Available online at www.sciencedirect.com
SCIENCE DIRECT
Fisheries Research 63 (2003) 155–168
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

Improving the selectivity of beam trawls in The Netherlands The effect of large mesh top panels on the catch rates of sole, plaice, cod and whiting

B. van Marlen*

Department of Biology and Ecology, Netherlands Institute for Fisheries Research RIVO, P.O. Box 68, 1970 AB IJmuiden, The Netherlands

Received 16 April 2002; received in revised form 29 January 2003; accepted 26 February 2003

Abstract

This paper presents the results of experiments aimed to improve the selectivity of beam trawls in the North Sea for roundfish whilst minimizing losses on target flatfish. Large-meshed top panels were designed for the tickler chain type of beam trawls used in this fishery. The design process involved model studies in a flume tank, feasibility trials at sea on a research vessel, and comparative fishing trials on chartered commercial fishing vessels. A total of 11 weeks with 450 hauls in total were fished on two categories of vessels, namely 300 and 1500–2000 hp, representing the major groups in the Dutch fleet. An economic evaluation was also carried out with the landings data from the fish auction. A reduction of 30–40% for cod and whiting could be obtained with the new gear design, with virtually no losses in flatfish (particularly sole and plaice). The results were communicated extensively with representatives of the fishing industry throughout the project. The new gears were found to be effective and acceptable for the fishing industry. Their implementation would help reducing fishing mortality of these species.

Keywords: Beam trawl; Selectivity; By-catch reduction; *Gadus morhua*; *Merlangius merlangus*

1. Introduction

The beam trawl is a very efficient fishing gear for catching flatfish, particularly sole (*Solea solea* L.) and plaice (*Pleuronectes platessa* L.) and is widely used within the European community, especially in The Netherlands, Belgium and the United Kingdom. The Dutch fleet consists of some 450 beam trawlers, the Belgian fleet of some 170 vessels and the fleet of the United Kingdom of approximately 100 vessels. Heavy tickler chains are used to scare the flatfish off the seabed. For operation on rough, stony grounds the gears are equipped with chain mats and flip-up ropes.

The minimum codend mesh size of 80 mm is adjusted to the minimum landing size (MLS) (i.e. 24 cm) for sole. This gear has a high selection factor on sole (SF = 3.1–3.6, van Beek et al., 1981a,b; 1983) as compared to other flatfish (*P. platessa* L., SF = 2.17), and dab (*Limanda limanda* L., SF = 2.18), and roundfish cod (*Gadus morhua* L.) and whiting (*Merlangius merlangus* L.). This implies that substantial by-catch of undersized plaice, dab, and roundfish are being caught (van Beek, 1998). The beam trawl fleet in The Netherlands contributes to 10% of the North Sea cod landings and 3% of the whiting landings, and outcompeted the specialized roundfish fleet operating otter trawls. In 1988–1989 the authorities imposed limitations on roundfish landings by beam trawlers, especially on cod. However, these measures exacerbated

* Tel.: +31-255-564780; fax: +31-255-564644.
E-mail address: b.vanmarlen@rivo.wag-ur.nl (B. van Marlen).

0165-7836/03/$ – see front matter
doi:10.1016/S0165-7836(03)00075-4

the discard problem, by forcing beam trawl vessels to discard marketable sized cod or land these illegally.

The question was raised whether technical solutions can be found to reduce the by-catch of undersized and marketably sized roundfish in beam trawl fisheries.

The reactions of roundfish species (haddock, whiting and cod) in otter trawls were investigated using direct observation techniques (Main and Sangster, 1981). Square mesh codends were shown to improve size selectivity for roundfish compared to the traditional diamond shaped meshes (Robertson and Stewart, 1988). However, no direct observations were available on cod in beam trawls. Some experiments were reported on whiting separation, but little research has been done on square mesh selectivity in beam trawls. Belgian experiments conducted in 1988 with square mesh codends in the coastal beam trawl fishery showed no changes in the selective properties of the codend for sole (Fonteyne and M'Rabet, 1992). A Canadian study on American plaice and flounder showed that square meshes were less selective than diamond meshes (Walsh et al., 1992). Commercial practice and preliminary tests showed that certain alterations to the rigging of the gear, such as attaching the headline at a lower position on the beam trawl heads could also contribute to a decline in cod catches.

This suggested that behavioral differences between flat- and roundfish could be utilized to separate these species once they entered the net. The expectation was that flatfish remained close to the lower panel of a trawl, while whiting, and possibly also cod orientate towards the upper panel. Large openings placed there would allow better escapement of these species.

The recent report on North Sea cod and whiting stocks with the—recommendation to minimize fishing mortality on these species brings this research renewed into current attention. A large part of the North Sea was closed to all fisheries likely to catch cod from 14 February until 30 April 2001, and a recovery plan suggested for the period after (Anon., 2001a,b).

2. Materials and methods

2.1. Gear selection procedure

Gear design started with a search through literature, followed by experiments with scale models on a number of alternative tickler chain V-nets in a flume tank. Feasibility trials and direct observations using underwater television equipment were carried out on selected designs aboard RV "Tridens". Consultation meetings with representatives of the fishing industry were held regularly to ensure that the solutions would meet criteria of practicality, acceptability and economy. The large diamond mesh configuration (abbreviated LMT for large mesh top) was finally selected for the commercial trials, because the fishermen expressed more confidence in this construction.

2.2. Selection of vessel classes

For the Dutch fleet the major groups are: the eurocutters with a maximum engine power of 300 hp, and the larger beam trawlers around 1500–2000 hp, the latter value being imposed upon the fleet in 1988 as maximum engine power for new vessels. The chartered commercial vessels were selected from these two groups.

2.3. Gears used

The conventional beam trawl net plans are given in Fig. 1 for a beam length of 12 m used on trip 1–3, and 8–10, in Fig. 2 for 4 m beams used on trip 4–6, and in Fig. 3 for 12 m used on trip 7, and 11–13.

The 12 m large top panel used in the first set of experiments on the 2000 hp Dutch beam trawler "Maarten Jacob" (OD-1) and the first series on the 1500 hp beam trawler "Cornelis Zeeman" (UK-284) is depicted in Fig. 4. The design is based on feasibility trials carried out on RV "Tridens" in April 1994. The headline length was 11.20 m, divided into five sections of 1.90 m and two sections of approximately 0.95 m. A total of 11 rows cut AN was used, starting from 2.40 m, ending in 1.00 m, so the full mesh size ranged from 4.80 to 2.00 m. The material used was Dyneema SK-60 braided twine with 9 mm thickness. The stretched length of this section was 19.20 m. A total of five triangles across and two half triangles were cut to make the join on 125 meshes in the connecting panel of 100 mm mesh size. The side meshes were attached to the selvedges on rings that enabled the twines to set whilst fishing.

Fig. 5 depicts the 4 m design used on the 300 hp eurocutter "Vrouwe Geertruida" (WR-23). The LMT panel starts with a half mesh of 1.35 m, and is seven

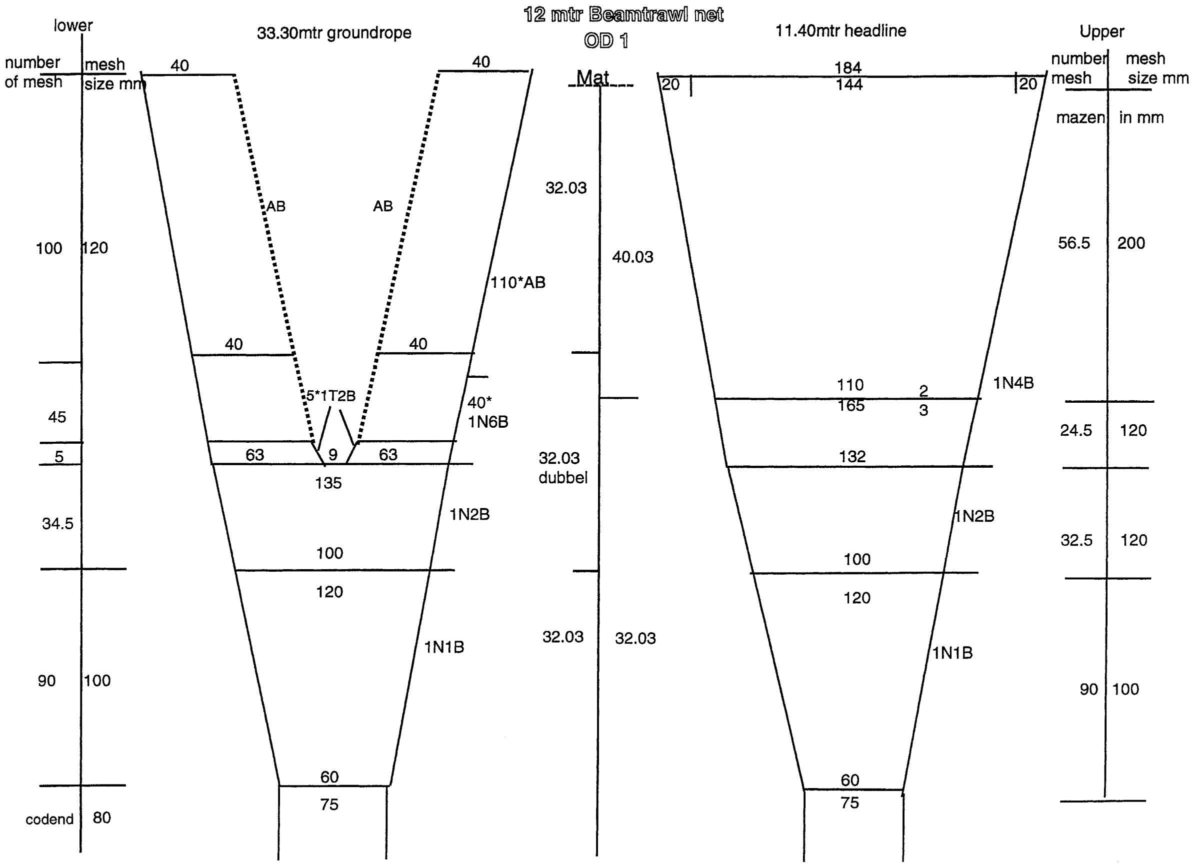


Fig. 1. Net plan conventional beam trawl used on trip 1–3, 8–10.

rows deep, ending in a row of 0.65 m mesh size. The material used for the large meshes is again SK-60, 9 mm in diameter. The total stretched length of the LMT is 7.40 m.

Fig. 6 depicts the 12 m LMT panel used in the second series of trials on the OD-1, and the UK-284. The panel was shortened to eight rows deep, starting from 2.50 m mesh size and ending in 1.30 m mesh, resulting in a stretched length of 14.60 m. The material was 18 mm braided Dyneema SK-60. The selvedges were made of 24 mm braided Dyneema SK-60, with a total length of 14.15 m. The side meshes were laced to the selvedge.

2.4. Comparative fishing trials

The sea work consisted of comparative fishing trials onboard chartered vessels during which both gears, a conventional and an experimental one, were fished simultaneously, thus resulting in a series of paired experiments. For all hauls the catches of marketable sole, and plaice, and all cod and whiting were taken from both nets and measured to the centimeter below. The catches of marketable fish were stored and landed separately for the two gears, thus enabling a direct comparison of weight and earnings after each landing.

2.5. Statistical analysis

The SAS™ (SAS Institute, Cary, NC, USA, 1992) statistical package was used for the statistical analysis of the landings data for the trips where these data were available using the GENMOD procedure. A linear model was used of the form:

$$\ln(\text{landings}) = \text{species} \times \text{week} + \text{species} \times \text{gear}$$

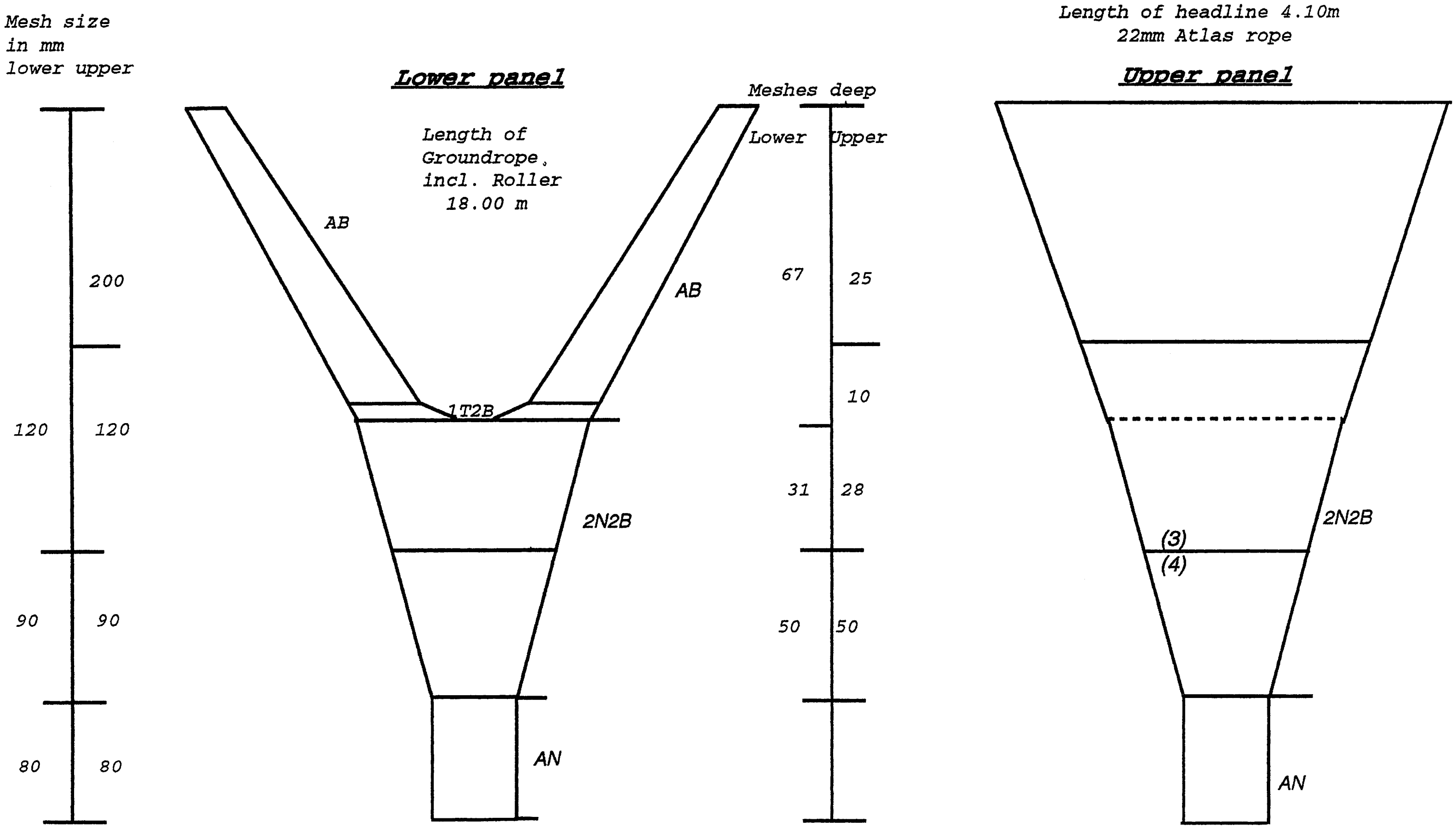


Fig. 2. Net plan conventional beam trawl used on trip 4–6.

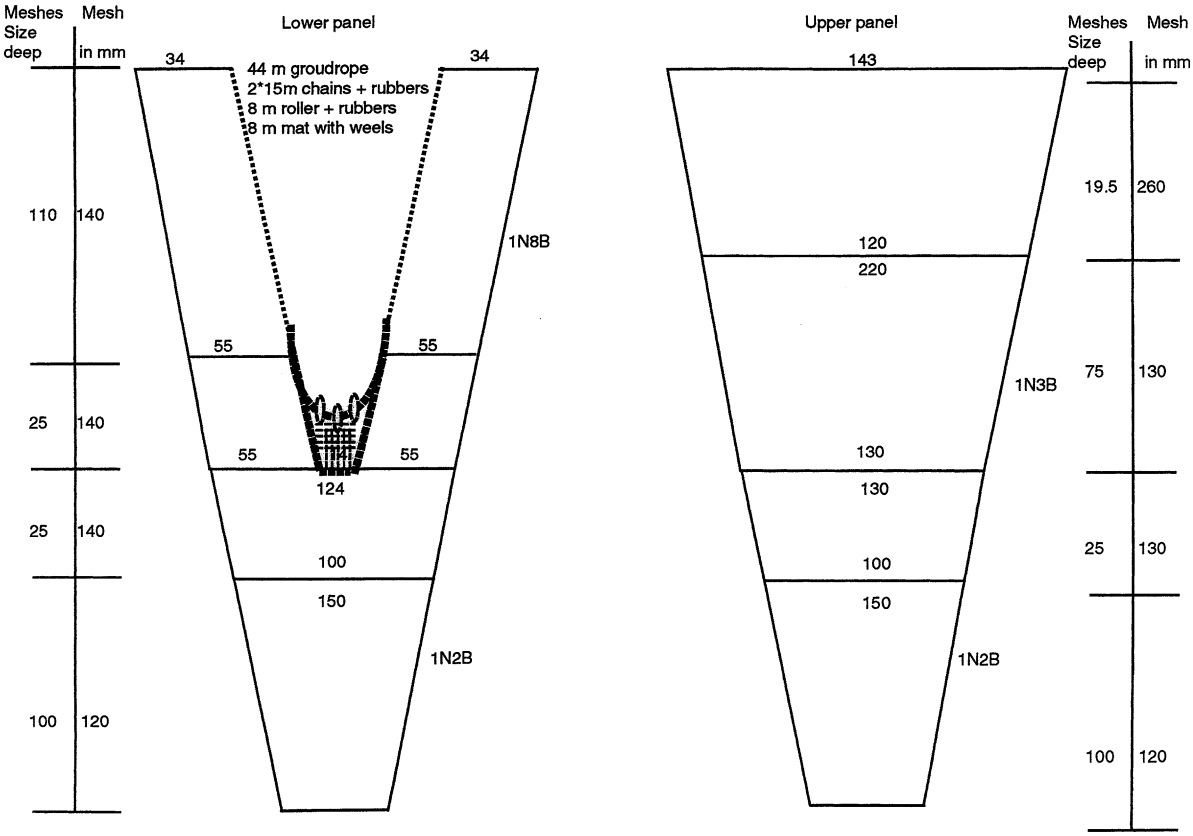


Fig. 3. Net plan conventional beam trawl used on trip 7, 11–13.

for the experiments on the OD-1 in 1994, on the WR-23 in 1995, and on the OD-1 in 1996. The species identified in this analysis are cod, whiting, plaice, sole, and turbot/brill. The cumulative catch data of the 9 weeks of sea trials are used. Experiments were defined as given in Table 1. A two-tailed paired *t*-test to compare differences in catch data for the vessel categories 300 and 1500–2000 hp, the latter being the most representative for the beam trawler fleet.

Table 1
Overview of experiments analyzed

Experiment	Vessel name	Vessel ID	Week
1	Maarten Jacob	OD-1	45, 46, 47 (1994)
2	Vrouwe Geertruida	WR-23	14, 15, 16 (1995)
3	Maarten Jacob	OD-1	10, 11, 12 (1996)

2.6. Economic appraisal

The data collected during the sea trials were also used to appraise the effects of catch differences on the earnings from fishing. A computational model was used in which the various species were sorted in length groups or grades for which average prices per unit of weight were used. Conversion from length to weight was done using the length–weight key of Coull et al. (1989). By comparing the number of fish caught in each grade and multiplying this number with an average price per grade, income differences between the experimental and the standard gear could be determined.

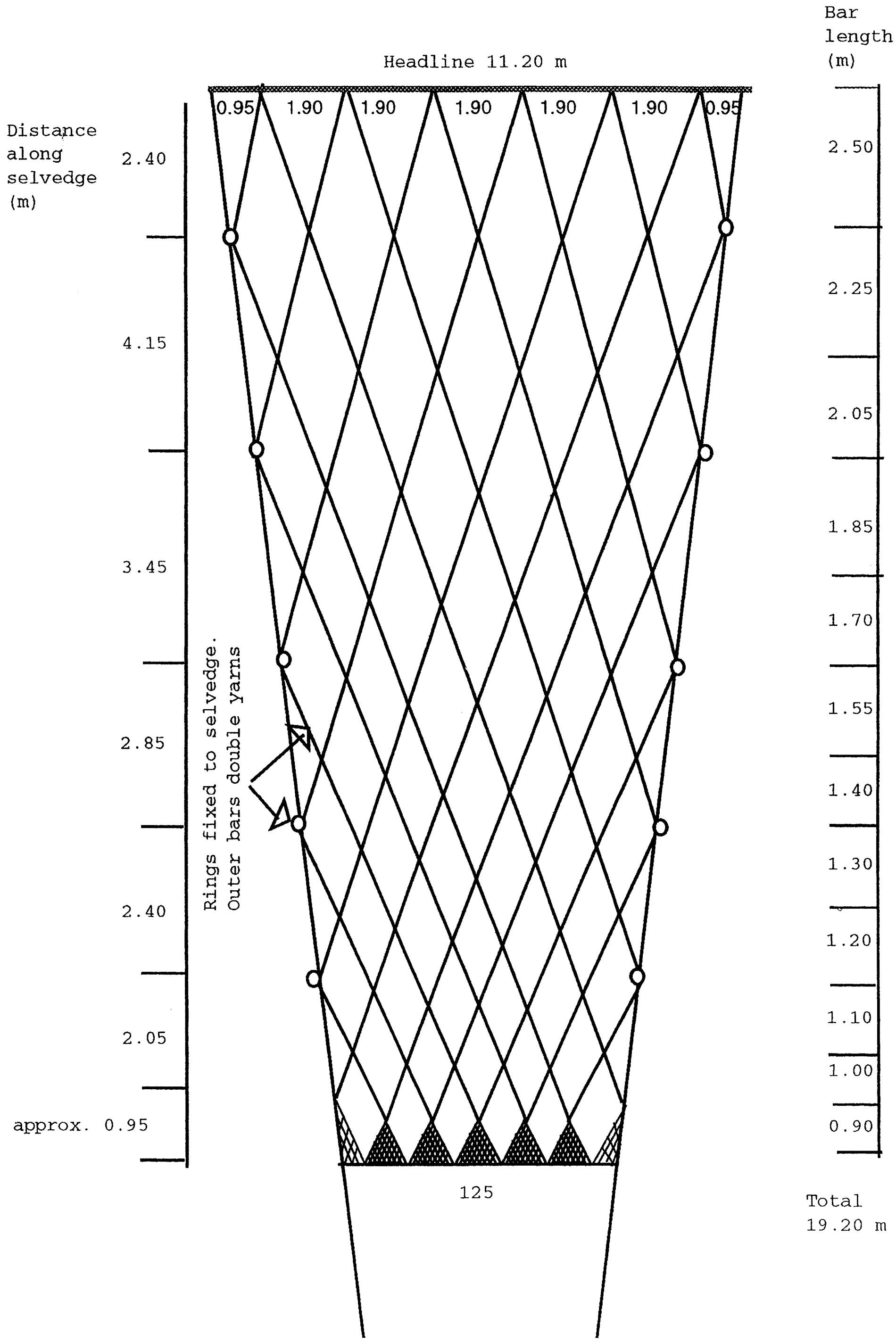


Fig. 4. Large diamond mesh top panel, 12 m version trip 1, 3 and 7.

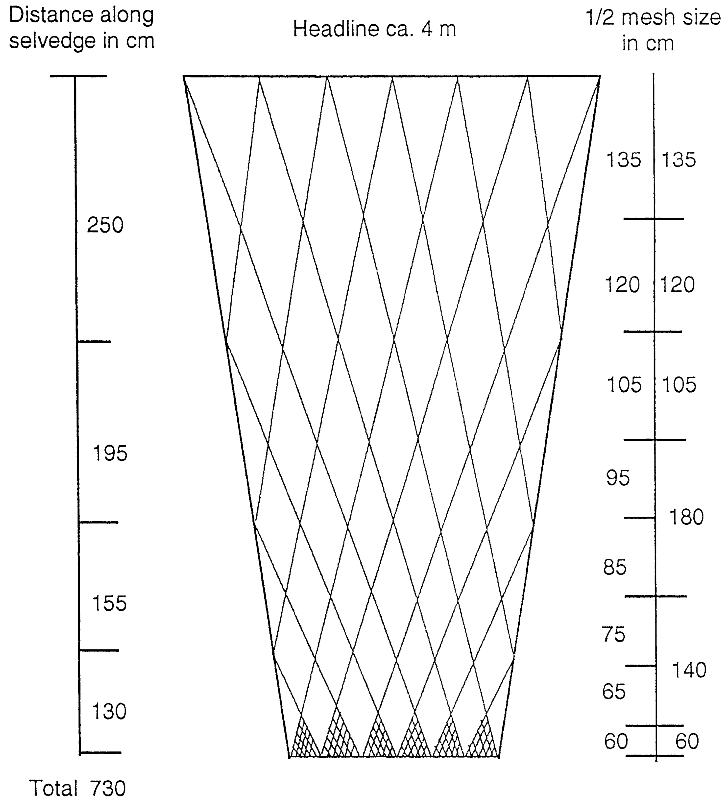


Fig. 5. Large diamond mesh top panel, 4 m version trip 2.

3. Results

3.1. Comparative fishing

A total of 15 1-week trips were carried out on chartered vessels, from which 2 weeks resulted in no data due to initial gear troubles on the UK-284 (Table 2). Not all trips produced adequate cod and whiting data. The total number of hauls that resulted in valuable data is also given in this table.

Table 3 summarizes the cod and whiting catch data in numbers below the minimum landings size, numbers above, total numbers, with percentages difference, and *P*-values.

The LMT-net caught about 84% of juvenile cod (MLS = 35 cm) for the 300 hp class, and 69% for the 1500–2000 hp class. Similarly 50% of marketable cod (300 hp), and 62% (1500–2000 hp). For whiting (MLS = 23 cm) these percentage juveniles were: 84 (300 hp) and 72% (1500–2000 hp), and legally sized 53 (300 hp) and 61% (1500–2000 hp). Statistically significant differences are printed in boldface in Table 3.

The percentages difference between the LMT and the conventional (abbreviated CON) gear of the total (undersized and marketable) catch in weight for the five species investigated in the SAS-analysis, and the *P*-value are given in Table 4 for the trips OD-1 (1994), WR-23 (1995), and OD-1 (1996). The auction data of the UK-284 were not available, and the results for this vessel are therefore not included. A significant lower catch was found in the LMT-net for cod, whiting, turbot and brill in experiment 1. A similar result was found for experiment 2 on the WR-23, with the addition of plaice. The comparison between the OD-1 trip in 1994 and 1996 (experiment 3) shows the effect of changing the net design, less flatfish was lost in the second trip. The effect on sole seems smaller, possibly due to their escape behavior directed towards

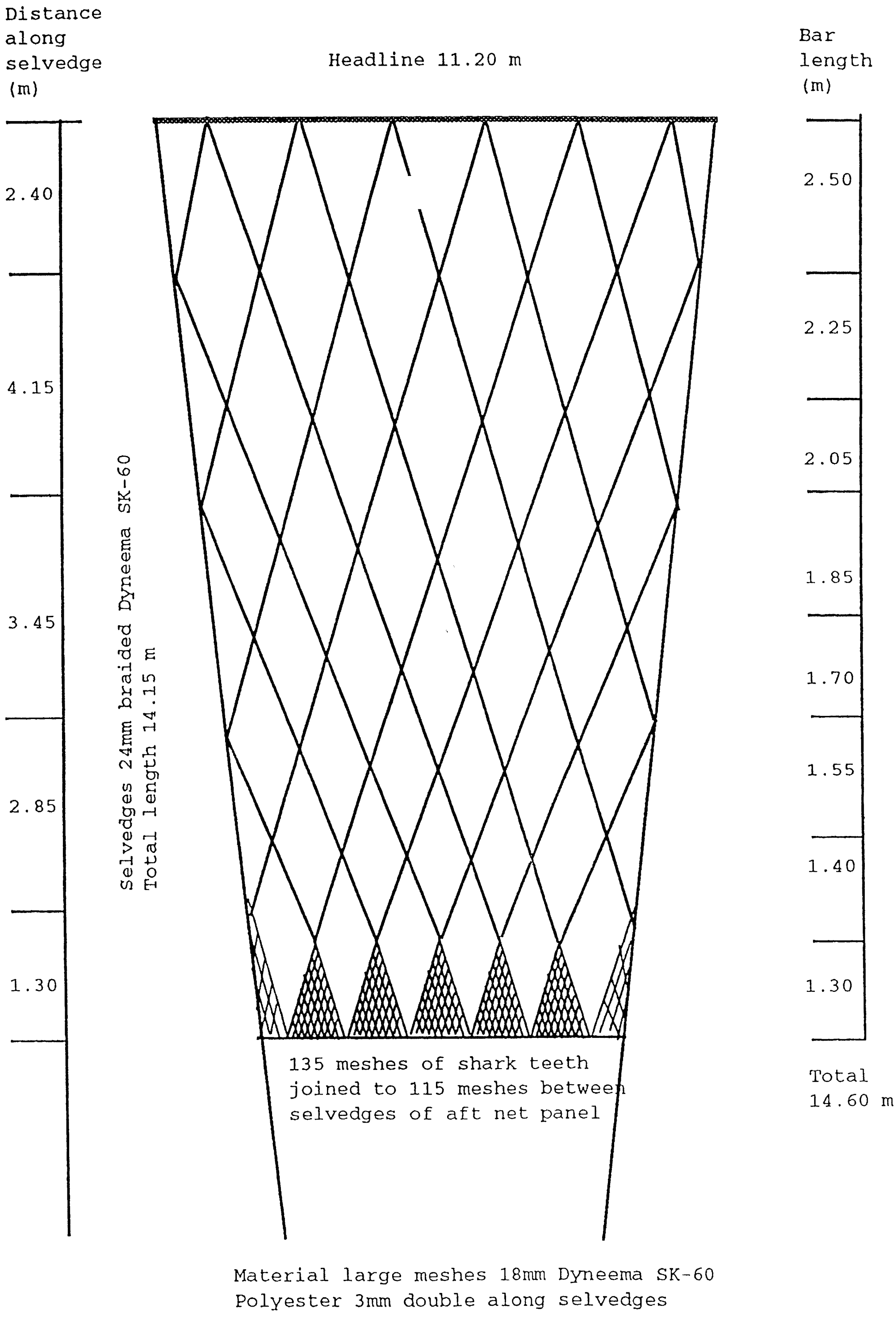


Fig. 6. Large diamond mesh top panel, 12 m version trip 4 and 5.

Table 2
Overview of trips

Trip	Vessel ID	Vessel name	hp	Period	No. of hauls	Gear	Configuration
1	OD-1	Maarten Jacob	2000	November 1994, 114 valid	44	V-net, 12 m	LMT 1
2					32		
3					38		
4	WR-23	Vrouwe Geertruida	300	April 1995, 112 valid	43	V-net, 4 m	LMT 2
5					31		
6					38		
7	UK-284	Cornelis Zeeman	1500	June 1995, 47 valid	47	V-net, 12 m	LMT 1
8	OD-1	Maarten Jacob	2000	March 1996, 118 valid	40	V-net, 12 m	LMT 3
9					48		
10					47		
11	UK-284	Cornelis Zeeman	1500	June 1996, 128 valid	42	V-net, 12 m	LMT 3
12					41		
13					42		

Table 3
Summary of cod and whiting data per vessel class (boldface = significant)[a]

Experiment	Species	No. of hauls	Item	LMT gear	CON gear	LMT/CON (%)	*P*-value
300 hp	Cod	112	NRS < MLS	**1134**	**1352**	**83.9**	**0.0051**
			NRS ≥ MLS	144	286	50.3	0.0369
			Total NRS	**1278**	**1638**	**78.0**	**0.0056**
300 hp	Whiting	132	NRS < MLS	577	673	83.7	0.4538
			NRS ≥ MLS	100	188	53.2	0.1866
			Total NRS	677	861	78.6	0.2822
1500–2000 hp	Cod	338	NRS < MLS	413	596	69.3	0.2428
			NRS ≥ MLS	**513**	**825**	**62.2**	**0.0068**
			Total NRS	**926**	**1421**	**65.2**	**0.0146**
1500–2000 hp	Whiting	249	NRS < MLS	78	109	71.6	0.1165
			NRS ≥ MLS	**3056**	**4993**	**61.2**	**0.0125**
			Total NRS	**3134**	**5102**	**61.4**	**0.0129**

[a] MLS: minimum landing size; LMT: large mesh top panel; CON: conventional gear; NRS: numbers.

Table 4
Differences in total catches landed (boldface = significant)

Species	Trip					
	OD-1, 1994		WR-23, 1995		OD-1, 1996	
	LMT/CON (%)	*P*-value	LMT/CON (%)	*P*-value	LMT/CON (%)	*P*-value
Cod	**66.61**	**0.0001**	**56.42**	**0.0001**	**59.39**	**0.0001**
Whiting	**80.56**	**0.0031**	**68.80**	**0.0001**	**94.63**	**0.0001**
Turbot/brill	**73.73**	**0.0001**	**74.02**	**0.0001**	96.34	0.4588
Sole	93.65	0.3689	91.45	0.1880	101.89	0.7100
Plaice	93.59	0.3640	83.69	0.0087	93.91	0.2114

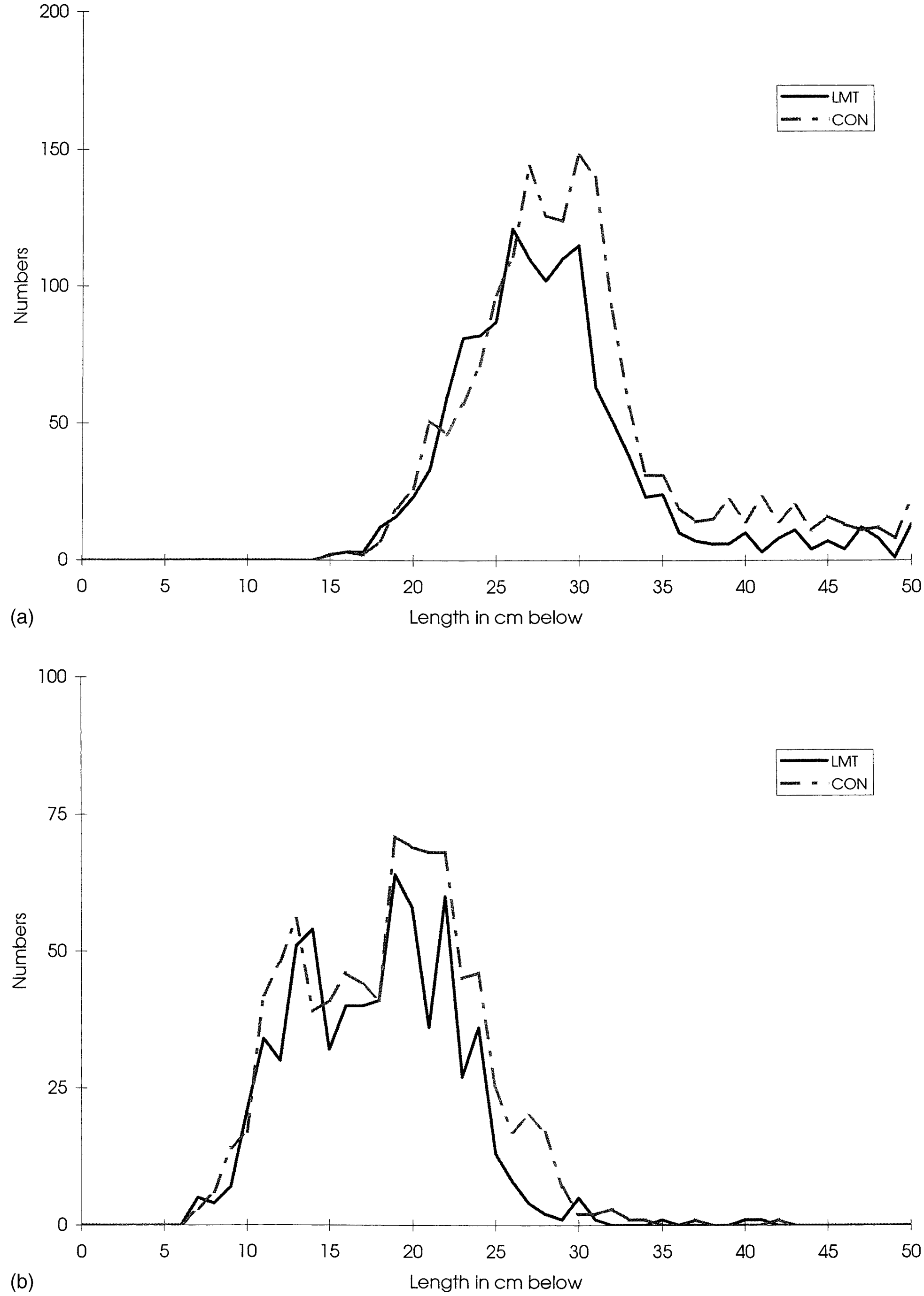
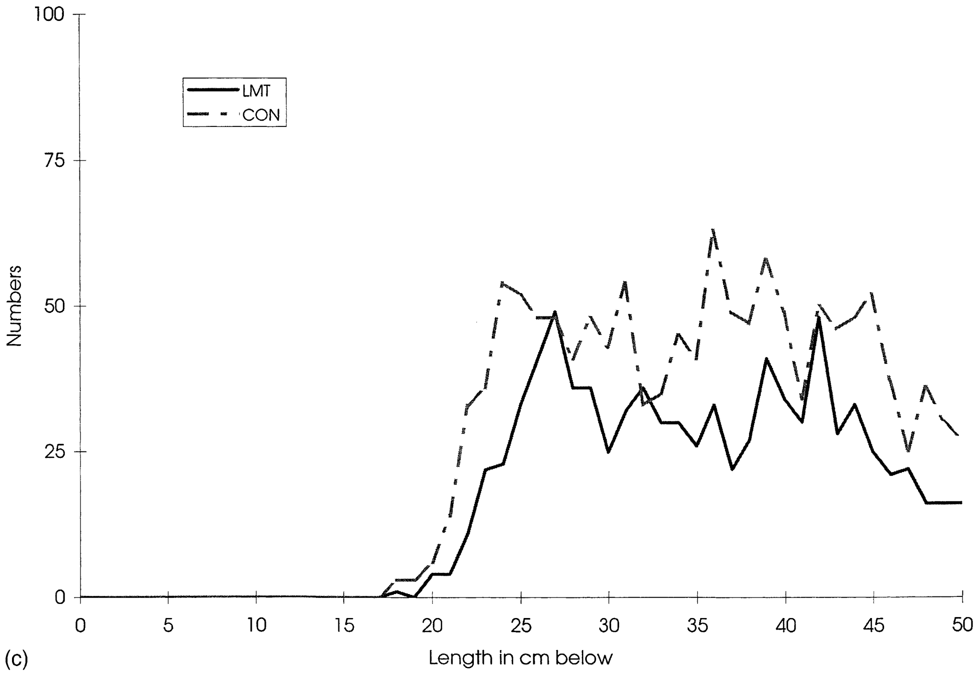


Fig. 7. (a) Length frequency distribution of cod catches (300 hp vessel); (b) length frequency distribution of whiting catches (300 hp vessel); (c) length frequency distribution of cod catches (1500–2000 hp vessels); (d) length frequency distribution of whiting catches (1500–2000 hp vessels). LMT: large mesh top panel; CON: conventional gear.



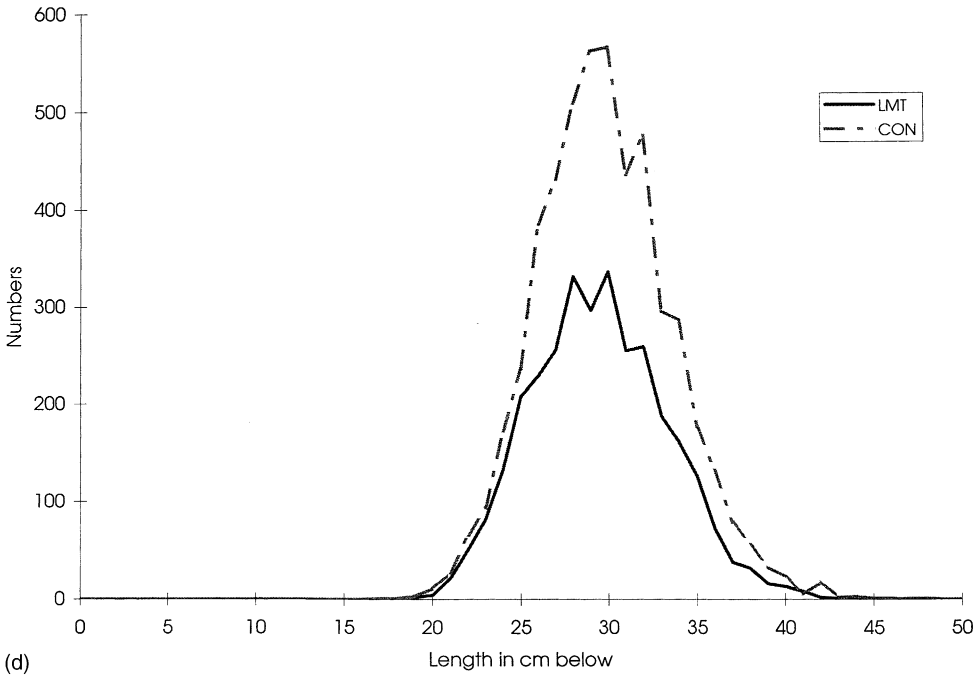


Fig. 7. (*Continued*).

the lower panel of the gear and the sea bed (digging in).

The number of cod in each length class for the 300 hp vessel is given in Fig. 7a. As can be seen from the graph the LMT resulted in lower catches of cod. The difference was statistically significant (two-tailed paired *t*-test, 95% confidence level). The reduction occurred in all length classes.

Fig. 7b depicts length frequencies for whiting for the 300 hp vessel. Again a clear difference was found with lower catches for the LMT-variant. Fig. 7c gives the length frequencies for cod for the 1500–2000 hp vessel, and Fig. 7d for whiting. In all these cases it can be seen, that the catches for the alternative design (LMT) were lower than the conventional net (CON) over the full length range.

3.2. Economics

The port and starboard catches in the Dutch trials were landed separately in the auction to enable a direct comparison between the weight and value of catches of the experimental net with the conventional net. The percentage of total averaged weight and value caught with conventional gears for the trials on the WR-23 and the OD-1 are given in Table 5 for all commercial species.

For the WR-23 the majority of income was generated by sole with plaice, turbot and brill and miscellaneous all sharing equally around 4%. Cod and whiting contributed about 1–2% to her income.

Sole contributes most to the earnings of the OD-1 between 50 and 75%, followed by plaice (15–30%). Turbot and brill can reach a fair percentage (5–15%), and miscellaneous contributes about 5%. The share of roundfish (cod and whiting) is low, i.e. between 1 and 1.5%. Apparently releasing these to a greater extent does not effect the vessel's earnings significantly.

4. Discussion

Although fish behavior inside these trawls could hardly ever be observed, due to sand clouds inside the net generated by the tickler chains (van Marlen et al., 1993; Fonteyne et al., 1997), the results confirm the premises that whiting and (juvenile) cod orientate towards the top panel, and flatfish remain closer to the lower panel. Similar behavior was observed for haddock and whiting in otter trawls (Main and Sangster, 1981). In many observations mature cod did not show a strong escape reaction, although these were mainly done at lower towing speeds, much lower than the attainable burst speed of these fish, and also lower than the normal towing speeds used in beam trawling. A comparison between various types and dimensions of beam trawls and towing speeds suggests that a relatively long escape section and lower towing speed gives the roundfish more escape opportunities (Fonteyne et al., 1997). In the Dutch designs a section of about half the length of the trawl showed to be effective.

The work resulted in effective and simple technical design modifications which were proven to improve the selectivity of beam trawls on roundfish and thus help to reduce such discards, but the uptake by the industry was minimal in spite of thorough dissemination of the results through a workshop and a video

Table 5
Percentage of average weekly catches and earnings on WR-23 and OD-1 using the conventional beam trawl

Species	Trials					
	Trips 1–3, 12 m, 2000 hp, OD-1 (% weight)	Trip 8–10, 12 m, 2000 hp, OD-1 (% weight)	Trip 4–6, 4 m, 300 hp, WR-23 (% weight)	Trip 1–3, 12 m, 2000 hp, OD-1 (% value)	Trip 8–10, 12 m, 2000 hp, OD-1 (% value)	Trip 4–6, 4 m, 300 hp, WR-23 (% value)
Sole	23.2	35.7	50.9	52.7	73.8	84.3
Plaice	51.0	32.2	9.6	27.7	14.9	4.1
Turbot-Brill	7.6	2.1	2.1	14.3	5.0	4.4
Cod	1.9	1.4	3.6	0.9	0.6	1.4
Whiting	2.5	1.7	1.4	0.4	0.4	0.3
Dab	–	–	7.2	–	–	1.5
Miscellaneous	13.7	27.0	25.3	4.0	5.4	4.0

presentation and information package sent to many individual skippers. One reason might have been that legislation affecting the levels of allowable by-catch of roundfish in beam trawling directly affect fishermen's income. There is anecdotical information from one skipper that the large-meshed top resulted in more fish damaged by abrasion, and therefore in lower product quality. This was neither reflected in the earnings data nor mentioned by the other skippers. It may have been caused by a larger inflow of water through the large meshes, and needs to be investigated in more detail. Although the economic analysis showed that the proportion to earnings of these by-catches is relatively small, i.e. less than 5%, fishermen are inclined to avoid any loss in catch, especially when having additional quota for these fish. During the mid 1990s the restrictions on roundfish landings for beam trawlers per week were lessened in the Dutch fishery, which further may have reduced the interest of fishermen. Nevertheless, the present situation concerning these roundfish stocks calls for alarm and new action (Anon., 2001a,b).

5. Conclusions

The study has shown that it is possible to release a substantial percentage (30–40%) of roundfish species (whiting and cod) from a beam trawl with minimal influence on the flatfish catches (sole, plaice) using a simple, practical and cheap technical modification to existing beam trawl designs.

The current poor catches of cod resulted in an advice to reduce fishing mortality for this species to the lowest possible level (ICES, 2000, 2001). This makes any technical modification in demersal gear to reduce the catch of cod an important contribution to sustainable development in fisheries.

Acknowledgements

The author is indebted to the European Commission and the Ministry of Agriculture, Nature Management and Fisheries for financial support of the projects: FAR TE-2-544 "Improved selectivity of fishing gears in the North Sea—Beam trawling", and AIR2-CT93-1015 "Optimization of a species selective beam trawl". The co-operation with the Sea Fish Industry Authority (SEAFISH) of Hull, UK, and the Centre for Agricultural Research Ghent—Sea Fisheries Department (CLO-DvZ) of Ostend, Belgium was pleasant and successful, while the contributions of skipper and crews onboard FRV "Isis" and "Tridens" and the chartered beam trawlers also deserve to be mentioned. The author also wishes to express gratitude for positive suggestions made by Dr. A.D. Rijnsdorp.

References

Anon., 2001a. Communication from the Commission to the Council and the European Parliament. Rebuilding stocks of cod and hake in community and adjacent waters. COM(2001) 326 final, 14 pp.

Anon., 2001b. North Sea cod recovery plan. Report of the Scientific Meeting on Improvement of Selectivity of Fishing Gears, Brussels, March 5–9, 2001, 45 pp.

Coull, K.A., Jermyn, A.S., Newton, A.W., Henderson, G.I., Hall, W.B., 1989. Length/weight relationships for 88 species of fish encountered in the north east Atlantic. Scottish Fisheries Research Report No 43. ISSN 0308 8022.

Fonteyne, R., M'Rabet, R., 1992. Selectivity experiments on sole with diamond and square mesh codends in the Belgian coastal beam trawl fishery. Fish. Res. 13, 221–233.

Fonteyne, R., Polet, H., van Marlen, B., McMullen, Ph., Swarbrick, J., 1997. Optimization of a species selective beam trawl. Abstract in the Report of the Working Group on Fishing Technology and Fish Behaviour. ICES, Fish Capture Committee, CM 1997/B:2.

ICES, 2000. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerak. ICES C.M. 2000/ACFM:7.

ICES, 2001. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerak. ICES C.M. 2001/ACFM:7.

Main, J., Sangster, G.I., 1981. A study of the fish capture process in a bottom trawl by direct observations from a towed underwater vehicle. Scottish Fisheries Research Report No. 23.

Robertson, J.H.B., Stewart, P.A.M., 1988. A comparison of size selection of haddock and plaice by square and diamond mesh codends. J. Constr. Int. Explor. Mer. 44, 148–161.

van Beek, F.A., 1998. Discarding in the Dutch beam trawl fishery. ICES CM 1998/BB:5.

van Beek, F.A., Rijnsdorp, A.D., van Leeuwen, P.I., 1981a. Results of mesh selection experiments on sole with commercial beam trawl vessels in North Sea and Irish Sea in 1979 and 1980. ICES C.M. 1981/B:31.

van Beek, F.A., Rijnsdorp, A.D., van Leeuwen, P.I., 1981b. Results of mesh selection experiments on North Sea plaice with a commercial beam trawler in 1981. ICES C.M. 1981/B:32.

van Beek, F.A., Rijnsdorp, A.D., van Leeuwen, P.I., 1983. Results of the mesh selection experiments on sole and plaice with commercial beam trawl vessels in the North Sea in 1981. ICES C.M. 1983/B:16.

van Marlen, B., Fonteyne, R., Polet, H., Arkley, K., 1993. EC-Project TE-12-554, Improved selectivity of fishing gears in the North Sea fishery—beam trawling. Fish Capture Committee. ICES CM 1993/B:13.

Walsh, S.J., Millar, R.B., Cooper, C.G., Hickey, W.M., 1992. Codend selection in American plaice: diamond versus square mesh. Fish. Res. 13, 235–254.