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FEEDING OF NORTH SEA TURBOT AND BRILL

by
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Introduction

The information on the food composition of flatfish has been extensively reviewed by DE GROOT (1971). The data available indicated that of the North Sea flatfish species turbot and brill are almost exclusive fish feeders, at least in the size range above 20 cm. According to DE GROOT (1971) turbots in the size range of 11 - 20 cm feed mainly on shrimps. The larger turbots in the Dutch coastal waters feed mainly on sandeels, but with increasing length the diet gradually shifts from sandeels towards gadoids. Brills above 20 cm had mainly sandeels in their stomachs. According to RAE & DEVLIN (1972) in Scottisch waters turbots of the size group 21 - 40 cm feed also mainly on sandeels, whereas the larger fish (41 - 85 cm) feed primarily on gadoids and to a lesser extent on sandeels, clupeoids and flatfishes.

However, the data available sofar seem to be of a qualitative nature, based mainly on frequencies of occurence. In 1980 a sampling program was started, in which the emphasis was laid upon the weight of the different components of the stomach contents and the size composition of the prey items. In future these quantitative data may be used as a basis to determine daily rations for turbot and brill, similarly to the study on cod by DAAN (1973). Before that will be possible information is needed on digestion time.

This paper must be seen as a first attempt to provide more insight in the quantitative aspects of feeding of turbot and brill.

Material and methods

The majority of the samples was collected during discard surveys with commercial fishing cutters in the southern North Sea, but in addition research vessel catches have been used. Fig. 1 shows the geographical distribution of the samples and also indicates the differences in distribution of the turbot and brill smaller and larger than 30 cm. In total 1249 turbot stomachs and 656 brill stomachs have been collected. No exact information about the origin is available for 83 turbot stomachs and 48 brill stomachs, which were collected along the Danish, German and Dutch coast. These samples have been classified in square 52G2. Fig. 1 illustrates the disadvantage of collecting stomachs on board of commercial fishing vessels: most of the samples are derived from often visited fishing grounds. On the other hand there was in this case no other choice, because research vessel catches of turbot and brill during routine trawling surveys are generally poor. Table I presents the collected number of turbot and brill stomachs by size class and quarter. The number of stomachs varied strongly by size class and quarter and particularly the smaller fish were only taken in the third quarter.

Directly after catch the turbots and brills were measured, and the stomachs grouped by size class and square were emptied in jars with 4% formalin for subsequent analysis in the laboratory. The number of empty stomachs was recorded. No split has been made between day and night catches nor between males and females. Signs of regurgitation by turbot and brill have never been noticed during this study.

In the laboratory the size group of each food item was determined and if possible the actual length was measured. The classification in size groups for prey as well as for predator is in accordance with the coding system used in the Stomach Sampling Programme for cod, haddock, whiting, saithe and mackerel (ANON., 1981). The wet weight by size group of the different taxa distinguished was determined. After awarding a taxonomical code according to the NODC system, the material was suitable for computer operation.

Results

Food composition

The average food composition of turbot and brill by size group is presented in table II. The smaller size classes have been excluded because of inadequate sampling over the year. Only the predominant food items and commercially important fish species are included. For each species or lower taxonomical group the mean weight per stomach ($\overline{W}$), the mean number per stomach ($\overline{N}$) and the weight percentage (W%) are given.

The $\overline{N}$ in the last column of table II approaches the value $\overline{N}$ = 1 for turbot and brill > 40 cm, saying that on average each fish has one item in its stomach. However, this figure may be rather variable from year to year. In quarter 81 - 1 for example values of $\overline{N}$ = 3.3 and 4.2 were found for turbot in the size classes of 40 - 50 cm and 50 - 70 cm respectively, when they had consumed large quantities herring and sprat.

The weight percentages of the food items in relation to size classes are given in fig. 2. Evertebrates made up only a small part of the food for turbot (20 - 30 cm) and brill (25 - 30 cm).

The most important fish species for young turbot (20 - 30 cm) were the sandgoby, the dragonet, sandeels and small cod. In the length range 30 - 50 cm the largest part of the food consisted of sandeels and gadoids, whereas dab also became an important food item. Turbot > 50 cm predated mainly on whiting and cod and to a lesser extent on dab. Clupeoids were not frequently found in 1980 and haddock and plaice were never found. Sole was only observed in the length groups 15 - 20 cm, 30 - 40 cm and 40 - 50 cm with weight percentages of 2.8, 0.3 and 0.2% respectively.

The most important food item for smaller brill (25 - 30 cm) was the sandgoby. Between 30 and 50 cm the most dominant food items were sandeels, while with increasing length gadoids became of more importance. Clupeoids represented a relatively constant component of the food of brill (25 - 50 cm). Haddock, plaice and sole were not found in brill stomachs.

Because of insufficient sampling no attempt has been made to discover seasonal patterns in food composition.

Size distribution of food items in weight and numbers

The frequency distribution by weight of prey size class by predator size class for turbot and brill is given in fig. 3A and 3B. Because of a logarithmic prey size scale a correction was required. The figures show the corrected weight percentages so that the surfaces of the different classes are directly comparable. Clearly, with increasing size classes of turbot and brill prey items of increasing size classes are taken. For the size classes 25 - 30 cm to 50 - 70 cm there is a tendency that turbot predates on somewhat larger prey than brill does.

Fig. 4A and 4B present the frequency distribution by numbers of prey size class (also corrected percentages) by predator size class for turbot and brill. Of course the pictures generally follow the same pattern as in fig. 3A and 3B, but the peaks are shifted to the left because it requires less larger individuals than smaller ones to result in the same percentage weight.

For some size classes a wide prey size spectrum can be observed, but for all size classes it appears that turbot and brill always select a distinct part of the total prey size spectrum.

Length distribution of commercial fish species

For information on trends in natural mortality with size it is important to know which part of a prey stock a predator stock precisely takes. For this purpose only food items in a stage of digestion which allowed precise length measurement have been used to produce fig. 5. In order to increase the number of observations and to reduce variation size classes have sometimes been taken together, and moreover for most species data of 1980 have been combined with data of the 1st quarter of 1981. Fig. 5 shows the results for whiting, cod, herring, sprat, sandeels, dab and sole. In accordance with the former section a shift from smaller towards larger prey with increasing length of turbot can be seen, particularly for whiting, cod, sprat and dab.

Empty stomachs

Table III presents the percentages of empty stomachs of turbot and brill for different size classes and quarters. For turbot the size classes 20-25 cm and 25-30 cm have been taken together. No statistical analysis has been made because of the empty cells and the highly variable sample sizes.

For turbot > 20 cm the total percentage of empty stomachs for the 4 quarters appears to be rather constant. Overall 53.7 % of the stomachs were empty. This high value is in close agreement with the 50 % empty stomachs found by RAE & DEVLIN (1972), based on 676 stomachs.

For brill > 25 cm the percentage empty stomachs in the second and third quarter differed strongly from the percentages observed during the first and fourth quarter. Overall 44.0 % of the stomachs appeared to be empty.

Weight stomach contents

Mean weights of the stomach contents by size class and quarter are presented in table IV. Because of large variation in the quarterly data sets a double logarithmic regression analysis has only been made for the total year data. For both species a rather good exponential relationship between mean length ($\bar{L}$) and mean weight of the stomach contents ($\bar{W}$) is observed ($r = 0.98$ and $r = 0.97$). For turbot the value $b = 3$ falls within the 95 % confidence interval for b. For brill the exponent is significantly smaller than 3. The observed mean weights of the stomach contents for brill are smaller than for turbot in all size classes.
A double logarithmic plot of the mean weight of the stomach contents and the mean length per size class is given in fig. 6.

Discussion

The observed food composition of turbot and brill in this study is in general agreement with the feeding habits described by other authors. From the present investigation it is of course not possible to draw any firm conclusions on the average food composition of the total stocks, because the sampling system lacks the randomness required to be representative for the total stocks. In fact, in the present analysis each stomach sampled has got the same weight independent of where it was taken, and some areas have obviously been oversampled.
To overcome this problem, a generalized picture of the distribution by size groups over the North Sea would be required in order to put weighting factors to the results obtained for individual squares, but it is hoped that by continuing the sampling over a number of years a more reliable picture of the average food composition will be obtained.
Still, it remains clear that large turbot and brill are exclusive fish feeders and that commercially important fish species, particularly whiting and cod make up a considerable part of the diet. Therefore it would seem worthwhile to collect reliable information on the size of the North Sea turbot and brill stocks and on the digestion rates in these species in order to assess the impact of the stocks on other fish populations.
Plaice and sole are almost completely lacking in the food spectrum of the two species. This is in contrast with the situation in North Sea cod, which appears to prey heavily on the discarded flatfish in the commercial fisheries (DAAN, 1973). Since the stomach samples for turbot and brill were taken in areas heavily exploited by beam trawlers, this suggests that these fish only take live food, which is in agreement with the observation by DE GROOT (1971) that turbot and brill represent visual hunters, whereas cod belongs to a scavenger type of predator.
From the distribution by weight and numbers of prey sizes it appeared that larger turbot and brill eat larger fish, but more important is that it can be deduced from these data how much bigger the average prey becomes. Obviously turbot and brill predate predominantly on a specific part of the prey size spectrum, each size group of the turbot eating fish of slightly larger size than the brill.
Although the number of data points is still limited, a stock-taking has been made of the size distribution of the commercial fish species eaten. Apparently, in most cases predation is directed towards the I-group of these species.

About 50 % of the stomachs of turbot > 30 cm appeared to be empty in all seasons. Although signs of regurgitation have never been noticed on deck, FLOWERDEW & GROVE (1979) sometimes noticed regurgitation in force-fed young turbots. If regurgitation does take place while the fish is in the trawl, this would seriously affect the quantitative results presented here. Emptiness of brill stomachs varied strongly from one season to another. This may however be the result of insufficient sampling during the seasons rather than of a real seasonal variation in food intake.
A double logarithmic regression analysis of the mean weight of the stomach contents in relation to mean length per size class shows that on average turbot stomachs contain more food than brill stomachs. Since the overall percentage of empty stomachs in brill is lower than in turbot, and thus the average weight of the stomach contents per stomach containing food is even smaller, this suggests the former species to have a smaller stomach volume.

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Table I - Number of turbot (A) and brill (B) stomachs sampled per length group and per quarter (80-1 = January, February and March; 80-2 = April, May and June; 80-3 = July, August and September; 80-4 = October, November and December 1980).

A. TURBOT

Size class (cm)	80-1	80-2	80-3	80-4	Total
7 - 10	-	-	12	-	12
10 - 15	-	-	8	-	8
15 - 20	-	-	37	-	37
20 - 25	3	1	48	3	55
25 - 30	4	1	6	12	23
30 - 40	347	93	100	105	645
40 - 50	143	35	97	78	353
50 - 70	27	24	34	26	111
70 -100	1	-	4	-	5
Total	525	154	346	224	1249

B. BRILL

Size class (cm)	80-1	80-2	80-3	80-4	Total
7 - 10	-	-	2	-	2
10 - 15	-	-	26	-	26
15 - 20	-	-	3	-	3
20 - 25	-	-	-	-	-
25 - 30	3	-	48	23	74
30 - 40	104	23	13	263	403
40 - 50	73	7	19	24	123
50 - 70	5	3	12	5	25
Total	185	33	123	315	656

Table II - Food composition of turbot (A) and brill (B). Per size class (mean length in parentheses) number of stomachs sampled and for the indices mean weight in grams per stomach ($\overline{W}$, empty stomachs included), numbers per stomach ($\overline{N}$, empty stomachs included) and weight percentages (W %), the results for: Evertebrates, commercially important fish species and fish species often found.

Size class (cm)	Numb. stom.	Index	Everte-brates	Clupea harengus	Sprattus sprattus	Gadus morhua	Merlang. merlang.	Other Gadidae	Ammody-tidae	Limanda limanda	Calliony-mus lyra	Pomato-schistus	Other Pisces	Total Pisces	Total
A. TURBOT															
20- 25	55	$\overline{W}$	0.76	0.073	-	-	0.20	-	-	0.30	0.15	0.97	0.19	1.88	2.63
(22.1)		$\overline{N}$	1.36	0.018	-	-	0.036	-	-	0.36	0.16	2.02	0.16	2.76	4.13
		W %	28.8	2.78	-	-	7.42	-	-	11.2	5.81	36.8	7.22	71.2	100
25- 30	23	$\overline{W}$	0.090	-	-	1.33	0.20	-	0.82	0.029	1.11	0.48	0.63	4.60	4.69
(27.2)		$\overline{N}$	0.13	-	-	0.22	0.043	-	0.17	0.087	0.96	0.91	0.35	2.74	2.87
		W %	1.92	-	-	28.4	4.29	-	17.5	0.61	23.7	10.2	13.4	98.1	100
30- 40	645	$\overline{W}$	0.037	0.035	0.24	0.80	1.65	1.04	2.52	0.25	0.33	0.14	0.22	7.22	7.26
(35.2)		$\overline{N}$	0.052	0.005	0.043	0.095	0.096	0.076	0.54	0.055	0.11	0.21	0.036	1.25	1.30
		W %	0.52	0.48	3.32	11.0	22.8	14.3	34.7	3.49	4.50	1.95	3.00	99.5	100
40- 50	353	$\overline{W}$	0.053	0.036	0.24	2.28	4.70	1.03	1.46	1.43	0.40	0.021	0.46	12.0	12.1
(43.8)		$\overline{N}$	0.029	0.007	0.039	0.14	0.22	0.070	0.27	0.11	0.042	0.025	0.044	0.96	0.98
		W %	0.43	0.30	1.97	18.8	38.9	8.52	12.1	11.8	3.29	0.17	3.76	99.6	100
50- 70	111	$\overline{W}$	0.025	0.35	-	8.52	18.8	1.44	0.78	4.37	0.24	-	-	33.9	33.9
(54.6)		$\overline{N}$	0.027	0.018	-	0.13	0.39	0.059	0.099	0.18	0.009	-	-	0.88	0.91
		W %	0.074	1.03	-	25.1	53.7	4.23	2.30	12.9	0.72	-	-	99.9	100
70-100	5	$\overline{W}$	-	-	-	28.3	54.0	-	-	-	-	-	-	82.3	82.3
(70.5)		$\overline{N}$	-	-	-	0.20	0.80	-	-	-	-	-	-	1.00	1.00
		W %	-	-	-	34.4	65.6	-	-	-	-	-	-	100	100
B. BRILL															
25- 30	74	$\overline{W}$	0.12	0.11	0.11	-	-	-	0.11	0.15	0.28	1.11	0.46	2.32	2.44
(27.8)		$\overline{N}$	0.19	0.023	0.046	-	-	-	0.055	0.37	0.58	2.56	0.20	3.82	4.01
		W %	4.82	4.59	4.49	-	-	-	4.29	6.28	11.5	45.3	18.8	95.2	100
30- 40	403	$\overline{W}$	0.009	0.029	0.20	0.11	0.13	0.071	1.72	0.047	0.32	0.11	0.69	3.43	3.44
(32.8)		$\overline{N}$	0.011	0.008	0.036	0.015	0.042	0.005	0.35	0.037	0.50	0.15	0.30	1.44	1.45
		W %	0.26	0.82	5.81	3.25	3.87	2.06	49.9	1.35	9.3	3.16	20.2	99.7	100
40- 50	123	$\overline{W}$	0.002	0.67	0.22	0.85	0.46	0.088	4.18	0.010	0.12	0.038	0.50	7.15	7.16
(43.5)		$\overline{N}$	0.016	0.066	0.056	0.037	0.047	0.028	0.57	0.041	0.073	0.056	0.085	1.06	1.07
		W %	0.034	9.36	3.11	11.9	6.48	0.69	58.5	0.13	1.73	0.54	7.56	100	100
50- 70	25	$\overline{W}$	-	-	0.63	1.10	5.39	0.21	1.31	0.74	0.027	0.008	0.94	10.3	10.3
(51.5)		$\overline{N}$	-	-	0.080	0.046	0.23	0.046	0.20	0.12	0.080	0.040	0.079	0.92	0.92
		W %	-	-	6.11	10.6	52.1	1.98	12.6	7.13	0.26	0.073	9.09	100	100

Table III - Number of turbot (A) and brill (B) stomachs sampled (N) and percentage empty (% E) per length-group and per quarter. The total figures refer to size classes from 20 and 25 cm upwards for turbot and brill respectively.

Size class (cm)	80-1		80-2		80-3		80-4		Total year	
	N	% E	N	% E	N	% E	N	% E	N	% E
A. TURBOT										
7 - 10	-	-	-	-	12	16.7	-	-	12	16.7
10 - 15	-	-	-	-	8	0	-	-	8	0
15 - 20	-	-	-	-	37	13.5	-	-	37	13.5
20 - 30	7	57.1	2	50.0	54	22.2	15	6.7	78	23.1
30 - 40	347	55.0	93	63.4	100	45.0	105	66.7	645	56.6
40 - 50	143	58.7	35	51.4	97	62.9	78	51.3	353	57.5
50 - 70	27	44.0	24	45.8	34	47.1	26	50.0	111	46.8
70 - 100	1	0	-	-	4	50.0	-	-	5	40.0
Total (> 20)	525	55.4	154	57.8	289	47.1	224	55.4	1192	53.7
B. BRILL										
7 - 10	-	-	-	-	2	50.0	-	-	2	50.0
10 - 15	-	-	-	-	26	11.5	-	-	26	11.5
15 - 20	-	-	-	-	3	0	-	-	3	0
25 - 30	3	0	-	-	48	8.3	23	34.8	74	16.2
30 - 40	104	46.2	23	87.0	13	0	263	39.9	403	42.9
40 - 50	73	60.3	7	85.7	19	36.8	24	75.0	123	61.0
50 - 70	5	40.0	3	66.7	12	83.3	5	60.0	25	68.0
Total (> 25)	185	50.8	33	84.8	92	22.8	315	42.5	625	44.0

Table IV - Mean weight stomach contents ($\overline{W}$, empty stomachs included) and mean length ($\overline{L}$) of turbot (A) and brill (B) per length group and per quarter. Double logarithmic regression analysis of mean weight stomach contents against mean length (log $\overline{W}$ = log a + b log $\overline{L}$) for the total year data.

A. TURBOT

Size class (cm)	80-1		80-2		80-3		80-4		Total year	
	$\overline{L}$	$\overline{W}$	$\overline{L}$	$\overline{W}$	$\overline{L}$	$\overline{W}$	$\overline{L}$	$\overline{W}$	$\overline{L}$	$\overline{W}$
7 - 10	-	-	-	-	7.5	0.23	-	-	7.5	0.23
10 - 15	-	-	-	-	13.2	0.70	-	-	13.2	0.70
15 - 20	-	-	-	-	17.4	2.20	-	-	17.4	2.20
20 - 25	22.5	2.47	22.5	0.0	21.5	2.77	22.3	1.57	22.1	2.63
25 - 30	27.0	6.12	29.0	4.63	27.5	5.53	26.2	3.80	27.2	4.69
30 - 40	35.4	9.57	35.7	4.20	34.1	4.87	35.1	4.58	35.2	7.26
40 - 50	43.7	14.25	43.8	14.19	43.8	5.95	44.2	14.84	43.8	12.10
50 - 70	54.2	47.83	55.2	29.07	54.3	32.15	55.3	26.35	54.6	33.94
70 - 100	70.5	243.0	-	-	70.5	42.11	-	-	70.5	82.28
n									9	
r									0.981	
b									2.58	
S (b)									0.19	
b 95 %									2.13-3.03	
a									0.000989	

B. BRILL

Size class (cm)	80-1		80-2		80-3		80-4		Total year	
	$\overline{L}$	$\overline{W}$	$\overline{L}$	$\overline{W}$	$\overline{L}$	$\overline{W}$	$\overline{L}$	$\overline{W}$	$\overline{L}$	$\overline{W}$
7 - 10	-	-	-	-	8.0	0.17	-	-	8.0	0.17
10 - 15	-	-	-	-	12.3	0.54	-	-	12.3	0.54
15 - 20	-	-	-	-	15.7	1.50	-	-	15.7	1.50
20 - 25	-	-	-	-	-	-	-	-	-	-
25 - 30	29.0	2.16	-	-	26.9	2.61	28.8	2.14	27.8	2.44
30 - 40	34.4	6.36	35.4	0.69	33.6	9.37	31.4	2.24	32.8	3.44
40 - 50	43.4	9.12	42.4	4.81	44.8	6.57	42.2	2.33	43.5	7.16
50 - 70	52.0	11.07	51.5	6.95	51.6	2.60	51.0	30.23	51.5	10.34
70 - 100	-	-	-	-	-	-	-	-	-	-
n									7	
r									0.968	
b									2.12	
S (b)									0.24	
b 95 %									1.50-2.74	
a									0.002499	

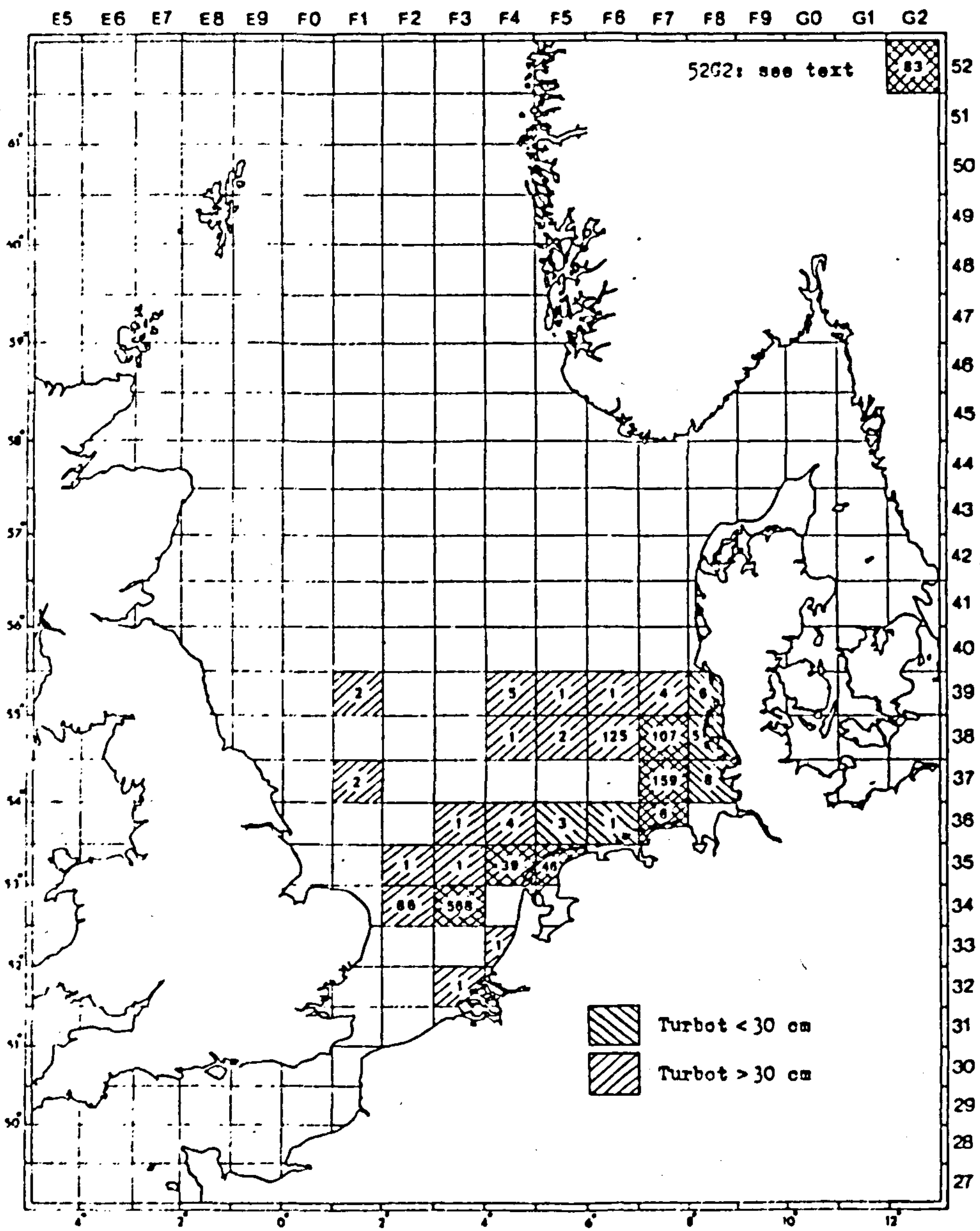

Fig.1A. Geographical distribution and numbers per square of the turbot stomachs sampled.

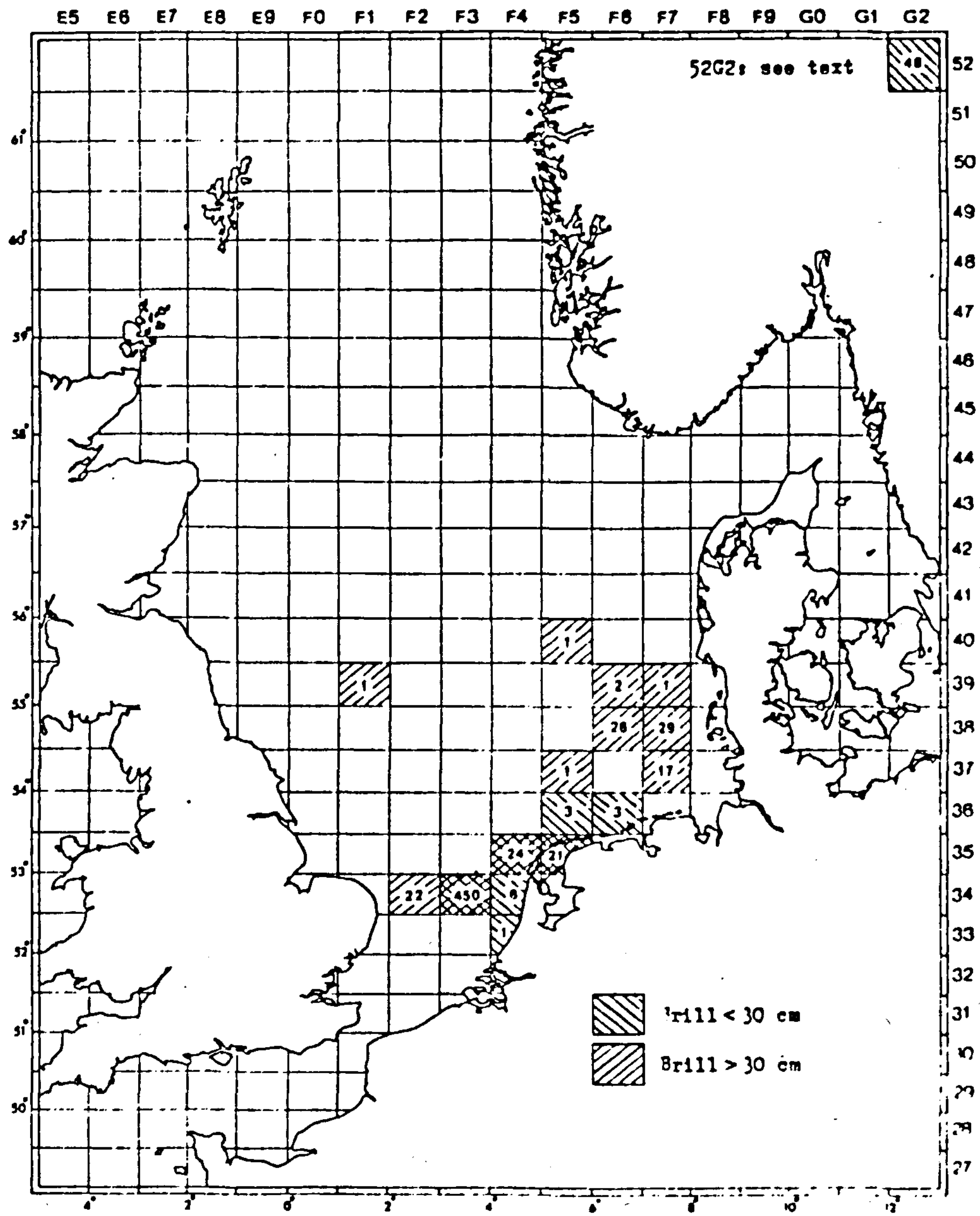

Fig.1B. Geographical distribution and numbers per square of the brill stomachs sampled.

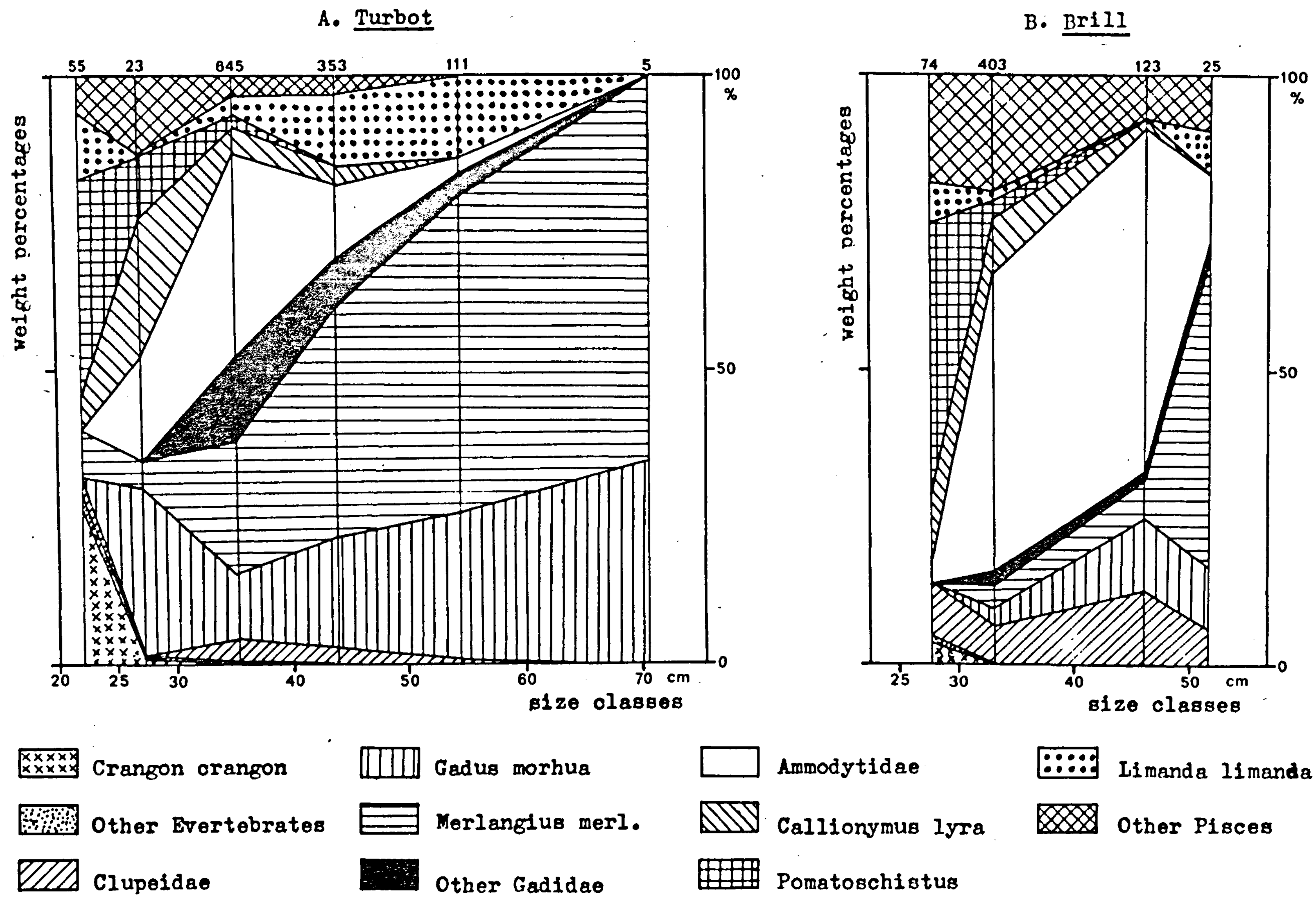

Fig.2. Food composition in weight percentages in relation to size classes of turbot (A) and brill (B) (at the top the numbers of stomachs per size class which have been investigated, vertical lines indicate mean length per size class).

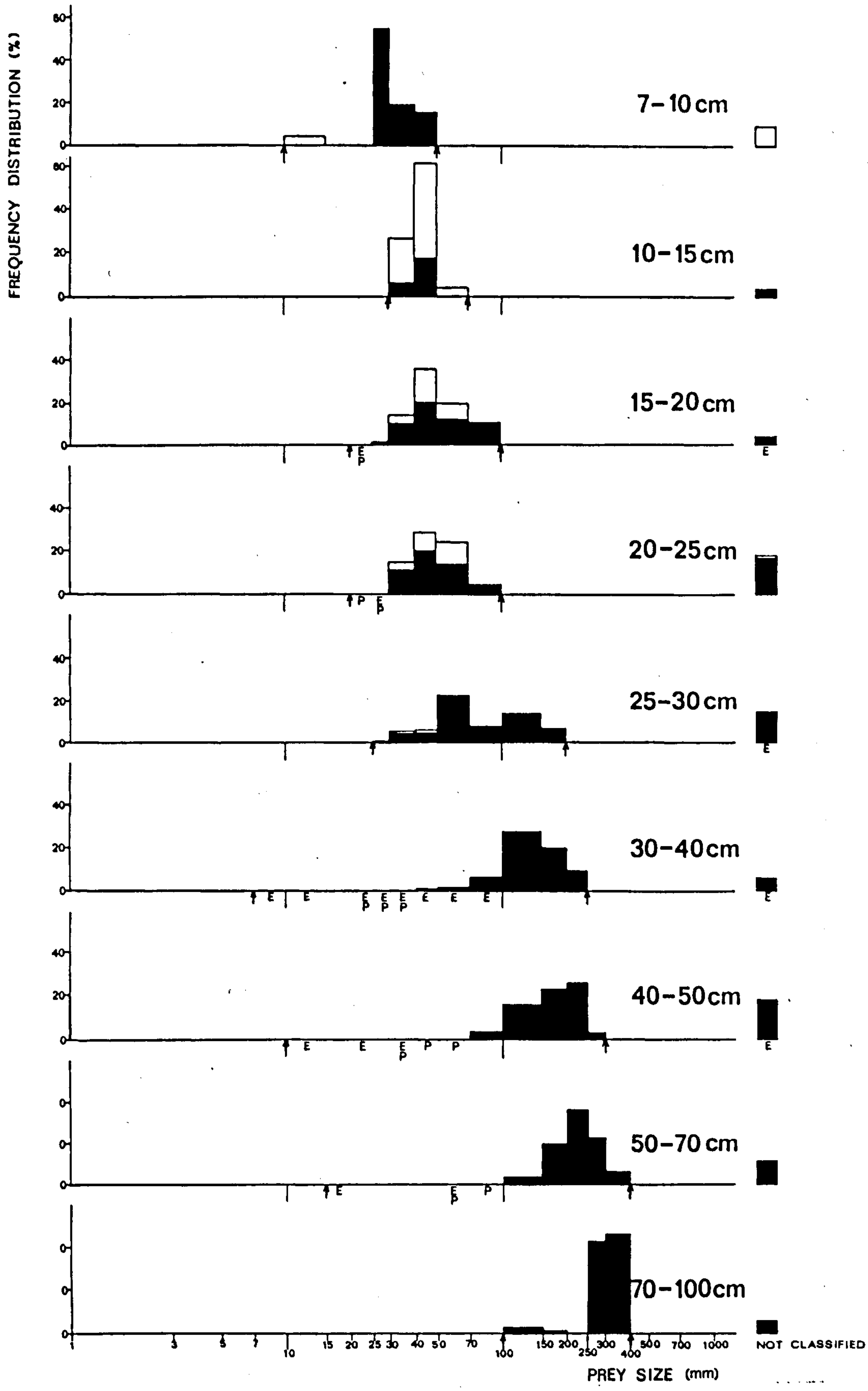

Fig.3A. Turbot. Frequency distribution by weight of prey size class (logarithmic scale) by predator size class. The black part of the column represents fish, the white part represents invertebrates. Unclassified items are given on the right side. Arrows indicate observed prey size spectrum. Values less than 0.5 % are indicated by E (Evertebrata) and P (Pisces).

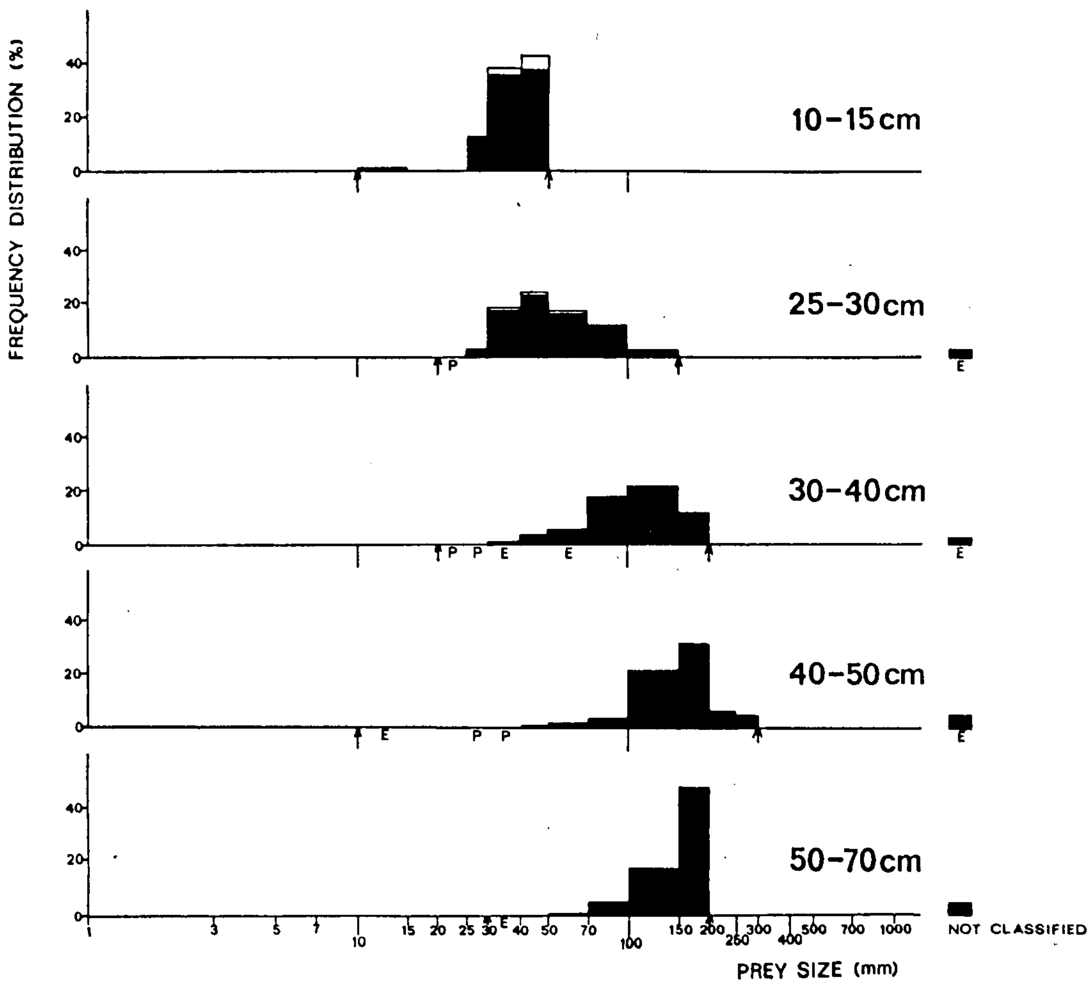

Fig.3B. Brill. Frequency distribution by weight of prey size class (logarithmic scale) by predator size class. The black part of the column represents fish, the white part represents invertebrates. Unclassified items are given on the right side. Arrows indicate observed prey size spectrum. Values less than 0.5 % are indicated by E (Evertebrata) and P (Pisces).

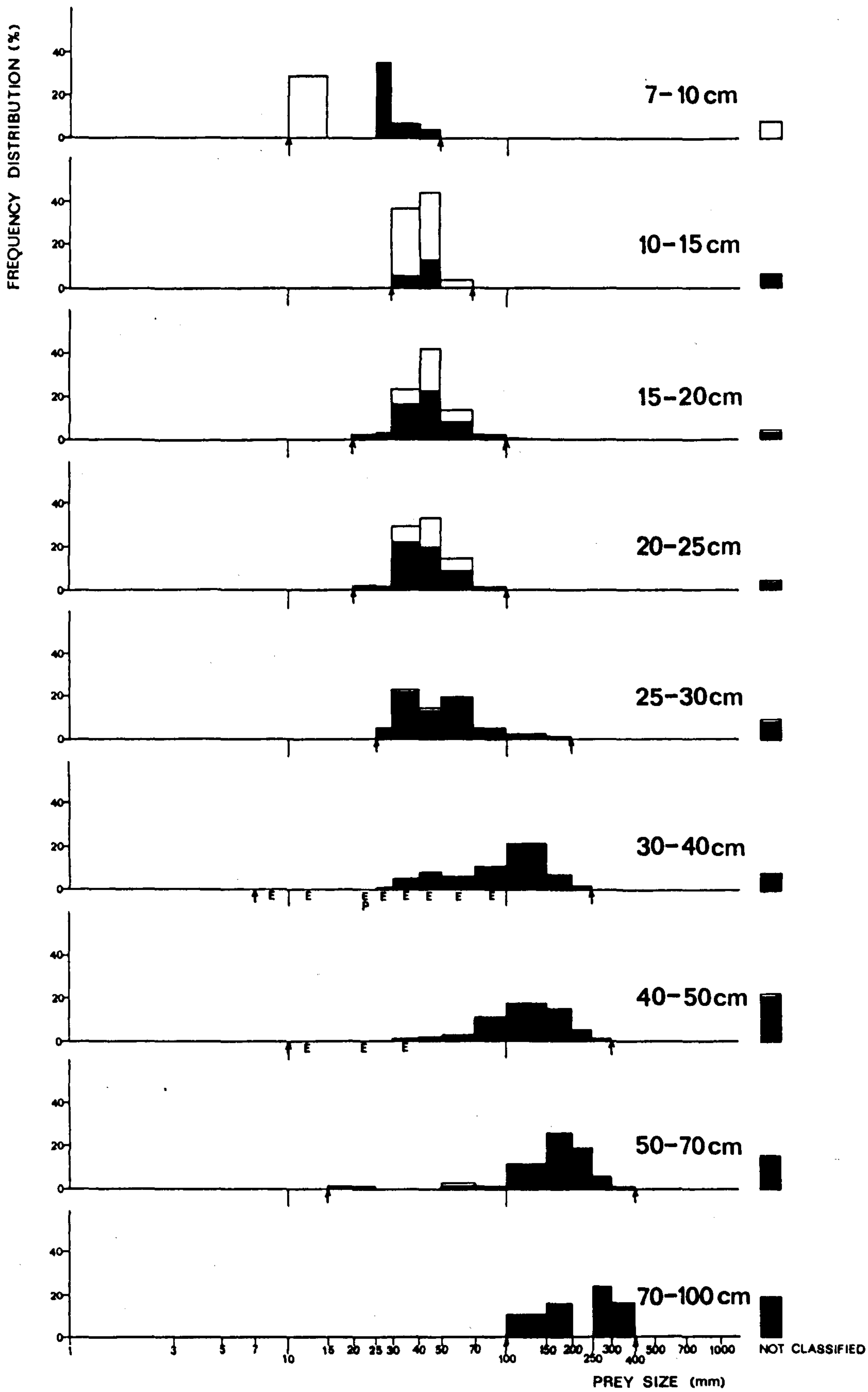

Fig.4A. Turbot. Frequency distribution by numbers of prey size class (logarithmic scale) by predator size class. The black part of the column represents fish, the white part represents invertebrates. Unclassified items are given on the right side. Arrows indicate observed prey size spectrum. Values less than 0.5 % are indicated by E (Evertebrata) and P (Pisces).

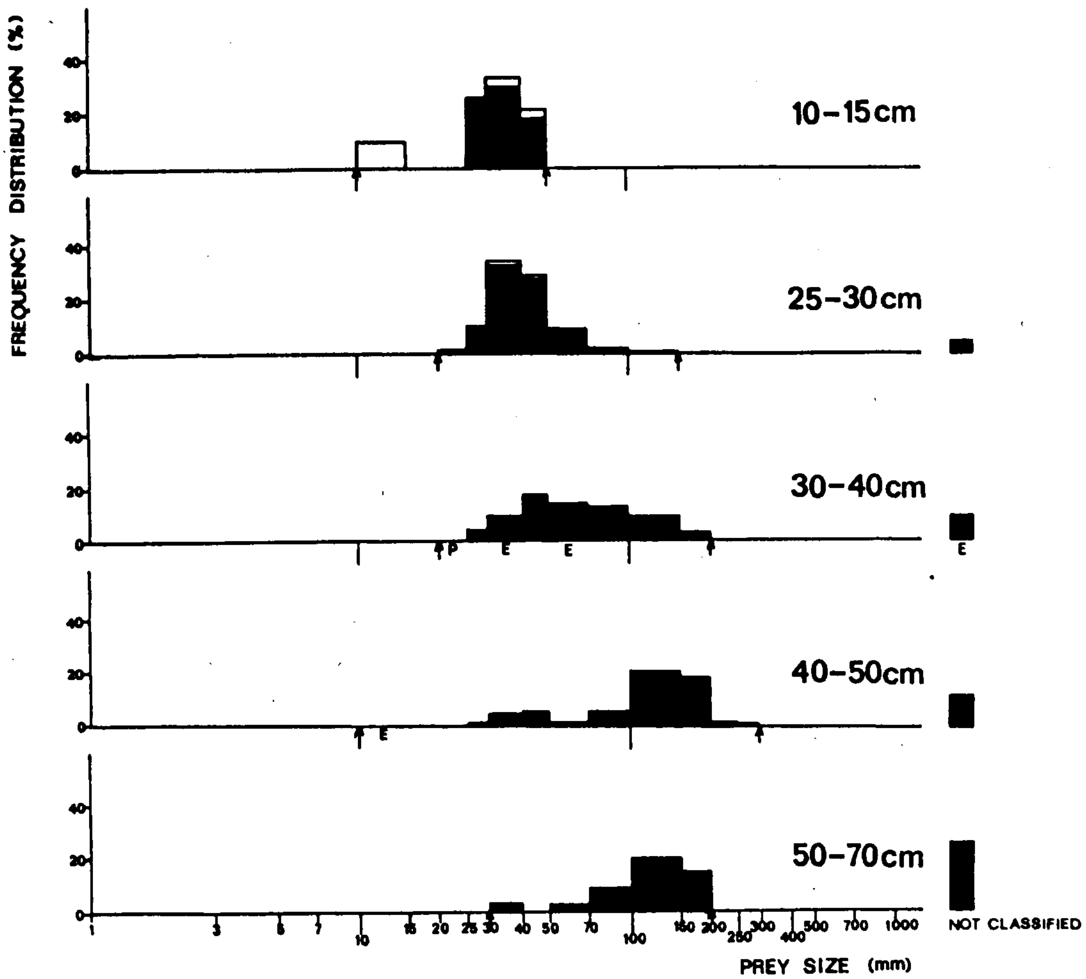

Fig.4B. **Brill.** Frequency distribution by numbers of prey size class (logarithmic scale) by predator size class. The black part of the column represents fish, the white part represents invertebrates. Unclassified items are given on the right side. Arrows indicate observed prey size spectrum. Values less than 0.5 % are indicated by E (Evertebrata) and P (Pisces).

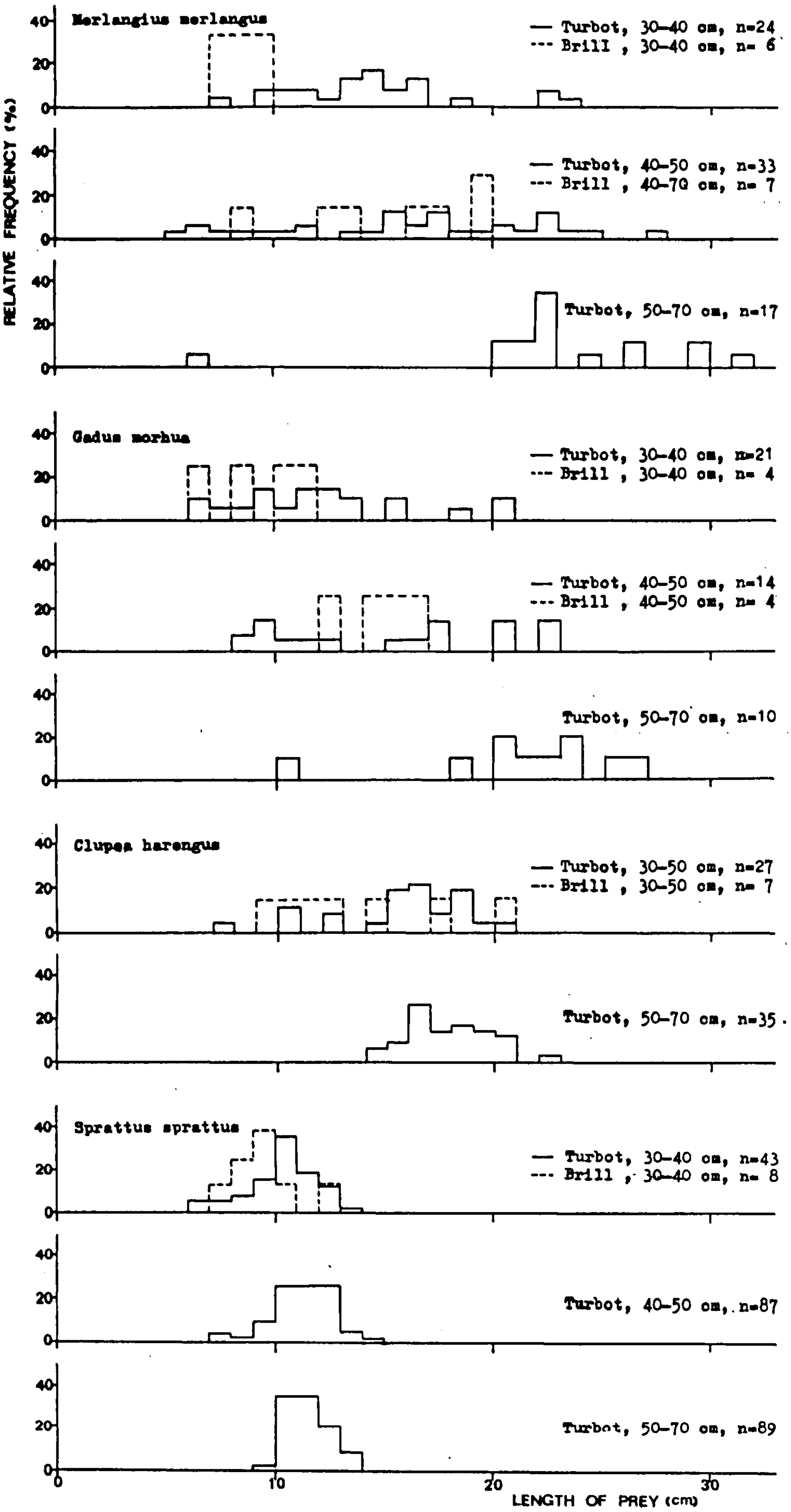

Fig.5. Percentage length distributions of commercial fish species in the food of turbot and brill of different size classes (number of measurements is indicated by n). For all species (except Ammodytidae and Limanda limanda) data of 1980 and 81-1 have been combined.

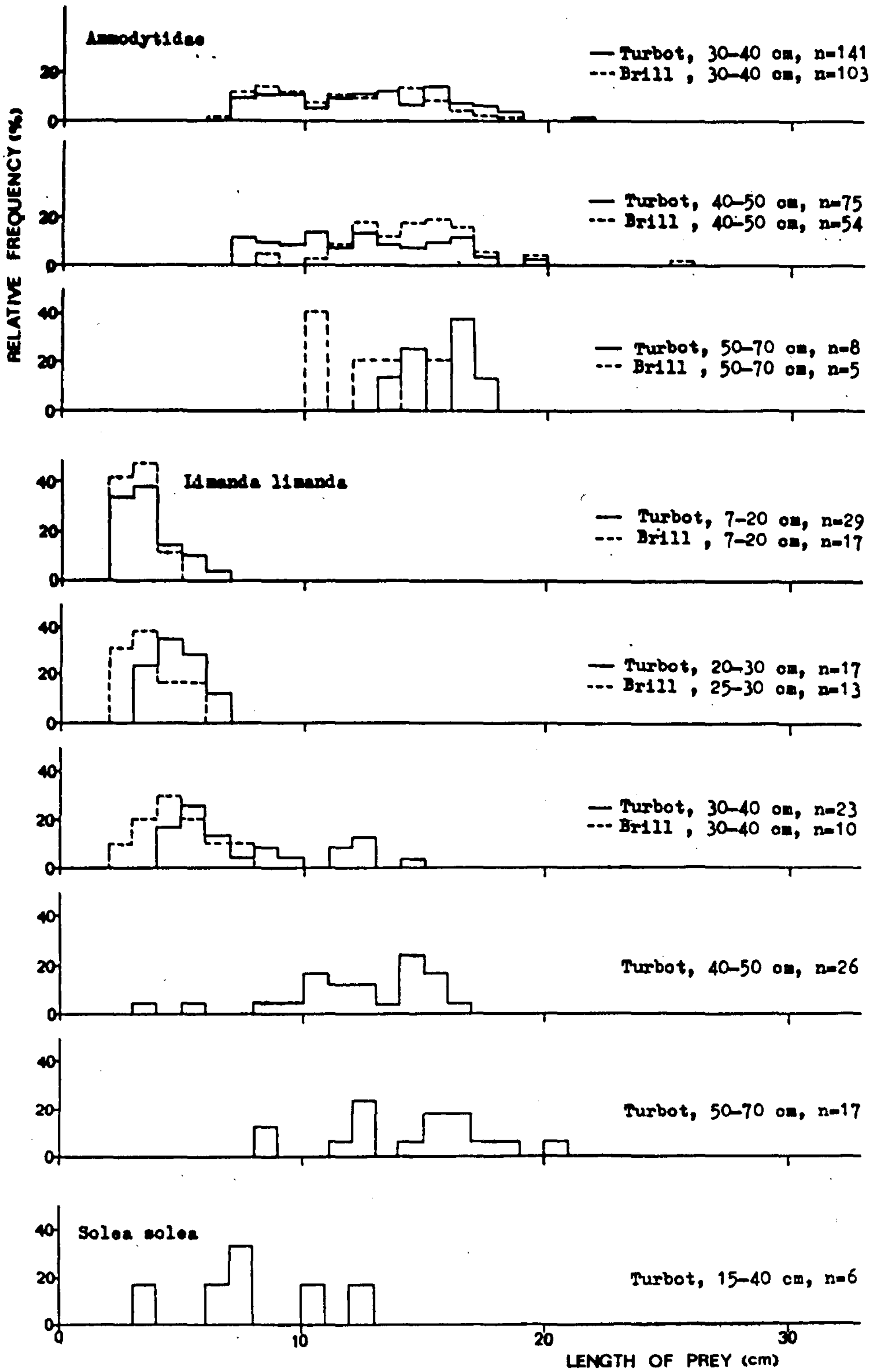

Fig.5. (continued).

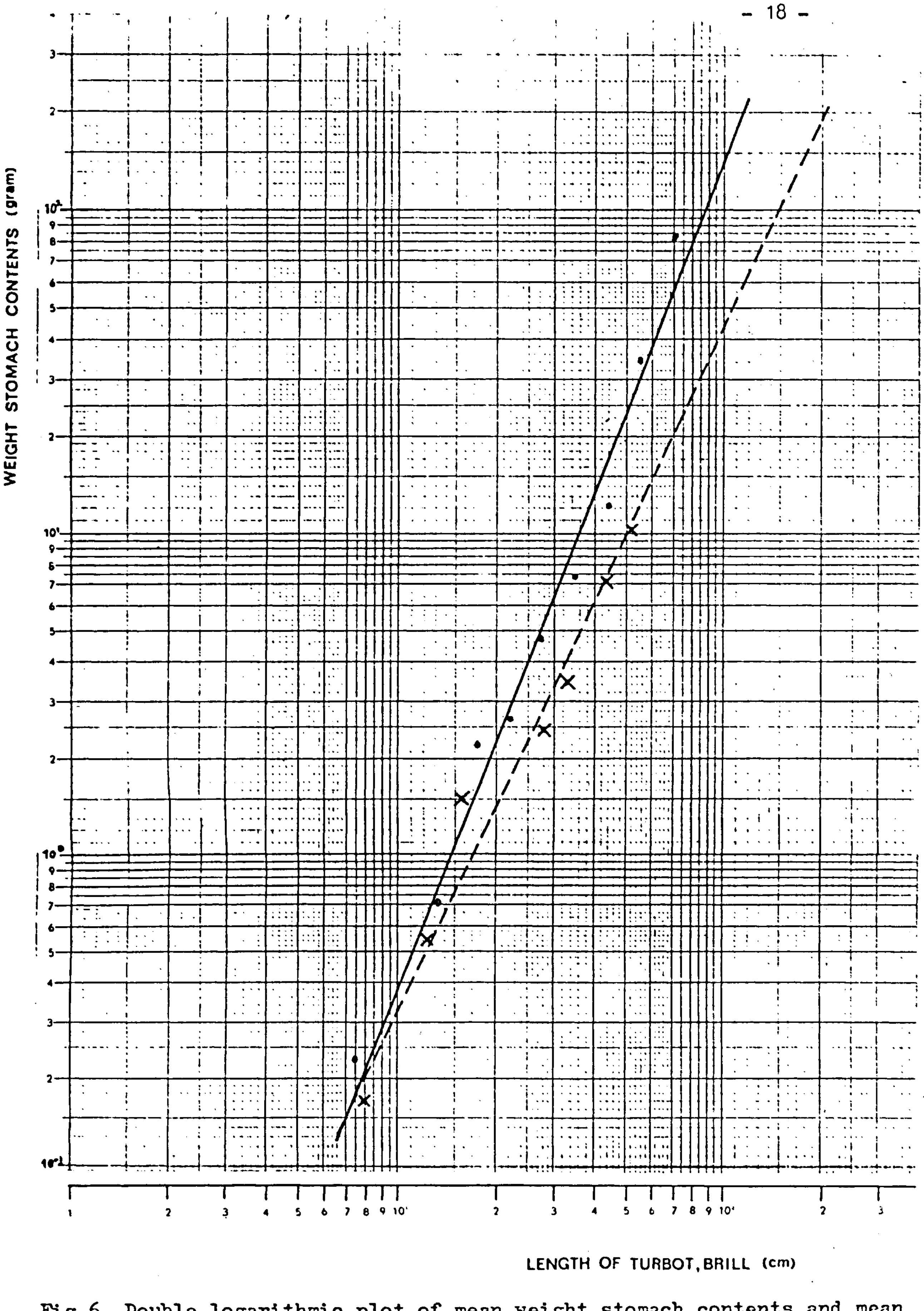

Fig.6. Double logarithmic plot of mean weight stomach contents and mean length per size class of turbot (•) and brill (x) for the total year data from table IV. (——) represents the estimated relationship for turbot: $\log \bar{W} = \log 0.000989 + 2.58 \log \bar{L}$, (---) represents the estimated relationship for brill: $\log \bar{W} = \log 0.002499 + 2.12 \log \bar{L}$.