

Reduction of discards by technical modifications of beam trawls

B. van Marlen, A.T.M. van Helmond, E. Buyvoets¹

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Client: Marloes Kraan, Paula den Hartog
Productschap Vis
Treibstraat 17
2288 EH Rijswijk

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¹ Researcher ILVO-Fishery Ostend Belgium

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Contents

Quality Assurance	5
Summary	5
Summary (in Dutch)	5
Introduction.....	7
Materials and methods.....	8
Preparation and feed-back.....	8
Sea trips	8
Gears	8
General	8
Discard reduction devices tested	8
Period 1	8
Period 2	8
Period 3	9
Methods 11	
Experimental conditions.....	11
Checks on catch efficiency of standard nets (T0-measurements)	11
Mesh size measurements	11
Sampling of the catch	11
Period 1 and 2.....	11
Period 3	11
Categories studied.....	12
Analysis	12
Economy	12
Results	13
Overview of experiments	13
Effect on bycatches	15
Effect on total bycatch	16
Period 1	16
Period 2	16
Period 3	16
Effect on total fish discards	16
Period 1	16
Period 2	16
Period 3	16
Effect on sole discards.....	17
Period 1	17
Period 2	17
Period 3	17

Effect on plaice discards	17
Period 1	17
Period 2	17
Period 3	17
Effect on benthos bycatches.....	17
Period 1	17
Period 2	17
Period 3	18
Effect on landings	18
Effect on all landings taken together	19
Period 1	19
Period 2	19
Period 3	19
Effect on target species sole	19
Period 1	19
Period 2	20
Period 3	20
Effect on target species plaice.....	20
Period 1	20
Period 2	20
Period 3	20
Effect on trawling economy	20
Effect on total gross earnings	20
Period 1	20
Period 2	21
Period 3	21
Effect on earnings from sole landings	21
Period 1	21
Period 2	21
Period 3	21
Effect on earnings from plaice landings	21
Period 1	21
Period 2	21
Period 3	21
Discussion	22
Conclusions and recommendations	23
Acknowledgements.....	24
References	24
Annex A: Additional tables	25
Annex B: Additional figures	50

Quality Assurance

IMARES utilises an ISO 9001:2000 certified quality management system (certificate number: 08602-2004-AQ-ROT-RvA). This certificate is valid until 15 December 2009. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. The last certification inspection was held the 16-22 of May 2007. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2000 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2009 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation, with the last inspection being held on the 12th of June 2007.

Summary

Experiments were carried out in 2007 and 2008 on discard reducing techniques in flatfish beam trawling onboard FRV "Tridens" in close cooperation with the fishing industry. A total of 38 gear tests were conducted in which modified beam trawls were compared in pair with a conventional 12 m beam trawl. The modifications consisted of a T90 aft part and various Square Mesh Panels (SMPs) in the bottom sheet, top sheet and combinations of both, and variations of a Benthos Release Hole with a guiding V-panel in the bottom sheet. It was found that a panel in the bottom sheet with 160 mm mesh size appeared to perform best without releasing too many marketable fish. The panel should extend relatively far aft just in front of the codend where the netting is off-ground. Panels placed only in the top sheet are not very suitable in reducing benthos bycatches. In addition the Benthos Release Hole with guiding device seems to be effective in reducing such bycatches. The cooperation between fishermen and scientists worked very well and created better mutual understanding. Further work is advocated to optimise the design of these devices. It is expected that such devices will get wider application in the Dutch beam trawling sector.

Summary (in Dutch)

Het tegengaan van vermeende negatieve ecosysteemeffecten van vistuigen, vooral boomkorren, is een belangrijk doel van het huidige visserijbeleid. Een van deze effecten is de weggooi (EN: 'discards') van ondermaatse vis (vooral schol) te verminderen. Daarnaast neemt de bereidheid bij consumenten en de vishandel af om producten af te nemen uit visserijen met een intensieve bodemberoering. De kottersector heeft deze signalen opgepakt en is zich terdege bewust van het belang aan deze maatschappelijke kritiek tegemoet te komen. Gefinancierd door Productschap Vis is door IMARES een project opgezet onder de titel: "Vermindering 'discards' in de kottervisserij door technische aanpassingen van de netten (VDTN)", met als doel door netaanpassingen de hoeveelheid 'discards' in de boomkorvisserij te verminderen.

In 2007 en 2008 werden vergelijkende visserijproeven gedaan aan boord van het visserijonderzoeksvaartuig "Tridens" door een samenwerkingsteam bestaande uit praktijkschippers uit de kottersector, onderzoekers van IMARES en het Instituut voor Landbouw en Visserij Onderzoek (ILVO) te Vlaanderen, België en natuurlijk de opvarenden van de "Tridens". In totaal werden 38 vistuigproeven uitgevoerd met aangepaste boomkornetten in vergelijking met een conventioneel boomkornet in gepaarde waarnemingen, waarbij één net werd aangepast en het andere uitgevoerd als controlenet. Maatse vis werd uit de vangsten van beide zijden gesorteerd en op lengte gemeten. Door middel van monsters werd de hoeveelheid ondermaatse vis en benthos (bodemdieren) bepaald. De wijzigingen bestonden uit verschillende uitvoeringen van een T90 achtereind (waarin mazen 90° gedraaid werden aangebracht), en verschillende varianten van zogenaamde 'Square Mesh Panels (SMPs)' uitgevoerd in maaswijdte van 120 mm, 160 mm of 200 mm van 3 mm dik Dyneema™ garen. De panelen werden aangebracht in de onderzijde van het net, in de bovenzijde of in beide. Tenslotte werden variaties van een zogenaamd 'benthosgaatje met schotje' bestudeerd. Aan het begin van elke periode en bij twijfel over het juist functioneren

van de netten werd een proef gedaan om de visnamigheid van beide netten in ongewijzigde vorm te vergelijken (T0 meting).

Door de grote hoeveelheid beproefde variaties en de doorgaans kleine reeksen van trekken is het moeilijk om harde conclusies te trekken. Ook waren er soms twijfels over de juiste vorm van de wijziging of de visnamigheid van de ongewijzigde tuigen. Toch zijn enkele voorlopige bevindingen vermeldingswaard. Een T90 achtereind kan een effectief middel zijn ter vermindering van discards, van vis en benthos. In het vierkante mazen paneel in de onderzijde leek een maaswijdte van 160 mm de beste resultaten te geven zonder te groot verlies aan marktwaardige vis. Zo'n paneel dient zó ver naar achteren door te lopen, dat het netdeel vlak voor de kuil, waar het want van de bodem komt, erin wordt opgenomen. Panelen, die alleen in de bovenzijde worden aangebracht geven geen vermindering van benthos bijvangsten. Het benthosgaatje met schotje bleek effectief in het verminderen van deze bijvangst, maar het effect op vis was minder duidelijk en de best werkzame variant moet nog worden gevonden.

De indruk bestaat, dat er een goede start is gemaakt met deze innovatieve en maatschappelijk gewenste verbetering van de boomkor, maar dat verder ontwikkelen en beproeven van de modificaties nog nodig is. Door de intensieve samenwerking is er een beter wederzijds begrip ontstaan tussen de vissers en onderzoekers. De verwachting is, dat de Nederlandse boomkorsector discardverminderende voorzieningen steeds meer zal gaan toepassen.

Introduction

Beam trawling is claimed to cause adverse effects on the marine ecosystem, such as mortality of benthic invertebrates living on and in the sea bed, and the capture and subsequent discarding of undersized and non-target fish and other organisms (Bergman and Santbrink, 1994; ICES, 2001; ICES, 2002; Jennings and Kaiser, 1998; Lindeboom and De Groot, 1998; Piet et al., 2000, Van Marlen, 2000a). The industry became aware of this criticism and is seeking ways to reduce these effects and make this fishery sustainable and acceptable.

The bycatch and discard problem in beam trawling has been addressed in several research projects in the past. Improving roundfish selectivity was the main objective of two European projects in which ways were sought to release whiting (*Merlangus merlangius*, L.) and cod (*Gadus morhua*, L.) from beamtrawls during fishing (FAR-TE-2.554 en AIR2-1993-1015 (SOBETRA). These studies led to the design of Large Mesh Top Panels (LMTPs) in the tickler chain type of gear enabling some 30-40% of these species to escape, thus offering some potential bycatch reduction (Van Marlen, 2003). Such panels did not work as well in the shorter chain mat gear, which was found in a later EU-project RECOVERY (Van Marlen et al., 2005a).

A reduction of impact on sea bed biota was studied in EU-project REDUCE (Van Marlen et al., 2005b). Large meshes in the lower part of the net could reduce bycatch of benthos, but the penalty was a loss in marketable fish (Van Marlen et al., 2005d). An alternative parallel tickler chain arrangement showed a heavier impact, but the use of electrical stimulation had potential to decrease the effects on the sea floor (Van Marlen et al., 2006; Van Marlen et al., 1999; 2000b; 2005b, c; 2006). This alternative is still under development, and currently questions raised by ICES are being addressed in further research (Van Marlen et al., 2007).

Encouraging results were obtained with Square Mesh Panels (SMPs) in beam trawls placed in the back of the lower panel just in front of the cod-end (Fonteyne and Polet, 2002; Revill and Jennings, 2005). Meshes turned 90° (so-called T90 mesh) is another promising alternative.

The reduction of discards stands high on the agenda in the EU (Anon., 2007) and in The Netherlands a Task Force on Sustainable North Sea Fisheries was established who articulated the following points of action (Anon., 2006):

- “To Carry out ‘pilot’ projects for the mid-term to reduce discards in the traditional beam trawl fisheries and increase the chances of survival for fish being discarded.”
- “To carry out research in close cooperation with the fishing industry on Technical Measures aimed at developing practical and effective technology which contribute to reducing discards, lower sea bed impact, higher product quality, in particular technical modifications in fishing gears to reduce bycatches.”

This study responds to those points of action and was carried out for Productschap Vis (Dutch Fish Product Board) in cooperation with the beam trawling sector. The Dutch ministry of Agriculture, Nature Management and Food Quality (LNV) offered the use of FRV “Tridens” for these trials. This report gives the results of this study.

Materials and methods

Preparation and feed-back

A one-day workshop was held to make an inventory of ideas of participating industry representatives for further investigation. After the first set of trials two meetings were organised to present the results and decide upon the follow-up work.

Sea trips

Three periods were used for trials at sea: Period 1 in 2007, and Period 2 and 3 in 2008 (Table 1). The comparative fishing experiments were carried out onboard FRV "Tridens" with a research team consisting of researchers from IMARES and ILVO, and a number (3-6) of differing beam trawler skippers from the fishing industry.

Haul duration and towing speed were comparable to the normal commercial situation. Haul duration varied between 1.15 h to 2 h in order to enable a suitable number per configuration tested. Towing speed ranged between 6-7 kts.

Gears

Two fishing gears were fished simultaneously with the port side as modified or test gear, denoted **MOD** in tables and graphs, and the starboard side as standard, conventional or control gear, denoted **CON**. Each trial period started with the comparison of both standard nets on port side and starboard, in order to check whether catch efficiency varied between both sides.

General

Both the control and the test net were 12 m beam trawls with a cod-end mesh size of 80 mm (90 mm in Hauls 1 and 2 in Period 1). A drawing of the standard net is given in Figure 6. A range of bycatch release devices were built in the port trawl during the experiments, and adjusted when the skippers thought they were not performing well enough. Devices tested were Square Mesh Panels (mostly in the bottom sheet, sometimes in the top sheet, and combinations), T90 aft sections, and Benthos Release Holes, were produced by the fishing industry. Table 7 to Table 11 give a detailed description of the size and the position of these devices.

Discard reduction devices tested

Period 1

The alternative selection devices tested in Period 1 were: a T90 extension (mesh size, with joining round of 100 T90 mesh to 80 diamond mesh). In addition a suite of Square Mesh Panels (SMPs) was used, denoted SMP1-SMP9, placed in the bottom sheet, and in the top sheet or a combination thereof. The SMPs had mesh sizes ranging from 200, 160 to 120 mm, made of material Dyneema™ double braided, with 3 mm thickness, with various lengths, widths, composition and position in the net.

Period 2

In the second period Square Mesh Panels (SMPs) were again used, denoted SMP10-SMP20 (e.g. Figure 1), placed in the bottom sheet, and in the top sheet or a combination thereof. These SMPs also had mesh sizes

ranging from 200, 160 to 120 mm, made of material Dyneema™ double braided, with 3 mm thickness, with various lengths, widths, composition and position in the net.

Period 3

In the third period Square Mesh Panels (SMPs), denoted SMP21-SMP26 were inserted in the top sheet of 130 mm diamond mesh, 1 m behind the front row and above the roller gear at the footrope bosom. The panels were 33 bars deep and 20 bars wide with a full mesh size of 300 mm (bar size 150 mm). Thus the panel length was 4.95 m and the width 3.0 m.

A Benthos Release Hole (abbreviated BRH, in Dutch “Schotje met gaatje”) was inserted at the bosom of the footrope. This device consists of a rope-mesh section in a V-shape placed along bars of the bottom sheet meshes to guide benthos to a drop-out hole (BRH1, see Figure 3).

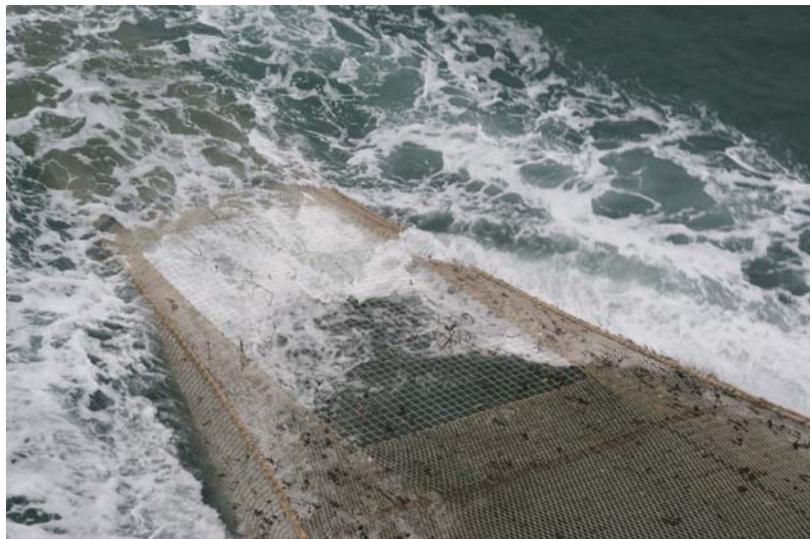


Figure 1: Square Mesh Panel (SMP23) inserted in top sheet of the port beam trawl



Figure 2: Square Mesh Panel (SMP26) inserted in top sheet of the port beam trawl



Figure 3: Benthos Release Hole (BRH1) inserted in bottom sheet of the port beam trawl, left the guider, right the escape hole (Photo P. den Hartog).

Various minor modifications were made to optimise the performance of the BRH, i.e. the length of the top rope increased with 30 cm (BRH2), a small triangular T90 panel with a smaller escape hole added (BRH3), and an additional cover sheet of small meshed netting put over the bottom panel at the inside to avoid escapement of small sole (BRH4), see Figure 4.



Figure 4: Benthos Release Hole with T90 meshes and smaller hole (BRH3, left), and cover sheet of small mesh netting (BRH4, right) inserted in bottom sheet of the port beam trawl (Photo P. den Hartog).

Methods

Experimental conditions

Environmental data were recorded on paper sheets by bridge personnel, among which: haul number, date-time shooting, date-time hauling, position shooting, position hauling, speed over ground, warp length, course, covered distance, water depth, wind speed and wind direction.

Checks on catch efficiency of standard nets (T0-measurements)

A preliminary research plan was made in consultation with the fishing skippers. A check on the performance of both standard (or conventional) nets was done in week 43 of 2007 in open sea prior to starting the experiments. In Period 1 two additional checks were made (Gear test, GT3, and 15), in Period 2 three (GT1, 3, and 6), and in Period 3 two (GT1, and 7).

Mesh size measurements

Mesh sizes (sequence of 20) were measured at various points in time using a wedge gauge and put into an Excel worksheet. An OMEGA mesh gauge was used occasionally in 2007 and 2008.

Sampling of the catch

Period 1 and 2

The catches of both port and starboard sides were collected separately in fish bins on the fish processing deck. All marketable target species were collected from the total catch and their length measured in Period 1 and 2. A sample of one basket of undersized fish, bycatch fish and benthos was taken from each catch by haul of differing portions from the conveyor belt. Undersized sole, plaice, dab and whiting were measured in cm below (and sub-sampled where appropriate). The weight of the total catch was measured with the onboard apparatus fitted to the conveyor belt. The weight of the sample taken from the catch and marketable fish was added. The data were recorded on paper log-sheets and put in input program Billie Turf™ version 6.2.1. The data collection, sampling and measurement protocol for Period 1 and 2 is given in Table 5.

Period 3

The catches of both port and starboard sides were collected separately in fish bins on the fish processing deck. In Period 3 a simpler protocol was followed than in the first two periods. Marketable sole, plaice, dab, and whiting were selected and divided in market categories and these fractions weighed. Other marketable species were lumped together and weighed. A sample of one basket of undersized fish, bycatch fish and benthos was taken from each catch by haul of differing portions from the conveyor belt. Undersized plaice and dab were taken from this sample and measured.

Undersized sole and whiting were taken from the entire catch in the third period, and undersized plaice and dab were taken from the sample basket and weighed with a motion-compensated scale onboard. The weight of the total catch was measured with the onboard apparatus fitted to the conveyor belt. The weight of the sample taken from the catch and marketable fish was added. The data were recorded on paper log-sheets and entered in Microsoft-Excel™-worksheets. The data collection, sampling and measurement protocol for Period 3 is given in Table 6.

Categories studied

Categories total bycatch weight landings, fish discards and discards are defined as follows:

Total bycatch weight: weight measured by the onboard weighing system + weight of sample basket contents

Landings: Period 1 and 2: All target fish species above Minimum Landing Size (MLS) or when not stipulated Minimum Weight, such as: sole (*Solea solea* L.), plaice (*Pleuronectes platessa* L.), dab (*Limanda limanda* L.), brill (*Scophthalmus rhombus* L.), turbot (*Psetta maxima* L.), whiting (*Merlangius merlangus* L.), cod (*Gadus morhua* L.), tub gurnard (*Trigla lucerna* L.), grey gurnard (*Eutrigla gurnardus* L.), haddock (*Melanogrammus aeglefinus* L.), flounder (*Platichthys flesus* L.), lemon sole (*Microstomus kitt* W.), and other commercial species.
Period 3: Recorded target fish species above Minimum Landing Size (MLS) or Minimum Weight: sole (*Solea solea* L.), plaice (*Pleuronectes platessa* L.), dab (*Limanda limanda* L.), , whiting (*Merlangius merlangus* L.), and other commercial species taken together.

Discard fish: All fish species < MLS (see list above). Same definition in all periods.

Benthos: Period 1 and 2: quahogs and prickly cockles from the total catch + quahogs, prickly cockles and other benthos, mainly swimming crab (*Liocarcinus spp.* L.), masked crab (*Corystes cassivelaunus* L.), common starfish (*Asterias rubens* L.), starfish species, (*Astropecten irregularis* L.), brittle star (*Ophiura spp.* L.), and hermit crab (*Pagurus bernhardus* L.) from the sample.
Period 3: All benthic species taken together, and not specified by species.

Analysis

The data were checked and put into the IMARES database FRISBE, and data check routines run for the data collected in Period 1 and 2. Analyses were run using the SAS-statistical software package. The mean Catch per Unit of Effort (CPUE) expressed as kg/hr, with weights calculated from length-weight keys (this is a formula containing constant parameters depending on species to calculate the weight of a fish from its length) in the first two periods (Coull et al., 1988) or measured CPUE (third period in which weights were measured by market grade), the percentage difference, as well as the standard error and the p-value of a statistical test on the log-transformed data were calculated for both the control net and the modified net separately. This was done for each gear test for defined categories such as landings, bycatch fish, bycatch benthos, discards, target species above and below MLS, etc..

Economy

In order to calculate the effect on the economy of fishing the fish records were split numerically in various market grades based on measured length in Period 1 and 2 (or direct selection and weight measurements in Period 3) and their derived or measured weights multiplied with the average price per kg for each grade over 2007 (source LEI, K. Taal, see Table 47). The totals expressed in € per hr were added for all relevant commercial species, and for sole and plaice, the most important species, separately.

Results

Overview of experiments

In total 171 hauls were carried out throughout the experiments (Table 1). 65 hauls were carried out in Period 1, with 15 gear tests; 51 hauls in Period 2; and 55 hauls in Period 3. The hauls were carried out at various positions in the North Sea (Figure 5).

Table 1: Overview of experimental periods, number of gear tests and number of hauls

Period	# gear tests	total # hauls	Weeks; year	Start – End date	Comments
1	15	65	44, 45 and 49; 2007	29/10/2007 - 07/12/2007	Extended catch monitoring (See Table 5)
2	11	51	21 and 22; 2008	19/05/2008 - 30/05/2008	Extended catch monitoring (See Table 5)
3	12	55	45 and 50; 2008	03/11/2008 - 12/12/2008	Restricted catch monitoring (See Table 6)
Total	38	171			

Table 2: List of discard reduction devices. Abbreviation and description. Period and gear test number.

Abbreviation	Description	Period	Gear test number
T90.1-90	T90 aft section of 100 mm meshsize attached to 90 mm codend.	1	1
T90.1-80	T90 aft section of 100 mm meshsize attached to 80 mm codend.	1	2
T90-2	Improved T90 aft section with 80 mm codend.	1	10, 11
Std	Conventional or standard, unmodified net with 80 mm codend	1	3, 15, 16
Std	Conventional or standard, unmodified net with 80 mm codend	2	1, 3, 6
Std	Conventional or standard, unmodified net with 80 mm codend	3	1, 7
SMP1	Square Mesh Panel 1 in lower panel 22 x 20 bars, 200 mm full mesh	1	4
SMP2	Square Mesh Panel 2 in lower panel 22 x 20 bars, 200 mm full mesh with net sheet underneath	1	5
SMP3	Square Mesh Panel 3 in lower panel 44 x 20 bars, 200 mm full mesh	1	6
SMP4	Square Mesh Panel 4 in lower panel, narrow variant with 29 x 20 bars, 160 mm full mesh	1	7
SMP5	Square Mesh Panel 5 in lower panel, narrow variant with 34 x 28 bars, 120 mm full mesh	1	8
SMP6	Square Mesh Panel 6 in lower panel, narrow variant with 29 x 33 bars, 160 mm full mesh), 12 meshes from the front edge of extension piece	1	9
SMP7	Square Mesh Panel 6 in lower panel, 47 x 32 bars of 80 mm, i.e. 160 mm full mesh, 2.5 mesh deep at front of lower panel	1	12

Abbreviation	Description	Period	Gear test number
SMP8	Square Mesh Panel 8: SMP7 in lower panel, with SMP9 in upper panel	1	13
SMP9	Square Mesh Panel 9 with 15 x 17 bars of 200 mm full mesh, 2.0 mesh deep from rear of upper panel,	1	14
SMP10	Square Mesh Panel 10 with 47 x 33 bars, 160 mm full mesh, 2.5 meshes at front of lower panel (section before the codend)	2	2
SMP11	Square Mesh Panel 11 with 41 x 35 bars, 160 mm full mesh size), 2.5 mesh deep at front of lower panel	2	4a
SMP12	Square Mesh Panel 12 with 41 x 31 bars, 160 mm full mesh size, 2.5 mesh deep at front of lower panel	2	4b
SMP13	Square Mesh Panel 13 with 31 x 31 bars, 160 mm full mesh size, 2.5 mesh deep at front of lower panel	2	4c
SMP14	Square Mesh Panel 14 with 20 x 30 bars, 160 mm full mesh size, 2.5 mesh deep at front of lower panel	2	5a
SMP15	Square Mesh Panel 15 with 20 x 31 bars, 200 mm full mesh size, 2.5 mesh deep at front of lower panel	2	5b
SMP16	Square Mesh Panel 16 with 18 x 33 bars, 160 mm full mesh size, 2.5 mesh deep at front of lower panel	2	7
SMP17	Square Mesh Panel 17 with 18 x 33 bars, 160 mm full mesh size, + extension of two times 11 bars deep), 2.5 mesh deep at front of lower panel	2	8
SMP18	Square Mesh Panel 18 with 18 x 42 bars, 160 mm full mesh size, + 24 x 54 bars, 120 mm full mesh size, 2.5 mesh deep at front of lower panel	2	9
SMP19	Square Mesh Panel 19 with 18 x 42 bars, 160 mm mesh size, + 18 x 54 bars 120 mm full mesh size at front of lower panel	2	10
SMP20	Square Mesh Panel 20 with 16 x 34 bars 160 mm full mesh size, at upper panel	2	11
SMP21	Square Mesh Panel 21 with 25 x 25 bars 130 mm full mesh size, in lower 110 mm panel 2.4 m in front of codend	3	2
SMP22	Square Mesh Panel 22 with 25 x 25 bars, 130 mm full mesh size, in lower 110 mm panel, 1 m from front join, in front of codend	3	3
SMP23	Square Mesh Panel 23 with 30 x 46 bars, 200 mm full mesh size, in lower 130 mm panel 1.0 m in front of codend	3	4
SMP24	Square Mesh Panel 24: combination of SMP23 with SMP25	3	5
SMP25	Square Mesh Panel 25 with 20 x 40 bars of 160 mm full mesh size, in upper 110 mm panel 2.4 m in front of codend	3	6
SMP26	Square Mesh Panel 26 with 20 x 33 bars of 300 mm full mesh size, in upper 130 mm panel 1.0 m behind the front row (above footrope bosom)	3	8
BRH1	Benthos Release Hole with guiding V at lower panel in front of codend	3	9
BRH2	Benthos Release Hole with guiding V at lower panel in front of codend. Rope on V 30 cm lengthened	3	10
BRH3	Benthos Release Hole with guiding V at lower panel in front of codend with T90 triangle added), in front of codend in lower panel	3	11
BRH4	Benthos Release Hole with guiding V at lower panel in front of codend, with sheet of small mesh netting underneath	3	12

Effect on bycatches

Table 3 shows the percentage difference between the modified gear and the conventional gear for total bycatch weight, all discard fish taken together, sole and plaice discards, and benthos bycatches, and gross earnings (total and sole and plaice separately) for the three experimental periods. Detailed tables giving the mean value, the percentages difference, the standard errors and the p-value of a T-Test on the means with 95% confidence limit are given in the Section "Additional tables".

Table 3: Effect on bycatch weights. Gear test number and period; type of modification; number of hauls; and CPUE in the modified gear expressed as the percentage of CPUE in the control gear, and gross earnings in the modified gear expressed as the percentage of earnings in the control gear. **Boldface** is significant.

Gear test	MOD	Hauls	Bycatch		Discard fish		Benthos	Gross earnings	Earnings from main target species	
			Total	Total	Sole	Plaice			Sole	Plaice
Period 1										
1	T90.1-90	2	113%	124%	87%	127%	68%	70%	62%	75%
2	T90.1-80	6	61%	65%	25%	71%	61%	78%	75%	102%
3	Std	2	66%	64%	79%	79%	71%	107%	92%	115%
4	SMP1	4	42%	65%	37%	95%	25%	105%	66%	196%
5	SMP2	3	60%	113%	117%	142%	47%	83%	65%	92%
6	SMP3	3	40%	54%	133%	49%	23%	71%	60%	124%
7	SMP4	3	51%	73%	115%	80%	33%	77%	91%	89%
8	SMP5	4	98%	118%	119%	131%	90%	115%	98%	119%
9	SMP6	5	91%	113%	95%	136%	95%	129%	121%	104%
10	T90.2	3	69%	77%	57%	92%	51%	117%	112%	103%
11	T90.2	6	84%	88%	150%	88%	81%	99%	67%	91%
12	SMP7	6	76%	72%	39%	80%	76%	102%	84%	102%
13	SMP8	8	79%	69%	48%	78%	74%	89%	74%	102%
14	SMP9	7	86%	74%	82%	82%	102%	83%	77%	103%
15	Std	5	88%	69%	95%	89%	84%	90%	96%	49%
16	Std	3	71%	66%	72%	69%	93%	81%	72%	95%
Period 2										
1	Std	11	107%	88%	100%	93%	85%	98%	90%	100%
2	SMP10	2	105%	110%	86%	115%	122%	93%	105%	85%
3	Std	10	73%	76%	110%	89%	73%	98%	102%	103%
4	SMP11-12-13	7	72%	68%	107%	81%	63%	56%	56%	101%
5	SMP14-15	6	97%	96%	107%	121%	84%	81%	69%	96%
6	Std	2	124%	423%	423%			100%	100%	
7	SMP16	5	119%	130%	129%	178%	136%	82%	99%	126%
8	SMP17	2	109%	90%	129%	92%	52%	86%	84%	87%
9	SMP18	2	101%	100%	112%	114%	99%	127%	94%	194%
10	SMP19	1	102%	73%	185%	73%	66%	95%	102%	106%
11	SMP20	2	82%	88%	82%	93%	85%	81%	64%	90%
Period 3										
1	Std	3	78%	69%	130%	68%	87%	96%	80%	127%
2	SMP21	6	129%	108%	159%	107%	167%	106%	103%	114%
3	SMP22	3	115%	98%	144%	104%	133%	98%	98%	104%
4	SMP23	5	115%	119%	176%	116%	117%	96%	97%	92%

Gear test	MOD	Hauls	Bycatch	Discard fish			Benthos	Gross earnings	Earnings from main target species		
				Total	Total	Sole			Plaice	Total	Sole
5	SMP24	4	90%	73%	108%	83%	110%	95%	90%	108%	
6	SMP25	4	96%	92%	80%	95%	100%	89%	87%	94%	
7	Std	6	126%	114%	109%	102%	148%	89%	92%	102%	
8	SMP26	6	119%	107%	122%	97%	126%	97%	96%	98%	
9	BRH1	2	29%	50%	83%	76%	19%	85%	80%	111%	
10	BRH2	1	46%	40%	19%	68%	49%	49%	47%	68%	
11	BRH3	5	66%	69%	44%	93%	64%	94%	90%	105%	
12	BRH4	3	70%	76%	107%	75%	65%	96%	102%	95%	

Effect on total bycatch

Period 1

The T90 aft part in Gear test 2 (GT2) caused a significant reduction in total bycatch weight (no landings included) expressed in kg/hr, as did the SMP1, SMP3, SMP4, SMP7, SMP8 and SMP9. The maximum reduction was found with the 200 mm SMPs (i.e. SMP1 and SMP3), and was about 60%. Decreasing the mesh size from 200 mm to 160 and 120 mm seemed to bring the difference down (GT6, 7 and 8, Table 14 and Figure 7).

Period 2

The total bycatch weight (exclusive of landings) in the first week showed both standard nets to fish equally. Unfortunately after the fastener and net repairs the starboard gear caught considerably more, and this difference works through the subsequent gear tests. GT7 is odd in this respect, as with a panel added the modified gear caught more instead of less (Table 15 and Figure 8).

Period 3

For the first set of gear tests the bycatches of the modified gear seemed to be higher than in the standard gear. The Benthos Release Holes (especially BHR1) were most successful in decreasing bycatches (Table 16) .

Effect on total fish discards

Period 1

Maximum reductions in discard fish of about 40-50% were found (GT2, 4, and 6). The only other significant results were found in GT 12 and 13 with a reduction of about 30% (Table 17 and Figure 10).

Period 2

There was a significant lower catch of discard fish in the modified gear in GT1, while both nets seem to have fished equally. Similarly in GT3 the second check on both standard nets. GT4 showed lower discards for the modified net. In GT6 only sole was measured, therefore discards were undersized sole only. In GT7 the panel resulted in a significant higher catch of discards, contrary to the expectation (Table 18 and Figure 11).

Period 3

Only GT5 showed a significant reduction of some 26%, all the other differences were non-significant. The BRHs seem to be most effective in reducing fish bycatches.

Effect on sole discards

Period 1

Only two cases turned out to give a significant reduction in the catch of undersized sole, i.e. GT4 and GT13 (Table 20 and Figure 13).

Period 2

None of the differences were significant. GT6 is odd with a large difference (n.s.) in the catch of undersized sole in both standard nets (Table 21 and Figure 14).

Period 3

The results in undersized sole were variable and not very conclusive with only a significant increase in GT4. It is noticeable that both comparisons of the standard nets also had higher undersized sole catches for the P-side (Table 22).

Effect on plaice discards

Period 1

Only two cases showed significantly lower catches for the modified gear, i.e. GT6 and GT12. Not much can be concluded from the results (Table 23 and Figure 16).

Period 2

One case turned out to give significant differences, i.e. GT7 with a higher catch in the modified gear (Table 24 Table 22 and Figure 17).

Period 3

The only significant reductions were found in GT5 and GT12. The BRHs showed a tendency of reducing bycatches of undersized plaice (Table 25).

Effect on benthos bycatches

Period 1

Most noticeable is the large reduction of some 75% with the 200 mm bottom panel (SMP1), almost vanishing with the 120 mm mesh size in the panel (GT8). See also Table 26 and Figure 19.

Period 2

The only significant differences were found in GT3 and GT4 with the modified gear catching less (Table 27 and Figure 20).

Period 3

In the set of gear tests with the SMPs higher benthos catches were found, with GT4 and GT8 showing a significant increase. Release panels in the top sheet of the trawl are apparently not effective in decreasing benthos bycatches. The BRHs were very effective in reducing benthos bycatches with GT9 and 11 showing significant reductions (Table 28).

Effect on landings

Table 4 shows the percentage difference between the modified gear and the conventional gear for total landings (expressed in kg/hour), and the sole and plaice landings separately for the three experimental periods. Detailed tables giving the mean value, the percentages difference, the standard errors and the p-value of a T-Test on the means with 95% confidence limit are given in the Section "Additional tables".

Table 4: Effect on landings. Gear test number and period; type of modification; number of hauls; and CPUE in the modified gear expressed as the percentage of CPUE in the control gear. **Boldface** is significant.

Gear test	MOD	Hauls	Landings		
			Total	Sole	Plaice
Period 1					
1	T90.1-90	2	90%	66%	82%
2	T90.1-80	6	81%	69%	94%
3	Std	2	105%	90%	119%
4	SMP1	4	125%	66%	181%
5	SMP2	3	108%	72%	92%
6	SMP3	3	77%	60%	76%
7	SMP4	3	76%	92%	84%
8	SMP5	4	108%	101%	112%
9	SMP6	5	128%	107%	99%
10	T90.2	3	99%	117%	120%
11	T90.2	6	105%	70%	86%
12	SMP7	6	98%	77%	107%
13	SMP8	8	94%	72%	96%
14	SMP9	7	85%	72%	94%
15	Std	5	83%	94%	51%
16	Std	3	78%	62%	86%
Period 2					
1	Std	11	103%	89%	102%
2	SMP10	2	78%	92%	79%
3	Std	10	86%	97%	103%
4	SMP11-12-13	7	72%	61%	111%
5	SMP14-15	6	90%	72%	95%
6	Std	2	107%	107%	
7	SMP16	5	100%	100%	142%
8	SMP17	2	103%	89%	93%
9	SMP18	2	142%	92%	211%
10	SMP19	1	91%	99%	118%
11	SMP20	2	65%	69%	99%

Gear test	MOD	Hauls	Landings <i>Total</i>	Main target species	
				<i>Sole</i>	<i>Plaice</i>
Period 3					
1	Std	3	104%	76%	127%
2	SMP21	6	109%	103%	114%
3	SMP22	3	95%	94%	106%
4	SMP23	5	96%	99%	92%
5	SMP24	4	103%	91%	107%
6	SMP25	4	93%	87%	95%
7	Std	6	92%	95%	95%
8	SMP26	6	99%	94%	98%
9	BRH1	2	93%	75%	111%
10	BRH2	1	55%	47%	70%
11	BRH3	5	100%	83%	105%
12	BRH4	3	92%	78%	95%

Effect on all landings taken together

Period 1

Significant reductions were only found in GT2 and GT7. The maximum reduction was about 25%, but most of the tests failed to reach significance apparently due to the low number of hauls. It is noticeable that the landings were affected to a lesser degree than the total catch weight. The conventional or standard nets seemed to fish equally in the beginning (GT3), but at the end of the trials the port gear seemed to have a lower catch efficiency (GT 15 and 16, Table 29 and Figure 22).

Period 2

Both standard nets resulted in similar marketable catches in week 22 (gear test GT1), and with SMP10 installed some loss seemed to occur, but the number of hauls was too small to get confidence. The port gear seemed to catch less (non significant, or n.s.) in gear test GT3 after the fastener, but a later check seemed to result in equal landings (n.s.). Only in GT9 a significant difference occurred, this time with a higher catch in the modified net (See also Table 30 and Figure 23).

Period 3

The only significant difference was found for GT12 with about 8% lower landings. All the other gear tests did not show a significant effect (Table 31 and Figure 24).

Effect on target species sole

Period 1

Sole is an active fish in escapement and panels may easily affect catch levels. The 200 mm mesh size in the panel causes substantial losses in the order of 30% (GT4 and 5), that were not confirmed with the smaller mesh sizes (e.g. 160 mm). In later versions of the panel a significant loss occurred (GT12 and 13), but this was also the case in the last comparison of both nets as standard (GT16), see also Table 32 and Figure 25.

Period 2

The comparison of both nets resulted in significantly lower catches of sole for the port side (GT1), although the total catches of both nets were quite the same. GT4, 5 (panel in bottom side) and 11 (panel in top side) with a range of panel designs with 160 mm mesh size resulted in significant losses in sole, about 35% (Table 33 and Figure 26).

Period 3

In most cases the sole catches were lower for the modified gear. It should be noted that this was also the case for the comparisons of both standard gears, so it is difficult to attribute this to the presence of the SMPs. Nevertheless, none of the differences were significant (Table 34 and Figure 27).

Effect on target species plaice

Period 1

The results in plaice were variable and inconclusive, and only one gear test (GT10) showed a significant difference (Table 35 and Figure 29).

Period 2

Again the results in plaice were variable and inconclusive (Table 36 and Figure 29).

Period 3

The results in marketable plaice were variable with sometimes higher catches sometimes lower ones. None of the differences were statistically significant (Table 37 and Figure 30).

Effect on trawling economy

Table 3 above shows the percentage difference between the modified gear and the conventional gear for the total gross earnings, and the earnings from sole and plaice catches separately for the three experimental periods. Detailed tables giving the mean value, the percentages difference, the standard errors and the p-value of a T-Test on the means with 95% confidence limit are given in the Section "Additional tables".

Effect on total gross earnings

Period 1

Only a few cases showed a significant difference, i.e. GT14 and GT16. The square mesh panels seemed to cause a loss of about 20-30% in €/hour in some cases, but also the comparison of the two nets without any modification showed a similar reduction (GT16), casting some doubt on the results (Table 38 and Figure 31).

Period 2

The economic performance of the standard nets was not very different in the gear tests where they were compared (GT1, 3 and 6), although the statistical test showed no significance. Significantly lower earnings were only found in GT4 ranging from 25-38%, most of the other SMPs had a tendency of creating lower values except SMP18 in GT9 (Table 39 and Figure 32).

Period 3

None of the differences was statistically significant, but the tendency was a slight loss for the modified gears (Table 40 and Figure 33).

Effect on earnings from sole landings

Period 1

The T90 section in GT2 showed a 25% loss in earnings from marketable sole. SMP1 in GT4 and SMP2 in GT5 caused a clear loss in sole, i.e. ~35%, but here again GT16 comparing both unmodified nets also seemed to cause a loss. GT11, 12 and 13 also had significantly lower sole earnings, ranging from 26-34%. See also Table 41 and Figure 34.

Period 2

The first comparison of both standard nets produced a reduction in sole earnings of 10% for the modified gear, not repeated in the second comparison (GT6). Significantly less income was generated in GT1, 4, and 5 from sole for the modified gear. The maximum loss can be as high as 44% (GT4). Most of the other SMPs had again a tendency of creating lower values except SMP19 in GT10, (Table 42 and Figure 35).

Period 3

Both standard comparisons and most modifications showed lower sole earnings, but none of these differences were significant (Table 43 and Figure 36).

Effect on earnings from plaice landings

Period 1

None of the comparisons in plaice earnings showed a significant result and in some cases higher catches seemed to occur while in other lower, indicating more variability and a less pronounced effect on this species (Table 44 and Figure 37).

Period 2

None of the differences found in income generated by plaice catches was significant and the comparison of both standard nets did not reveal any differences. See also Table 45 and Figure 38.

Period 3

The only significant difference was found for the standard comparison in GT1 with 27% higher earnings for the P-side. All of the other gear tests showed no significant differences with variable results, sometimes higher and sometimes lower (Table 46 and Figure 39).

Discussion

During the experiments there were some difficulties that complicate the interpretation of the results. The set of trials in Period 1 in 2007 may have suffered from inequality in fishing capacity of both nets. It was decided to focus on making both nets fish well and with similar catch rates in the beginning of the second series in Period 2 in 2008. In addition the first set was characterised by frequent changes in the test gear in attempts to avoid losses of target fish, particularly sole. Dutch beam trawl fishermen depend largely on sole for their income and therefore aim to maintain catches of this key species as large as possible. The second period suffered from the net damage in Week 21 when a severe gear fastener was met, and consequently the sea trip had to be shortened. The intention was to put more emphasis on collecting statistically valid data resulting in more hauls per gear test, but continuous doubts on the equality of the catching performance of the two gears as unmodified caused shorter gear tests in Week 22 than foreseen. The results of Period 3 may also have been biased by inequality of the catching performance of both unmodified or standard gears, but nevertheless seem to point out that panels in the top sheet are not effective in reducing benthos catches, while the Benthos Release Hole concept seems to work well.

The results for the 200 mm SMPs in this project are different from results found in previous research by Revill (2005). Good results were obtained by Revill, 2005 when using a combination of a 200 mm SMP in the bottom sheet and in the top sheet of a chain mat type of beam trawl with an 80 mm square mesh codend. This combination could reduce discards by 60% with little loss in target species. It should be borne in mind, that the chain mat round net type of gears used by Revill are very different in design and shape compared to the tickler chain V-nets we tested, that have much more slack in the bottom sheet. We found that the 200 mm panel released too many sole. The 160 mm square mesh panel seems to be a better solution, although the release rate in undersized fish and benthos is somewhat smaller.

The results of this study show us that it will be difficult to use only gear adjustments to reach the discard reduction targets suggested by the European Committee. Reducing discards, particularly of plaice, has become a prime target in the fisheries policy of the EU. We calculated the percentage reduction in undersized plaice based on our experiments of 2007 and found that even with the distinct reduction in bycatch found with SMP1 the outcome would be a discard rate of 52% of the total catch in weight and 72% of the total catch in numbers, indicating how difficult it will be to reach the targets set by the EU, and still be able to earn enough income to make a profit from flatfish beam trawling in the present time of high fuel costs.

Good cooperation between fishermen and scientists works well to improve gear adjustments. There were many enthusiastic inputs from both sides. Both groups have their own specific input to the process, i.e. by the industry: practical experience and detailed knowledge of fishing gears on a daily basis at sea vs. by the researchers: knowledge of scientific procedures, extended data collection, report writing, statistical inference, and having an international network of colleagues. It was learned over time that by closely working together mutual understanding grew. Such cooperation should be facilitated to a greater extent in the future.

It was found over the years by many researchers in this field that considerable time is needed to come to effective innovations in fishing gears, rather a matter of years than of months. Work at sea is subject to harsh and very variable conditions and in order to statistically prove differences in performance of fishing gears large sets of hauls in various seasons are needed. Using a research vessel without the pressure of required earnings from catches forms an excellent experimental starting point, but in most cases longer test periods on commercial boats should be added in the research programme to gain confidence and acceptance in the solutions found.

The simplified sampling procedure used in Period 3 may be a cost effective alternative in the earlier phases of the research. In order to appraise wider ecosystem effects the sampling procedure of Period 1 and 2 is more suitable. In future research the order of sampling procedure used might be reversed, keeping costs limited in the starting phase and focussing in on the most promising solutions later on. A pitfall may be though that essential effects on vulnerable non-target species may only be disclosed at a very late stage, and this should of course be avoided.

Conclusions and recommendations

Many gear modifications were tried out in an enthusiastic cooperation. It is difficult to draw firm conclusions and the feeling exists that more experiments are needed to optimise the designs and get more confidence in the results. Nevertheless a great deal was learnt about the potential of gear modifications to reduce the bycatches of undersized fish and benthos. The first set of trials in 2007 suggested that a panel of 160 mm mesh size would release a fair share of discard fish and benthos without too much of a penalty in landings and earnings. The second set of trials could not generate more confidence on optimum mesh size and position of the panel. It does seem, however, that a bottom panel will only be effective if it will not touch the sea bed over its entire length. The third set of trials gave indication that the Benthos Release Hole can be a very effective solution for reducing benthos bycatches. It is recommended therefore to extend this work and optimise the devices tested.

It is also recommended to stimulate further cooperation between scientists with experience in fishing gear research and practicing skippers and net makers from the industry, facilitating the use of research vessels in the early phase and commercial boats in later phase of a project. A simplified sampling procedure could be considered for the early phase with more extended sampling later on using the most promising gear modifications to keep costs limited.

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References

- Anonymous, 2006. Vissen met tegenwind, Advies Task Force Duurzame Noordzeevervisserij, April 2006, 47 p. (In Dutch)
- Anonymous, 2007. A policy to reduce unwanted by-catches and eliminate discards in European Fisheries, Commission non-paper: COM (2007) 136 final
- ICES, 2001. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 2001/ACME:09.
- ICES, 2002. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 2002/ACE:03.
- Bergman, M.J.N., van Santbrink, J., 1994. Mortality in megafaunal benthic populations caused by trawl fisheries on the Dutch continental shelf in the North Sea. ICES J. Mar. Sci. 57 (5), 1321–1331.
- Coull, K.A., Jermyn, A.S., Newton, A.W., Henderson, G.I. and Hall, W.B., 1989. Length/weight relationships for 88 species of fish encountered in the North East Atlantic. Scottish Fisheries Research Report No 43, 1989, ISSN 0308 8022.
- Fonteyne, R., Polet, H., 2002. Reducing the benthos by-catch in flatfish beam trawling by means of technical modifications. Fish. Res. 55, 219–230.
- Jennings, S., Kaiser, M.J., 1998. The effects of fishing on marine ecosystems. Adv. Mar. Biol. 34, 221–233.
- Lindeboom H.J., Groot, S.J. de (Eds.), 1998. The effects of different types of fisheries on the North sea and Irish sea benthic ecosystems. EU-project AIR2-CT94-1664 (IMPACT-II), Final Report ISSN 0923–3210, 404pp.
- Marlen, B. van, Lavieren, H. van, Piet, G.J., and Duijn, J.B. van, 1999. Catch comparison of a prototype 7 m electrical beam trawl and a conventional tickler chain beam trawl. RIVO internal report 99.006b, April 1999.
- Marlen, B. van, 2000. Technical modifications to reduce the by-catches and impacts of bottom gears on non-target species and habitats. In: Kaiser, De Groot (Eds.), 2000a. Effects of Fishing on Non-target Species and Habitats: Biological, Conservation and Socio-economic Issues. ISBN 0-632-05355-0, pp. 253– 268.
- Marlen, B van, A.R. Boon, L.G. Oschatz, J.B van Duijn, M. Fonds, 2000. Experiments in 1999 on a 7 m beam trawl with electrical stimulation. RIVO-report C028/01, May 2001
- Marlen, B. van, 2003. 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. Fisheries Research, 63, 155-168.
- Marlen, B. van, Ybema, M.S. and Duijn, J.B. van, 2005a. Research on by-catch reduction in a beam trawl (Onderzoek naar vermindering van de bijvangst van een boomkortuig). RIVO Rapport C030/05.
- Marlen, B. van, Ybema, M.S., Kraayenoord, A., Vries, M. de en Rink, G., 2005b. Catch comparison of a 12 m pulse beam trawl with a conventional tickler chain beam trawl. RIVO-Report C043b/05
- Marlen, B. van, Vis, J.W. van de, Groeneveld, K., Groot, P.J., Warmerdam, M.J.M., Dekker, R., Lambooj, E., Kals, J., Veldman, M. and Gerritzen, M.A., 2005c. Survival and physical condition of sole and plaice caught with a 12 m pulse beam trawl and a conventional tickler chain beam trawl. RIVO-report Nr. C044b/05
- Marlen, B. van, M.J.N. Bergman, S. Groenewold, M. Fonds, 2005d. New approaches to the reduction of non-target mortality in beam trawling. Fisheries Research, 72: 333-345.
- Marlen, B. van, Grift, R., O. van Keeken, M.S. Ybema, R. van Hal, 2006. Performance of pulse trawling compared to conventional beam trawling. RIVO-report Nr. C014/06
- Marlen, B. van, Vis, H. v.d., Haan, D. de, Burggraaf, D., Heul, J. van der, Terlouw, A., 2007. The effect of pulse stimulation on biota – Research in relation to ICES advice – Progress report with preliminary results. IMARES Report No C098/07
- Piet, G.J., Rijnsdorp, A.D., Bergman, M.J.N., van Santbrink, J., 2000. A quantitative evaluation of the impact of beam trawling on benthic fauna in the southern North sea. ICES J. Mar. Sci. 57 (5), 1332–1339.
- Revill, A.S. and Jennings, S., 2005. The capacity of benthos release panels to reduce the impacts of beam trawls on benthic communities. Fisheries Research 75 (2005) 73–85.

Annex A: Additional tables

Table 5: Data collection, sampling and measurement protocol in Period 1 and 2

GROUP	SPECIES	SAMPLES	MEASUREMENTS
		sample: minimal 1 basket, always weigh	
marketable fish	sole, plaice, dab, lemon sole, flounder, brill, turbot, whiting, cod, tub gurnard, and grey gurnard	always from total unsorted catch, sub-sample when too numerous	length measurements by individual
undersized fish	sole, whiting, cod	from total catch except when too numerous, than from sample	length measurements by individual
	plaice, dab	from sample	length measurements by individual
	other species	from sample	weigh total fraction
benthos	quahog, prickly cockle, whelk, Norway lobster	always from total unsorted catch (or sub-sampled)	count and weigh
	Hermit crab, common starfish, brittle star, helmet crab, swimming crab, edible crab, sea mouse, starfish species, and other	from sample	count and weigh, also determine total benthos weight in sample

Table 6: Data collection, sampling and measurement protocol in Period 3

GROUP	SPECIES	SAMPLES	MEASUREMENTS
		sample: minimal 1 basket, always weighed	
marketable fish	plaice, dab, whiting, other	always from total unsorted catch, sub-sample when too numerous	Sort in market grades (2-5) and weigh per grade
undersized fish	sole, and whiting	from total catch except when too numerous, than from sub-sample	weigh per grade
	plaice, dab	from sample	weigh per grade
	other species	from sample	weigh total fraction
benthos	all species together	from sample	weigh total
	debris	from sample	weigh total

Table 7: Summary of trials in week 44, 2007 Period 1

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
1 2	1	29/10/2007	T90	Std	Comparison T90 with standard net, both with 90 mm cod-ends.	Some loss of marketable sole, few losses in under-sized sole, and plaice (also marketable), clear reduction in benthos catch
3 4 5 6 7 8	2	29/10/2007	T90	Std	Comparison T90 with standard net, both with 80 mm cod-ends.	Some loss of marketable sole, few losses in under-sized sole, and plaice (also marketable), clear reduction in benthos catch
9 10	3	30/10/2007	Std	Std	Comparison of both standard nets, both with 80 mm cod-ends.	Equal catches

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
11	-	30/10/2007	Std	Std	Comparison of both standard nets, both with 80 mm cod-ends.	Invalid haul due to scooping up sand
12 13 14 15	4	30/10/2007 31/10/2007	SMP1	Std	Comparison SMP1 (22 x 20 bars, 200 mm full mesh) with standard net.	Some loss of marketable sole, less so in plaice, benthos 50%
16 17 18	5	31/10/2007	SMP2	Std	Comparison SMP2 (SMP1 with net sheet underneath) with standard net.	Some loss of marketable sole, less so in plaice, benthos 50%
19 20 21	6	31/10/2007	SMP3	Std	Comparison SMP3 (= wider variant with 44 x 20 bars, 200 mm full mesh) with standard net.	Sole losses did still occur, benthos 50%
22 23 24	7	31/10/2007	SMP4	Std	Comparison SMP4 (= narrow variant with 29 x 20 bars, 160 mm full mesh) with standard net.	Sole losses still, plaice almost equal, benthos 50%. Unclear result.
25 26 27 28	8	01/11/2007	SMP5	Std	Comparison SMP5 (narrow variant with 34 x 28 bars, 120 mm full mesh) with standard net.	No more loss of marketable sole, benthos almost equal
29 30 31 32 33	9	01/11/2007	SMP6	Std	Comparison SMP6 (narrow variant with 29 x 33 bars, 160 mm full mesh), 12 meshes from the front edge of extension piece with standard net.	Ca. 30% smaller bags caught with little loss in sole and plaice.
34 35 36	10	01/11/2007	T90-2	Std	Comparison T90-2 with standard net, both with 80 mm cod-ends.	No more loss of marketable sole and plaice, benthos results varying.

Table 8: Summary of trials in week 45, 2007 Period 1

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
37 38 39 40 41 42	11	05/11/2007 06/11/2007	T90-2	Std	Comparison T90-2 with standard net, both with 80 mm cod-ends (Aft part of standard net adapted).	Loss of marketable sole. Hole of 0.5 m in sole-flipper at P-side! Repaired from Haul 41.

Table 9: Summary of trials in week 49, 2007

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
43 44 45 46 47 48	12	03- 04/12/2007	SMP7	Std	Comparison of test net with only SMP (47 x 32 bars of 80 mm, i.e. 160 mm full mesh), 2.5 mesh deep at front of lower panel with standard net.	P-net has somewhat less sole and less miscellaneous.
49 50 51 52 53 54 55 56	13	04- 05/12/2007	SMP8	Std	Comparison of test net with SMP7 at front of lower panel, and SMP (15 x 17 bars of 200 mm full mesh), 2.0 mesh deep from rear of upper panel, with standard net.	Reasonable sole and good plaice catches.
57 58 59 60 66 67 68	14	05- 06/12/2007	SMP9	Std	Comparison of test net with only SMP at the upper panel, with standard net.	Less miscellaneous on the P side (test net). Also fewer plaice discards, and sole loss. Fastener occurred during Haul 60 on the P-side.
61 62 63 64 65	15	06/12/2007	Std	Std	Comparison of both standard nets, both with 80 mm cod-ends.	

Table 10: Summary of trials in week 21, 2008 Period 2

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
1 11	1 (16)	19/05/2008	Std	Std	Comparison of both standard nets, both with 80 mm cod-ends. Checking the fishing capacity of both nets.	Net catch efficiency almost equal.
12 13	2 (17)	20/05/2008	SMP10	Std	Comparison of test net with only SMP10 (47 x 33 bars), 160 mm full mesh, 2.5 meshes at front of lower panel with standard net.	Total catch was not affected to a great extent. Panel may have been too much forward.
14						Both gears ran into bottom obstruction and got damaged, trials terminated

Table 11: Summary of trials in week 22, 2008 Period 2

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
15 ... 24	3	26/05/2008	Std	Std	Comparison of both standard nets, both with 80 mm cod-ends. Checking the fishing capacity of both nets.	Starboard gear caught more discard fish and benthos, tried to level catches between both gears.
25 26 27	4a	27/05/2008	SMP11	Std	Comparison of test net with SMP11 (41 x 35 bars, 160 mm full mesh size), 2.5 mesh deep at front of lower panel with standard net.	Both gears caught about the same quantities.
28 29 30	4b	27/05/2008	SMP12	Std	Comparison of test net with SMP12 (160 mm full mesh size, 41 x 31 bars), 2.5 mesh deep at front of lower panel with standard net.	P gear caught more.
31	4c	27/05/2008	SMP13	Std	Comparison of test net with SMP13 (160 mm full mesh size, 31 x 31 bars), 2.5 mesh deep at front of lower panel with standard net.	Extra check.
32 33 34	5a	28/05/2008	SMP14	Std	Comparison of test net with only SMP14 (160 mm full mesh size, 20 x 30 bars), 2.5 mesh deep at front of lower panel with standard net.	
35 36 37	5b	28/05/2008	SMP15	Std	Comparison of test net with only SMP15 (200 mm full mesh size, 20 x 31 bars), 2.5 mesh deep at front of lower panel with standard net.	
38 39	6	28/05/2008	Std	Std	Comparison of both standard nets, both with 80 mm cod-ends. Checking the fishing capacity of both nets.	
40 41 42 43 44	7	28- 29/05/2008	SMP16	Std	Comparison of test net with only SMP16 (160 mm full mesh size, 18 x 33 bars), 2.5 mesh deep at front of lower panel with standard net.	After haul 42 P-net footrope adjusted by taking off two links.
45	8	29/05/2008	SMP17	Std	Comparison of test net	

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
46					with only SMP17 (160 mm full mesh size, 18 x 33 bars + extension of two times 11 bars deep), 2.5 mesh deep at front of lower panel with standard net.	
47 48	9	29/05/2008	SMP18	Std	Comparison of test net with only SMP18 (160 mm full mesh size, 18 x 42 + 120 mm full mesh size, 24 x 54 bars), 2.5 mesh deep at front of lower panel with standard net.	
49	10	29/05/2008	SMP19	Std	Comparison of test net with only SMP19 (160 mm? mesh size, 18 x 42 + 120 mm 18 x 54 bars) at front of lower panel with standard net.	
50 51	11	29/05/2008	SMP20	Std	Comparison of test net with SMP20 (160 mm mesh size, 16 x 34 bars) at upper panel with standard net.	

Table 12: Summary of trials in week 45, 2008 Period 3

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
1 2 3 4	1	03/11/2008	Std	Std	Comparison of both standard nets, both with 80 mm cod-ends. Checking the fishing capacity of both nets.	Net catch efficiency almost equal.
5 6 7 8 9 10	2	04/11/2008	SMP21	Std	Comparison of test net with only SMP21 (130 mm, 25 x 25 bars), in lower 110 mm panel 2.4 m in front of codend with standard net.	No difference in benthos, same or more in landings.
11 12 13	3	04/11/2008	SMP22	Std	Comparison of test net with only SMP22 (130 mm, 25 x 25 bars), in lower 110 mm panel, 1 m from front join, in front of codend with standard net.	More undersized sole and fish, no difference in benthos seen.

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
14 15 16 17 18	4	05/11/2008	SMP23	Std	Comparison of test net with only SMP22 (200 mm, 30 x 46 bars), in lower 130 mm panel 1.0 m in front of codend with standard net.	Fewer small dab and plaice.
19 20 21 22 23 24	5	05/11/2008 06/11/2008	SMP24	Std	Comparison of test net with SMP22 and SMP23 (160 mm, 20 x 40 bars), in upper 110 mm panel 2.4 m in front of codend with standard net.	
25 26 27 28 29	6	06/11/2008	SMP25	Std	Comparison of test net with only SMP24 (160 mm, 20 x 40 bars), in upper 110 mm panel 2.4 m in front of codend with standard net.	

Table 13: Summary of trials in week 50, 2008 Period 3

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
30 31 32 33 34 35	7	08/12/2008 09/12/2008	Std	Std	Comparison of both standard nets, both with 80 mm cod-ends. Checking the fishing capacity of both nets.	Net catch efficiency almost equal.
36 37 38 39 40 41	8	09/12/2008	SMP26	Std	Comparison of test net with only SMP26 (300 mm full mesh, 20 x 33 bars), in upper 130 mm panel 1.0 m behind the front row (above footrope bosom) with standard net.	
42 43 44	9	10/12/2008	BRH1	Std	Comparison of test net with BRH1, placed in front of codend in lower panel with standard net.	Haul 42 invalid
45 46 47	10	10/12/2008	BRH2	Std	Comparison of test net with BRH2 (Rope with 30 cm lengthened, in front of codend in lower panel with standard net.	Haul 45 and 47 invalid.

Haul	Gear test	Date	P gear test	S gear control	Objective	Comments
48 49 50 51 52	11	10/12/2008	BRH3	Std	Comparison of test net with BRH3 (T90 triangle added) and SMP, in front of codend in lower panel with standard net.	
53 54 55	12	11/12/2008	BRH4	Std	Comparison of test net with BRH4 with sheet of small mesh netting underneath, in front of codend in lower panel with standard net.	

Table 14: CPUE for total bycatches – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		kg/hour		stderr		p-value
			MOD	CON	MOD/CON	MOD	CON		
1	T90.1-90	2	306.14	271.04	113.0%	89.82	31.46	0.875	
2	T90.1-80	6	180.27	297.37	60.6%	42.6	27.95	0.019	
3	Std	2	71.87	109.73	65.5%	29.09	18.14	0.159	
4	SMP1	4	214.98	513.93	41.8%	87.63	178.51	0.004	
5	SMP2	3	559.67	933.98	59.9%	165.11	142.25	0.059	
6	SMP3	3	89.45	223.83	40.0%	27.65	85.73	0.045	
7	SMP4	3	181.11	352.75	51.3%	33.62	82.02	0.005	
8	SMP5	4	284.24	289.04	98.3%	39.89	43.42	0.896	
9	SMP6	5	673.16	739.06	91.1%	167.12	75.95	0.358	
10	T90.2	3	309.02	450.81	68.5%	71.29	96.27	0.138	
11	T90.2	6	164.31	196.80	83.5%	31.13	32.34	0.051	
12	SMP7	6	184.07	242.13	76.0%	32.72	36.21	0.004	
13	SMP8	8	254.69	321.22	79.3%	43.18	50.35	0.000	
14	SMP9	7	187.57	217.28	86.3%	86.78	105.04	0.041	
15	Std	5	349.52	398.92	87.6%	.	.	.	
16	Std	3	195.49	274.93	71.1%	47.24	14.68	0.245	

Table 15: CPUE for total bycatches – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		kg/hour		stderr		p-value
			MOD	CON	MOD/CON	MOD	CON		
1	Std	11	582.15	543.75	107.1%	161.91	138.33	0.519	
2	SMP10	2	815.69	777.89	104.9%	156.27	98.77	0.677	
3	Std	10	247.44	338.03	73.2%	21.42	25.94	0.000	
4	SMP11-12-13	7	233.01	325.96	71.5%	35.25	40.96	0.037	
5	SMP14-15	6	884.96	915.65	96.6%	94.56	94.97	0.647	
6	Std	2	947.37	765.79	123.7%	.	.	.	
7	SMP16	5	1312.37	1106.84	118.6%	180.66	210.61	0.030	
8	SMP17	2	1125.68	1033.06	109.0%	15.12	43.54	0.204	
9	SMP18	2	1108.70	1099.28	100.9%	261.33	207.8	0.976	
10	SMP19	1	744.00	730.90	101.8%	.	.	.	
11	SMP20	2	940.00	1147.80	81.9%	328.6	541.6	0.519	

Table 16: CPUE for total bycatches – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	3	397.47	506.68	78.4%	112.14	211.8	0.203
2	SMP21	6	1059.58	819.02	129.4%	675.69	349.62	0.129
3	SMP22	3	1978.23	1725.64	114.6%	441.46	145.04	0.337
4	SMP23	5	1490.74	1291.86	115.4%	234	152.4	0.009
5	SMP24	4	623.28	691.08	90.2%	282.54	292.03	0.273
6	SMP25	4	586.22	611.79	95.8%	66.17	101.25	0.420
7	Std	6	435.96	345.78	126.1%	81.12	126.3	0.104
8	SMP26	6	450.38	379.68	118.6%	389.53	417.04	0.071
9	BRH1	2	542.48	1887.94	28.7%	129.92	426.09	0.005
10	BRH2	1	973.39	2119.77	45.9%	.	.	.
11	BRH3	5	461.77	699.72	66.0%	478.05	677.63	0.004
12	BRH4	3	696.96	991.93	70.3%	582.8	369.15	0.167

Table 17: CPUE for discard fish – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	T90.1-90	2	149.60	120.89	123.7%	53.32	12.68	0.805
2	T90.1-80	6	99.08	152.37	65.0%	27.22	24.87	0.022
3	Std	2	39.04	60.66	64.4%	16.99	10.39	0.117
4	SMP1	4	105.67	163.55	64.6%	67.8	100.46	0.030
5	SMP2	3	218.58	193.90	112.7%	19.15	27.14	0.282
6	SMP3	3	61.25	112.69	54.4%	19.08	39.69	0.038
7	SMP4	3	96.16	131.61	73.1%	28.38	49.52	0.112
8	SMP5	4	126.63	107.08	118.3%	23.46	18.41	0.286
9	SMP6	5	269.56	239.60	112.5%	106.25	68.22	0.746
10	T90.2	3	155.05	200.64	77.3%	47.77	55.18	0.295
11	T90.2	6	80.18	90.72	88.4%	16.99	15.65	0.223
12	SMP7	6	82.93	115.95	71.5%	19.64	22.04	0.006
13	SMP8	8	76.47	111.52	68.6%	8.62	13.13	0.004
14	SMP9	7	68.79	92.68	74.2%	20.67	29.93	0.060
15	Std	5	92.22	132.98	69.3%	.	.	.
16	Std	3	91.99	138.64	66.4%	16.11	15.25	0.059

Table 18: CPUE for discard fish – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	11	342.76	389.91	87.9%	94.1	101.85	0.026
2	SMP10	2	700.31	637.68	109.8%	45.38	16.81	0.498
3	Std	10	181.53	237.46	76.4%	27.22	31.33	0.002
4	SMP11-12-13	7	179.10	263.56	68.0%	29.68	28.45	0.021
5	SMP14-15	6	436.66	456.94	95.6%	93.72	111.31	0.693
6	Std	2	3.47	0.82	423.2%	.	.	.
7	SMP16	5	1052.30	808.34	130.2%	177.51	132.86	0.001
8	SMP17	2	808.85	897.92	90.1%	184.03	39.02	0.719
9	SMP18	2	816.88	815.89	100.1%	194.43	253.89	0.820
10	SMP19	1	508.44	700.76	72.6%	.	.	.
11	SMP20	2	655.72	744.52	88.1%	148.48	270.99	0.682

Table 19: CPUE for discard fish – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	3	122.57	177.55	69.0%	27.72	75.46	0.238
2	SMP21	6	309.37	287.58	107.6%	129.36	79.11	0.903
3	SMP22	3	459.04	469.09	97.9%	222.28	184.45	0.658
4	SMP23	5	316.73	265.20	119.4%	108.58	20.08	0.430
5	SMP24	4	130.38	177.52	73.4%	56.52	79.04	0.031
6	SMP25	4	142.84	155.54	91.8%	42.47	50.42	0.358
7	Std	6	121.05	106.31	113.9%	35.83	60.15	0.381
8	SMP26	6	83.63	78.38	106.7%	77.5	52.77	0.732
9	BRH1	2	150.17	300.96	49.9%	33.16	95.53	0.066
10	BRH2	1	138.36	346.89	39.9%	.	.	.
11	BRH3	5	91.06	132.82	68.6%	58.36	98.26	0.054
12	BRH4	3	179.65	235.45	76.3%	95.54	65.7	0.137

Table 20: CPUE for sole < MLS – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	T90.1-90	2	0.26	0.30	86.7%	0.08	0.16	0.914
2	T90.1-80	6	0.23	0.93	24.7%	0.11	0.39	0.114
3	Std	2	1.08	1.36	79.4%	0.5	0.58	0.498
4	SMP1	4	0.35	0.94	37.2%	0.14	0.32	0.036
5	SMP2	3	0.21	0.18	116.7%	0.03	0.07	0.514
6	SMP3	3	0.72	0.54	133.3%	0.05	0.25	0.518
7	SMP4	3	1.88	1.63	115.3%	0.62	0.11	0.551
8	SMP5	4	2.34	1.96	119.4%	0.44	0.5	0.153
9	SMP6	5	5.28	5.59	94.5%	2.11	1.04	0.511
10	T90.2	3	0.90	1.57	57.3%	0.47	1.37	0.834
11	T90.2	6	0.18	0.12	150.0%	0.04	0.03	0.644
12	SMP7	6	0.15	0.39	38.5%	0	0.18	0.764
13	SMP8	8	0.38	0.79	48.1%	0.09	0.18	0.008
14	SMP9	7	1.25	1.53	81.7%	1.16	1.05	0.203
15	Std	5	1.87	1.96	95.4%			
16	Std	3	1.35	1.88	71.8%	0.42	0.54	0.277

Table 21: CPUE for sole < MLS – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	11	0.87	0.87	100.0%	0.28	0.21	0.737
2	SMP10	2	1.31	1.52	86.2%	1.14	0.6	0.602
3	Std	10	0.88	0.80	110.0%	0.17	0.15	0.624
4	SMP11-12-13	7	1.87	1.75	106.9%	0.55	0.36	0.956
5	SMP14-15	6	1.95	1.82	107.1%	0.24	0.32	0.579
6	Std	2	3.47	0.82	423.2%			
7	SMP16	5	1.98	1.53	129.4%	0.52	0.35	0.185
8	SMP17	2	2.64	2.04	129.4%	0.86	0.59	0.135
9	SMP18	2	2.40	2.14	112.1%	0.75	0.85	0.344
10	SMP19	1	2.66	1.44	184.7%			
11	SMP20	2	2.63	3.19	82.4%	0.09	1.15	0.770

Table 22: CPUE for sole < MLS – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	3	0.95	0.73	130.1%	0.78	0.4	0.664
2	SMP21	6	3.43	2.16	158.8%	1.8	0.82	0.100
3	SMP22	3	4.78	3.32	144.0%	2.46	2.26	0.118
4	SMP23	5	3.67	2.08	176.4%	1.36	0.99	0.004
5	SMP24	4	1.27	1.18	107.6%	1.43	1.09	0.788
6	SMP25	4	0.63	0.79	79.7%	0.87	0.92	0.317
7	Std	6	0.98	0.90	108.9%	0.9	1.17	0.219
8	SMP26	6	1.29	1.06	121.7%	0.63	0.6	0.367
9	BRH1	2	0.94	1.14	82.5%	0.07	0.09	0.341
10	BRH2	1	0.56	3.00	18.7%			
11	BRH3	5	0.61	1.39	43.9%	0.9	2.33	0.375
12	BRH4	3	0.15	0.14	107.1%		0	0.478

Table 23: CPUE for plaice < MLS – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	T90.1-90	2	100.87	79.60	126.7%	31.12	18.26	0.765
2	T90.1-80	6	59.31	83.99	70.6%	13.37	9.57	0.068
3	Std	2	20.50	25.81	79.4%	10.4	4.57	0.251
4	SMP1	4	50.14	52.84	94.9%	27.54	23.26	0.487
5	SMP2	3	106.22	75.05	141.5%	35.94	20.89	0.234
6	SMP3	3	37.21	76.21	48.8%	12.64	27.21	0.035
7	SMP4	3	70.40	88.24	79.8%	27.82	43.1	0.273
8	SMP5	4	86.17	66.02	130.5%	24.67	17.46	0.167
9	SMP6	5	157.04	115.49	136.0%	59.13	39.86	0.477
10	T90.2	3	97.68	105.84	92.3%	36.55	23.83	0.634
11	T90.2	6	51.97	59.24	87.7%	11.23	9.68	0.189
12	SMP7	6	59.67	75.07	79.5%	21.29	24.09	0.018
13	SMP8	8	51.78	66.79	77.5%	4.62	7.16	0.058
14	SMP9	7	57.64	70.13	82.2%	15.48	19.51	0.140
15	Std	5	46.96	52.94	88.7%			
16	Std	3	72.22	104.57	69.1%	16.13	15.04	0.063

Table 24: CPUE for plaice < MLS – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	11	71.50	76.70	93.2%	18.27	20.49	0.309
2	SMP10	2	110.40	96.41	114.5%	22.43	16.88	0.792
3	Std	10	53.19	59.64	89.2%	6.45	7.15	0.264
4	SMP11-12-13	7	53.49	65.89	81.2%	4.88	11.98	0.355
5	SMP14-15	6	102.78	84.86	121.1%	26.66	23.81	0.025
6	Std	2						
7	SMP16	5	211.92	118.99	178.1%	38.94	29.59	0.007
8	SMP17	2	230.65	251.43	91.7%	72.07	43.71	0.560
9	SMP18	2	204.36	178.95	114.2%	53.35	64.29	0.368
10	SMP19	1	110.10	150.34	73.2%			
11	SMP20	2	196.31	211.05	93.0%	51.36	84.9	0.921

Table 25: CPUE for plaice < MLS – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	3	91.80	135.48	67.8%	37.48	71.03	0.155
2	SMP21	6	143.83	133.87	107.4%	69.56	57.44	0.803
3	SMP22	3	224.83	216.66	103.8%	106.49	75.65	0.977
4	SMP23	5	152.37	131.78	115.6%	41.51	32.68	0.460
5	SMP24	4	74.05	89.79	82.5%	45.05	53.53	0.006
6	SMP25	4	82.18	86.36	95.2%	43.85	44.66	0.744
7	Std	6	99.08	97.50	101.6%	34.64	36.38	0.347
8	SMP26	6	44.33	45.61	97.2%	36.3	28.44	0.495
9	BRH1	2	44.21	58.03	76.2%	21.2	34.07	0.229
10	BRH2	1	54.89	80.77	68.0%			
11	BRH3	5	35.46	38.22	92.8%	26.95	30.15	0.176
12	BRH4	3	86.36	114.49	75.4%	45.34	54.14	0.012

Table 26: CPUE for benthos – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	T90.1-90	2	67.64	99.95	67.7%	6.81		0.572
2	T90.1-80	6	56.71	93.16	60.9%	11.14	9.37	0.067
3	Std	2	28.84	40.62	71.0%	10.34	6.22	0.285
4	SMP1	4	108.80	444.41	24.5%	24.94	149.06	0.002
5	SMP2	3	336.00	713.22	47.1%	123.05	167.18	0.196
6	SMP3	3	22.05	97.32	22.7%	12.19	40.86	0.036
7	SMP4	3	65.36	198.06	33.0%	3.33	22.43	0.015
8	SMP5	4	137.49	153.34	89.7%	17.5	21.2	0.202
9	SMP6	5	313.39	329.47	95.1%	85.51	40.44	0.467
10	T90.2	3	74.96	147.36	50.9%	14.84	21.07	0.068
11	T90.2	6	44.40	54.72	81.1%	8.4	10.94	0.405
12	SMP7	6	77.79	102.60	75.8%	24.14	30.82	0.184
13	SMP8	8	122.45	166.21	73.7%	26.4	32.74	0.024
14	SMP9	7	107.94	105.74	102.1%	70.35	71.77	0.247
15	Std	5	205.90	243.88	84.4%			
16	Std	3	82.52	89.00	92.7%	22.89	15.4	0.507

Table 27: CPUE for benthos – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	11	200.89	235.58	85.3%	76.16	84.44	0.129
2	SMP10	2	478.63	393.85	121.5%	27.37	8.82	0.249
3	Std	10	48.88	67.11	72.8%	9.2	11.85	0.008
4	SMP11-12-13	7	58.65	92.60	63.3%	11.49	13.12	0.013
5	SMP14-15	6	249.53	296.17	84.3%	47.86	17.67	0.415
6	Std	2	0.00	0.00	#DIV/O!	0	0	0.000
7	SMP16	5	359.25	264.43	135.9%	55.15	19.68	0.194
8	SMP17	2	150.15	288.12	52.1%	121.56	59.18	0.544
9	SMP18	2	279.82	281.39	99.4%	60.47	84.71	0.876
10	SMP19	1	222.49	339.11	65.6%			
11	SMP20	2	232.85	272.81	85.4%	102.75	149.51	0.646

Table 28: CPUE for benthos – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	3	40.50	46.82	86.5%	11.28	23.49	0.667
2	SMP21	6	211.05	126.09	167.4%	241.43	161.28	0.077
3	SMP22	3	511.07	385.85	132.5%	30.22	146.56	0.287
4	SMP23	5	447.76	382.00	117.2%	103.47	70.29	0.010
5	SMP24	4	182.98	166.82	109.7%	91.43	77.06	0.445
6	SMP25	4	148.20	148.87	99.5%	29.31	30.24	0.848
7	Std	6	96.51	65.06	148.3%	61.07	26.96	0.184
8	SMP26	6	137.15	108.66	126.2%	116.56	153.72	0.022
9	BRH1	2	114.24	612.31	18.7%	29.01	109.25	0.020
10	BRH2	1	345.10	708.74	48.7%			
11	BRH3	5	136.90	213.63	64.1%	206.63	266.82	0.027
12	BRH4	3	164.71	254.74	64.7%	190.68	112.78	0.184

Table 29: CPUE for landings – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	T90.1-90	2	114.38	127.10	90.0%	9.75	19.56	0.396
2	T90.1-80	6	47.93	59.26	80.9%	2.42	5.13	0.026
3	Std	2	42.67	40.77	104.7%	11.59	5.95	0.804
4	SMP1	4	68.52	54.88	124.9%	25.34	5.63	0.759
5	SMP2	3	134.28	123.82	108.4%	26.28	31.26	0.724
6	SMP3	3	38.11	49.73	76.6%	7.98	14.73	0.248
7	SMP4	3	55.55	72.93	76.2%	8.19	12.45	0.012
8	SMP5	4	54.86	51.02	107.5%	7	6.04	0.646
9	SMP6	5	101.19	78.86	128.3%	32.06	19.6	0.418
10	T90.2	3	123.48	124.56	99.1%	28.72	18.57	0.799
11	T90.2	6	65.73	62.65	104.9%	17.09	8.18	0.705
12	SMP7	6	64.19	65.25	98.4%	4.83	5.94	0.836
13	SMP8	8	71.34	75.61	94.4%	11.56	12.67	0.451
14	SMP9	7	40.24	47.36	85.0%	8.34	9.59	0.119
15	Std	5	40.86	49.26	82.9%			
16	Std	3	56.69	73.05	77.6%	2.81	5.01	0.138

Table 30: CPUE for landings – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	11	95.41	92.29	103.4%	18.12	14.6	0.694
2	SMP10	2	101.06	129.28	78.2%	8.1	18.77	0.172
3	Std	10	102.62	118.77	86.4%	12.21	16.2	0.053
4	SMP11-12-13	7	62.65	86.92	72.1%	6.26	4.14	0.019
5	SMP14-15	6	96.71	106.98	90.4%	15.9	14.99	0.438
6	Std	2	29.08	27.10	107.3%	.	.	.
7	SMP16	5	176.15	175.99	100.1%	42.17	32.79	0.545
8	SMP17	2	210.13	203.68	103.2%	25.4	35.17	0.596
9	SMP18	2	306.75	215.83	142.1%	101.47	73.37	0.018
10	SMP19	1	147.69	162.44	90.9%	.	.	.
11	SMP20	2	92.19	141.85	65.0%	1.09	34.7	0.369

Table 31: CPUE for landings – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	3	62.52	60.00	104.2%	25.96	24.38	0.398
2	SMP21	6	69.03	63.56	108.6%	16.17	14.75	0.079
3	SMP22	3	50.21	53.11	94.5%	11.26	11.43	0.497
4	SMP23	5	58.50	61.18	95.6%	5.51	3.7	0.168
5	SMP24	4	63.66	61.57	103.4%	16.81	10.17	0.859
6	SMP25	4	62.03	67.05	92.5%	10.43	10.43	0.156
7	Std	6	68.85	74.90	91.9%	28.69	24.62	0.117
8	SMP26	6	82.33	83.60	98.5%	24.73	20.82	0.396
9	BRH1	2	46.07	49.41	93.2%	1.67	1.1	0.340
10	BRH2	1	26.36	48.28	54.6%	.	.	.
11	BRH3	5	49.43	49.46	99.9%	31.18	30.07	0.893
12	BRH4	3	108.81	117.84	92.3%	26.46	29.83	0.035

Table 32: CPUE for sole > MLS – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	T90.1-90	2	6.84	10.34	66.2%	2.67	1.48	0.315
2	T90.1-80	6	12.46	17.97	69.3%	2.64	3.9	0.038
3	Std	2	13.96	15.55	89.8%	7.44	4.57	0.285
4	SMP1	4	9.98	15.24	65.5%	2.23	3.22	0.010
5	SMP2	3	11.96	16.51	72.4%	3.31	4.9	0.047
6	SMP3	3	7.75	12.87	60.2%	3.24	5.2	0.146
7	SMP4	3	20.86	22.70	91.9%	1.56	1.16	0.402
8	SMP5	4	16.45	16.25	101.2%	2.41	1.91	0.998
9	SMP6	5	40.21	37.72	106.6%	9.9	6.01	0.984
10	T90.2	3	9.12	7.83	116.5%	1.45	2.38	0.379
11	T90.2	6	7.89	11.29	69.9%	1.71	2.02	0.002
12	SMP7	6	8.35	10.80	77.3%	0.74	0.91	0.007
13	SMP8	8	12.97	18.06	71.8%	1.58	3.01	0.015
14	SMP9	7	15.65	21.72	72.1%	8.17	11.06	0.268
15	Std	5	30.50	32.60	93.6%			
16	Std	3	17.36	27.96	62.1%	2.86	2.87	0.020

Table 33: CPUE for sole > MLS – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	11	16.22	18.30	88.6%	3	2.75	0.014
2	SMP10	2	27.87	30.16	92.4%	6.37	10.92	0.846
3	Std	10	18.72	19.30	97.0%	2.29	2.25	0.554
4	SMP11-12-13	7	17.07	28.22	60.5%	1.6	3.35	0.005
5	SMP14-15	6	19.82	27.38	72.4%	2.05	2.62	0.014
6	Std	2	29.08	27.10	107.3%			
7	SMP16	5	23.54	23.49	100.2%	3.65	3.74	0.848
8	SMP17	2	31.01	34.98	88.7%	3.15	1.12	0.324
9	SMP18	2	32.40	35.14	92.2%	7	4.75	0.456
10	SMP19	1	36.48	37.04	98.5%			
11	SMP20	2	25.26	36.67	68.9%	9.39	13.01	0.028

Table 34: CPUE for sole > MLS – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	3	7.64	10.06	75.9%	7.56	9.12	0.381
2	SMP21	6	19.63	19.13	102.6%	5.8	3.71	0.975
3	SMP22	3	28.80	30.57	94.2%	6.64	9.22	0.482
4	SMP23	5	25.45	25.67	99.1%	6.76	2.04	0.772
5	SMP24	4	16.69	18.44	90.5%	6.65	6.49	0.434
6	SMP25	4	12.83	14.68	87.4%	1.39	2.79	0.451
7	Std	6	11.51	12.16	94.7%	3.66	3.07	0.333
8	SMP26	6	11.56	12.32	93.8%	3.09	2.3	0.283
9	BRH1	2	14.21	18.96	74.9%	3.36	2.99	0.482
10	BRH2	1	11.39	24.39	46.7%			
11	BRH3	5	13.20	15.83	83.4%	14.37	16.94	0.161
12	BRH4	3	8.32	10.67	78.0%	3.73	3.07	0.265

Table 35: CPUE for plaice > MLS – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	T90.1-90	2	24.18	29.47	82.0%	4.43	6.8	0.167
2	T90.1-80	6	12.09	12.86	94.0%	0.83	2.09	0.747
3	Std	2	10.65	8.92	119.4%	2.38	0.35	0.666
4	SMP1	4	46.59	25.77	180.8%	24.99	5.16	0.363
5	SMP2	3	86.52	93.71	92.3%	16.39	25.7	0.707
6	SMP3	3	19.51	25.62	76.2%	2.69	9.85	0.733
7	SMP4	3	27.92	33.28	83.9%	6.66	6.9	0.375
8	SMP5	4	20.63	18.46	111.8%	4.57	1.91	0.628
9	SMP6	5	34.34	34.66	99.1%	11.48	15.45	0.332
10	T90.2	3	21.93	18.30	119.8%	2.72	1.88	0.047
11	T90.2	6	21.58	24.98	86.4%	3.28	2.38	0.310
12	SMP7	6	43.91	41.04	107.0%	5.03	5.91	0.140
13	SMP8	8	45.45	47.59	95.5%	12.9	13.79	0.628
14	SMP9	7	14.98	15.87	94.4%	4.7	2.07	0.605
15	Std	5	1.93	3.78	51.1%			
16	Std	3	29.27	33.89	86.4%	4.94	2.95	0.454

Table 36: CPUE for plaice > MLS – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	11	34.10	33.30	102.4%	10.24	8.74	0.316
2	SMP10	2	47.87	60.81	78.7%	7.68	4.06	0.231
3	Std	10	20.97	20.35	103.0%	2.8	2.85	0.916
4	SMP11-12-13	7	10.79	9.70	111.2%	1.83	2.03	0.334
5	SMP14-15	6	31.87	33.54	95.0%	5.7	3.23	0.391
6	Std	2						
7	SMP16	5	69.91	49.32	141.7%	22.09	13.97	0.065
8	SMP17	2	99.71	107.66	92.6%	30.78	35.01	0.162
9	SMP18	2	186.77	88.73	210.5%	86.28	26.43	0.179
10	SMP19	1	58.46	49.54	118.0%			
11	SMP20	2	48.78	49.35	98.8%	1.27	4.91	0.965

Table 37: CPUE for plaice > MLS – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		kg/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	3	41.26	32.51	126.9%	10.18	4.63	0.058
2	SMP21	6	40.72	35.62	114.3%	12.1	10.05	0.131
3	SMP22	3	10.77	10.18	105.8%	2.32	2.4	0.830
4	SMP23	5	19.94	21.61	92.3%	4.5	3.22	0.189
5	SMP24	4	36.89	34.45	107.1%	21.47	16.78	0.698
6	SMP25	4	41.40	43.56	95.0%	9.89	12.62	0.499
7	Std	6	50.06	52.78	94.8%	26.24	23.53	0.206
8	SMP26	6	58.25	59.56	97.8%	22.02	20.63	0.292
9	BRH1	2	24.35	21.95	110.9%	4.93	2.11	0.428
10	BRH2	1	13.20	18.96	69.6%			
11	BRH3	5	31.42	29.98	104.8%	23.16	22.51	0.628
12	BRH4	3	98.43	103.67	94.9%	26.74	32.83	0.389

Table 38: Total Gross Earnings per hour – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		€/hour		stderr		p-value
			MOD	CON	MOD/CON	MOD	CON		
1	T90.1-90	2	155.60	221.56	70.2%	40.91	37.06	0.166	
2	T90.1-80	6	224.96	288.19	78.1%	40.3	50.43	0.065	
3	Std	2	161.39	151.19	106.7%	53.5	36.06	0.742	
4	SMP1	4	220.84	211.34	104.5%	13.24	28.68	0.712	
5	SMP2	3	287.56	346.24	83.1%	50.94	90.69	0.202	
6	SMP3	3	138.81	195.10	71.1%	44.28	82.53	0.580	
7	SMP4	3	196.00	253.84	77.2%	54.31	29.11	0.351	
8	SMP5	4	207.47	180.78	114.8%	39.55	39.46	0.505	
9	SMP6	5	432.88	334.85	129.3%	110.11	67.66	0.254	
10	T90.2	3	221.44	189.34	117.0%	25.7	43.74	0.242	
11	T90.2	6	202.82	205.81	98.5%	32.18	18.75	0.729	
12	SMP7	6	234.63	229.89	102.1%	12.82	15.05	0.690	
13	SMP8	8	233.62	263.41	88.7%	23.72	28.63	0.226	
14	SMP9	7	190.05	228.75	83.1%	59.51	64.47	0.025	
15	Std	5	280.99	311.39	90.2%				
16	Std	3	197.08	242.22	81.4%	14.6	21.41	0.042	

Table 39: Total Gross Earnings per hour – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		€/hour		stderr		p-value
			MOD	CON	MOD/CON	MOD	CON		
1	Std	11	283.27	288.60	98.2%	41.24	34.66	0.390	
2	SMP10	2	424.96	456.58	93.1%	79.05	142.42	0.824	
3	Std	10	308.88	316.49	97.6%	23.31	27.94	0.890	
4	SMP11-12-13	7	215.46	385.24	55.9%	17.09	47.37	0.012	
5	SMP14-15	6	303.58	377.16	80.5%	34.03	34.25	0.105	
6	Std	2	221.98	223.14	99.5%				
7	SMP16	5	365.18	446.01	81.9%	61.81	120.48	0.350	
8	SMP17	2	502.56	583.53	86.1%	31	6.59	0.205	
9	SMP18	2	678.03	532.01	127.4%	287	134.34	0.529	
10	SMP19	1	451.23	477.19	94.6%				
11	SMP20	2	349.17	432.35	80.8%	14.4	87.4	0.447	

Table 40: Total Gross Earnings per hour – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		€/hour		stderr		p-value
			MOD	CON	MOD/CON	MOD	CON		
1	Std	3	189.90	197.85	96.0%	128.2	133.39	0.910	
2	SMP21	6	292.69	276.23	106.0%	64.43	48.78	0.155	
3	SMP22	3	353.87	359.61	98.4%	93.26	115.08	0.998	
4	SMP23	5	324.42	338.22	95.9%	64.7	10.72	0.554	
5	SMP24	4	271.32	286.23	94.8%	63.8	42.08	0.630	
6	SMP25	4	242.70	272.19	89.2%	43.95	43.98	0.221	
7	Std	6	254.43	285.65	89.1%	79.26	61.65	0.141	
8	SMP26	6	276.00	284.88	96.9%	64.06	45.73	0.464	
9	BRH1	2	234.82	275.40	85.3%	51.41	52.8	0.678	
10	BRH2	1	160.97	328.66	49.0%				
11	BRH3	5	244.17	260.13	93.9%	201.59	191.99	0.404	
12	BRH4	3	263.87	274.78	96.0%	133.58	143.59	0.459	

Table 41: Gross Earnings on sole – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		€/hour		stderr		p-value
			MOD	CON	MOD/CON	MOD	CON		
1	T90.1-90	2	74.30	120.00	61.9%	33.67	22.61	0.303	
2	T90.1-80	6	128.54	170.56	75.4%	25.36	33.1	0.041	
3	Std	2	96.73	104.94	92.2%	48.96	32.86	0.286	
4	SMP1	4	88.83	134.51	66.0%	18.01	29.01	0.020	
5	SMP2	3	112.12	173.93	64.5%	30.57	55.81	0.044	
6	SMP3	3	65.91	109.78	60.0%	27.35	44.76	0.111	
7	SMP4	3	148.58	162.73	91.3%	11.37	4.47	0.406	
8	SMP5	4	114.91	117.26	98.0%	30.79	28.69	0.879	
9	SMP6	5	321.19	264.72	121.3%	87.69	47.81	0.542	
10	T90.2	3	95.79	85.92	111.5%	12.85	26.81	0.470	
11	T90.2	6	80.42	120.92	66.5%	19.99	22.02	0.003	
12	SMP7	6	97.30	116.19	83.7%	7.38	10.71	0.031	
13	SMP8	8	121.08	164.01	73.8%	13.84	24.83	0.037	
14	SMP9	7	135.98	176.34	77.1%	72.29	78.2	0.279	
15	Std	5	271.65	283.18	95.9%				
16	Std	3	131.94	184.55	71.5%	20.14	17.03	0.076	

Table 42: Gross Earnings on sole – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		€/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	11	169.74	188.70	90.0%	29.89	24.94	0.031
2	SMP10	2	303.55	290.41	104.5%	68.83	99.77	0.641
3	Std	10	200.51	197.52	101.5%	21.08	25.02	0.725
4	SMP11-12-13	7	158.72	281.79	56.3%	13.38	35.95	0.008
5	SMP14-15	6	182.70	263.85	69.2%	17.75	26.81	0.015
6	Std	2	221.98	223.14	99.5%	.	.	.
7	SMP16	5	204.65	206.02	99.3%	36.64	33.17	0.944
8	SMP17	2	285.65	341.10	83.7%	51.93	36.67	0.244
9	SMP18	2	279.24	297.05	94.0%	56.6	53.04	0.229
10	SMP19	1	340.87	335.38	101.6%	.	.	.
11	SMP20	2	204.27	318.45	64.1%	96.41	105.9	0.200

Table 43: Gross Earnings on sole – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		€/hour	stderr		p-value
			MOD	CON	MOD/CON	MOD	CON	
1	Std	3	102.49	128.45	79.8%	110.4	121.89	0.674
2	SMP21	6	203.94	197.93	103.0%	52.08	34.04	0.826
3	SMP22	3	329.00	334.66	98.3%	87.42	120.11	0.930
4	SMP23	5	279.05	288.40	96.8%	67.65	14.71	0.608
5	SMP24	4	190.46	211.55	90.0%	69.9	53.85	0.432
6	SMP25	4	153.78	177.65	86.6%	24.89	30.22	0.328
7	Std	6	159.11	173.19	91.9%	46.77	37.02	0.235
8	SMP26	6	147.15	153.12	96.1%	39.49	30.11	0.522
9	BRH1	2	177.99	224.00	79.5%	61	50.93	0.654
10	BRH2	1	134.56	289.61	46.5%	.	.	.
11	BRH3	5	222.01	246.35	90.1%	172.09	160.05	0.315
12	BRH4	3	135.20	132.96	101.7%	.	.	.

Table 44: Gross Earnings on plaice – experiments Period 1, 2007

Gear test	MOD	No of hauls	mean		€/hour		stderr		p-value
			MOD	CON	MOD/CON	MOD	CON		
1	T90.1-90	2	16.63	22.22	74.8%	2.44	6.33	0.327	
2	T90.1-80	6	18.78	18.40	102.1%	2.57	2.83	0.885	
3	Std	2	14.99	13.06	114.8%	2.3	1.15	0.652	
4	SMP1	4	66.60	34.00	195.9%	29.9	5.11	0.288	
5	SMP2	3	120.98	131.45	92.0%	28.71	32.27	0.364	
6	SMP3	3	28.58	23.09	123.8%	3.79	6.31	0.198	
7	SMP4	3	31.71	35.74	88.7%	8.77	6.09	0.255	
8	SMP5	4	26.85	22.62	118.7%	5.37	2.69	0.237	
9	SMP6	5	47.22	45.63	103.5%	15.24	22.92	0.305	
10	T90.2	3	18.29	17.76	103.0%	1.87	1.83	0.250	
11	T90.2	6	26.09	28.79	90.6%	3.25	3.36	0.504	
12	SMP7	6	66.20	65.25	101.5%	7.31	7.04	0.754	
13	SMP8	8	59.69	58.67	101.7%	16.89	16.28	0.989	
14	SMP9	7	20.01	19.41	103.1%	8.75	7.49	0.739	
15	Std	5	3.41	6.94	49.1%				
16	Std	3	49.44	51.91	95.2%	11.93	7.83	0.538	

Table 45: Gross Earnings on plaice – experiments Period 2, 2008

Gear test	MOD	No of hauls	mean		€/hour		stderr		p-value
			MOD	CON	MOD/CON	MOD	CON		
1	Std	11	51.14	51.01	100.3%	16.4	13.89	0.174	
2	SMP10	2	81.98	96.92	84.6%	16.55	22.1	0.108	
3	Std	10	27.84	27.00	103.1%	3.33	3.75	0.700	
4	SMP11-12-13	7	12.23	12.06	101.4%	1.45	2.04	0.585	
5	SMP14-15	6	49.84	52.06	95.7%	8.58	8.87	0.900	
6	Std	2							
7	SMP16	5	100.25	79.89	125.5%	31.69	23.99	0.346	
8	SMP17	2	153.99	176.41	87.3%	61.93	54.37	0.352	
9	SMP18	2	265.44	136.72	194.1%	154.97	39.96	0.404	
10	SMP19	1	65.14	61.23	106.4%				
11	SMP20	2	64.21	71.38	90.0%	12.05	7.15	0.411	

Table 46: Gross Earnings on plaice – experiments Period 3, 2008

Gear test	MOD	No of hauls	mean		€/hour		stderr	p-value
			MOD	CON	MOD/CON	MOD		
1	Std	3	84.46	66.59	126.8%	19.34	11.37	0.025
2	SMP21	6	84.23	74.18	113.5%	24.93	21.5	0.156
3	SMP22	3	22.88	21.94	104.3%	5.69	4.45	0.898
4	SMP23	5	40.91	44.32	92.3%	9.42	6.56	0.178
5	SMP24	4	78.33	72.57	107.9%	48.04	34.89	0.746
6	SMP25	4	88.15	93.34	94.4%	20.85	27.89	0.513
7	Std	6	112.41	110.78	101.5%	55.31	48.67	0.314
8	SMP26	6	127.10	130.14	97.7%	48.35	45.21	0.280
9	BRH1	2	51.98	46.79	111.1%	9.69	5.08	0.325
10	BRH2	1	25.50	37.45	68.1%			
11	BRH3	5	82.07	78.01	105.2%	36.35	35.65	0.662
12	BRH4	3	218.80	230.46	94.9%	59.44	72.98	0.390

Table 47: Average price in € per kg in various market grades (year 2007), used in the economic calculations (source: K. Taal, LEI The Netherlands)

year	2007		
species	grade	length range (cm; kg)	price in €/kg
sole	1	> 38 cm	18.55
	2	33 - 38	19.32
	3	30 - 33	14.13
	4	27 - 30	8.46
	5	24 - 27	6.70
mean			10.08
plaice	1	> 41 cm	2.78
	2	35 - 41	2.24
	3	31 - 35	1.99
	4	27 - 31	1.88
mean			2.04
dab	1	> 30 cm	1.16
	2	23 - 30	0.95
mean			0.96
flounder	1	> 31 cm	0.76
	2	25 - 31	0.80
mean			0.80
lemon sole	1	> 37 cm	5.82
	2	31 - 37	4.99
	3	25 - 31	4.49
mean			4.63

year	2007		
species	grade	length range (cm; kg)	price in €/kg
turbot	1+	> 6 kg	23.46
	1	4 - 6	23.46
	2	3 - 4	18.52
	3	2 - 3	14.80
	4	1 - 2	9.96
	5	0.5 - 1	7.76
	6	< 0.5 kg	4.71
mean			9.90
brill	1+	> 2 kg	9.57
	1	> 40 cm	9.57
	2	30 - 40	7.03
	3	25 - 30	4.28
mean			7.57
whiting	1	> 40 cm	2.13
	2	36 - 40	2.08
	3	32 - 36	1.91
	4	27 - 32	1.32
mean			1.42
cod	1	> 88 cm	3.76
	2	72 - 88	3.71
	3	55 - 72	3.43
	4	46 - 55	2.79
	5	35 - 46	2.20
mean			2.78
tub gurnard	1	> 41 cm	n/a
	2	35 - 41	n/a
	3	27 - 35	n/a
	4	< 27 cm	n/a
mean			1.34
grey gurnard	1		0.37
mean			0.37

Annex B: Additional figures

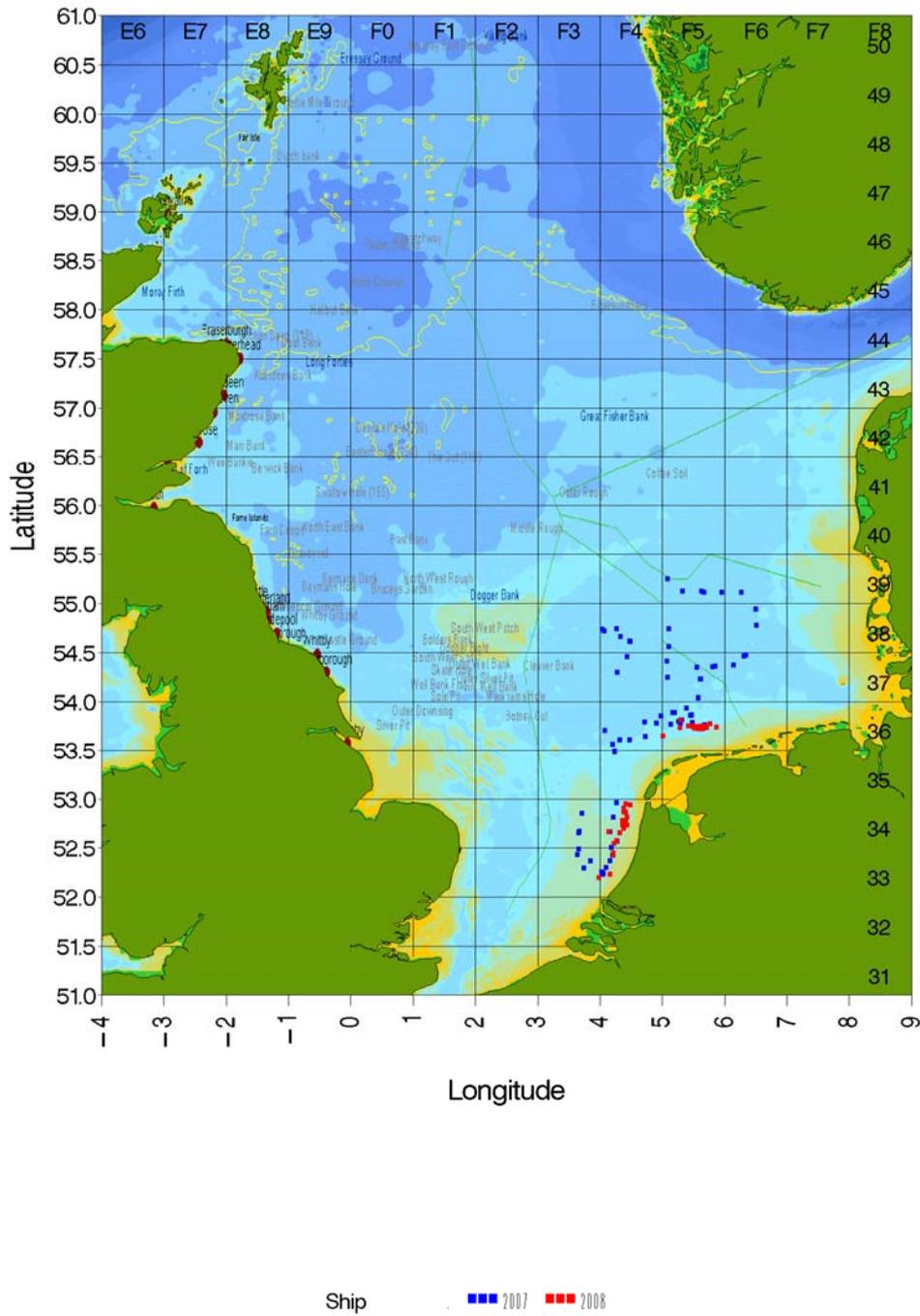


Figure 5: Positions fished in 2007(Period 1) and 2008 (Period 2)

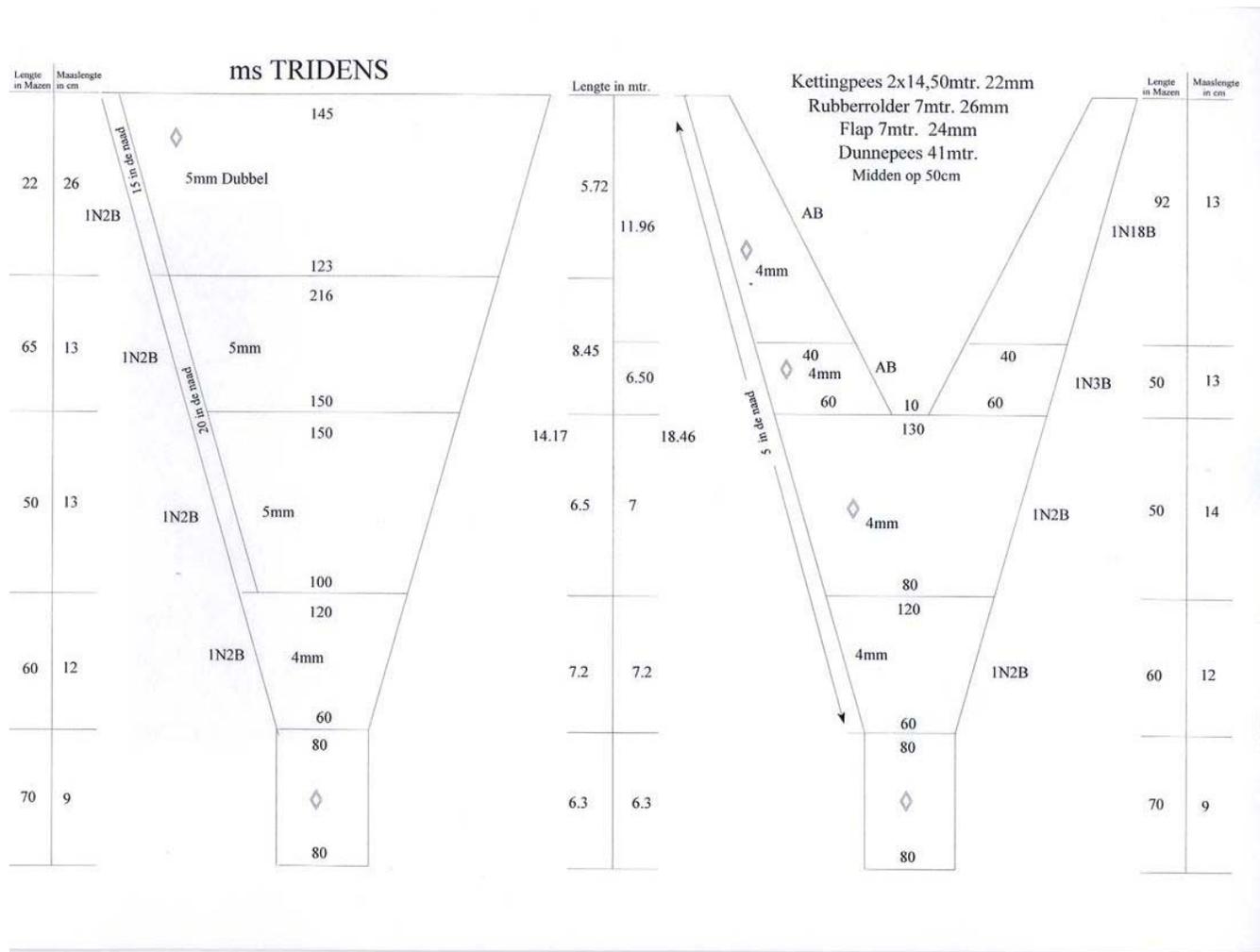


Figure 6: Net drawing of conventional gear

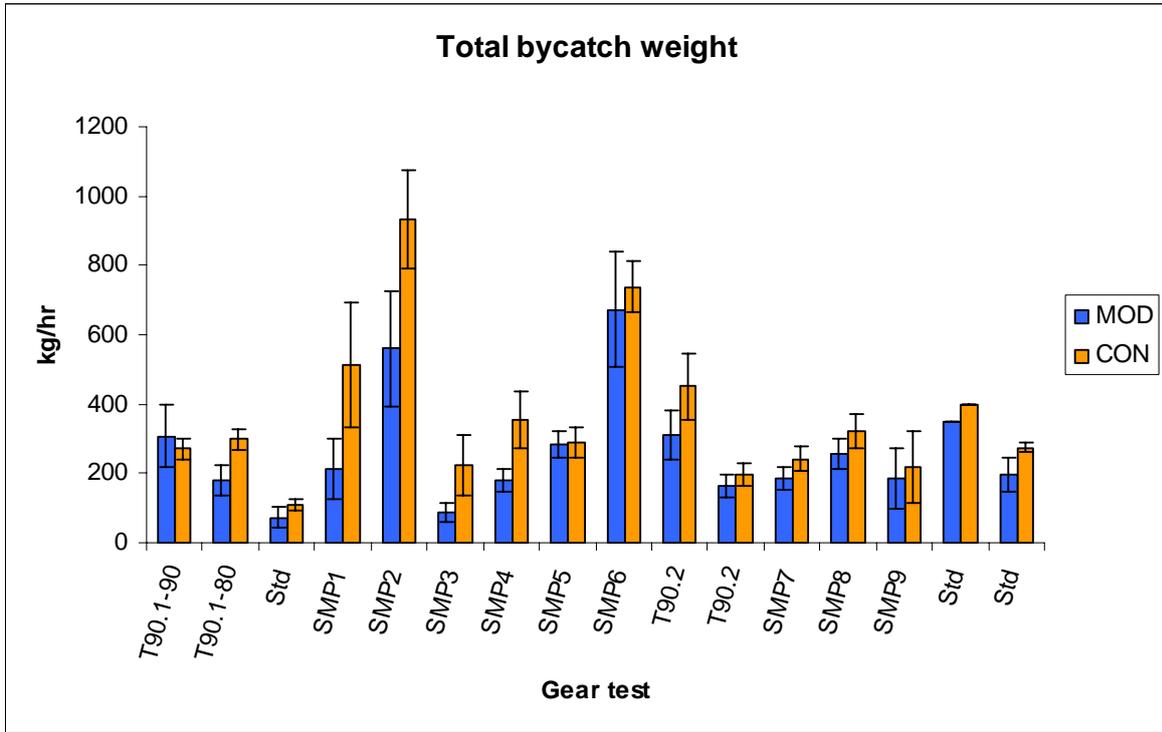


Figure 7: Comparison of total bycatch weight – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

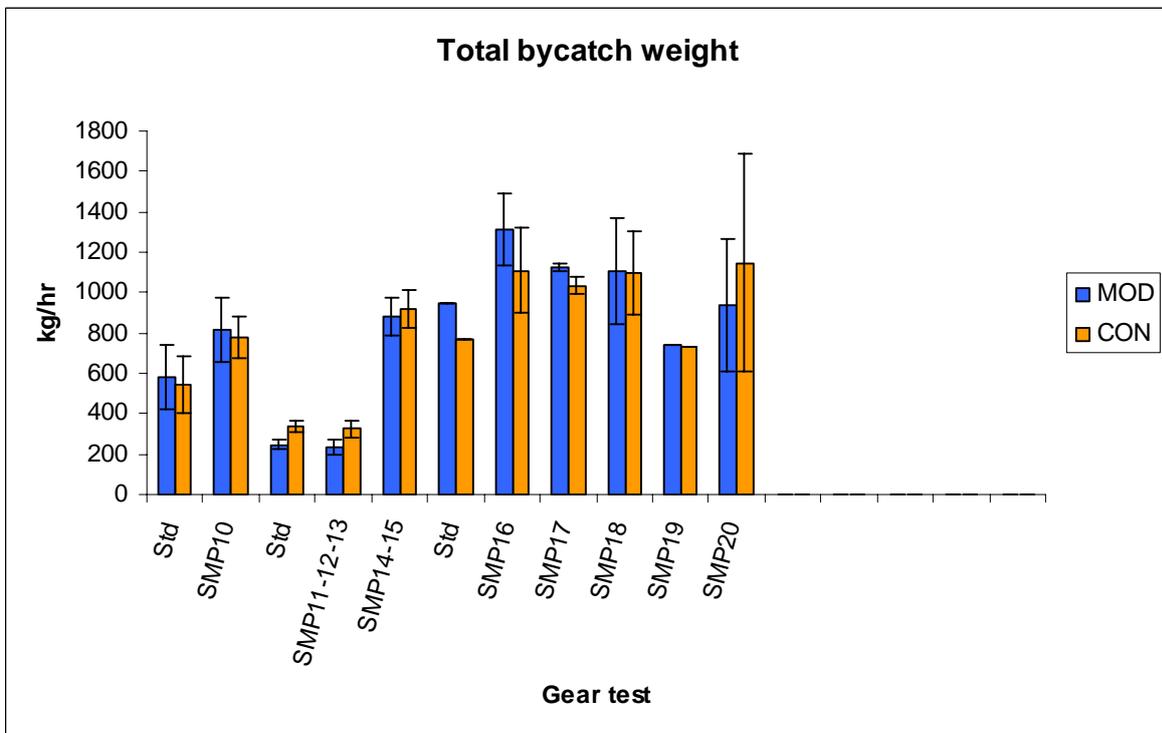


Figure 8: Comparison of total bycatch weight – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

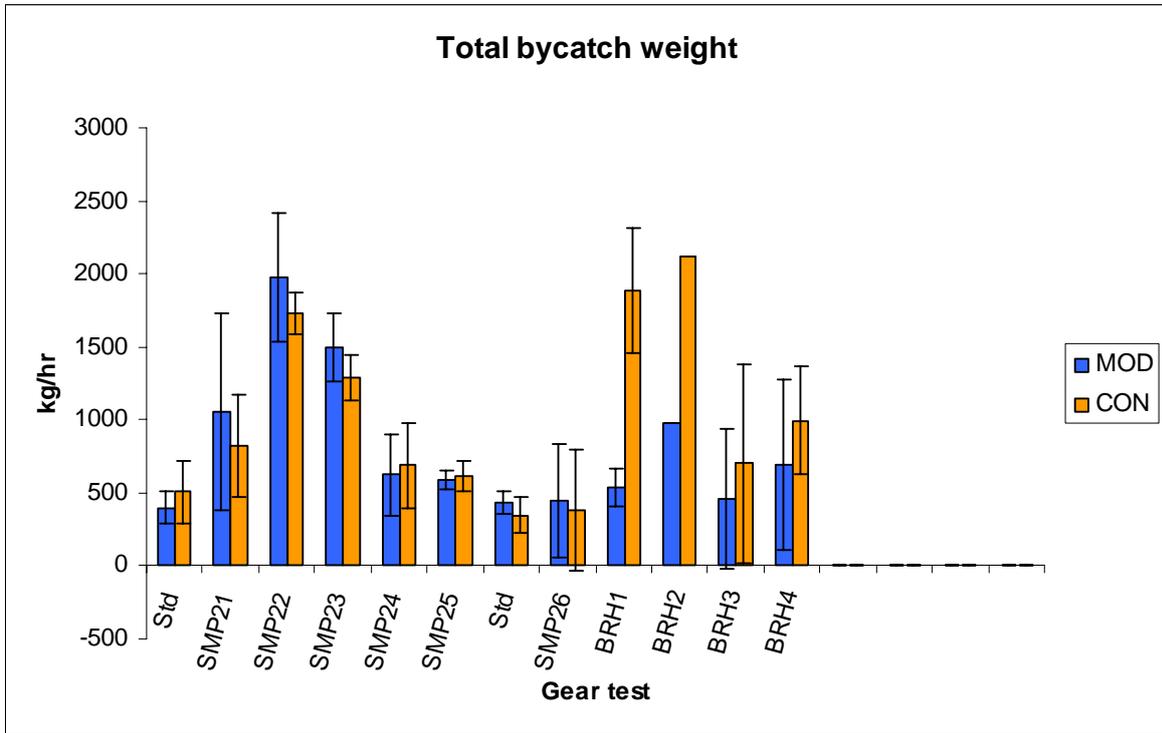


Figure 9: Comparison of total bycatch weight – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

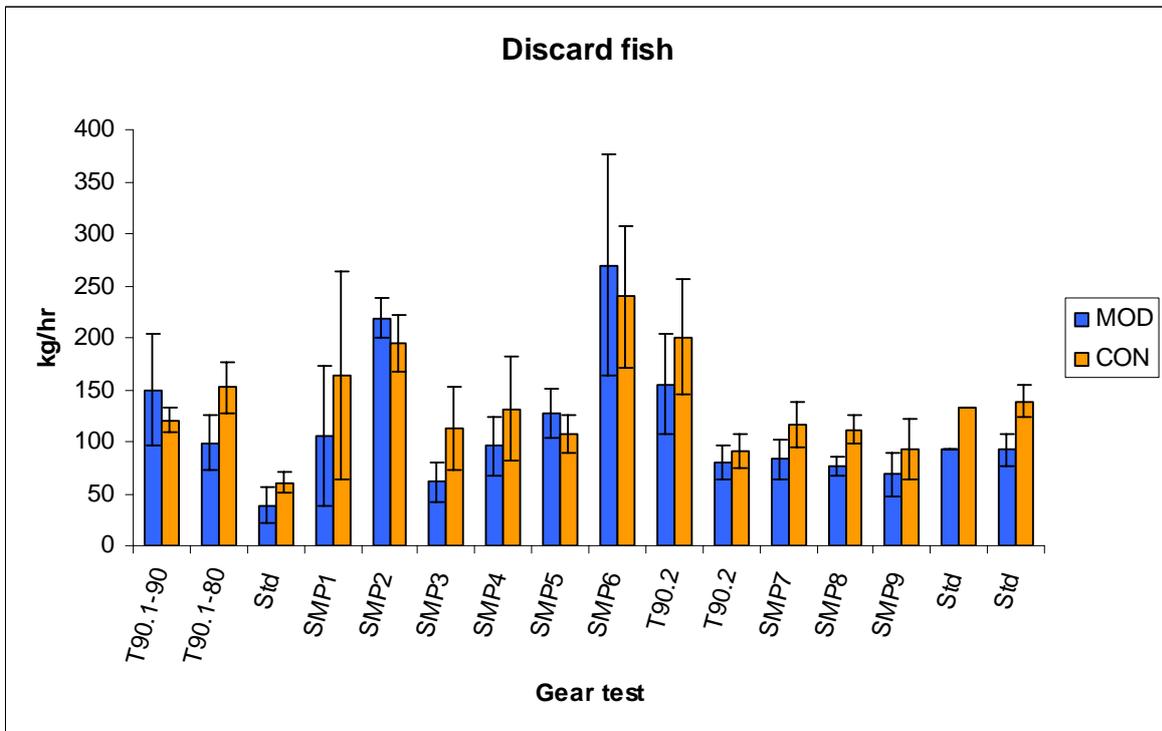


Figure 10: Comparison of discard fish – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

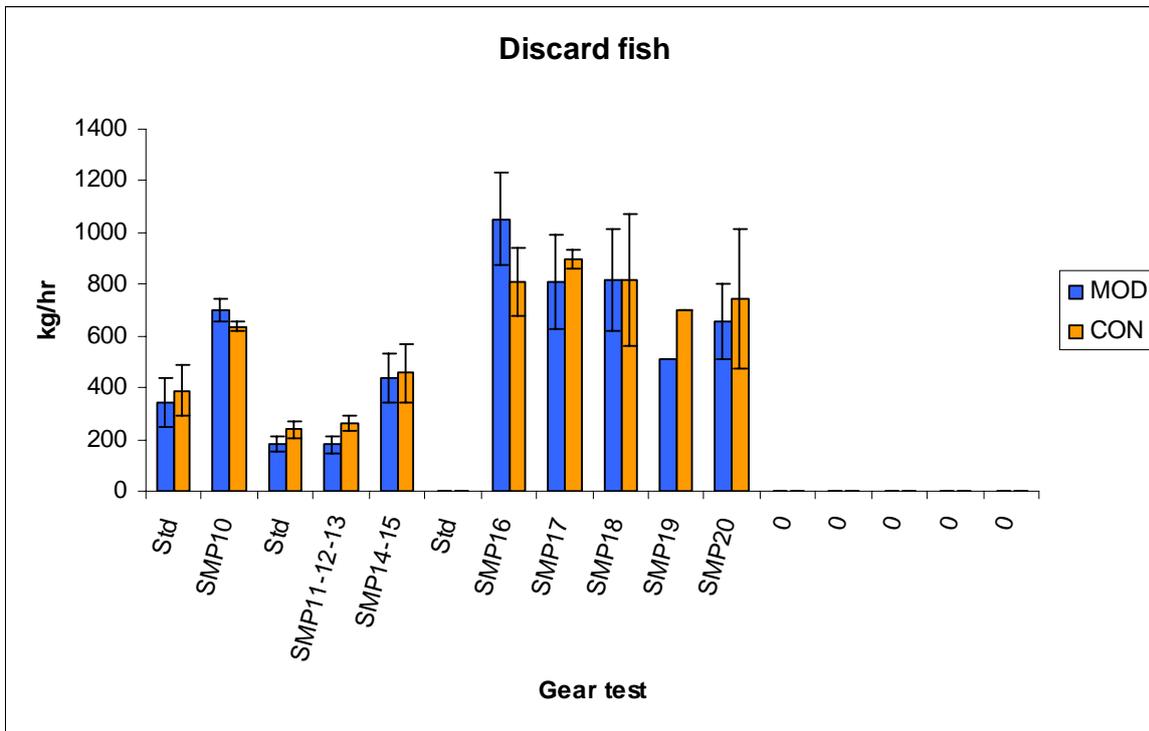


Figure 11: Comparison of discard fish – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

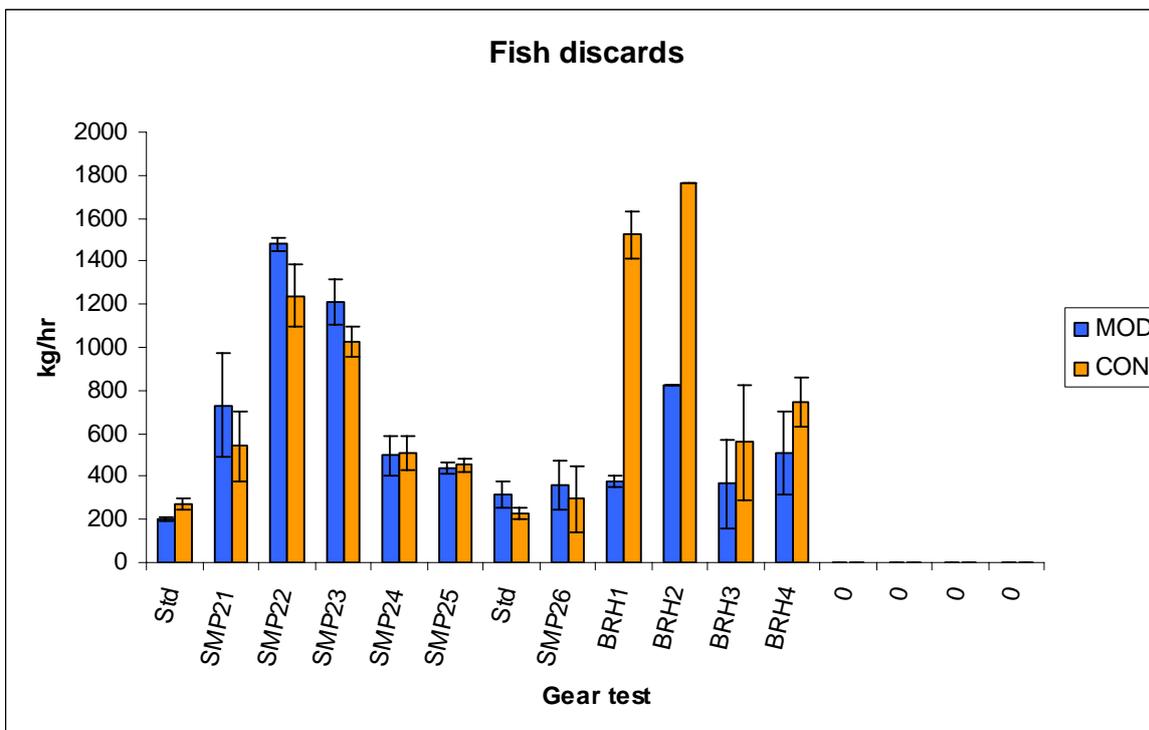


Figure 12: Comparison of discard fish – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

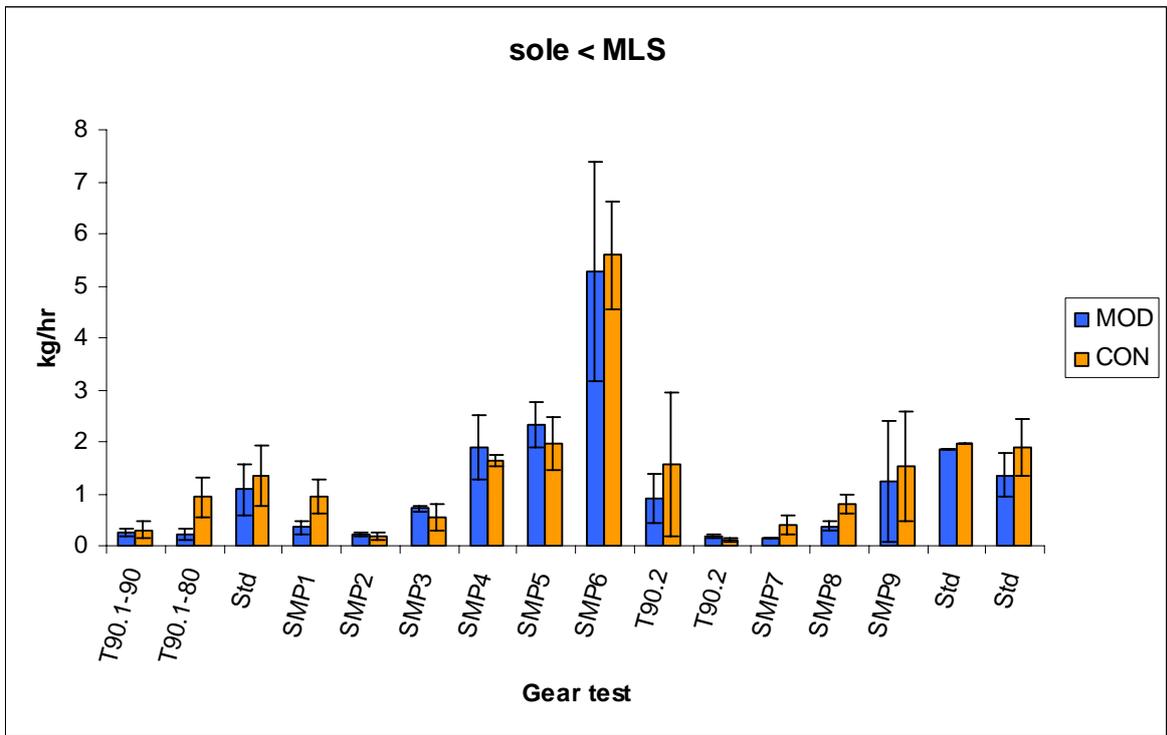


Figure 13: Comparison of sole < MLS – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

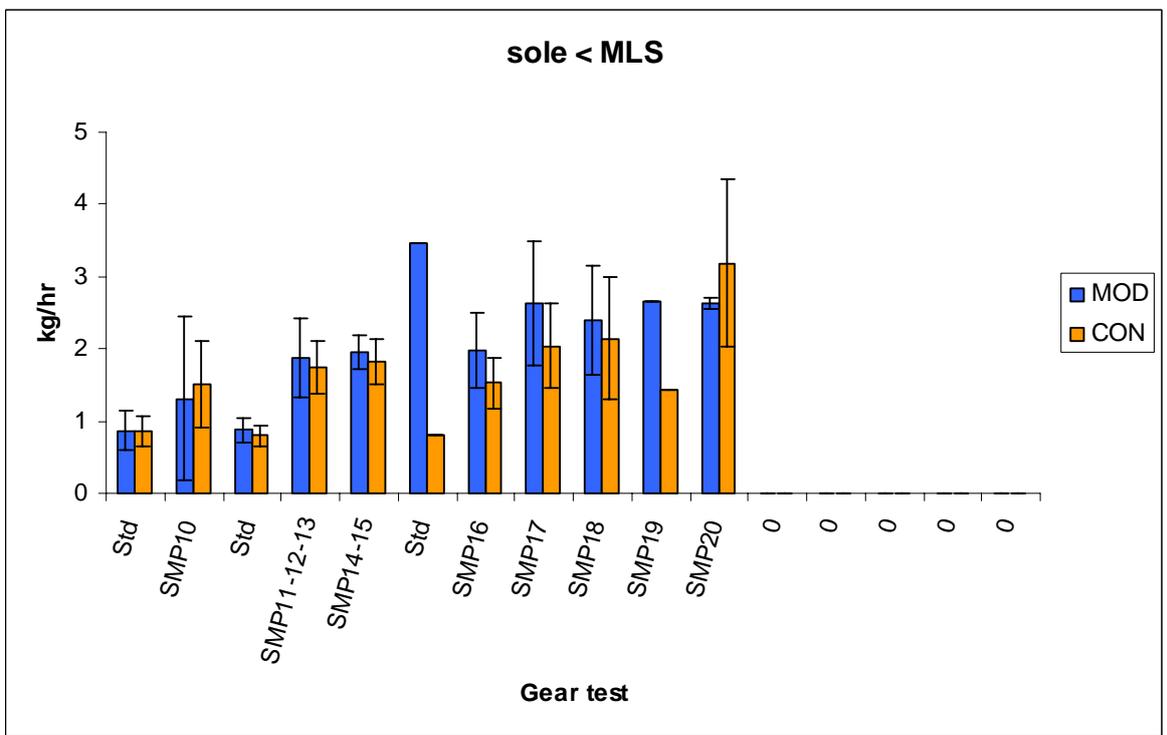


Figure 14: Comparison of sole < MLS – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

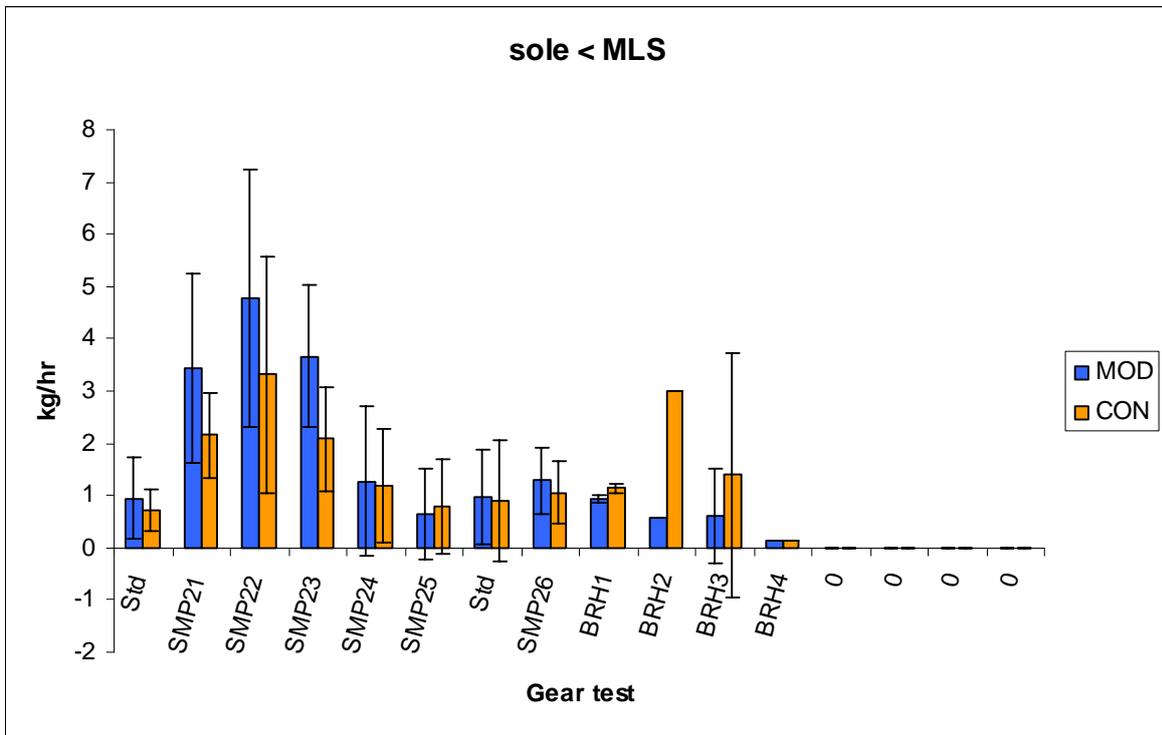


Figure 15: Comparison of sole < MLS – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

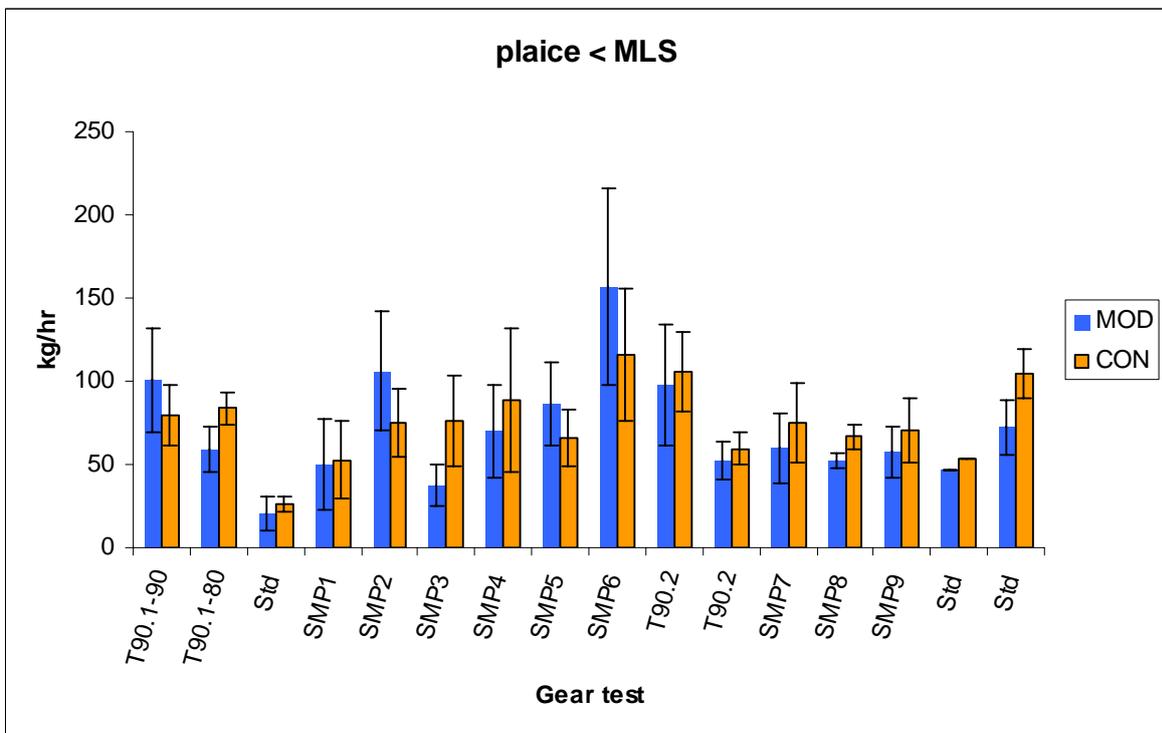


Figure 16: Comparison of plaice < MLS – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

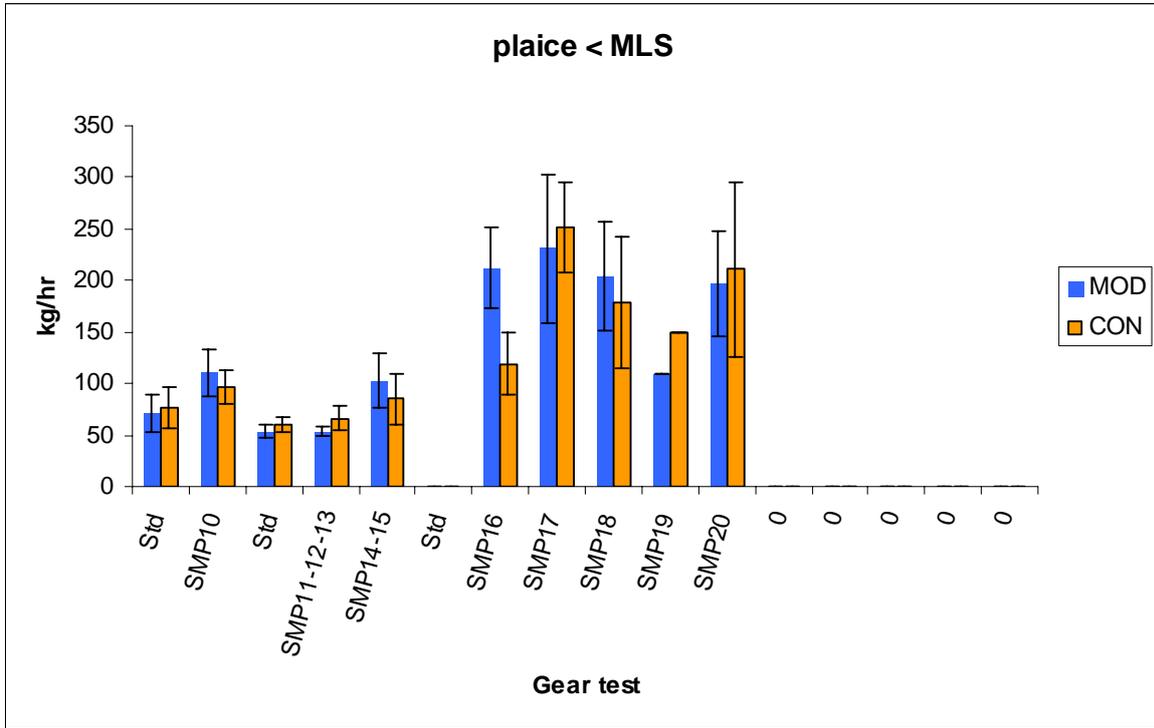


Figure 17: Comparison of plaice < MLS – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

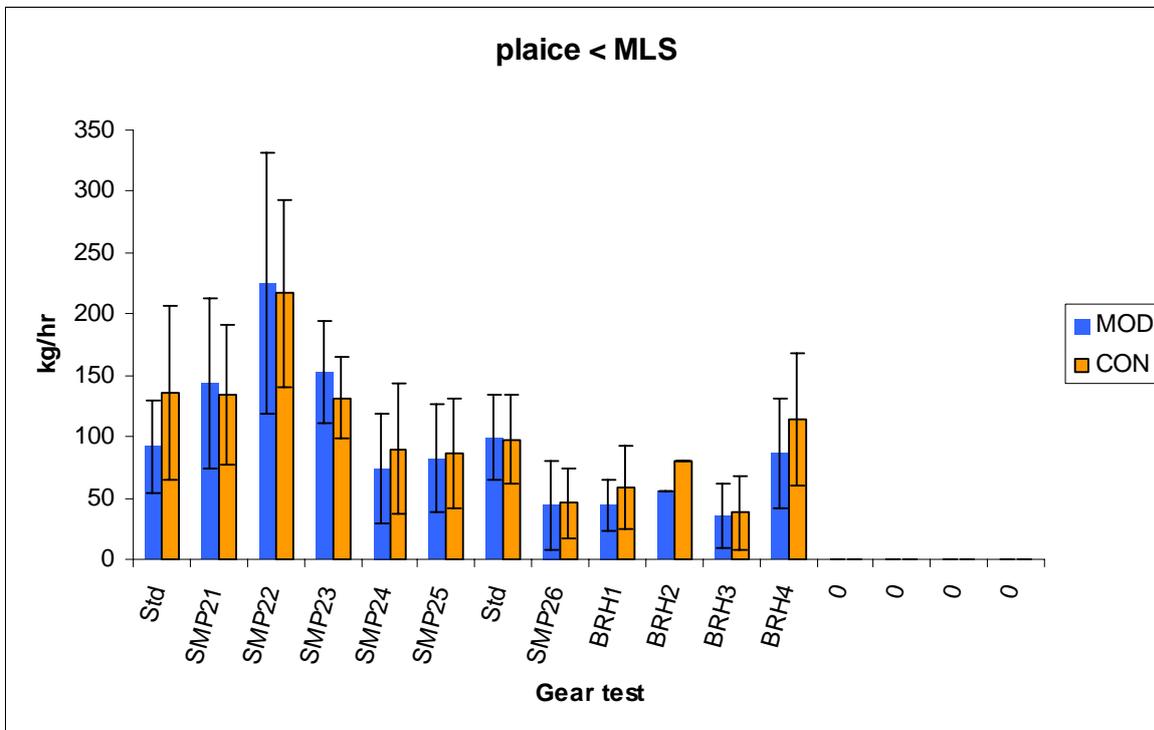


Figure 18: Comparison of plaice < MLS – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

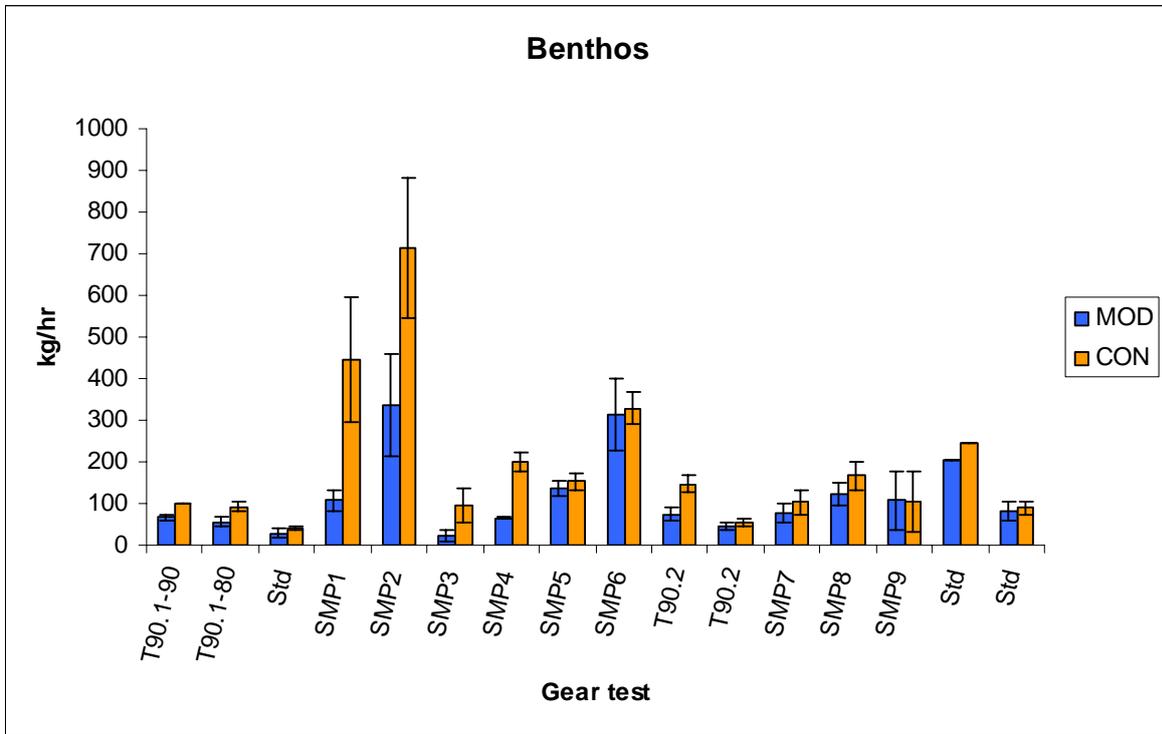


Figure 19: Comparison of benthos – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

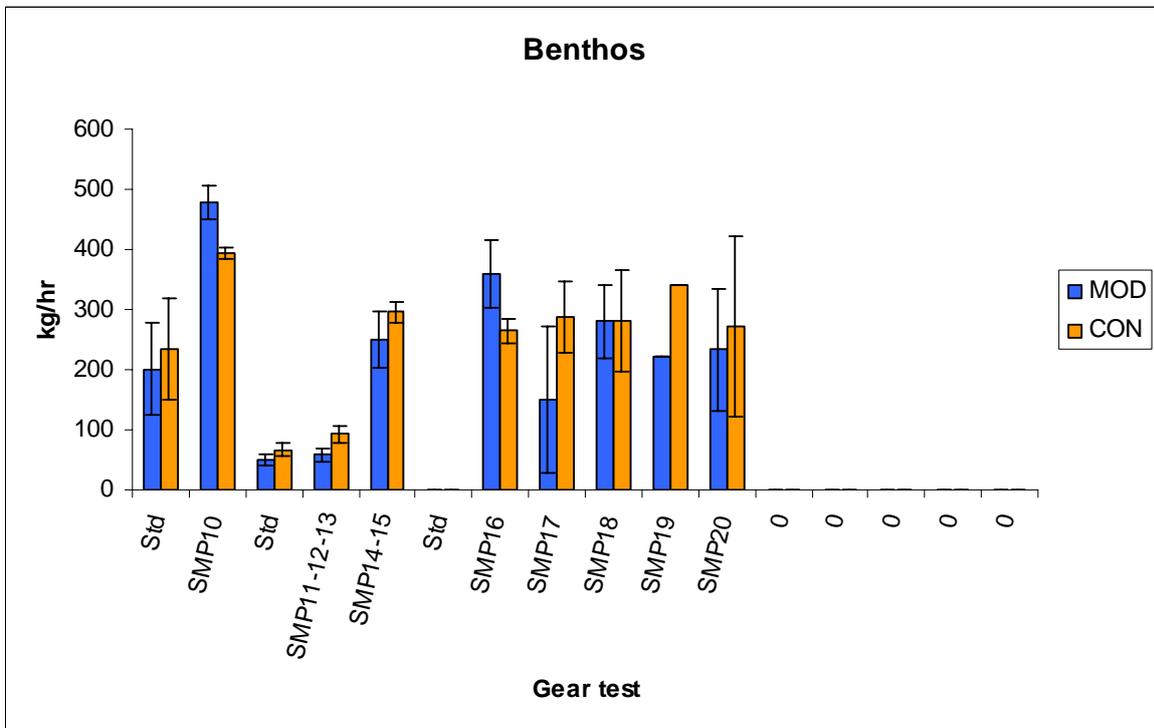


Figure 20: Comparison of benthos – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

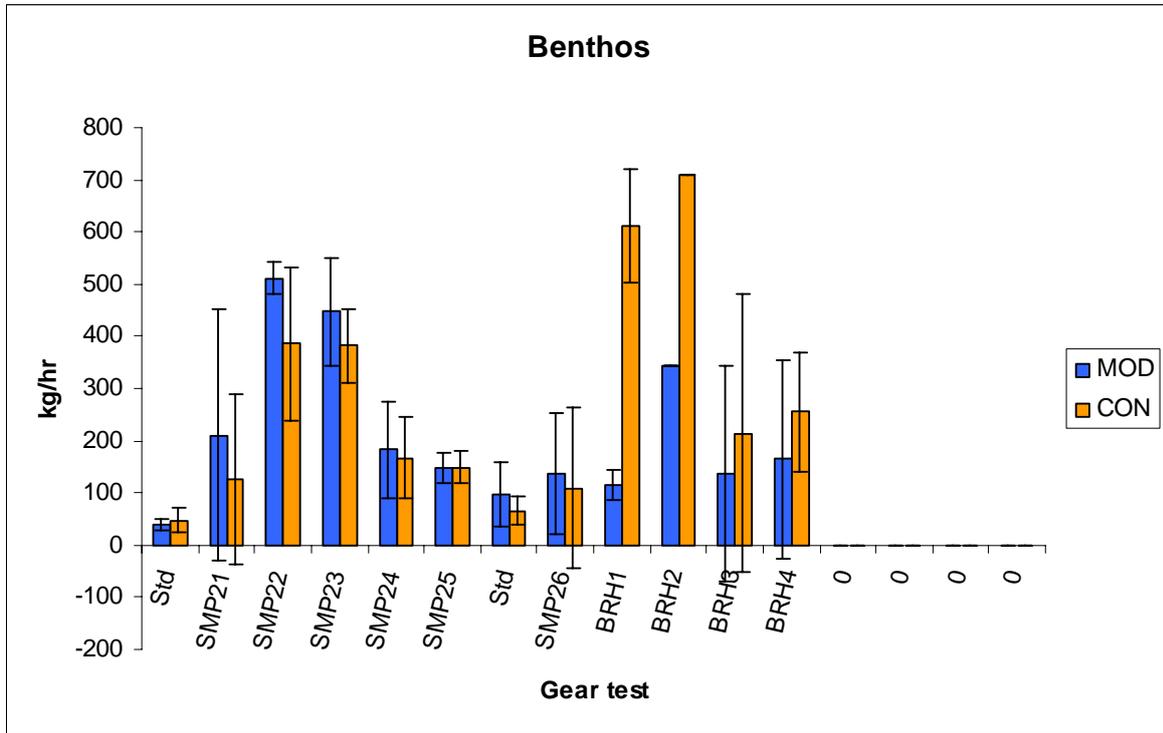


Figure 21: Comparison of benthos – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

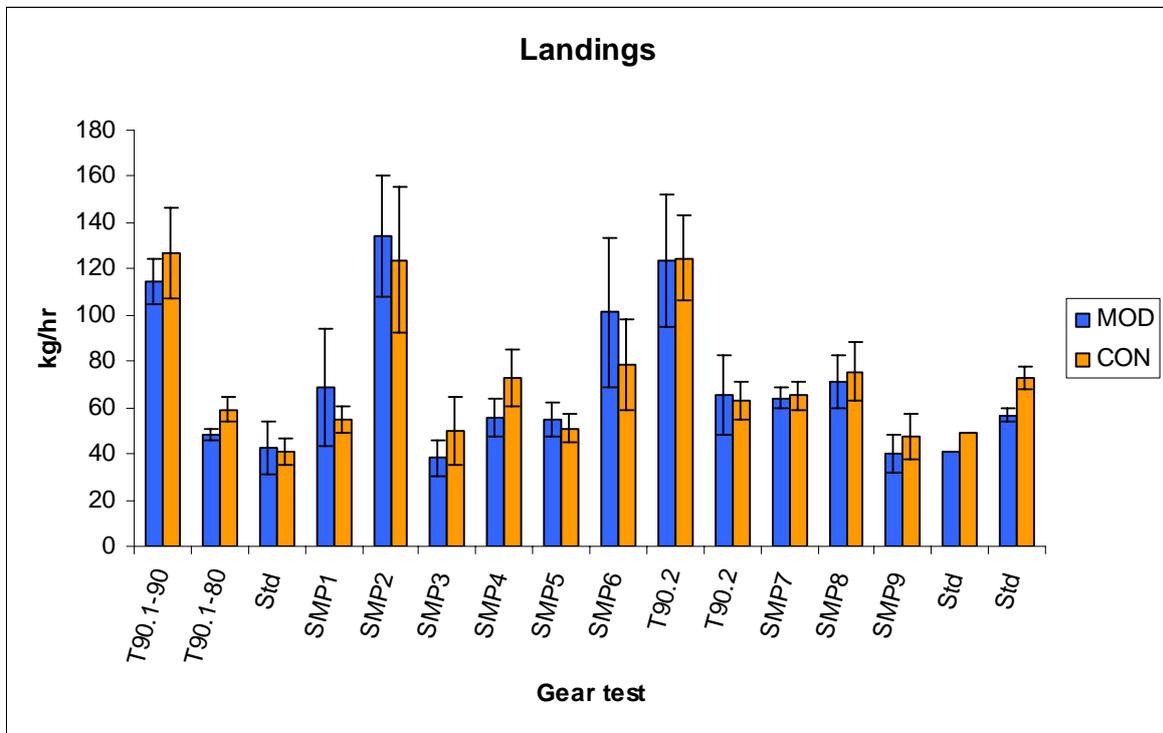


Figure 22: Comparison of landings – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

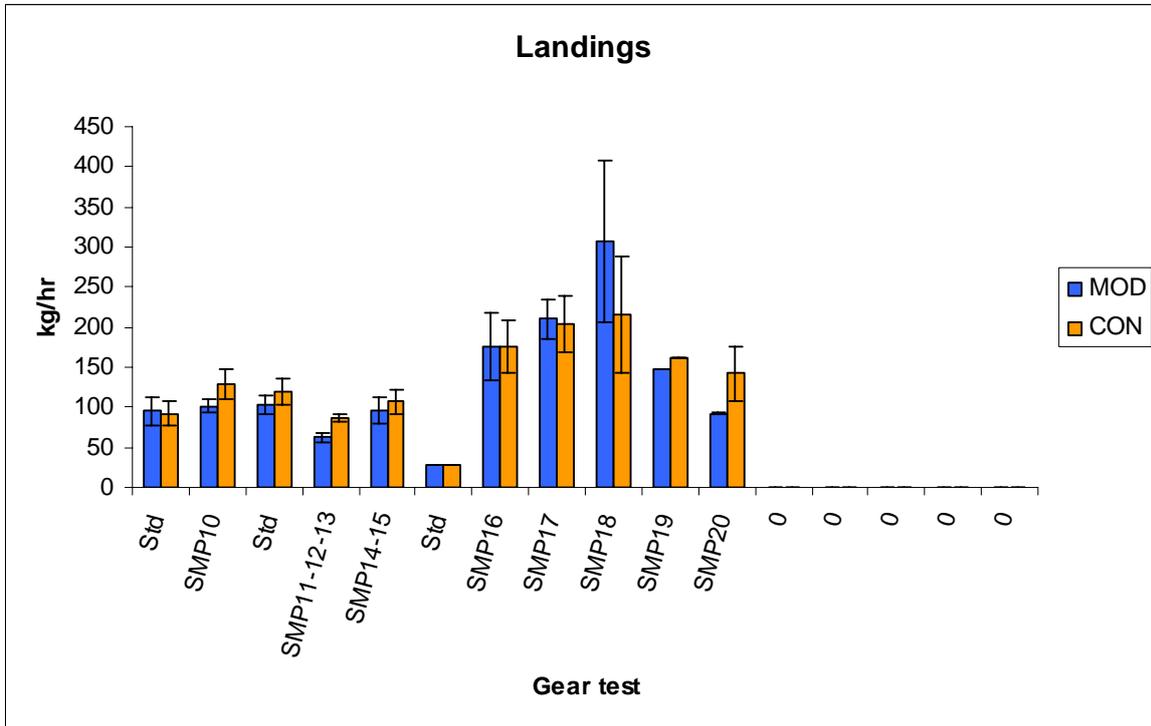


Figure 23: Comparison of landings – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

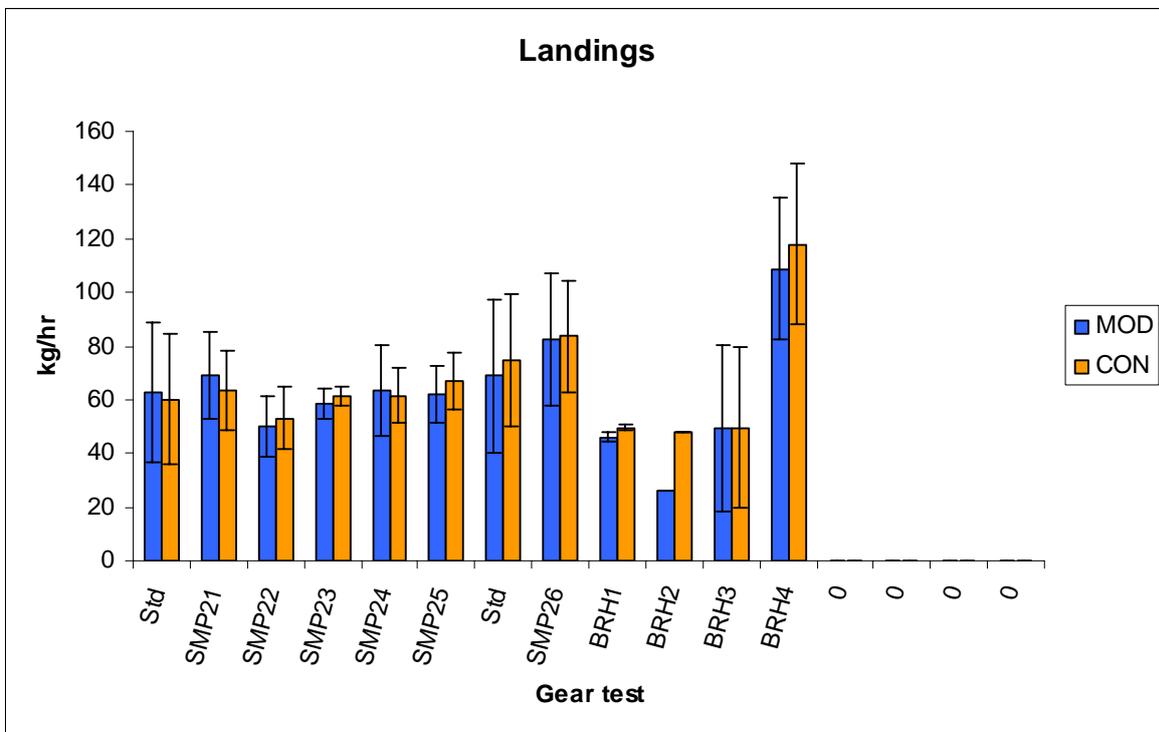


Figure 24: Comparison of landings – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

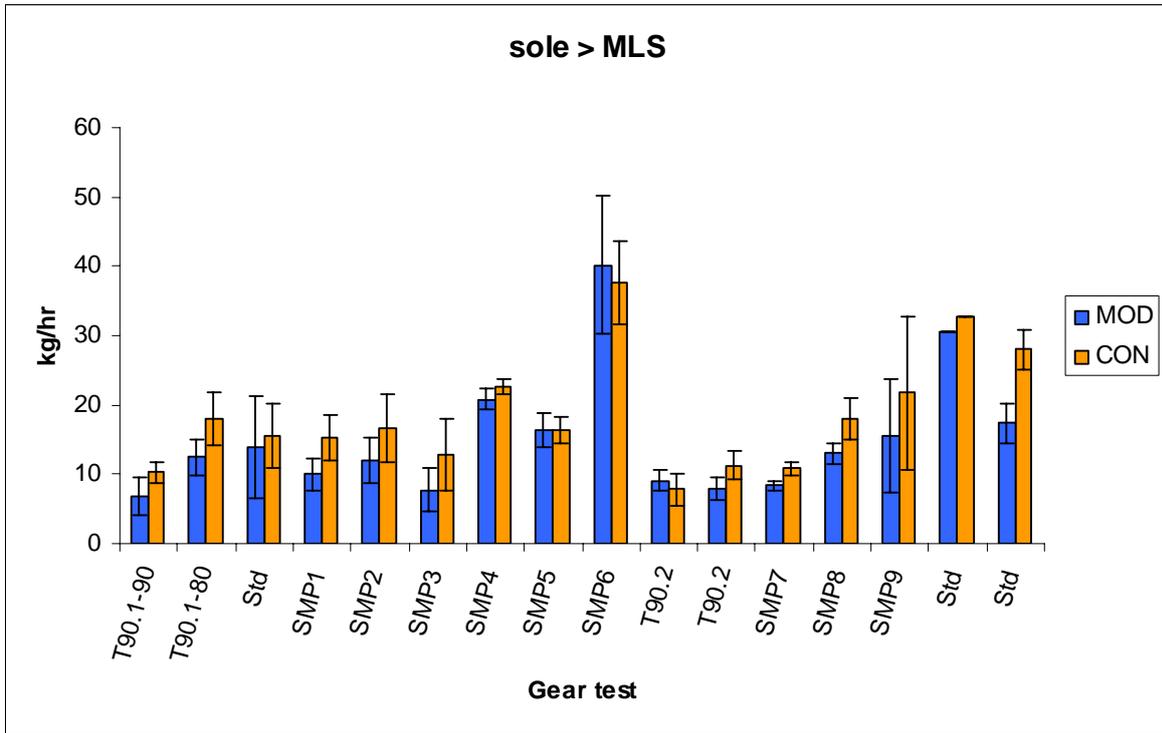


Figure 25: Comparison of sole > MLS – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

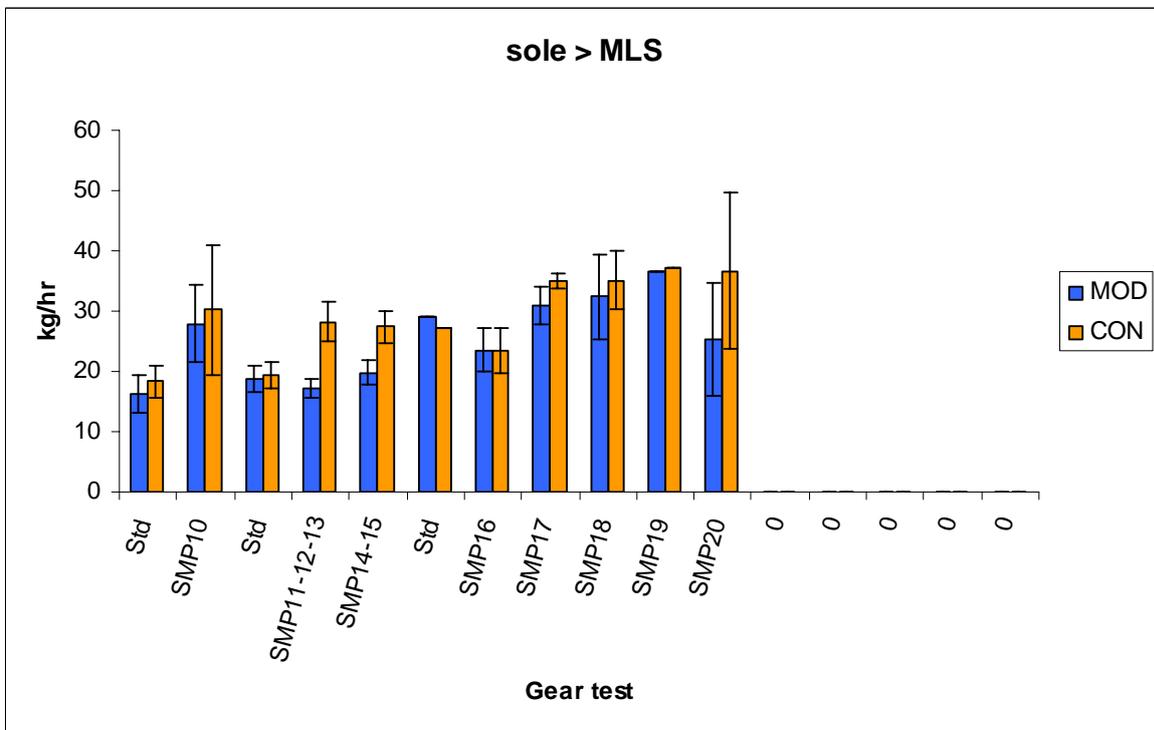


Figure 26: Comparison of sole > MLS – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

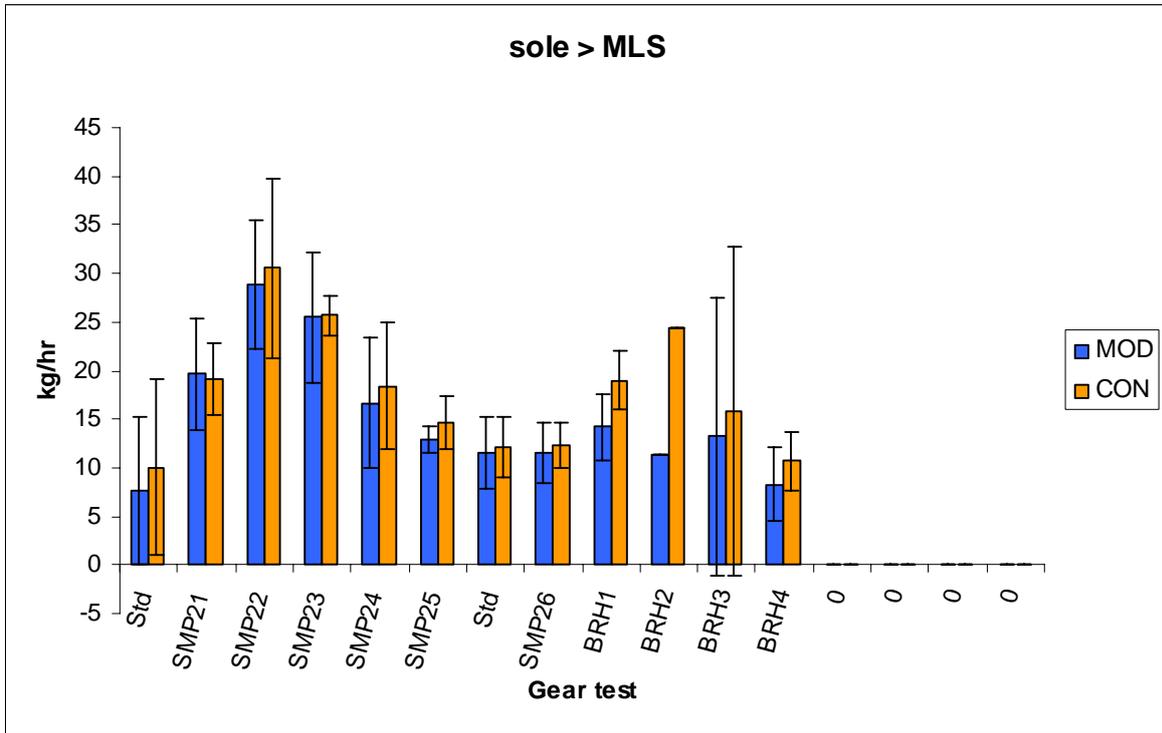


Figure 27: Comparison of sole > MLS – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

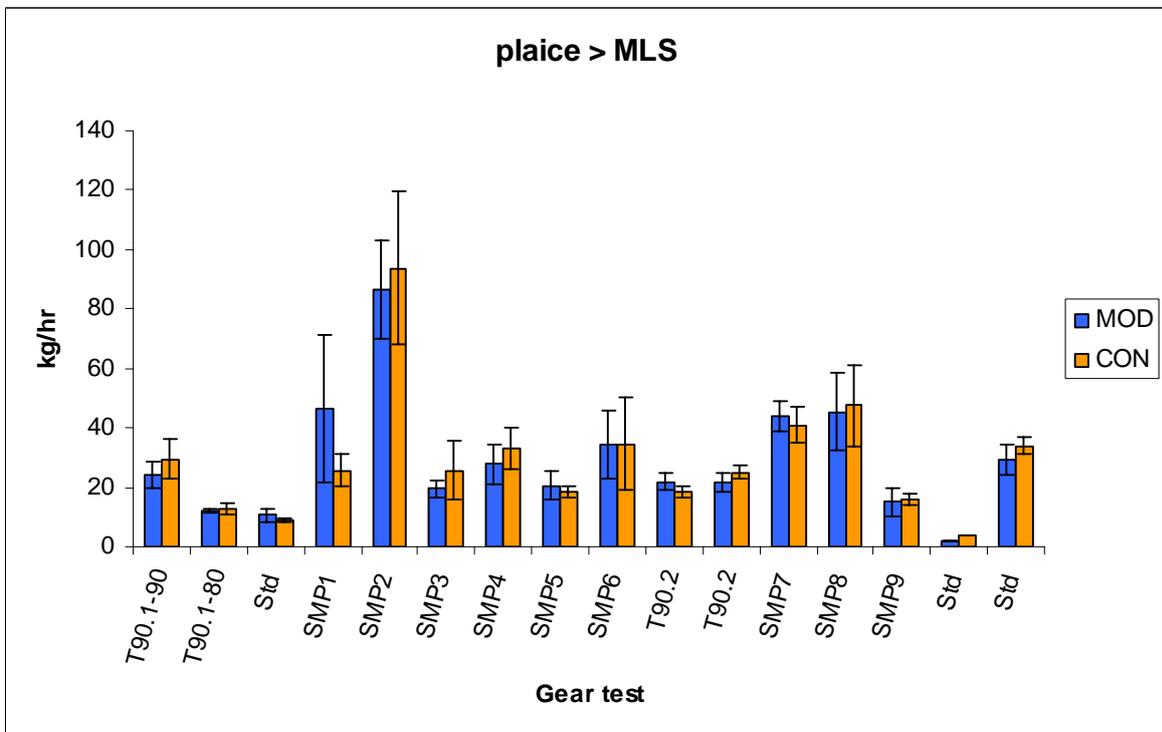


Figure 28: Comparison of plaice > MLS – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

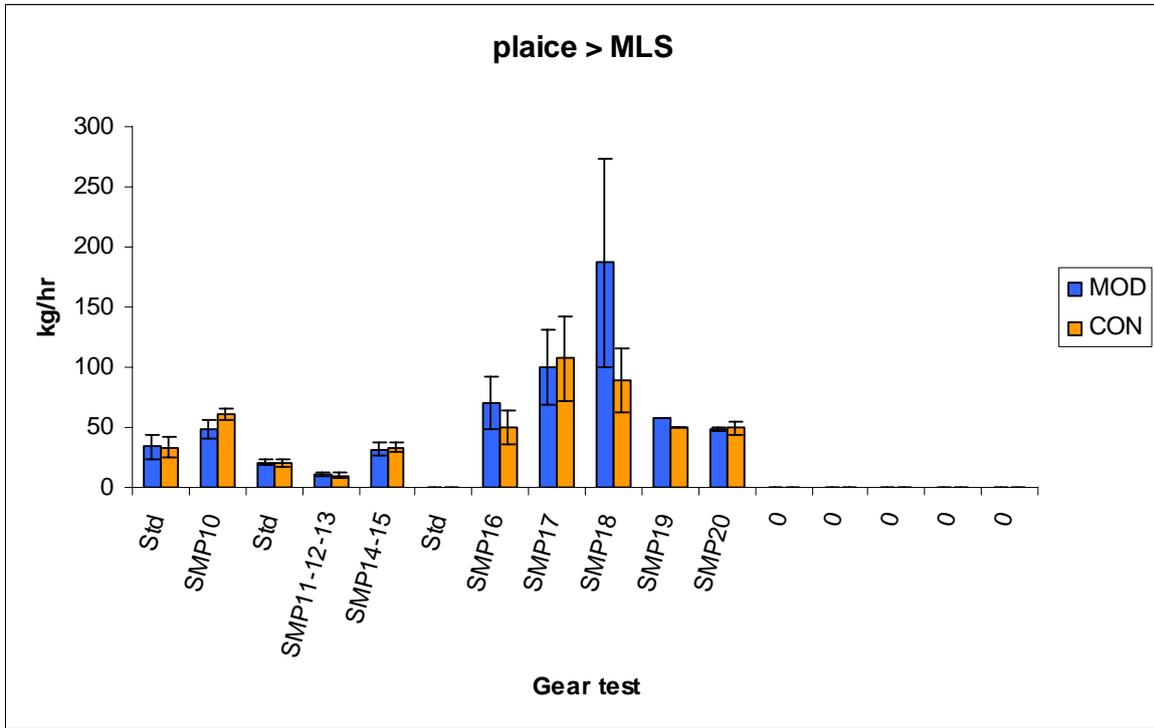


Figure 29: Comparison of plaice > MLS – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

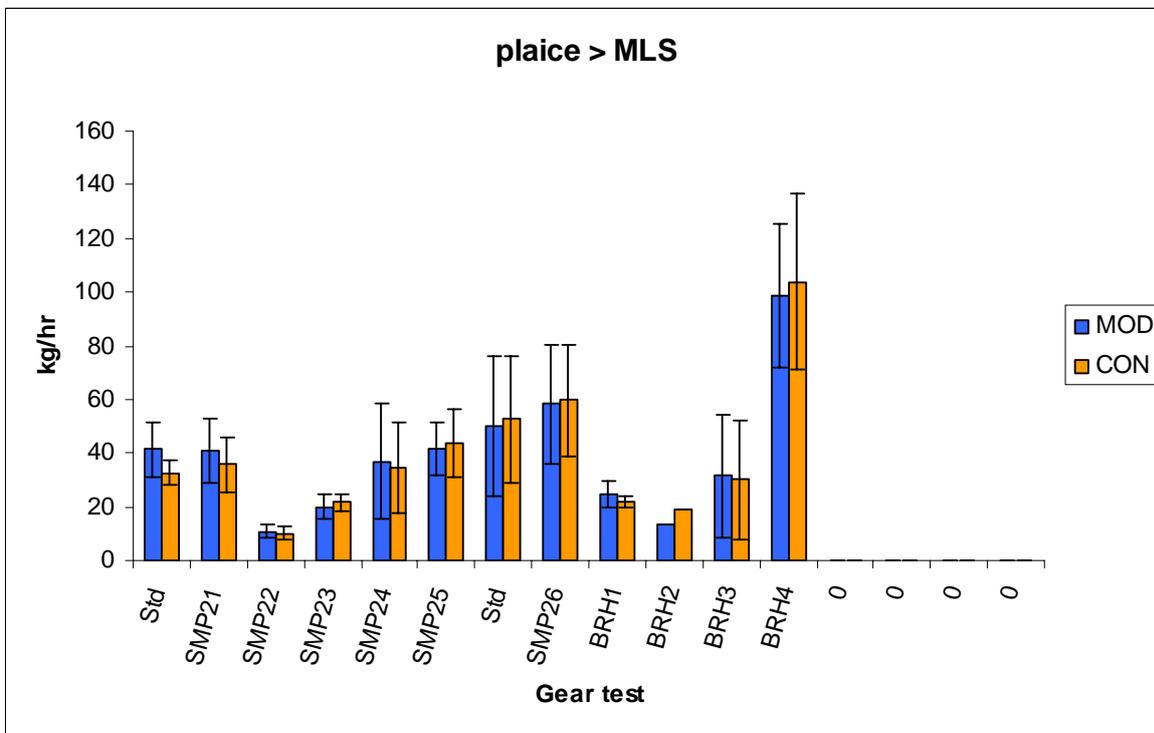


Figure 30: Comparison of plaice > MLS – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

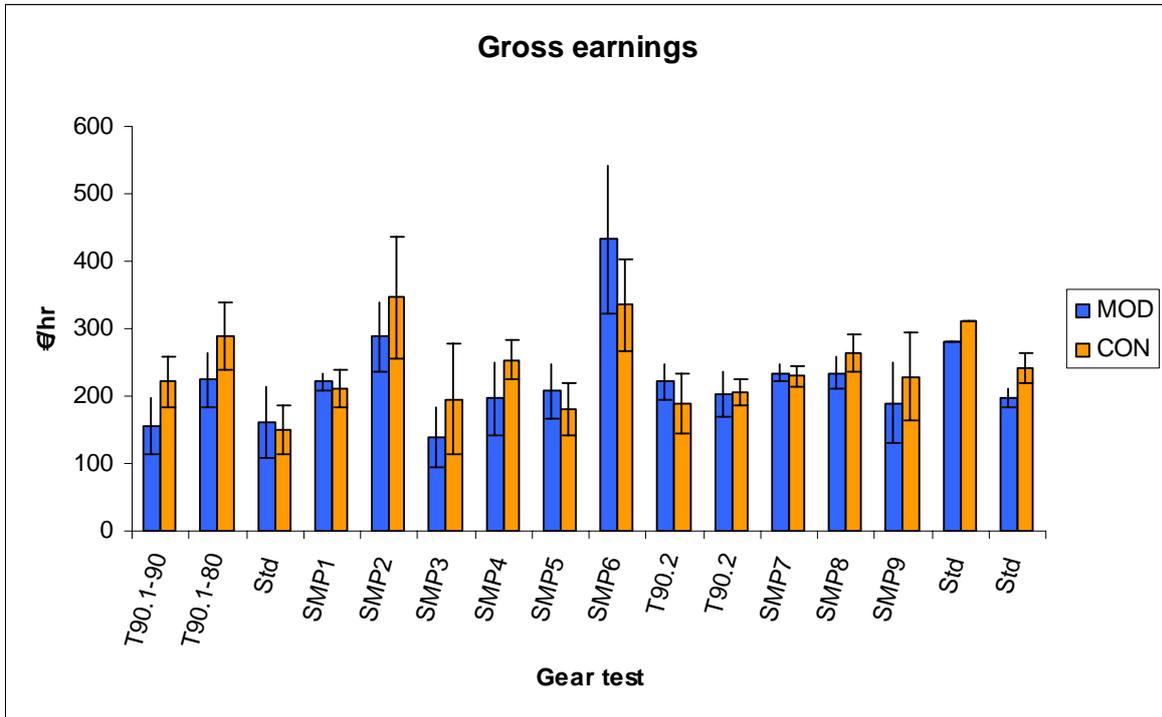


Figure 31: Comparison of gross earnings – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

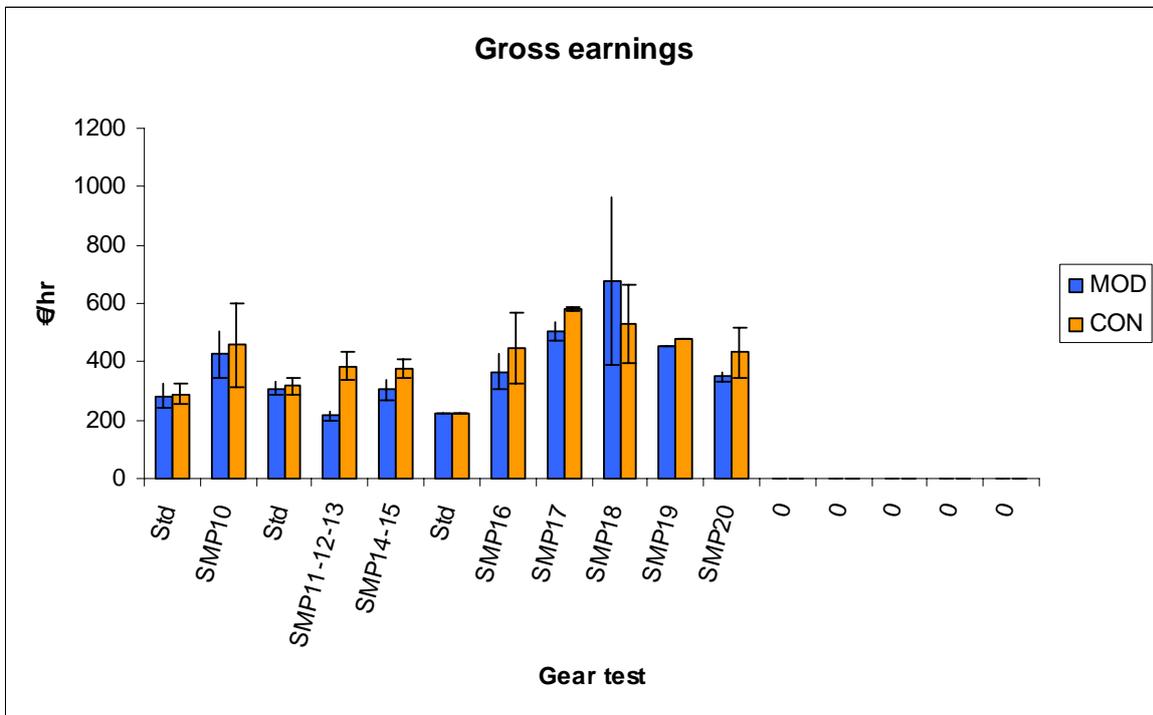


Figure 32: Comparison of gross earnings – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

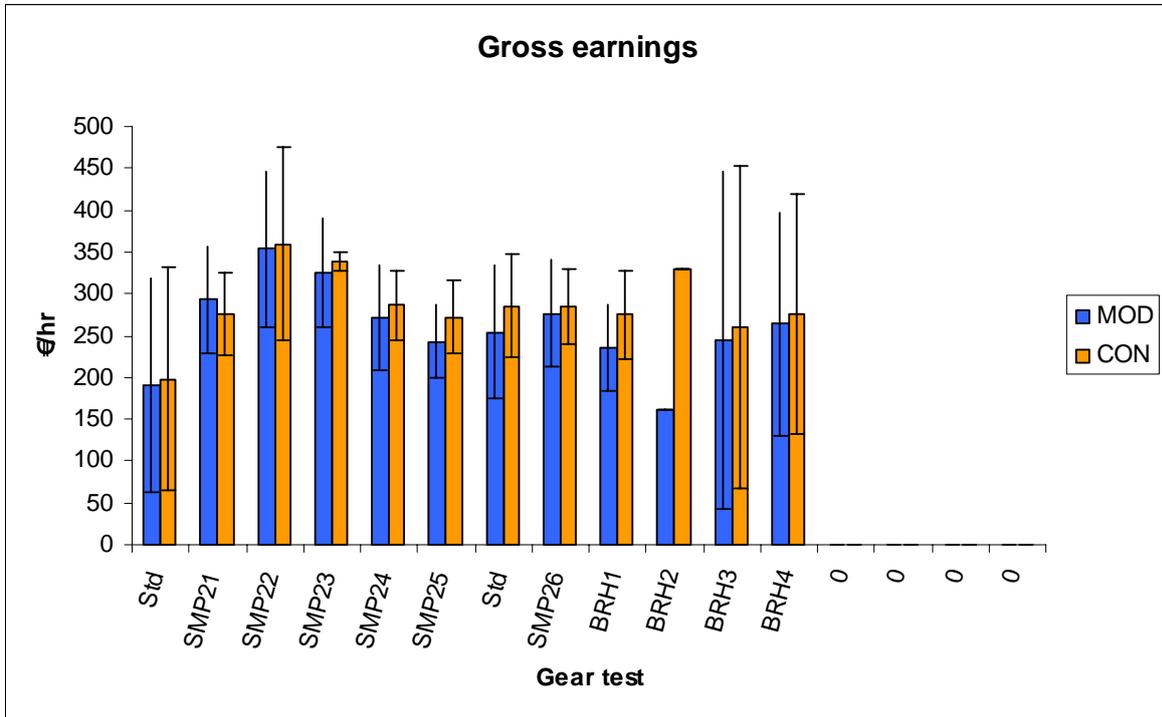


Figure 33: Comparison of gross earnings – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

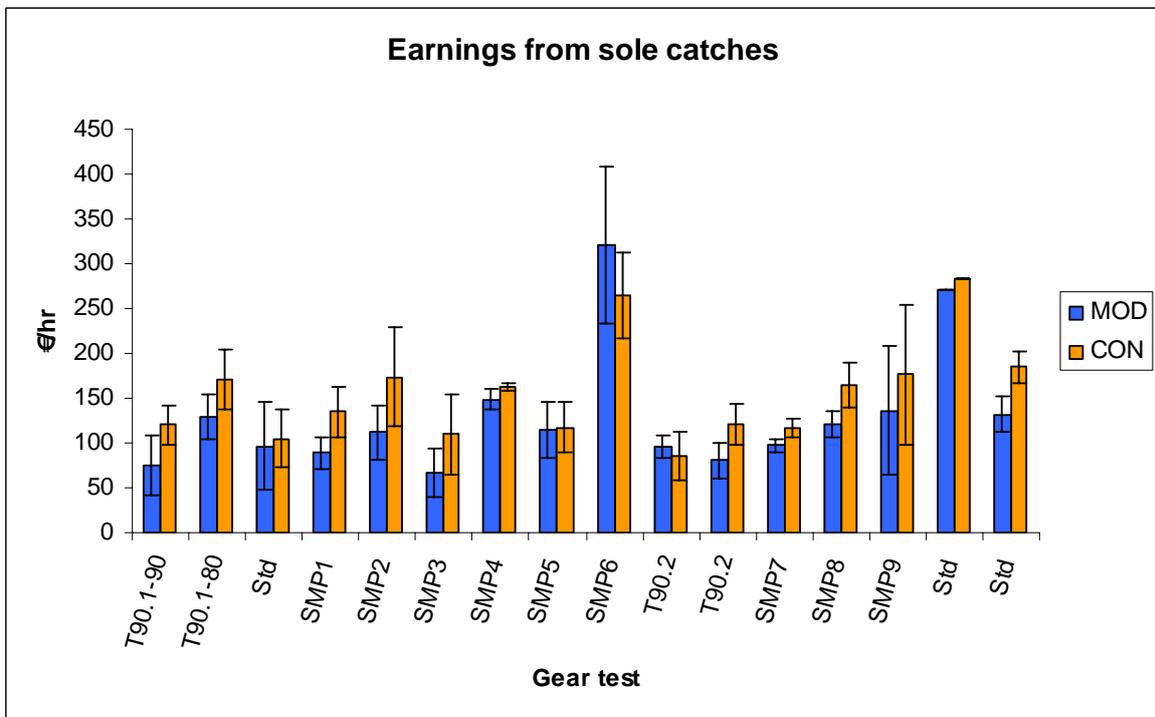


Figure 34: Comparison of earnings from sole catches – trials 2007 Period 1 (MOD = modified gear; CON = conventional gear)

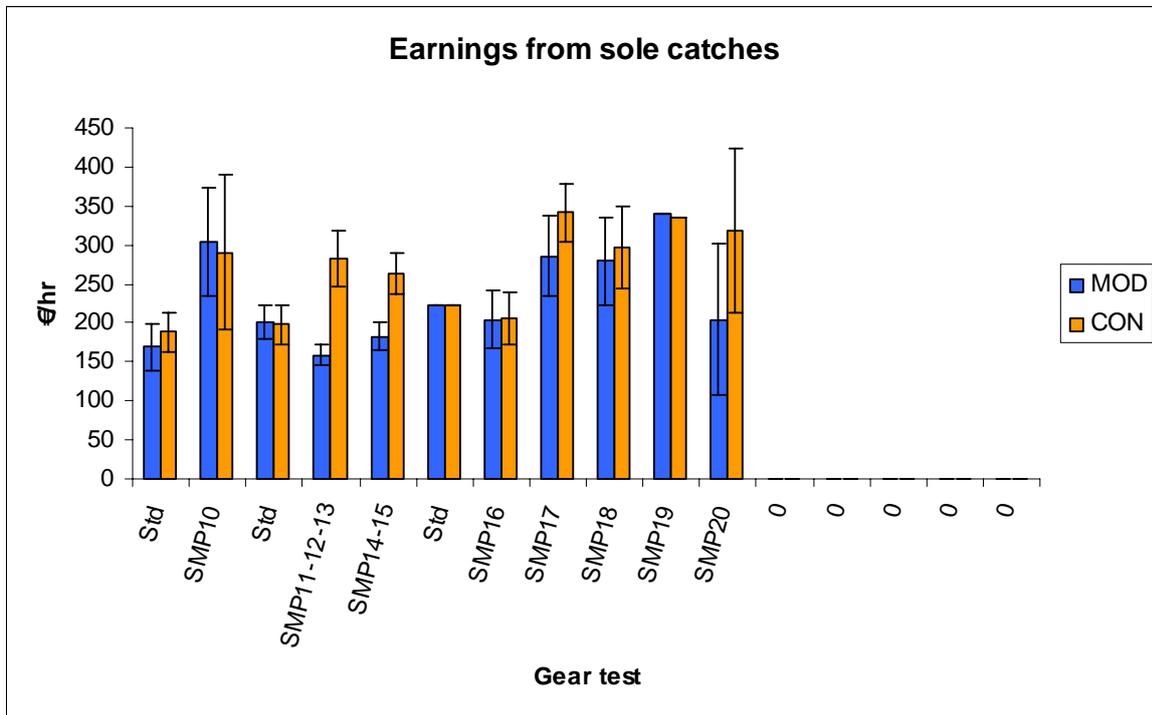


Figure 35: Comparison of earnings from sole catches – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

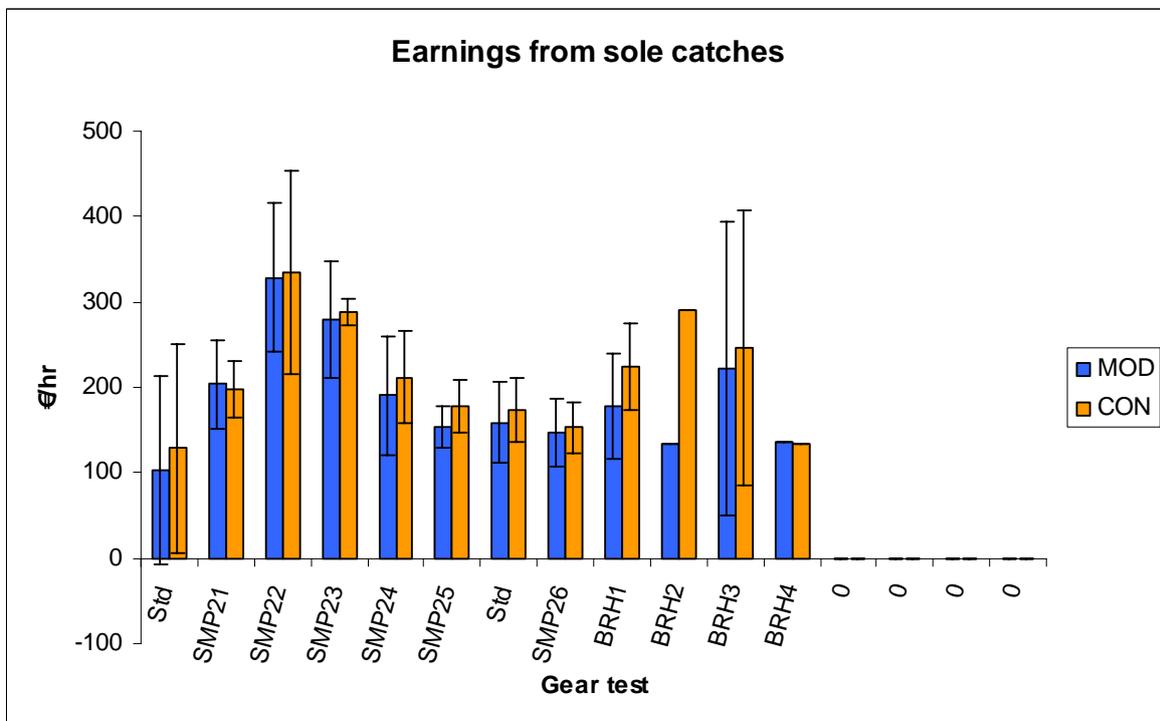


Figure 36: Comparison of earnings from sole catches – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

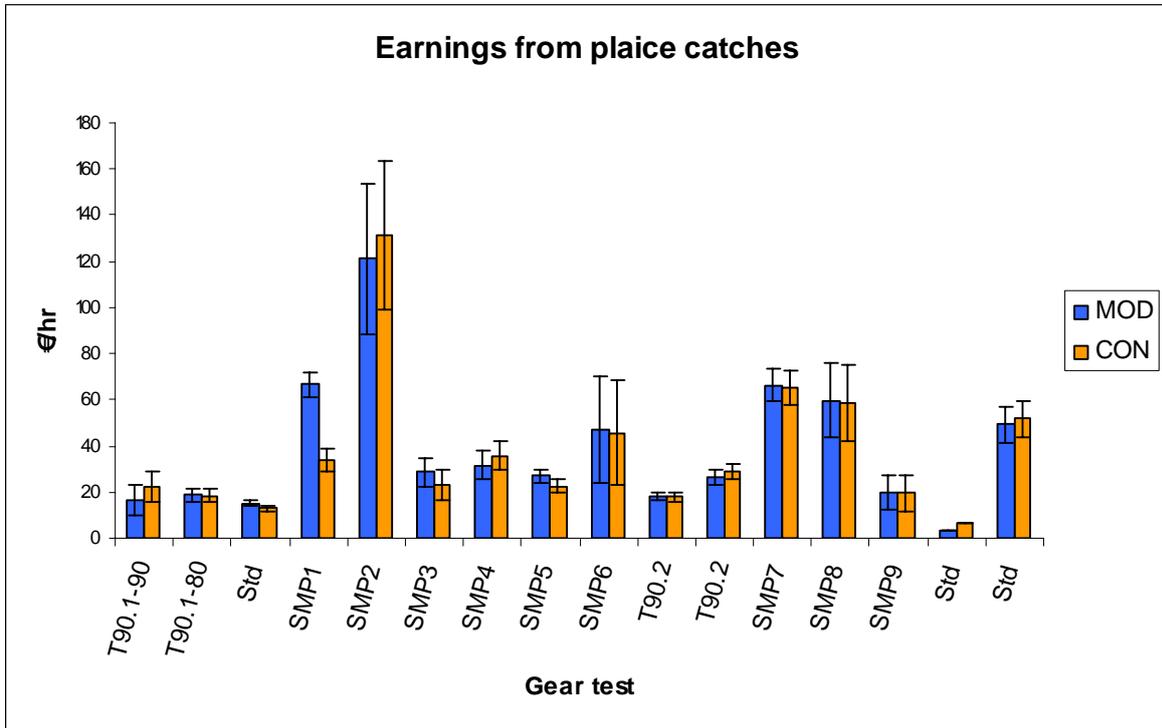


Figure 37: Comparison of earnings from plaice catches – trials 2007 Period 1

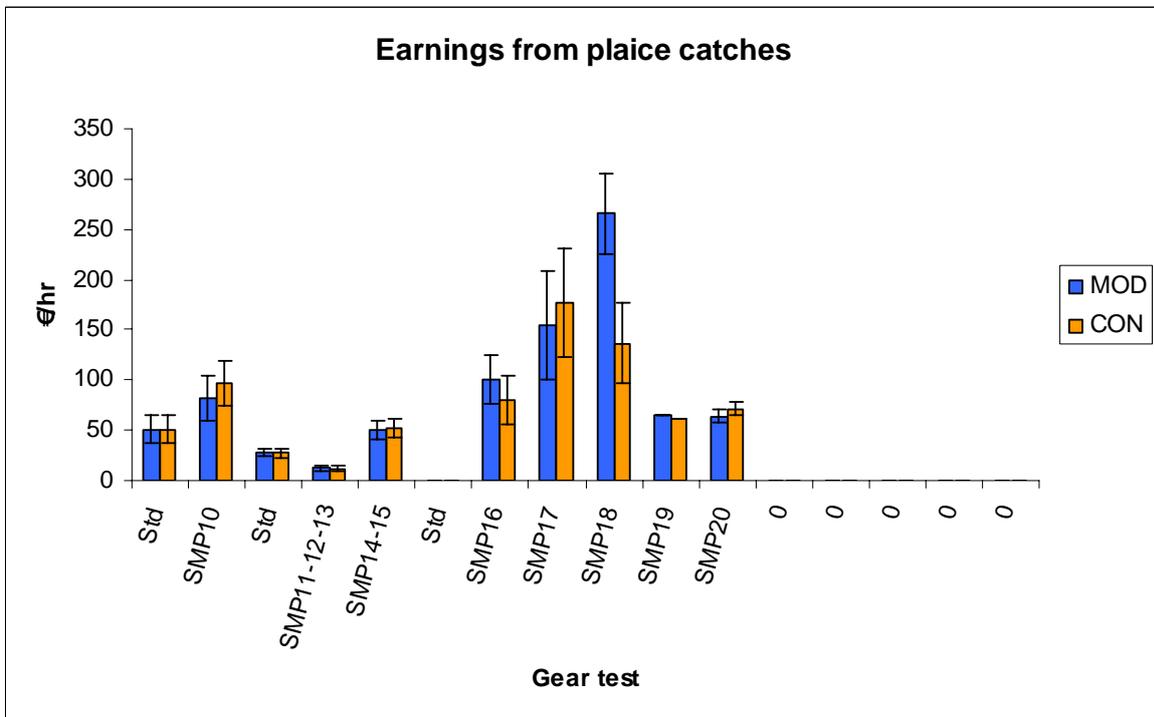


Figure 38: Comparison of earnings from plaice catches – trials 2008 Period 2 (MOD = modified gear; CON = conventional gear)

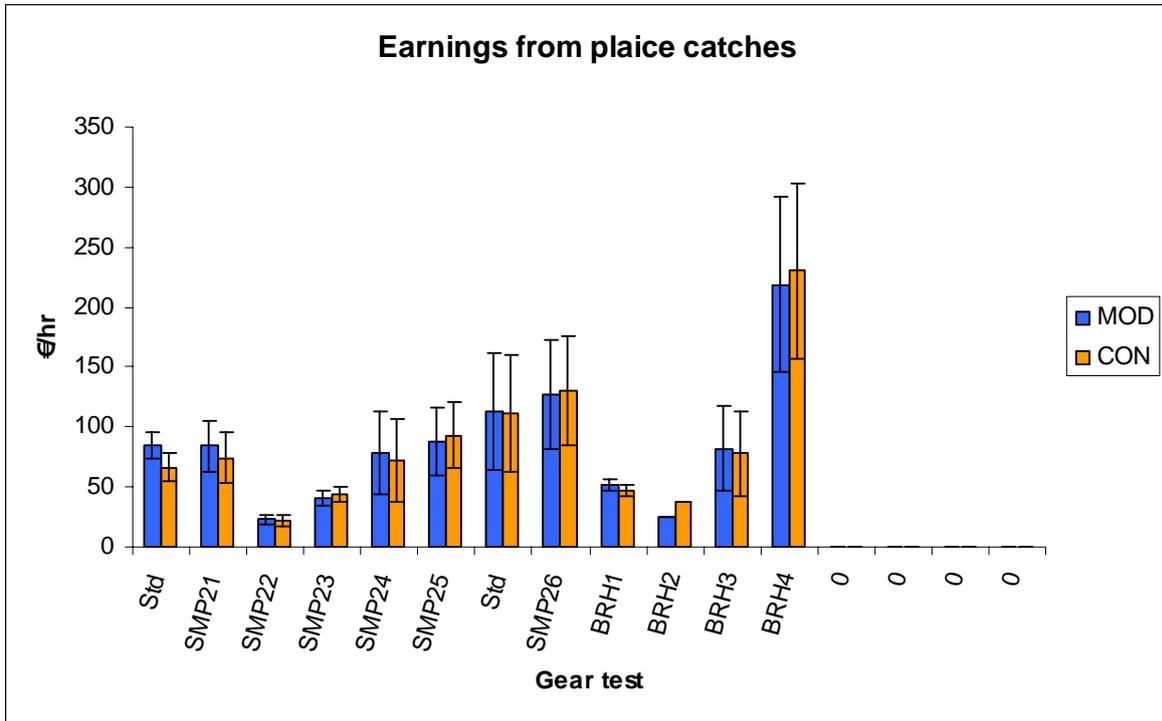


Figure 39: Comparison of earnings from plaice catches – trials 2008 Period 3 (MOD = modified gear; CON = conventional gear)

Referees and Authors

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Project Number: 439.15008.02

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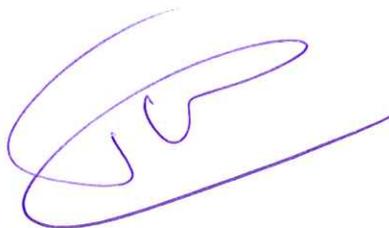
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Fisheries Researcher


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