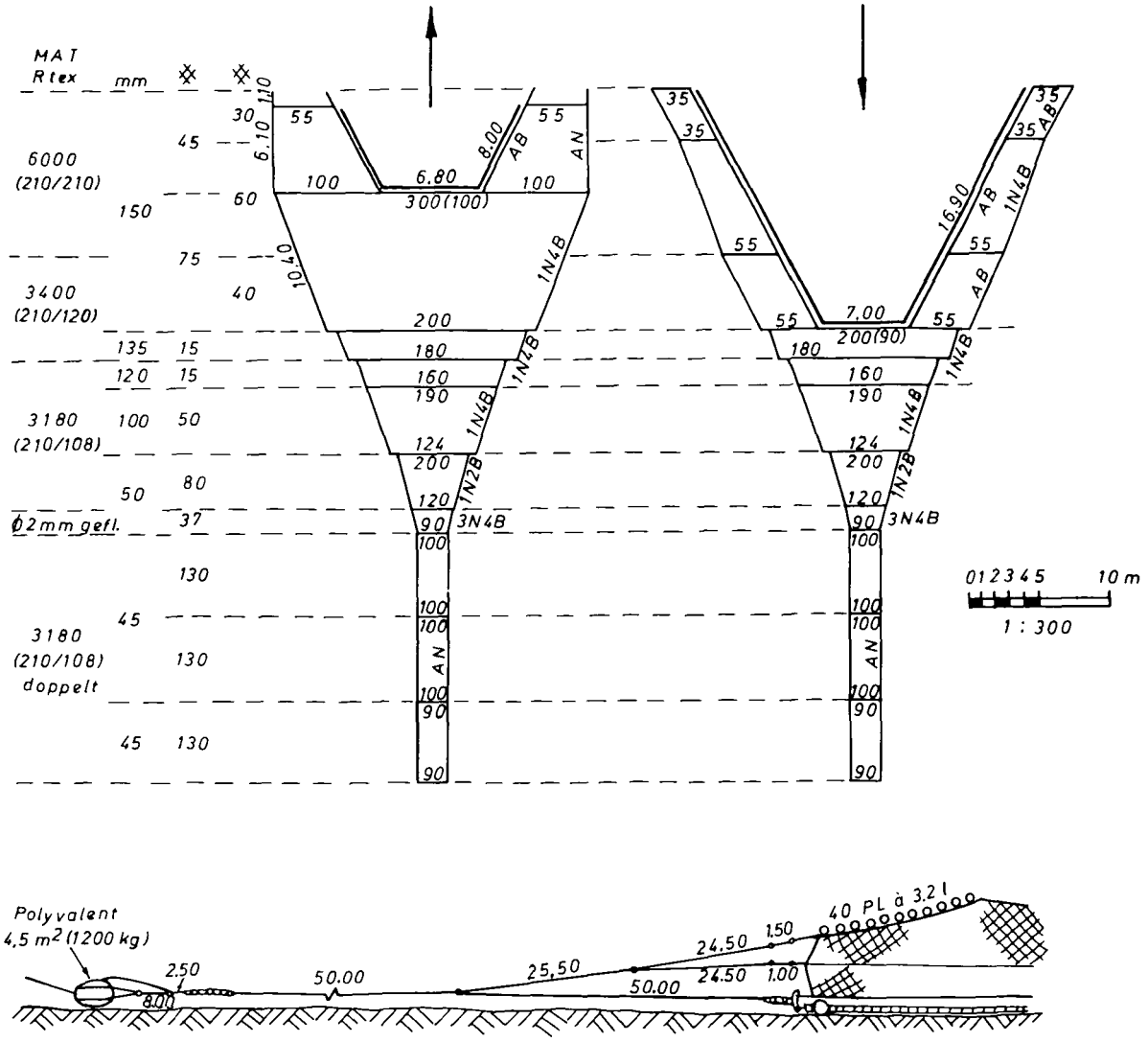


Figure 2. (b) German "180-foot herring trawl".

Cod

Compared with haddock, the density of cod was lower, the variability of the catches higher and the catch probability within the area seemingly more or less uniformly distributed. A division of the area into density strata was therefore not necessary.

The catch frequency distributions for each of the three ship-gear combinations are strongly asymmetric and a logarithmic transformation of the catch data only partly fulfilled the requirement for parametric analysis. For further analysis, non-parametric tests were therefore used and the median was used to calculate a conversion factor.

Considering the length compositions of the cod catches by the three different ship-gear combinations in Figure 5b, the small proportions of young cod in both "Anton Dohrn" data sets are remarkable. The capture efficiency seemed to depend on the length of the fish. To calculate length-specific conversion factors between the combinations, the data sets had to be split into two length groups, smaller than 32 cm and larger or equal to 32 cm total length.

To begin with, the independent data sets of the time-based migration check had to be compared. Using the non-parametric Kolmogoroff–Smirnoff two-sample test of homogeneity, no significant differences between both "Walther Herwig" catch (by weight) data sets were

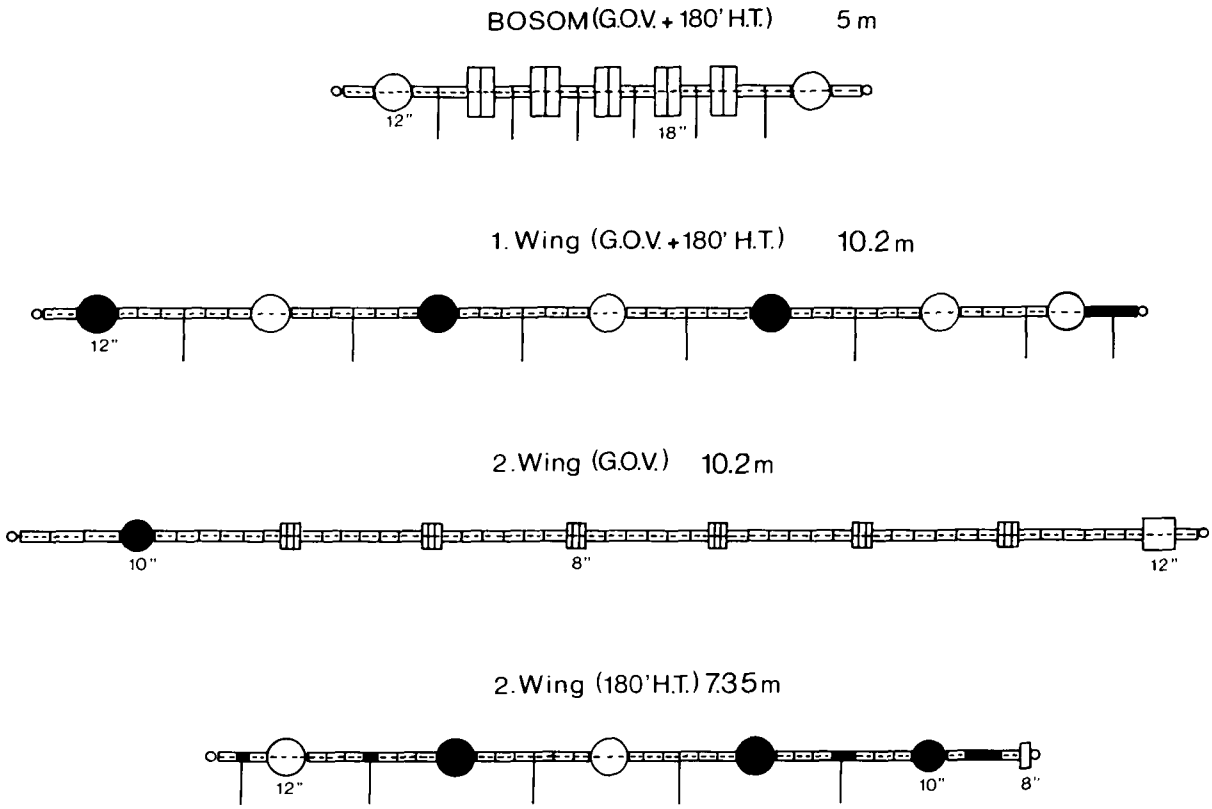


Figure 3. Groundgear for the "GOV trawl" and for the "180-foot herring trawl" as used on the "Anton Dohrn" (diameter in inches); ● iron, ○ rubber.

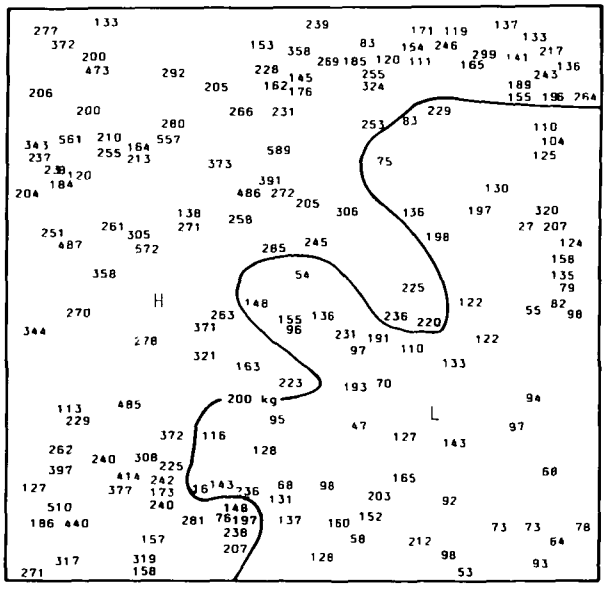


Figure 4. Haddock. Distribution of the total catches (kg) within the area: H: stratum of high density; L: stratum of low density.

found, either for cod smaller than 32 cm or for cod larger or equal to 32 cm (significance levels 0.147 and 0.326 respectively) (see also catch in number, Table 5).

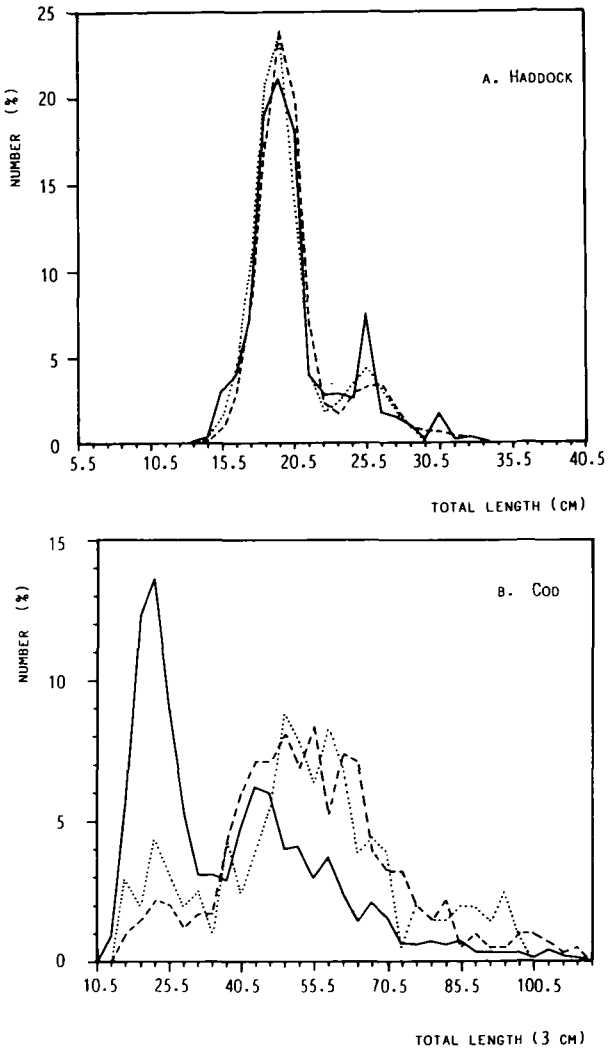
After ascertaining that the distribution pattern within the area during the period of the experiment was more or less constant, comparison of the three ship-gear combinations became possible. For big cod (>32 cm), no significant differences were found between the "Walther Herwig" and the "Anton Dohrn", in spite of the use of different gear (Table 4, test nos. 1 and 2). In contrast, the capture efficiency of the "GOV trawl" was significantly higher than that of the "180-foot herring trawl" (relationship = 1:0.41) when used on the "Anton Dohrn" (table 4, test no. 3).

For small cod (<32 cm), an evaluation using the catch by weight data was not made because of the high number of zero catches in the "Anton Dohrn" data sets and the low weight of the small cod caught, combined with the possible error in weighing them at sea. Instead, the catch in number was taken, totalled over all the hauls and standardized to 100 hauls. The results of both "Walther Herwig" legs correspond well. The proportion

Table 3. Mean values of haddock catch by weight (kg) and results of the t-test (n = number of hauls, s.d. = standard deviation).

Test no.	Ship-gear pairing	Density stratum	Catch n	Catch s.d.	Arithmetic mean (kg)	Arithmetic mean con. lim. (%)	t-test t-value	t-test Significance level
1	WH. GOV I	H	22	112	257	19.2	0.34	0.73
	WH. GOV II		33	75	248	10.7		
2	WH. GOV	H	55	91	251	9.8	1.43	0.156
	AD. GOV		32	108	221	17.6		
3	WH. GOV	H	55	91	251	9.8	2.80	0.0064*
	AD. HT		25	128	321	16.4		
4	WH. GOV	L	24	49	106	19.5	2.41	0.020*
	AD. HT		24	63	146	18.2		
5	AD. GOV	H	32	108	221	17.6	3.23	0.0021*
	AD. HT		25	128	321	16.4		

* Significantly separated at the 5% level.



of cod <32 cm in the combined data set was 49%, whereas in the "Anton Dohrn" catches these percentages were very low (10.5% and 17.6% with respect to the two gear sets).

The differences appear even more pronounced with the standardized numbers (Table 5). The results of the comparison are totally different in the two length groups. Anticipating the discussion below, the heavy bobbin footrope as used for both net types on "Anton Dohrn" produced a decrease in the proportion of small cod (age groups 1 and 2), the numbers per 100 hauls comprising only 15% (GOV) and 13% (HT) of those of the "Walther Herwig", which used the recommended rubber disc groundrope.

Discussion

The real distribution pattern of a fish species within a limited area is normally unknown, since a bottom trawl, towed over a certain distance, integrates the amount of fish present within the area swept by the gear. The catch frequency distribution is not only related to species-specific "variables", but also to environmental conditions, the net, the trawl rigging (doors, footrope, length of sweeps and bridles), the vessel, the selection of the stations, the towing direction, the size of the area and, not least, to the method of handling the sample aboard the vessel.

The *distribution pattern of the fish* is the most important factor affecting catch rate. This experiment has shown that there often exists in the catch considerable

Figure 5. Length-frequency distributions: (A) Haddock, (B) cod. ——— "Walther Herwig" GOV; - - - - "Anton Dohrn" GOV; · · · · · "Anton Dohrn" 180-foot herring trawl.

Table 4. Median values of the cod (>32 cm) catches in weight (kg) and the results of the Kolmogoroff-Smirnoff test.

Test no.	Ship-gear pairing	No. of hauls (n)	Median (kg)	Test	
				Test value	Significance level
1	WH. GOV	79	11.9	0.20	0.183
	AD. GOV	50	15.3		
2	WH. GOV	79	11.9	0.216	0.210
	AD. HT	49	6.3		
3	AD. GOV	50	15.3	0.335	0.008*
	AD. HT	45	6.3		

* Significantly separated at the 5% level.

differences (a factor greater than 2) between consecutive hauls by the same vessel, caused solely by density differences in the distribution of the target species.

The method of paired comparison of catches from simultaneous hauls by vessels towing close together on parallel courses requires the same amount of fish in the areas swept by both nets. This prerequisite is not fulfilled, as shown above. The same procedure, but a comparison of the mean values per vessel and species, could be a possible method of decreasing the variance, as parallel fishing – in contrast to separated operations – avoids the contingency of fishing on different density patterns caused by possible short-term immigration into or emigration out of the area under consideration.

On the basis of experience, such an interdependence of the vessels implies in practice a lower number of valid paired hauls per unit of time than could be achieved by independent operation of the vessels. Ten hauls within a 12-hour period (towing time = 30 min) was possible during this experiment with independent operation. Thus, if the changes in the distribution pattern are small and statistically not significant during the test period, as for example for cod and haddock in this experiment, then the higher number of hauls would decrease the variance of the catches. Closely connected with the problem of the distribution pattern is the selection of the size of experimental area. If a uniform distribution pattern within the area is assumed, then it should be large enough to avoid interaction between the vessels, such as might be created by the influence of vessel noise on fish behaviour and the "thinning out" effect produced by the actual fishery operation.

The total area swept by the nets in the 178 hauls of this experiment was estimated to be approximately 4.4 nm^2, i.e. only 1.8% of the total working area of 15 × 16 mm. The influence of a "thinning out" effect on the catch data can therefore be disregarded. Further, interaction between the vessels was avoided by dividing the area into four sub-areas, of which only one was allocated to one vessel on a daily basis. After evaluation of this experiment and further experience with fish distribution patterns within smaller areas (Ehrich, 1988; Ehrich and Groeger, 1989), a square of 10 nm side length seems to be appropriate for the experiments in question.

Apart from the biological variables, environmental factors also contribute to the variability of the catches. Thus hydrographic parameters in the area were recorded at the beginning and end of the experiment. During the ten days, only small changes in temperature and salinity and no intrusion of a different water mass into the area were detected.

The influence of currents and tides can largely be neglected, for the high number of hauls with randomly selected courses smooth out these effects. Again, the wind of less than force 7 (Beaufort scale) was not strong enough to influence the catch rates (Ehrich and Groeger, 1989).

The catch rate is the only variable which integrates

Table 5. Total and standardized cod catches in number per combination and length group.

Combination	No. of hauls	Catch in number			<32 cm	
		Total	<32 cm	≥32 cm	N(%)	N per 100 hauls
WH. GOV I	39	450	229	221	50.9	587
WH. GOV II	40	490	232	258	47.3	580
WH. GOV	79	940	461	479	49.0	584
AD. GOV	50	418	44	374	10.5	88
AD. HT	49	210	37	173	17.6	76

Time-based migration check: WH. GOV I against WH. GOV II.

all the gear and vessel-specific variables and the reaction of the fish species to them. Only this quantity is therefore suitable for determining conversion factors between different gears or vessels within a time series. Nevertheless, it is important for many reasons to know which variable is responsible for the differences in the catches. Unfortunately it was not possible to measure the gear parameters due to the lack of time and the absence of suitable equipment.

Possible reasons for the large differences in the *length compositions of the cod catches* of both vessels were investigated with respect to: (1) differences in handling the catch aboard the vessels; (2) representativeness of the catches in relation to the spatial and temporal distribution of young cod in the area; (3) differences in the material and design of the net; (4) differences in the mesh size of the codend.

No influence of any of these four factors was detected. It seems therefore that the differences could only be caused by the differences in the groundrope. Engas and Godo (1989) obtained similar results in the Barents Sea by catching the escaped fish in bags which were mounted under the fishing line and by comparative fishing with standard bobbin and with rockhopper gear.

Both experiments indicate a decreasing chance of escape under the fishing line with increasing length of the cod. Because of the different length composition, the results from the North Sea are not directly comparable with those from the Barents Sea, although the orders of magnitude are similar.

For haddock, the results of our experiments are the opposite to those given by Engas and Godo (1989), in that in the Barents Sea the haddock show the same behaviour as cod, whereas there are no indications of an escape of haddock under the groundrope in the North Sea. The reason for this is not known.

In the North Sea, small cod are able to escape between the bobbins under the fishing line. This special behaviour indicates a possible way of protecting juvenile cod without impairing the capture efficiency of the gear for haddock.

The capture efficiency of the "GOV trawl" compared with the "180-foot herring trawl", both as towed by the "Anton Dohrn", is significantly higher for cod but lower for haddock. The longer groundgear (by more than 6 m) of the "GOV trawl" produces a larger distance between the wing-ends and can therefore be responsible for the higher catch of cod. Reasons for the lower haddock catch could be found in the behaviour of haddock in front of the gear in relation to the different design of the nets, in that the more forward-extending square of the "180-foot herring trawl" (Fig. 2) produced a lower rate of escape over the headline of the trawl. This behaviour, directly observed by different authors (Main and Sangster, 1981; Engås and Ona, 1990; Dahm, pers. comm.) could be a possible explanation.

Acknowledgements

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