Catch comparison of pulse trawls vessels and a tickler chain beam trawler

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Summary

Comparative fishing trials were conducted in May 2011 (week 19) on commercial beam trawlers fishing with conventional tickler chain beam trawls (on MFV GO4), pulse wings made by HFK-Engineering of Baarn, the Netherlands (MFV TX36), and pulse trawls produced by the DELMECO-Group of Goes, the Netherlands (version used on MFV TX68). The three vessels fished side-by-side as much as possible. Landings and discards of these vessels were monitored. Special emphasis was given on cod and whiting, that were dissected to study possible spinal damage. Result for TX36 and TX68 are expressed in terms of percentages of GO4.

The pulse characteristics were as follows: TX36: voltage 45 $V^{0\text{ to peak}}$, pulse frequency: 45 Hz, pulse duration 380 µs; electric power on single gear: 7.0 kW; TX68: voltage 50 $V^{0\text{ to peak}}$, pulse frequency: 50 Hz, pulse duration 220 µs; electric power on single gear: 8.5 kW. The fuel consumption recorded over the whole week was considerably lower for the pulse trawls, i.e. on TX36 (40%) and on TX68 (54%), than for the tickler chain beam trawls used on the GO4. The net earnings (taken as gross earnings minus fuel costs) for the TX36 were almost twice as large at 186%, and for the TX68 also considerably higher at 155%.

The vessels with pulse trawls caught fewer (65-69%) target species, but also less (30-50%) immature and non-target fish ('discards'), and benthic species (48-73%) than the vessel with tickler chains on these fishing grounds and in this period. The pulse gears caught fewer (19-42%) kg per hour cod than the tickler chain beam trawls, but the catches of cod on all three vessels were very small.

For plaice and dab these differences were statistically proven, for brill, turbot and cod this was not the case. There was no marked difference between both pulse trawl vessels in total landings. The TX68 caught less marketable sole, but not significantly less undersized sole than the GO4. The TX36 caught less undersized sole, but here the difference in marketable fish was not significant. Catches of brill and turbot were so small that no statistically substantiated conclusion could be drawn. Only for undersized turbot the TX36 caught less. For whiting we found a demonstrable reduction in both marketable and undersized fish in both pulse fishing vessels. The TX36 caught less whiting in number per hour.

The CPUEs found from the auction data and the sampled hauls correlated reasonably well for the most abundant species, such as plaice and sole. However, for less abundant species the results did not match very well, and care should be taken to increase the sampling rate in future comparative fishing studies.

Spinal fracture in cod occurred under pulse stimulation but to a limited extent in both marketable and undersized fish. There is an indication that this happens slightly more on TX68 (11%) than on TX36 (7%). Whiting hardly seems to suffer any damage.

1. Introduction

Research into the possible effects of the Verburg-DELMECO pulse trawl on the ecosystem has been carr-ied out since 1998. These effects were studied by looking at catches of target species, by-catches of undersized fish and benthos, and bottom impact, first with a prototype with 7m beam width, later with a 12 m prototype.

In 2006 and 2009 ICES gave advice on pulse trawling (at the request of the European Commission). In its advice ICES was on the whole positive about the potential effects of the pulse trawl, but also raised some additional questions. In the advice of 2006, the following recommendations were given (ICES, 2010):

"Further tank experiments are needed to determine whether injury is being caused to fish escaping from the pulse trawl gear. The experiments need to be conducted on a range of target and non-target fish species that are typically encountered by the beam trawl gear and with different length classes. In these trials it should be ensured that the exposure matches the situation in situ during a passage of the pulse beam trawl. Fish should be subjected to both external and internal examination after exposure.

If the pulse trawl were to be introduced into the commercial fishery, there would be a need to closely monitor the fishery with a focus on the technological development and bycatch properties."

Following the ICES advice of 2006, IMARES conducted tank experiments in 2007-2009 (de Haan et al., 2008, de Haan et al., 2009; of Marlen et al., 2009; of Marlen et al., 2007), which in 2009 led to further questions from ICES. The recommendation by ICES goes beyond identifying the current effects of pulse fishing. In fact, ICES also asked for a method of monitoring and controlling future developments.

It is important to not only look at technical aspects, but also explicitly at policy related issues. Any decision to remove the current prohibition of using electricity in fishing from the existing regulation is will only take place only if, there is sufficient confidence within the European member states that removing the ban will not lead to uncontrolled growth in fishing efficiency.

In the past the research activities dealt with the pulse trawl developed by Verburg Holland Ltd. (further denoted as Verburg, recently acquired by the DELMECO-group). All results and evaluations were based on the specifications of the Verburg-DELMECO gear. Meanwhile, the 'sumwing' and later 'pulse wing' made by HFK Engineering entered the market, and so a new situation has emerged.

2. Assignment

In view of the advice of ICES and taking into account current developments in pulse trawl gears, the following objectives were defined:

1. To monitor catches and by-catches on-board vessels fishing with HFK-pulse wings, with DELMECO-pulse trawls), and with conventional tickler chain beam trawls, with a particular emphasis on cod and possible spinal damage due to pulse stimulation.
2. To bring the research on pulse trawls on an international level by inviting foreign experts to join the comparative fishing experiments.

This report gives the outcome of the research on these two objectives.

3. Materials and Methods

Foreign experts

Three scientists from ILVO, Ostend, Belgium joined on the trials, one on each vessel, all are given in the list of authors.

Vessels

The trials were carried out on three vessels, MFV TX36 (fishing with HFK pulse wings), MFV TX68 (fishing with DELMECO pulse trawls), and MFV GO4 (fishing with conventional tickler chain beam trawls), Figure 3-1 and Figure 3-2.

Figure 3-1: TX36 (left), TX68 (middle) en GO4 (right) fishing 'side-by-side'

The main particulars of these vessels are given below.

Table 3-1: Main particulars of participating vessels

Vessel	TX36	TX68	GO4
Length o.a. (m)	42.35	41.15	40.11
Beam (m)	8.50	8.50	8.50
Depth (m)	5.15	5.30	4.71
Main engine power	1999 hp; 1470 kW	2000 hp; 1471 kW	1995 hp; 1467 kW
Gross Tonnage (GT)	494	438	417
Year of built	2000	1993	1992
Fishing gear used	HFK Pulse wing 12 m	DELMECO pulse trawl 12 m	Tickler chain beam trawl 12 m

Fishing gears

All cod-ends were made of the same batch of netting with a nominal mesh size of 80 mm to avoid differences due to mesh size. Measurements were done to check mesh sizes. A total of 25 meshes were measured on-board GO4 both on the port and starboard side, and at the beginning and end of the trials. Mesh sizes were only measured at the beginning of the trials on the TX36. No data was supplied for the TX68, but measurements were done prior to the trials, and a nominal mesh size of 80 mm reported.

A T-test was used to see whether the average of both sets of observations differed. This was the case for GO4 (T-test, $p<0.05$), but not for the TX36 (Table 3-2).

Table 3-2: Results of mesh size measurements in the cod-ends used onboard GO4 and TX36. P: port, S: starboard

Ship:		Method:	Gear Type:	# meshes	# meshes	T-test type	p-value
GO4		OMEGA	Beam trawl	25	25	two-sample, unequal variance	
		Date:		P	S		
	Mean.	08/05/2011		80.56	81.52		0.2638
	Stdev.			2.81	3.18		
	Mean.	13/05/2011		80.92	81.96		0.1910
	Stdev.			2.86	2.68		
TX36		OMEGA	Pulse wing	20	20	two-sample, unequal variance	
		Date:		P	S		
	Mean.	08/05/2011		79.65	80.75		0.0301
	Stdev.			1.69	1.37		

Figure 3-2: Fishing gears used, left on-board TX36, mid TX68 en right GO4

GO4 fished with two conventional 12 m tickler chain beam trawls, of which technical data are given in Table 3-3. The gears were fitted with 8 tickler chains and 10 net ticklers.

Table 3-3: Technical data for GO4

Item	Value
Warp load port side (P, tonne)	9 → P-net harder on-bottom than S-net
Warp load starboard side (S, tonne)	10 → older net
Towing speed (knots)	6 – 6.7
Motor r.p.m.	860
Fuel consumption (ltr)	33000 in 4 days (of 24 h)
Beam trawl shoe weight (kgf)	750 per shoe
Beam length (m)	12
Length tickler chains (m) → 26 mm (n=8)	25.50; 24.00; 22.60; 21.30; 20.10; 19.00; 18.00; 17.00
Length net ticklers (m) → 26 mm (n=2)	3.40; 3.70
Length net ticklers (m) → 22 mm (n=1)	5.20
Length net ticklers (m) → 20 mm (n=2)	6.30; 4.30
Length net ticklers (m) → 18 mm (n=1)	7.30
Length net ticklers (m) → 14 mm (n=4)	8.20; 9.20; 10.20; 11.20
Ground rope length (m)	34
Mesh sizes used	
• Net (cm)	40; 20; 12 from beam to cod-end
• Extension and cod-end (cm	9; 8.1 (cod-end)
• Chafing bag (cm)	24
• Side panel (cm)	12
• Belly (cm)	12
Warp length (m)	4 x water depth
Quotum (tonne)	240 plaice; 150 sole

The pulse wing is a trawl in which the 'SumWing' concept is integrated with pulse stimulation, and was used onboard TX36. A total of 28 pulse modules spaced 41.5 cm apart are placed inside the wing and connected with parallel electrodes. The dimensions of the wing and electrodes are given in Figure 3-3, and weights in Table 3-4. The electrode array extends over ~6 m. The nets used on TX36 differ from the conventional model. The aft part was made of two identical parts next to each other (Figure 3-4).

Table 3-4: Technical data for pulse wing of TX36

Item	Value
Warp load (tonne)	3
Weight in air (kgf)	2800
Weight in water (kgf)	800
Groundrope length (m)	36
Diameter discs on groundrope (mm)	200
Towing speed (knots)	5
Mesh sizes used	
• Net (cm)	22; 10 from beam to cod-end

In practice warp loads of 4 tonnes are also used while fishing. This requires an alternative setting of the angle of incidence to avoid the wing lifting the sea bed (Info: Harmen Klein Woolthuis, HFK Engineering, Baarn, the Netherlands).

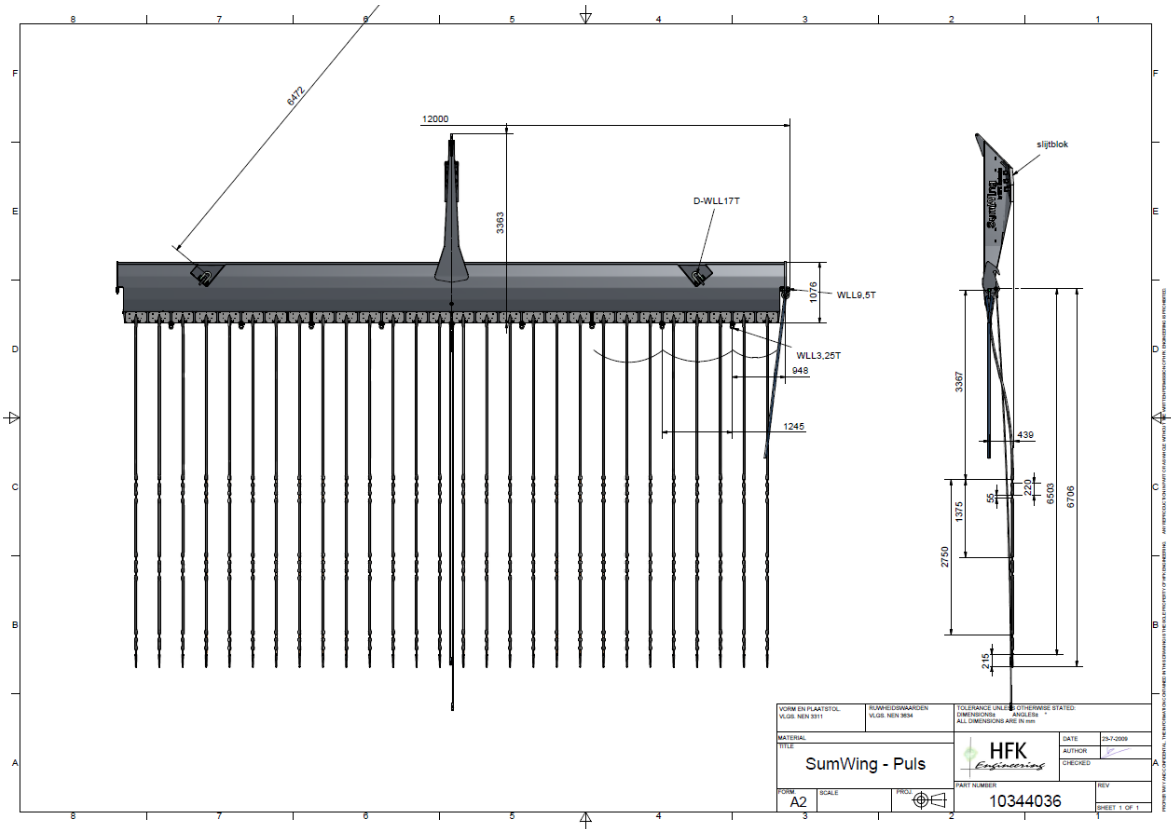


Figure 3-3: Construction drawing of pulse wing and electrodes on TX36

The DELMECO pulse trawl has 25 electrode across its width spaced 42.5 cm apart, and was used onboard TX68. A square box had been placed behind the beam to carry electronic circuits and a unit on top of the beam in the centre (Figure 3-5). This configuration was hydro-dynamically non-optimal.

The nets used on TX68 were derived from the conventional beam trawl design. The mesh size in the square was 20 cm, connected to netting of 10 cm mesh size (Figure 3-6; Table 3-5).

It should be stated that this report relates to the state of technology prior to May 2011 (week 19), and the technical configuration has been improved since, *e.g.* for the DELMECO pulse trawls, in which at present a wing-shaped beam is used, but still with two beam trawl shoes (*Personal communication* Ko Zwemer of DELMECO).

Table 3-5: Technical data for pulse wing of TX68

Item	Value
Groundrope length (m)	32
Groundrope weight under water(kgf)	30
Diameter discs on groundrope (mm)	240
Towing speed (knots)	5
Mesh sizes used	
• Net (cm)	20; 10 from beam to cod-end

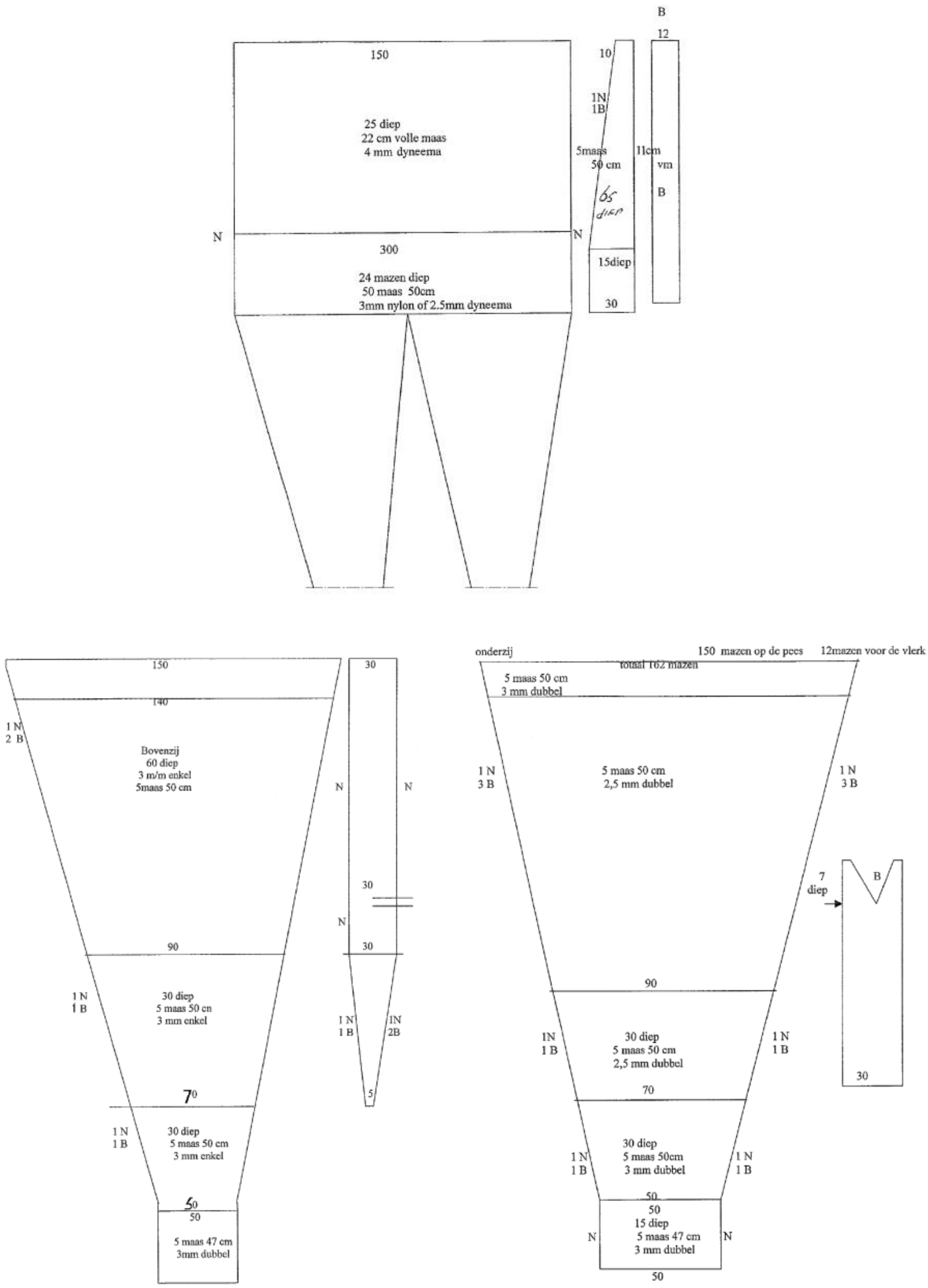


Figure 3-4: Net drawing TX36, upper: front part, lower: top (left) and bottom (right) panel of the two aft parts

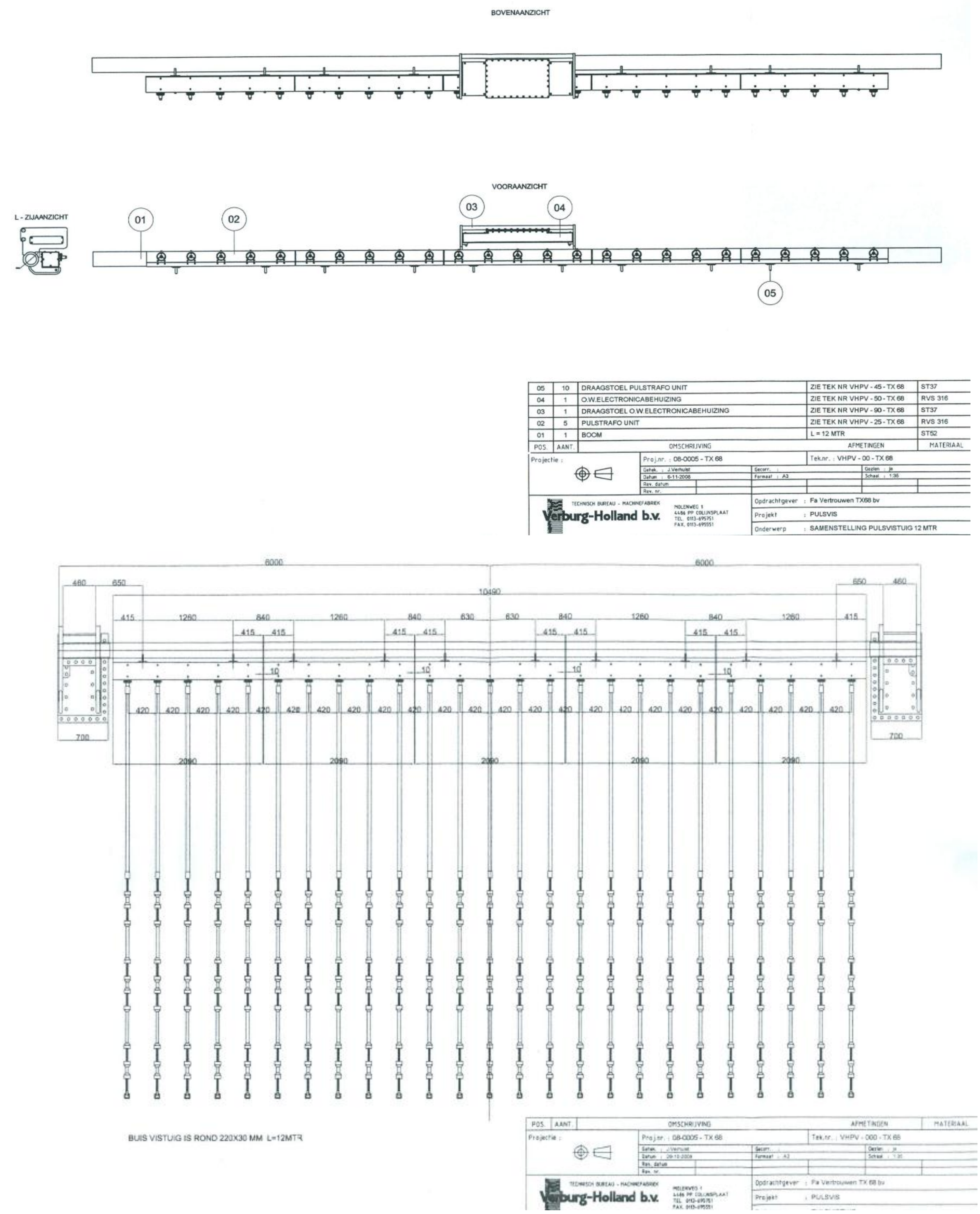


Figure 3-5: Construction drawing of pulse trawl and beam, electrodes on TX68

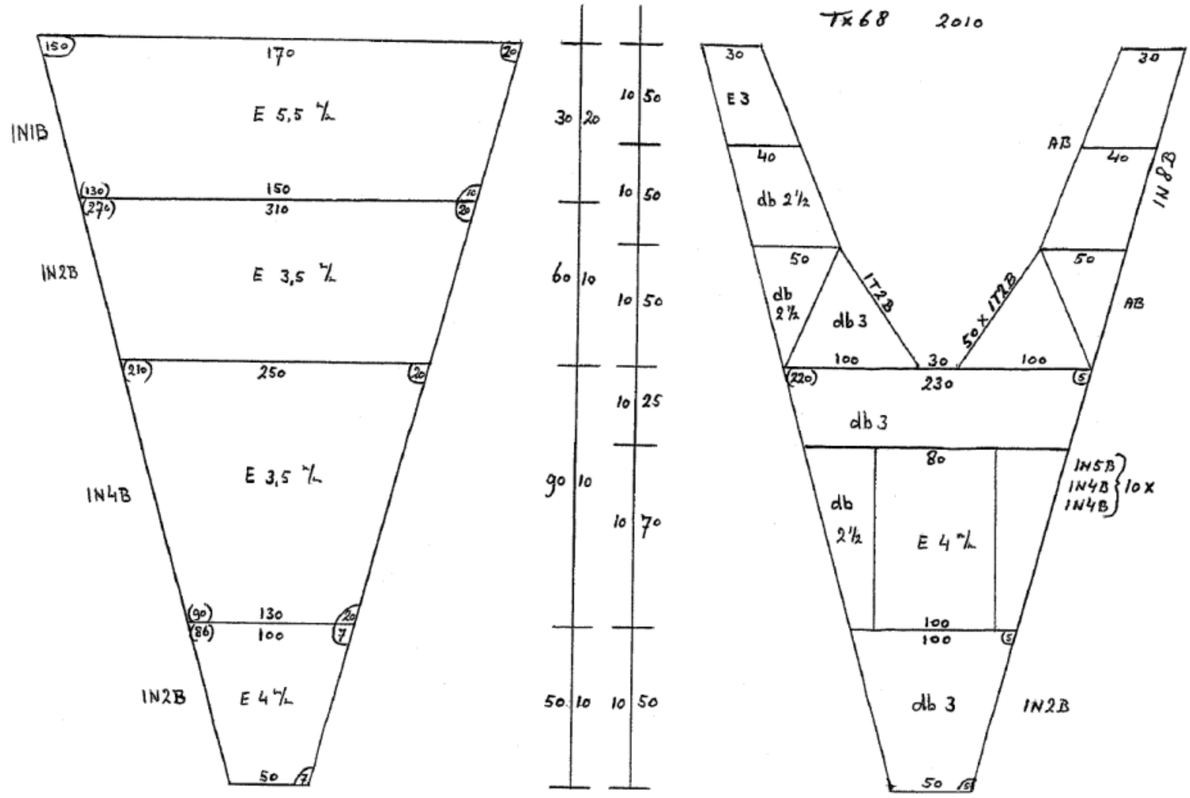


Figure 3-6: Net drawing TX68

Pulse stimulation

Field strength measurements were carried out on-board MFV “Dirkje” TH10 and on MFV “Buis” OD17 in November 2011 with gears laid on the bottom. TH10 is a euro-cutter, but the electrode length, spacing and other dimensions were fully comparable to the ones used on TX68. OD17 used the same gear configuration as has been used on TX36 in May 2011 (Table 3-6).

Table 3-6: Overview of main pulse parameters of the two systems (from: De Haan et al., 2011)

Pulse system	Electric power single gear (kW)	Electrode Voltage ($V^{0 \text{ to peak}}$)	Pulse Freq. (Hz)	Pulse duration (µs)	Electrode		
					Nr	Distance (m)	Conductor (nr) (l x d (mm))
DELMECO TX68	5.5	50	40	220*	25	0.425	6 (180x26)
HFK TX36	7	45	45	380	28	0.415	2 (125x27) + 10 (125x33)

*The pulse duration refers to the a single pulse period

Comparative fishing

The fishing trials were conducted in week 19 (08/05/2011-13/05/2011) with the three vessels fishing 'side-by-side' as much as possible given the differences in towing speeds. A total of was 45 hauls were done on-board the TX36 and the GO4, and 48 on the TX68 (Table 3-7). The positions fished are given in Figure 3-7.

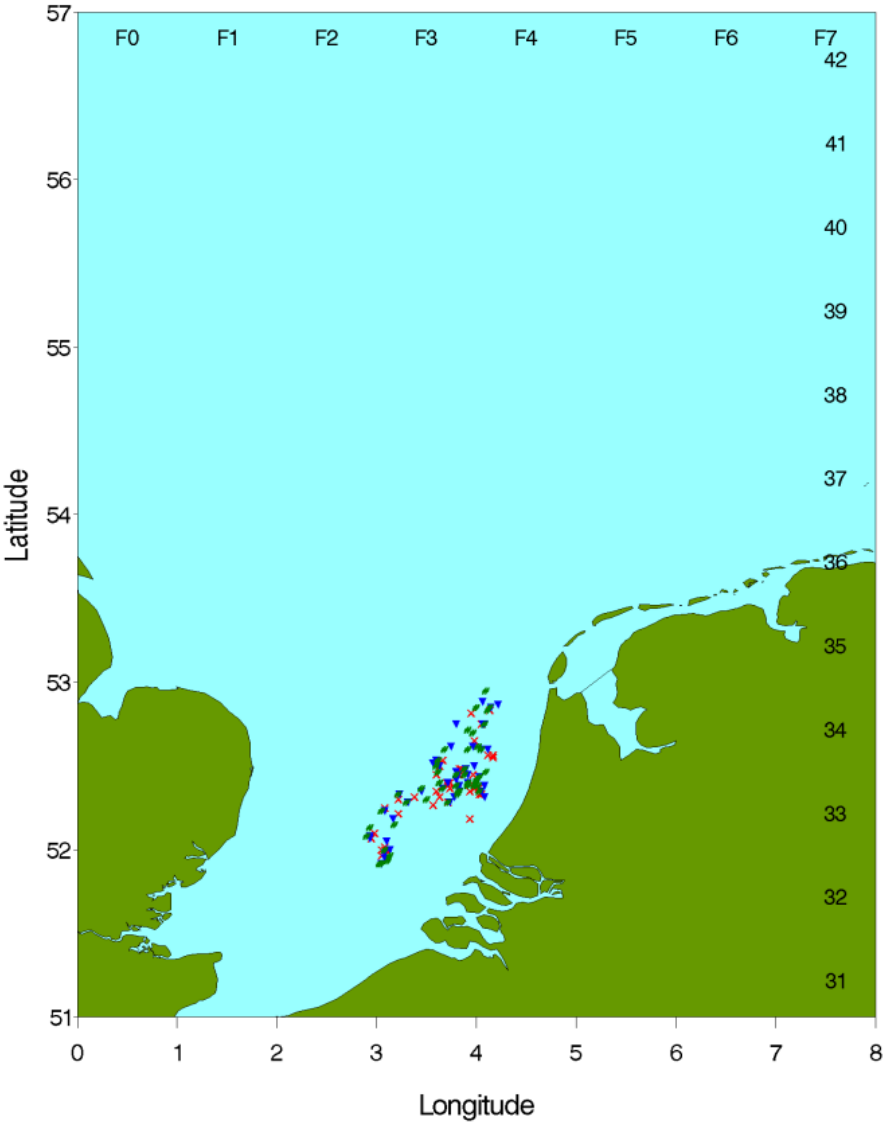


Figure 3-7: Fished positions (red = GO4; green =TX36; blue = TX68)

Data collection

Detailed cruise reports are added (See Appendix A). For data collection the so-called 'discard'-protocol of IMARES was used, with extra emphasis on cod. This protocol is described in detail in "Handboek discards" of IMARES (Anonymous, 2010).

Total catch volume was measured using special catch sampling bins constructed on-board, with which the number of baskets could be counted. Samples were taken of landings and discards for 56-70% of all hauls (Table 3-7). Fish were measured in cm-below, benthos recorded by species and number, and data fed in IMARES input program Billie Turf™ with sampling factors related to total catch by weight. Data on environmental conditions (vessel, trip and haul number, port of call, times of leaving and entering port, gear used, date-time of shooting, date-time of heaving, haul duration, shooting position, heaving position, distance covered or towing speed, water depth, wind speed and wind direction) and estimated catch per species were recorded by haul on a 'trawllist' in MicroSoft Excel™ for plaice (*Pleuronectes platessa* L.), sole (*Solea vulgaris* L.), dab (*Limanda limanda* L.), turbot (*Psetta maxima* L.), brill (*Scophthalmus rhombus* L.), cod (*Gadus morhua* L.), whiting (*Merlangius merlangus* L.), Norway lobster (*Nephrops Norvegicus* L.) and other (See Appendix B).

Landed catches were also recorded on 'auctionlists' in Excel in market categories (See Appendix C). By dividing with total fishing duration CPUE in kg/h was calculated. The following minimum landing sizes (MLS) were used, based on auction data: plaice 27 cm, sole 24 cm, dab 23 cm, turbot 25 cm, brill 25 cm, lemon sole 25 cm, flounder 25 cm, whiting 27 cm, cod 35 cm, tub gurnard 28 cm and grey gurnard 28 cm.

All cod that were captured on the TX36 and TX68, were measured and filleted, by which spines were made visible for inspection and digitally photographed (See Appendix E). The corresponding haul numbers were also recorded for each fish (See Appendix D). On the TX36 this was also done for whiting. During the trials cod were inspected visually and manually on the GO4, but not internally investigated. At the time no spinal fractures were seen. Because there were still some doubts whether cod in the tickler chain beam trawl may get damaged a box of landed cod was purchased from the GO4 in October 2011 (week 42) measured, filleted and photographed (See Appendix E).

Table 3-7: Summary of total number of hauls in which landings (Land) or discards (Disc) were sampled.

week	SHIP	land_hauls	disc_hauls	Total_hauls	Total_h	Land_h	Disc_h	Land_perc	Disc_perc
19	GO4	34	34	45	74	52	52	70.3%	70.3%
19	TX36	33	33	45	80	55	55	68.8%	68.8%
19	TX68	28	33	48	82	46	54	56.1%	65.9%

Statistical analysis

Data were checked and corrected and then put into IMARES-database FRISBE, after which a SAS™-data-set was made for analysis.

It appeared to be the case that some fish larger than MLS were classified as discards and fish smaller than MLS as landings. Code was written in SAS to correct these fish and put them in the right category.

SAS-code was also written for making 'boxplots' or box-and-whisker diagrams (SAS PROC BOXPLOT), giving the mean (using symbol +), lower quartile, median, upper quartile, as well as the smallest observation (sample minimum) and the largest observation (sample maximum) for each of the three vessels.

We used a generalized linear model (SAS PROC GLM) of the form:

Dependent variable (log CPUE) = ship (independent variable)

The CPUEs in #/h or kg/h were log-transformed to ensure normality of the residuals. With PROC GLM we investigated whether the independent variable ship contributed significantly to the variance of the results, in other words whether CPUE differences were really caused by the vessel (and gear).

In this analysis we looked at catches in overall categories (landings and discards (benthos and fish (undersized target and non-target species)) as well as catches by species separately: plaice, sole, dab, brill, turbot, whiting and cod.

The mean CPUE (in #/h or kg/h) over sampled hauls in which catches were found were calculated by category or by species. PROC GLM also supplies the 95% confidence limits. By comparing these limits for the three vessels one can deduct whether differences are statistically significant (further denoted as 's') or non-significant (denoted as 'ns'). When the confidence limits do not overlap a difference is statistically significant (s).

We also used SAS-code to raise CPUEs to trip level by using the fraction of total sampled haul duration over total fishing duration (of all hauls added). Where appropriate calculated weights were corrected with total weight by species found recorded at the auction. Details of raising procedures are given in Appendix F.

Length dependency of results for major target species

Recently software code was developed for analysing catch comparisons to appraise the catch efficiency (at length) of one gear relative to that of another gear, which deviates from the classical selectivity experiment where one of the gears is assumed to catch the entire population (Holst and Revill, 2009). They used 'Generalised Linear Mixed Models (GLMM)' and polynomial approximations for the logistic function describing the probability of retaining a fish at length in what they call the 'test' gear, related to the total catch in the 'test' and 'control' gear. The binomial probability distribution, which is a function used for discrete data giving the number of successes in a sequence of n independent yes/no experiments (fish entering a gear compartment or not), each of which yields success with probability p.
In selectivity experiments the selectivity curve can be fitted for each haul, given the data is adequate, and mean curves can be calculated for a range of hauls. In the case of catch comparisons there is no data set describing the control values of the entire population, and therefore low-order polynomial approximations are used. The method gives approximated means and 95% confidence bands at length for the logit of the expected proportion of the total catch caught in the test cod-end. The line of 0.5 corresponds with equal catches in both gears. When the confidence bands are narrow, the result is more clearly distinguishable from chance events. Often one sees confidence bands widen when fish are less abundant, e.g. at higher lengths. The method starts with 3^{rd} order polynomials, and reduces the order until all terms are significant. Usually a 2^{nd} order fit is sufficient.

We compared hauls for this analysis which are paired in time (having more or less the same start and end times) and looked at TX36 vs. GO4, TX68 vs. GO4, and TX36 vs. TX68. The GO4 (conventional gear) is used as control in the first two comparisons with the pulse trawls as test gear, while the TX68 in the last one, with the TX36 as test gear.

4. Results

Overall performance

The TX36 preformed best in terms of Net Revenue, followed by the TX68. The lower fuel consumption for TX36 was the main reason, as Gross Revenues were about the same for both pulse trawl vessels. Both pulse trawl vessels caught a much smaller mean number of baskets per sampled haul. In spite of the higher earnings on GO4, the higher fuel costs of this boat caused a lower economic performance (Table 4-1).

Table 4-1: Summary of overall performance for the three vessels

Ship	Fuel	Perc.	Fuel costs	Mean number of baskets (35 kg) per haul	Perc.	Landings	Gross Revenue	Net Revenue	Perc.
	(x1000 ltr)	(%)	(€; 1 ltr = 0.56€)		(%)	(kg)	(€)	(€)	(%)
GO4	35	**100**	19600	30	**100**	6620	29000	9400	**100**
TX36	14	**40**	7840	10	**32.9**	4580	25366	17526	**186**
TX68	19	**54**	10640	12	**40.1**	5078	25192	14552	**155**

Landings recorded at the auction

Based on auction data and total fishing time the GO4 caught most marketable fish in kg/h, i.e. 90, followed by TX68 (63) then TX36 (58), see Table 4-2. The split in species is also given in this table. Cod on the two pulse trawl vessels were not actually landed, but their weights calculated by market grade from the length measurements of the dissected and photographed fish. Most cod was caught by GO4 (1.8 kg/h), followed by TX36 (0.8) and TX68 (0.3).

Table 4-2: Summary of Catches Per Unit of Effort (CPUEs) based on auction data

ship	GO4	TX36	TX68	TX36/GO4	TX68/GO4	TX36/TX68
species	kg/h	kg/h	kg/h	%	%	%
PLE	34.9	24.7	25.2	70.8%	72.1%	98.2%
SOL	17.6	14.8	15.4	84.4%	87.4%	96.6%
DAB	3.4	2.5	4.6	73.9%	135.4%	54.6%
TUR	3.6	3.1	2.8	85.3%	78.4%	108.9%
BLL	2.0	2.1	2.0	103.7%	99.8%	103.9%
COD	1.8	0.8	0.3	42.3%	19.2%	220.8%
WHG	2.7	0.1	1.3	3.2%	47.0%	6.9%
NEP	0.0	0.0	0.0	n/a	n/a	n/a
VAR	24.1	10.4	11.0	43.2%	45.6%	94.6%
Landings (sum)	90.1	58.4	62.5	64.9%	69.4%	93.4%

Landings and discards raised to total trip duration

Target fish species

Landings and discard data for major target species raised to total trip duration are given in Table 4-3. Expressed in percentage of the total number or weight for plaice and sole we see a small decline for both pulse trawls.

Table 4-3: Landings and discards of target species cod, dab, plaice, sole and whiting raised to total trip duration (perc_n and perc_w are percentages in number (n) and weight (w) of discards related to total catch (landings + discards) for that species)

ship	species	total fishing time (min)	measured (kg)	landings (kg)	landings (kg/h)	landings (#/h)	discards (kg/h)	discards (#/h)	perc_n	perc_w
GO4	Cod	4410				0.4				
GO4	Dab	4410					56.6	1052.0		
GO4	Plaice	4410	287.0	2565.0	34.9	101.7	106.8	1443.9	93	75
GO4	Sole	4410	292.5	1291.0	17.6	72.3	2.8	41.2	36	14
GO4	Whiting	4410					9.9	111.8		
TX36	Cod	4775					0.0	0.1		
TX36	Dab	4775					16.3	290.2		
TX36	Plaice	4775	202.8	1965.0	24.7	71.3	49.6	624.7	90	67
TX36	Sole	4775	188.0	1180.0	14.8	61.4	1.0	10.8	15	6
TX36	Whiting	4775					1.1	14.8		
TX68	Cod	4900					0.2	1.0		
TX68	Dab	4900					24.7	459.9		
TX68	Plaice	4900	112.0	2054.0	25.2	72.3	61.2	833.0	92	71
TX68	Sole	4900	123.0	1254.0	15.4	56.1	1.7	18.7	25	10

TX36 caught less marketable plaice (s) raised to total trip duration than GO4 (70.8% in kg/h and 70.2% in #/h), and also discards (46.4% in kg/h and 43.3% in #/h). For TX68 we found: landings (72.1% in kg/h en 71.1% in #/h) and discards (57.3% in kg/h and 57.7% in #/h), see Table 4-4.

TX36 caught fewer marketable sole raised to total trip duration than GO4 (84.4% in kg/h and 84.9% in #/h), and also less undersized sole (36.0% in kg/h and 26.2% in #/h). For TX68 these values were: landings (87.4% in kg/h and 77.5% in #/h) and undersized sole (62.0% in kg/h and 45.4% in #/h), see Table 4-4.

Table 4-4: Comparison of landings and discards of target species plaice and sole raised to total trip duration

species	comparison	Landings (kg)	Landings (kg/h)	Landings (#/h)	discards (kg/h)	Discards (#/h)
Plaice	TX36/GO4	76.6%	70.8%	70.2%	46.4%	43.3%
Sole	TX36/GO4	91.4%	84.4%	84.9%	36.0%	26.2%
Plaice	TX68/GO4	80.1%	72.1%	71.1%	57.3%	57.7%
Sole	TX68/GO4	97.1%	87.4%	77.5%	62.0%	45.4%

Non-target fish species

Table 4-5: CPUE in #/h raised to total trip duration of non-target fish species for the three vessels with the ratio pulse gear/conventional beam trawl in %

Species	Name (EN)	#/h GO4	#/h TX36	#/h TX68	TX36/GO4	TX68/GO4
Pomatoschistus sp.		1.9	2.56	1.08	137.1%	57.9%
Callionymus lyra	Dragonet	25.2	9.77	50.16	38.8%	199.0%
Hyperoplus lanceolatus	Greater sand-eel	11.1	5.95	3.65	53.5%	32.8%
Clupea harengus	Herring	0.0	0.22	0.00		
Agonus cataphractus	Hooknose	3.3	5.22	4.50	158.2%	136.4%
Trachurus trachurus	Horse mackerel	19.9	1.60	2.53	8.0%	12.7%
Echiichthys vipera	Lesser weever	17.8	3.93	21.02	22.1%	118.2%
Cyclopterus lumpus	Lumpsucker	0.3	0.00	0.26	0.0%	78.9%
Callionymus reticulatus	Reticulated dragonet	0.0	6.47	0.00		
Arnoglossus laterna	Scaldfish	35.1	27.99	20.54	79.6%	58.4%
Taurulus bubalis	Sea scorpion	1.8	0.00	0.00	0.0%	0.0%
Buglossidium luteum	Solenette	55.5	49.00	39.52	88.2%	71.2%
Sprattus sprattus	Sprat	1.6	0.00	0.00	0.0%	0.0%
Trisopterus luscus	bib	0.0	0.00	0.37		
		173.50	**112.69**	**143.63**	**65.0%**	**82.8%**

TX36 caught less in #/h of all species added together than TX68 compared to GO4, but looking at individual species catches of *Pomatoschistus* and hooknose (*Agonus cataphractus* L.) were higher. The most abundant species were solenette (*Buglossidium luteum* L.), followed by *scaldfish* (*Arnoglossus laterna* L.), dragonet (*Callionymus lyra* L.), and lesser weever (*Echiichthys vipera* L.), (Table 4-5).

Benthic species

Table 4-6: CPUE in #/h raised to total trip duration of non-target benthic species for the three vessels with the ratio pulse gear/conventional beam trawl in %

Species	Name (EN)	#/h GO4	#/h TX36	#/h TX68	TX36/GO4	TX68/GO4
Ammodytes sp.		15.0	9.61	5.28	64.1%	35.2%
Anthozoa		3.1	0.87	0.37	27.7%	11.8%
Asterias rubens	common star fish	1321.4	683.67	837.32	51.7%	63.4%
Buccinum undatum		3.0	0.00	0.00	0.0%	0.0%
Cancer pagurus		2.3	0.73	0.76	31.6%	33.3%
Corystes cassivelaunus		37.9	58.37	18.38	153.8%	48.4%
Echinidae		5.9	0.00	0.00	0.0%	0.0%
Echinocardium cordatum	sea potato	4.7	89.71	287.26	1893.5%	6063.0%
Ensis sp.		4.5	1.49	0.45	32.7%	9.8%
Hyas coarctatus		0.9	0.29	0.00	33.9%	0.0%
Laevicardium crassum		0.0	0.29	0.00		
Liocarcinus depurator		21.9	10.06	12.91	46.0%	59.1%
Liocarcinus holsatus	swimming crab	1483.7	952.24	1115.83	64.2%	75.2%
Liocarcinus marmoreus		0.0	11.98	11.80		
Loligo sp.		1.9	7.14	0.22	375.3%	11.7%
Loligo subulata		0.0	0.00	0.63		
Necora puber		2.0	0.00	2.98	0.0%	147.4%
Ophiura ophiura	brittle star	1802.3	1538.56	164.99	85.4%	9.2%
Pagurus bernhardus	hermit crab	208.4	369.46	54.96	177.3%	26.4%
Psammechinus miliaris		0.0	5.37	5.62		
Spatangus purpureus		5.6	0.00	0.00	0.0%	0.0%
Spisula sp.		1.5	0.00	0.00	0.0%	0.0%
Myoxocephalus scorpius	Bull-rout	31.4	14.74	28.09	47.0%	89.5%
Mytilus edulis	Common mussel	0.7	0.00	1.49	0.0%	225.4%
Crangon crangon	Common shrimp	14.2	29.15	7.07	205.6%	49.9%
		4972.35	**3783.72**	**2556.41**	**76.1%**	**51.4%**

The most abundant benthic species in the catches were brittle star (*Ophiura ophiura* L.), swimming crab (*Liocarcinus holsatus* L.), common star fish (*Asterias rubens* L.) and hermit crab (*Pagurus Bernardus* L.). When adding all catch components TX68 caught less than TX36 compared to GO4. The only remarkable difference in the pulse trawls was the higher catch of sea potato (*Echinocardium cordatum* L.), (Table 4-6).

Catch comparison from sampled hauls

Overall categories

Landings ('lan'), discards of target species ('cdi'), discards of non-target fish species ('fdi'), discards of benthos ('ben').

The results given in the BoxPlots are calculated means over the sampled hauls, and not raised to trip duration.

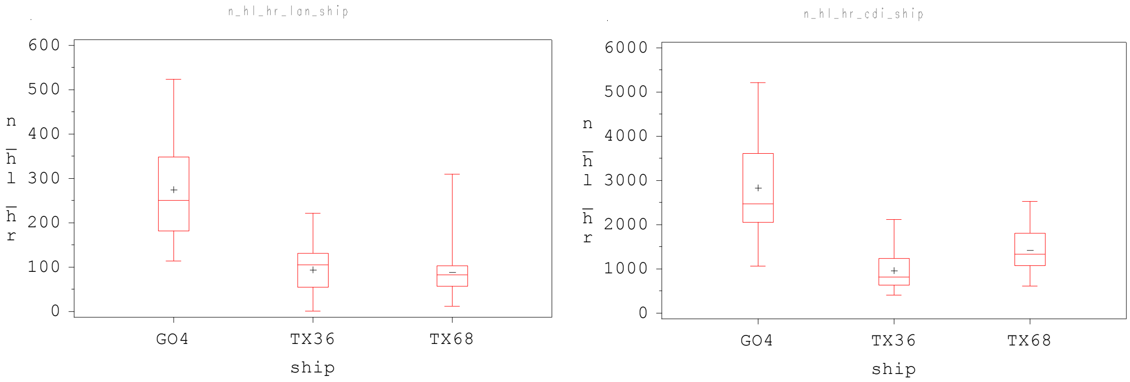


Figure 4-1: BoxPlots for left: landings per unit of effort ('lan') and right: discards per unit of effort of undersized target species ('cdi') expressed in mean #/h over sampled hauls

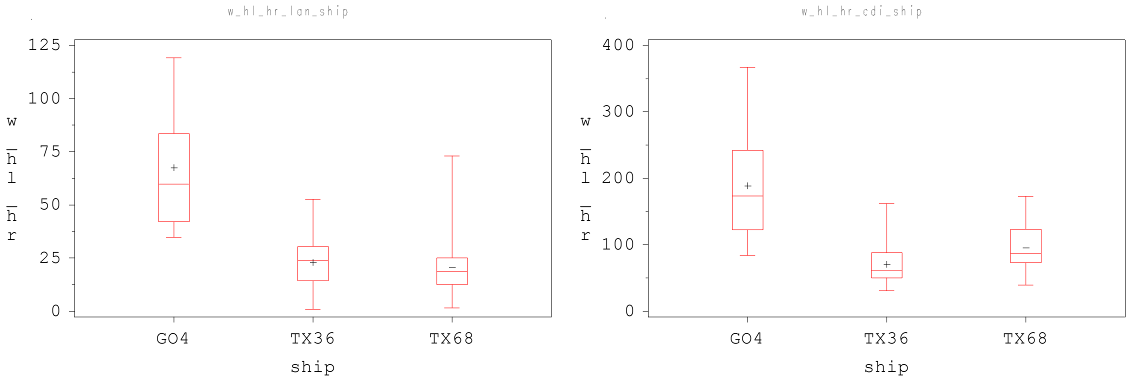


Figure 4-2: BoxPlots for left: landings per unit of effort ('lan') and right: discards per unit of effort of undersized target species ('cdi') expressed in mean kg/h over sampled hauls

The GO4 (273.9 ± 110.0) caught more landings (s) in numbers per hour (#/h) than the TX36 (93.5 ± 54.8) and TX68 (87.8 ± 54.7), with no differences (ns) between the two pulse vessels. Both pulse vessels caught fewer (s) discards of undersized target species (GO4: 2826.0 ± 1112.4; TX36: 959.9 ± 427.4; TX68: 1416.9 ± 447.3, see Figure 4-1 and Table 4-7. In kg/h both pulse trawlers caught less (s) marketable target species (GO4: 67.4 ± 27.3), (TX36: 22.9 ± 13.0) and (TX68: 20.5 ± 12.6), and fewer discards (s) of undersized target species (GO4: 188.7 ± 80.4; TX36: 70.2 ± 31.5; TX68: 95.3 ± 31.8), see Figure 4-2 and Table 4-7.

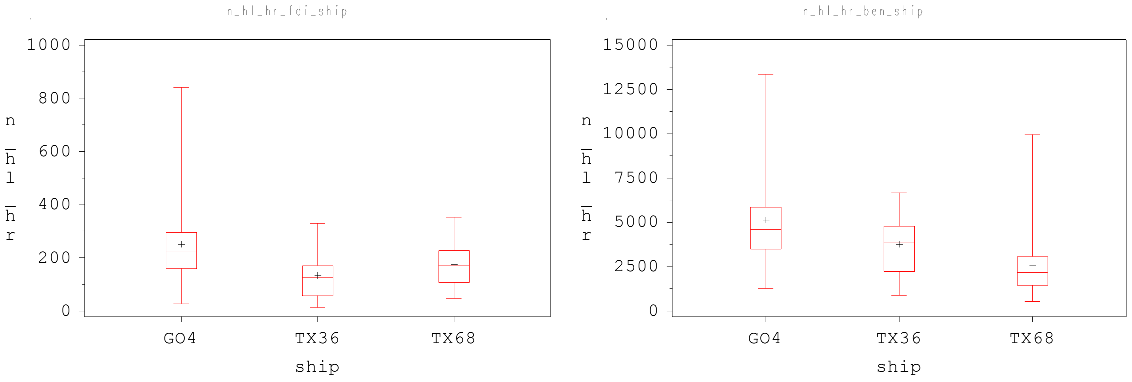


Figure 4-3: BoxPlots for left: discards of undersized non-target species per unit of effort (‘fdi) and right: catches of benthos per unit of effort of undersized target species (‘ben’) expressed in mean #/h over sampled hauls

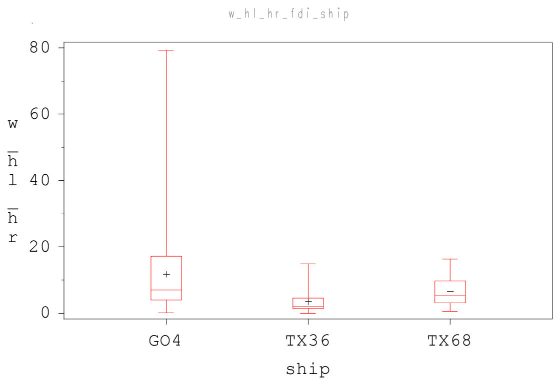


Figure 4-4: BoxPlot for discards of undersized non-target species per unit of effort (‘fdi) expressed in mean kg/h over sampled hauls

For fish discards of non-target species in #/h we found GO4: 250.1 ± 160.8; TX36: 133.4 ± 85.4; and TX68: 175.3 ± 83.8. TX68 caught less benthos (s) in #/h (GO4: 5126.4 ± 2506.2; TX36: 3763.1 ± 1688.0; TX68: 2550.2 ± 1881.9, see Figure 4-3 and Table 4-7.

For discards of non-target fish in kg/h we found GO4: 11.7 ± 14.6, TX36: 3.5 ± 3.4) and TX68: 6.6 ± 4.7. TX36 caught significantly less (s) than GO4, see Figure 4-4 and Table 4-7.

Target species

Plaice

Some species appear in almost every sample (e.g. plaice, sole, and dab, while others are less frequent (*e.g.* brill, turbot, whiting, cod).

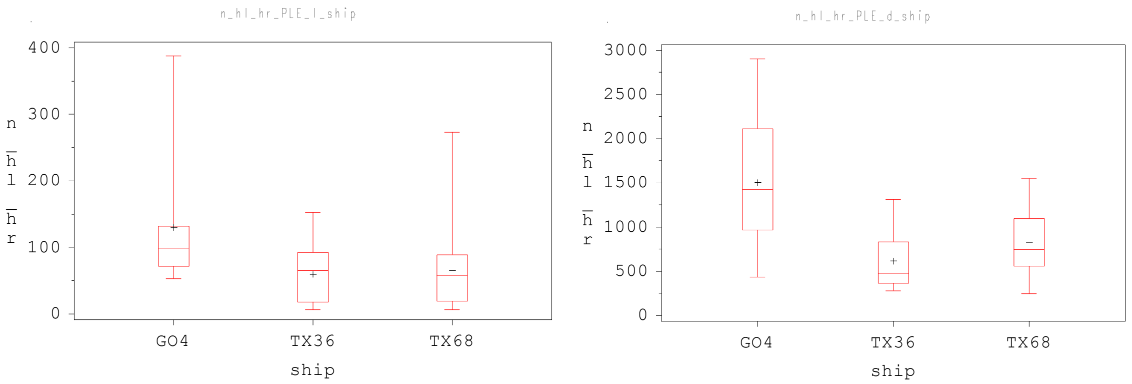


Figure 4-5: BoxPlots for catch per unit of effort of plaice (mean #/h over sampled hauls, left: landings, right: discards)

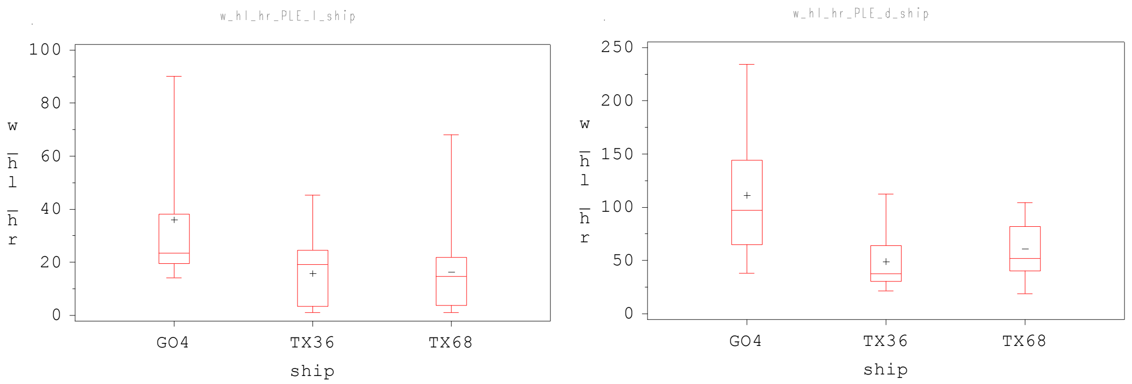


Figure 4-6: BoxPlots for catch per unit of effort of plaice (mean kg/h over sampled hauls, left landings, right discards)

The mean CPUE in #/h over the sampled hauls of marketable plaice was highest for GO4 (129.7 ± 85.6), and lowest for TX36 (59.3 ± 44.3, s) followed by TX68 (65.0 ± 60.0, s difference with GO4). The highest CPUE in #/h for discard plaice was found for GO4 (1502.2 ± 707.2), with TX36 as lowest (615.7 ± 311.7, s difference), followed by TX68 (827.6 ± 340.6, s), see Figure 4-5 and Table 4-8.

The CPUEs for undersized plaice in kg/h were: GO4 (35.9 ± 22.6), TX36 (15.7 ± 13.0) and TX68 (16.3 ± 15.3), clearly lower for both pulse trawl vessels (s). For CPUE of undersized plaice in kg/h we found GO4 (111.1 ± 57.4), TX36 (48.9 ± 25.9, s) en TX68 (60.9 ± 25.9, s) also distinctly lower for the pulse trawls, see Figure 4-6 and Table 4-8.

Sole

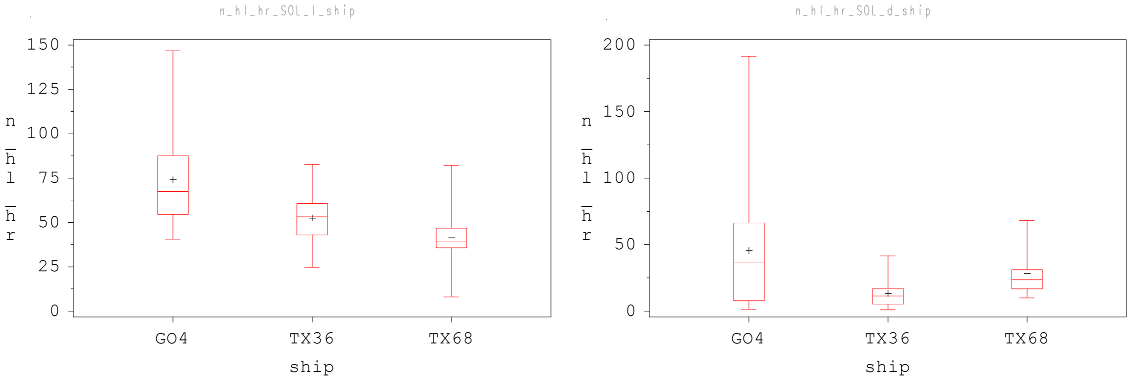


Figure 4-7: BoxPlots for catch per unit of effort of sole (mean #/h over sampled hauls, left: landings, right: discards)

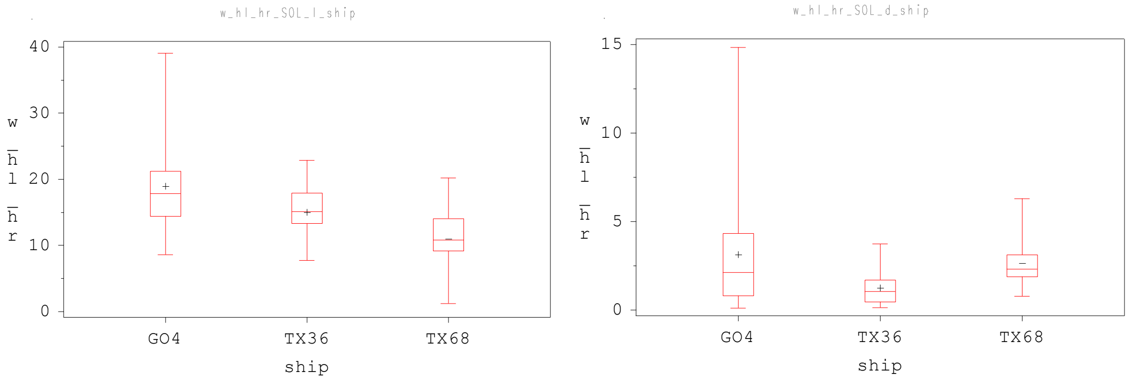


Figure 4-8: BoxPlots for catch per unit of effort of sole (mean kg/h over sampled hauls, left: landings, right: discards)

The mean CPUE in #/h of marketable sole was highest for GO4 (74.1 ± 27.4), followed by TX36 (52.4 ± 15.7, ns difference with GO4) then by TX68 (41.4 ± 20.4, s difference). The highest CPUE for undersized sole in #/h was also found for GO4 (45.6 ± 46.4), met de TX36 as lowest (13.2 ± 10.8, s), followed by TX68 (28.2 ± 17.1, ns), see Figure 4-7 and Table 4-8.

Expressed in kg/h we found for marketable sole: GO4 (18.9 ± 6.6), TX36 (15.0 ± 3.7, ns) en TX68 (10.9 ± 5.7, s). For undersized sole in kg/h these were: GO4 (3.1 ± 3.6), TX36 (1.2 ± 0.9, s) en TX68 (2.6 ± 1.5, ns difference), see Figure 4-8 and Table 4-8.

Dab

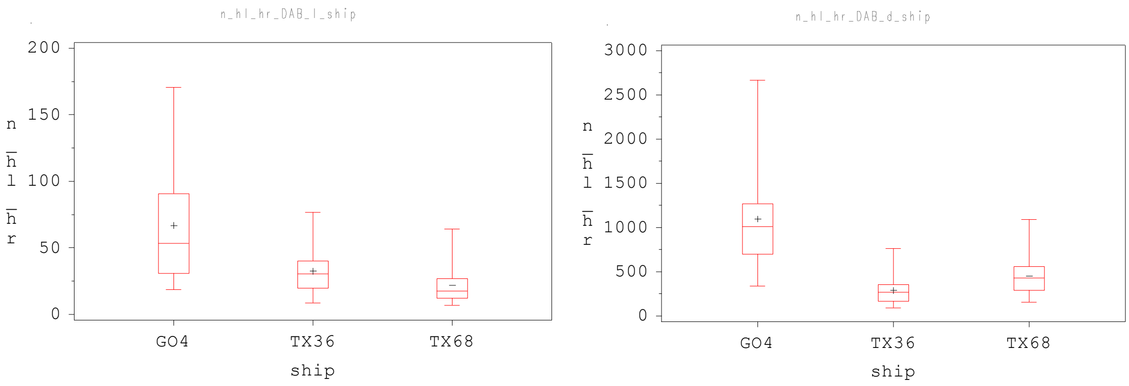


Figure 4-9: BoxPlots for catch per unit of effort of dab (mean #/h over sampled hauls, left: landings, right: discards)

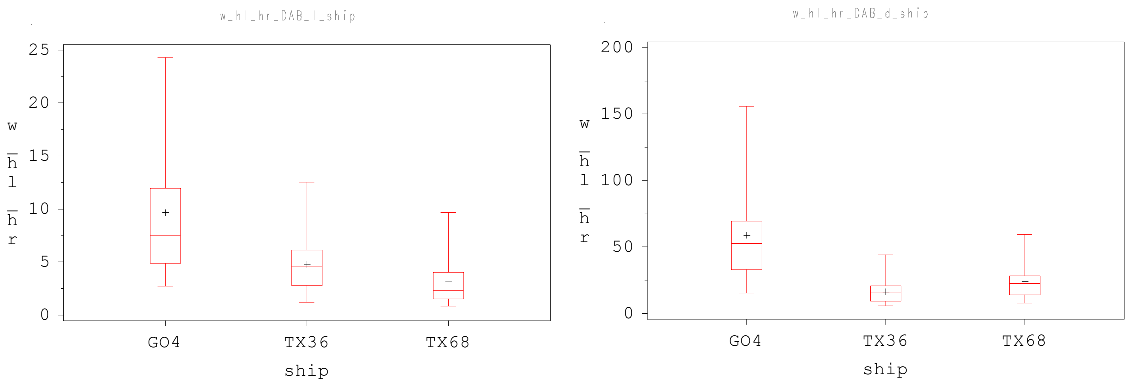


Figure 4-10: BoxPlots for catch per unit of effort of dab (mean kg/h over sampled hauls, left: landings, right: discards)

More or less the same results were found for dab. The mean CPUE in #/h for marketable dab was for GO4 (66.8 ± 40.7), then TX36 (32.4 ± 17.9, s) followed by TX68 (21.9 ± 14.3, s). The CPUE for undersized dab in #/h was for GO4 (1094.6 ± 556.4), with TX36 as lowest (287.7 ± 152.2, s), and TX68 in between (450.7 ± 227.6, s), see Figure 4-9 and Table 4-8.

CPUEs in kg/h for marketable dab were: GO4 (9.7 ± 5.8), TX36 (4.7 ± 2.8, s) en TX68 (3.1 ± 2.1, s). For undersized dab in kg/h GO4 (58.9 ± 33.4), TX36 (16.2 ± 8.1, s) en TX68 (24.2 ± 13.2, s), see Figure 4-10 and Table 4-8.

Brill

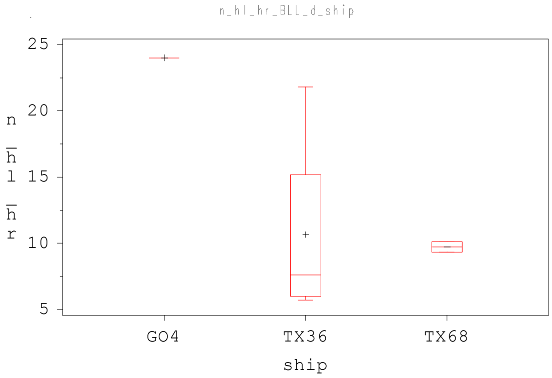


Figure 4-11: BoxPlot for catch per unit of effort of brill (mean #/h over sampled hauls, discards)

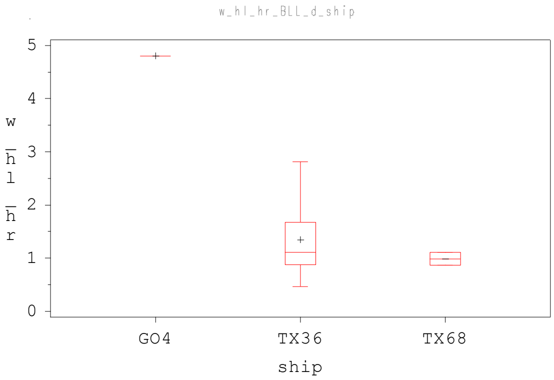


Figure 4-12: BoxPlot for catch per unit of effort of brill (mean kg/h over sampled hauls, discards)

We did not find any marketable brill in our samples. Undersized brill in #/h resulted in: GO4 (24.0), with TX36 coming next (10.6 ± 6.5, ns), and TX68 (9.7 ± 0.5, ns) as lowest, see Figure 4-11 and Table 4-8.

CPUEs of undersized brill in kg/h were: GO4 (4.8), TX36 (1.3 ± 0.8, ns) en TX68 (1.0 ± 0.2, ns), see Figure 4-12 and Table 4-8. Notable is the low number of observations (hauls) at 6.

Turbot

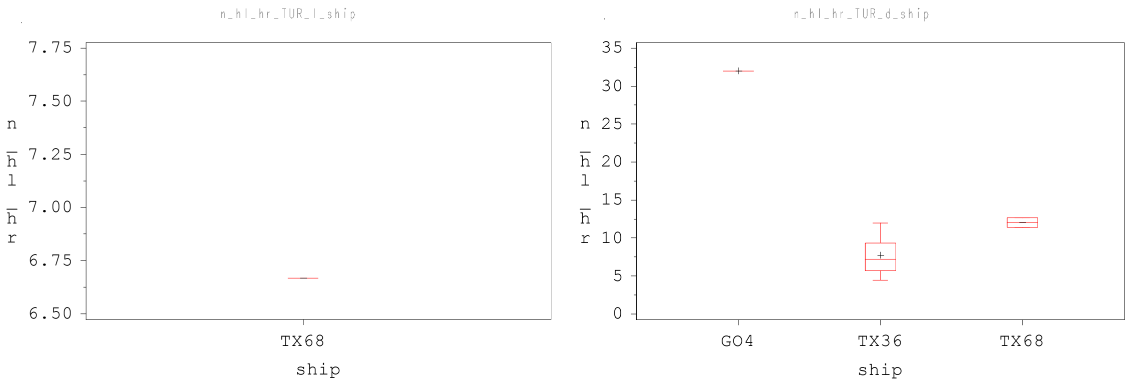


Figure 4-13: BoxPlots for catch per unit of effort of turbot (mean #/h over sampled hauls, left: landings, right: discards)

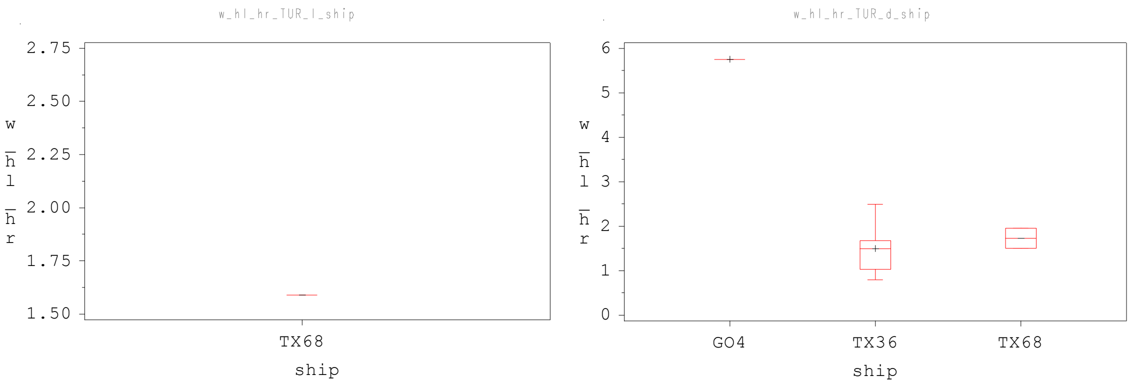


Figure 4-14: BoxPlots for dab (mean kg/h over sampled hauls, left: landings, right: discards)

In turbot we found a similar trend as in brill. In #/h the mean CPUE for marketable turbot of TX68 was 6.7, with no turbot found in the samples on the other two vessels. For undersized turbot in mean #/h GO4 caught 32.0, TX36 (7.7 ± 3.0, s) en TX68 (12.0 ± 0.9, ns), see Figure 4-13 and Table 4-8.

Expressed in kg/h we found the CPUE of undersized turbot for TX68 of 1.6, again for the other two boats, and for undersized turbot in kg/h GO4 5.8, while TX36 gave (1.5 ± 0.7, s) and TX68 (1.7 ± 0.3, ns), see Figure 4-14 and Table 4-8. Again a low number of observations with only 5 hauls.

Whiting

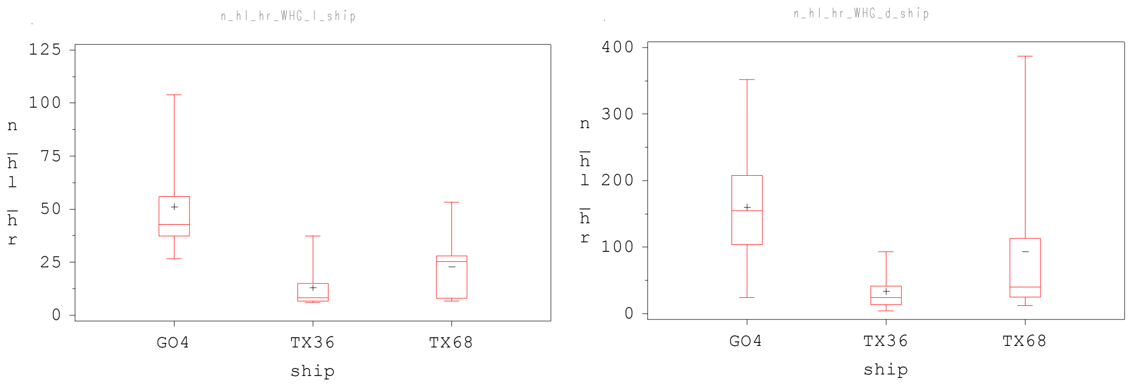


Figure 4-15: BoxPlots for catch per unit of effort of whiting (mean #/h over sampled hauls, left: landings, right: discards)

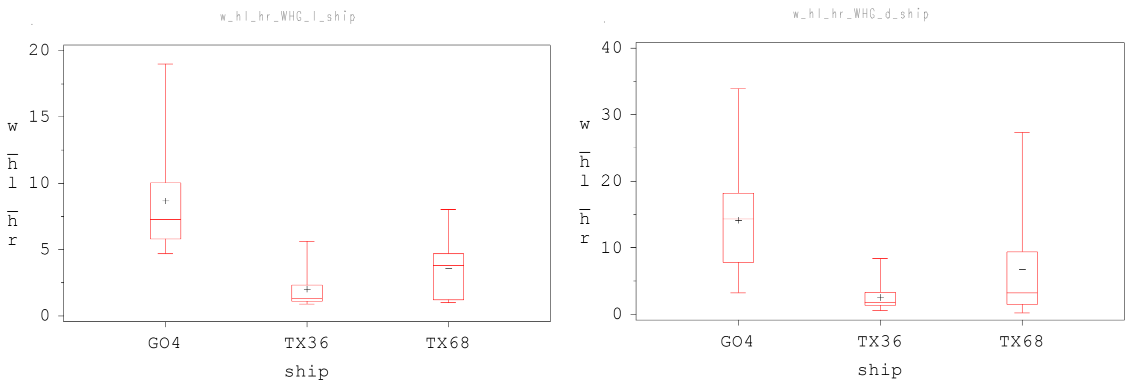


Figure 4-16: BoxPlots for catch per unit of effort of whiting (mean kg/h over sampled hauls, left landings, right discards)

For marketable whiting we found in #/h for GO4 (51.1 ± 22.6), with lowest values for TX36 (12.9 ± 10.7, s), then TX68 (22.7 ± 16.5, s). For undersized whiting in #/h this resulted in GO4 (159.9 ± 82.3), again TX36 being lowest (33.3 ± 27.1, s), followed by TX68 (93.0 ± 105.9, s), see Figure 4-15 and Table 4-8.

In kg/h for marketable whiting these were: GO4 (8.7 ± 4.2), TX36 (2.0 ± 1.6, s) and TX68 (3.6 ± 2.5, s). Undersized whiting in kg/h resulted in: GO4 (14.1 ± 7.8), TX36 (2.5 ± 2.0, s) en TX68 (6.7 ± 7.8, s), see Figure 4-16 and Table 4-8.

Cod

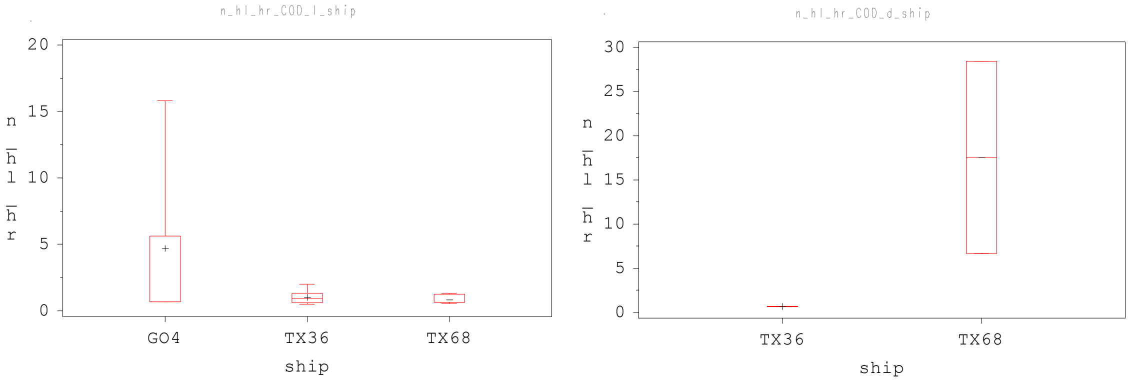


Figure 4-17: BoxPlots for catch per unit of effort of cod (mean #/h over sampled hauls, left: landings, right: discards)

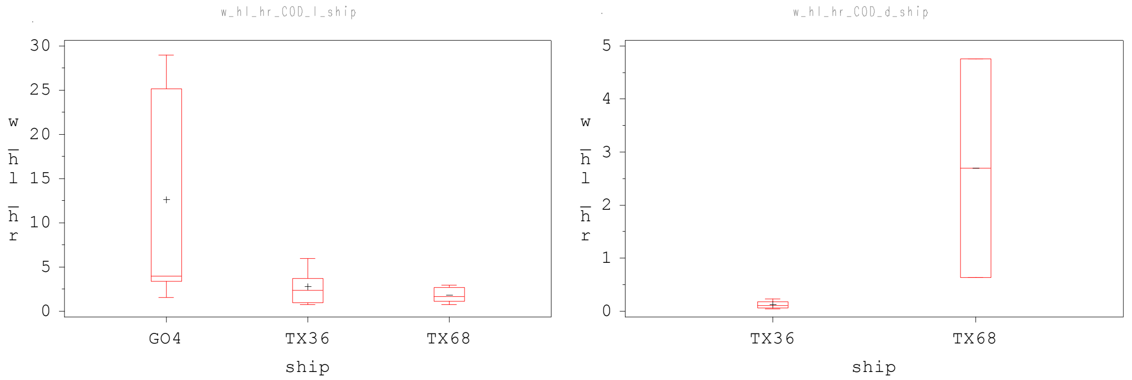


Figure 4-18: BoxPlots for catch per unit of effort of cod (mean kg/h over sampled hauls, left: landings, right: discards)

The CPUE of marketable cod in #/h was for GO4 (4.7 ± 6.6), with TX36 coming next (1.0 ± 0.5, ns) and TX68 last (0.8 ± 0.3, ns). In the case of undersized cod in #/h no fish were found for GO4, fewest on TX36 (0.6 ± 0.0, ns), followed by TX68 (17.5 ± 15.4, ns), see Figure 4-17 and Table 4-8.

Expressed in kg/h we found for marketable cod: GO4 (12.6 ± 13.3), TX36 (2.8 ± 1.9, s) en TX68 (1.8 ± 0.8, s). And for undersized cod in kg/h on GO4 none, on TX36 (0.1 ± 0.1, ns) en TX68 (2.7 ± 2.9, ns), see Figure 4-18 and Table 4-8.

The number of hauls with cod in the samples was low (2 to 13), and conclusions therefore are backed-up by statistics only for CPUE in kg/h of marketable cod.

Table 4-7: Mean landings and discards over sampled hauls, (green = favourable, red = unfavourable, boldface is significant (**s**), statistical tests based on log-transformed data)

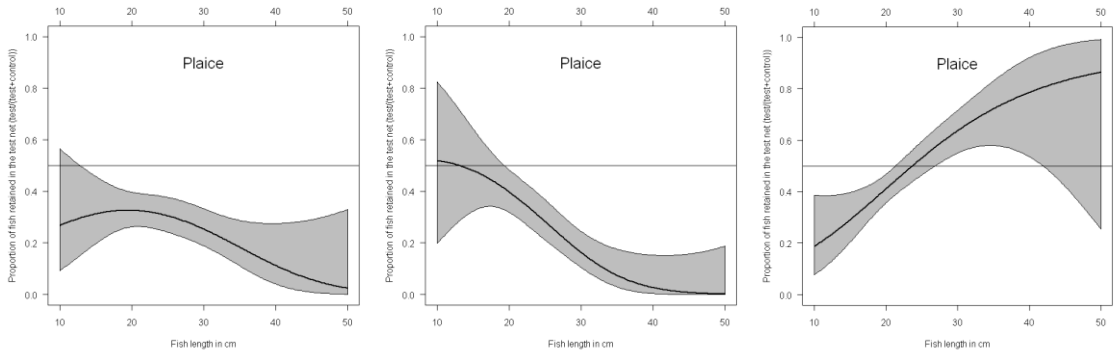
Ship				GO4			TX36			TX68		TX36/GO4	TX68/GO4	TX36/TX68		GLM_output	
Variable	species	cat	n	Mean	Stdev	n	Mean	Stdev	n	Mean	Stdev	%	%	%	Diff TX36 vs. GO4	Diff TX68 vs. GO4	Diff TX36 vs. TX68
n_hl_hr	**lan**	**lan**	33	273.9	110.0	**39**	**93.5**	**54.8**	**32**	**87.8**	**54.7**	**34.1%**	**32.0%**	106.6%	**s**	**s**	ns
w_hl_hr			33	67.4	27.3	**39**	**22.9**	**13.0**	**32**	**20.5**	**12.6**	**34.0%**	**30.4%**	111.8%	**s**	**s**	ns
n_hl_hr	**cdi**	**dis**	**33**	**2826.0**	**1112.4**	**33**	**959.9**	**427.4**	**33**	**1416.9**	**447.3**	**34.0%**	**50.1%**	**67.7%**	**s**	**s**	**s**
w_hl_hr			**33**	**188.7**	**80.4**	**33**	**70.2**	**31.5**	**33**	**95.3**	**31.8**	**37.2%**	**50.5%**	**73.6%**	**s**	**s**	**s**
n_hl_hr	**fdi**	**dis**	30	250.1	160.8	**33**	**133.4**	**85.4**	33	175.3	83.8	**53.3%**	70.1%	76.1%	**s**	ns	ns
w_hl_hr			30	11.7	14.6	**33**	**3.5**	**3.4**	33	6.6	4.7	**29.9%**	56.5%	**53.0%**	**s**	ns	**s**
n_hl_hr	**ben**	**dis**	**33**	**5126.4**	**2506.2**	33	3763.1	1688.0	**33**	**2550.2**	**1881.9**	73.4%	**49.7%**	147.6%	ns	**s**	ns

Table 4-8: Summary of mean CPUE over sampled hauls expressed in #/h and kg/h for landings ('lan') en discards ('dis') of plaice (PLE), sole (SOL), dab (DAB), brill (BLL), turbot (TUR), whiting (WHG) and cod (COD) for the three vessels with the result of the test in significance using the generalized linear model (GLM) (green = favourable, red = unfavourable, boldface is significant (**s**), statistical tests based on log-transformed data)

Ship				GO4			TX36			TX68		TX36/GO4	TX68/GO4	TX36/TX68	GLM_output		
Variable	species	cat	n	Mean	Stdev	n	Mean	Stdev	n	Mean	Stdev	%	%	%	Diff TX36 vs. GO4	Diff TX68 vs. GO4	Diff TX36 vs. TX68
n_hl_hr	**PLE**	**lan**	33	129.7	85.6	**27**	**59.3**	**44.3**	**20**	**65.0**	**60.0**	**45.7%**	**50.1%**	91.1%	**s**	**s**	ns
w_hl_hr			33	35.9	22.6	**27**	**15.7**	**13.0**	**20**	**16.3**	**15.3**	**43.7%**	**45.4%**	96.3%	**s**	**s**	ns
n_hl_hr	**PLE**	**dis**	**33**	**1502.2**	**707.2**	**33**	**615.7**	**311.7**	**33**	**827.6**	**340.6**	**41.0%**	**55.1%**	74.4%	**s**	**s**	ns
w_hl_hr			**33**	**111.1**	**57.4**	**33**	**48.9**	**25.9**	**33**	**60.9**	**25.9**	**44.0%**	**54.8%**	80.4%	**s**	**s**	ns
n_hl_hr	**SOL**	**lan**	**33**	**74.1**	**27.4**	18	52.4	15.7	**18**	**41.4**	**20.4**	70.7%	**55.9%**	126.5%	ns	**s**	ns
w_hl_hr			**33**	**18.9**	**6.6**	18	15.0	3.7	**18**	**10.9**	**5.7**	79.4%	**57.8%**	137.2%	ns	**s**	ns
n_hl_hr	**SOL**	**dis**	31	45.6	46.4	**27**	**13.2**	**10.8**	22	28.2	17.1	**29.0%**	61.9%	**46.8%**	**s**	ns	**s**
w_hl_hr			31	3.1	3.6	**27**	**1.2**	**0.9**	22	2.6	1.5	**39.8%**	84.5%	**47.1%**	**s**	ns	**s**
n_hl_hr	**DAB**	**lan**	**23**	**66.8**	**40.7**	**29**	**32.4**	**17.9**	**25**	**21.9**	**14.3**	**48.5%**	**32.8%**	147.8%	**s**	**s**	ns
w_hl_hr			**23**	**9.7**	**5.8**	**29**	**4.7**	**2.8**	**25**	**3.1**	**2.1**	**49.2%**	**32.2%**	152.6%	**s**	**s**	ns
n_hl_hr	**DAB**	**dis**	**33**	**1094.6**	**556.4**	**33**	**287.7**	**152.2**	**33**	**450.7**	**227.6**	**26.3%**	**41.2%**	**63.8%**	**s**	**s**	**s**
w_hl_hr			**33**	**58.9**	**33.4**	**33**	**16.2**	**8.1**	**33**	**24.1**	**13.2**	**27.5%**	**40.9%**	**67.1%**	**s**	**s**	**s**
n_hl_hr	BLL	dis	1	24.0	.	6	10.6	6.5	2	9.7	0.5	44.4%	40.5%	109.6%	ns	ns	ns
w_hl_hr			1	4.8	.	6	1.3	0.8	2	1.0	0.2	27.9%	20.5%	136.2%	ns	ns	ns
n_hl_hr	**TUR**	**dis**	1	32.0	.	**5**	**7.7**	**3.0**	2	12.0	0.9	**24.2%**	37.6%	64.3%	**s**	ns	ns
w_hl_hr			1	5.8	.	**5**	**1.5**	**0.7**	2	1.7	0.3	**26.0%**	30.1%	86.5%	**s**	ns	ns
n_hl_hr	**WHG**	**lan**	**14**	**51.1**	**22.6**	**8**	**12.9**	**10.7**	**7**	**22.7**	**16.5**	**25.2%**	**44.4%**	56.7%	**s**	**s**	ns
w_hl_hr			**14**	**8.7**	**4.2**	**8**	**2.0**	**1.6**	**7**	**3.6**	**2.5**	**23.2%**	**41.4%**	56.0%	**s**	**s**	ns
n_hl_hr	**WHG**	**dis**	**24**	**159.9**	**82.3**	**15**	**33.3**	**27.1**	**28**	**93.0**	**105.9**	**20.8%**	**58.1%**	**35.8%**	**s**	**s**	**s**
w_hl_hr			**24**	**14.1**	**7.8**	**15**	**2.5**	**2.0**	**28**	**6.7**	**7.8**	**18.0%**	**47.6%**	37.9%	**s**	**s**	ns
n_hl_hr	COD	lan	5	4.7	6.6	13	1.0	0.5	10	0.8	0.3	21.7%	17.6%	123.5%	ns	ns	ns
w_hl_hr			**5**	**12.6**	**13.3**	**13**	**2.8**	**1.9**	**10**	**1.8**	**0.8**	**21.9%**	**14.4%**	152.1%	**s**	**s**	ns
n_hl_hr	COD	dis	0	n/a	n/a	4	0.6	0.0	2	17.5	15.4			3.7%	ns	ns	ns
w_hl_hr			0	n/a	n/a	4	0.1	0.1	2	2.7	2.9			4.6%	ns	ns	ns

Length dependency of results for major target species

Plaice

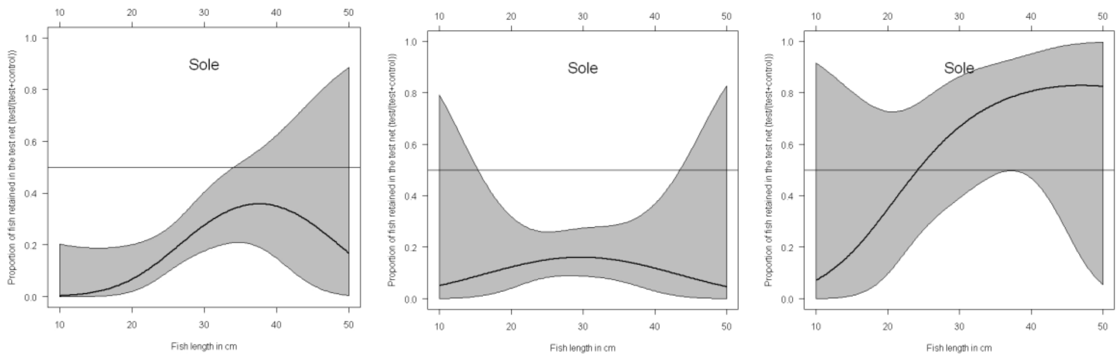


TX36 vs. GO4 | TX68 vs. GO4 | TX36 vs. TX68

Figure 4-19: Proportion of fish retained in the test net (=test/(test+control) vs. length for <u>plaice</u> (value 0.5 means both gears catch equal numbers, the solid line gives the mean, and the grey band gives the 95% confidence limit)

TX36 caught fewer plaice over the entire length range than GO4. The difference is lowest around 20 cm, and especially lower numbers of larger plaice were caught. This is also the case for the TX68, but here the catch of small fish is equal. When comparing both pulse trawlers TX68 seems to catch more large plaice, but given the wide confidence bands, this result is uncertain (Figure 4-19).

Sole

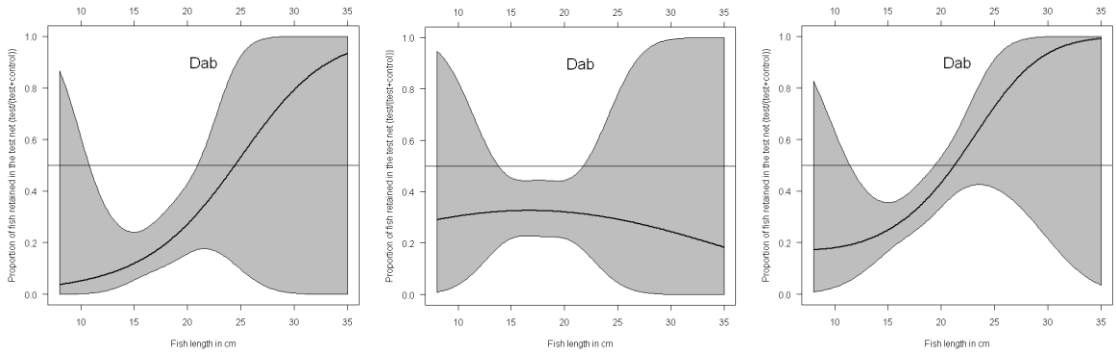


TX36 vs. GO4 | TX68 vs. GO4 | TX36 vs. TX68

Figure 4-20: Proportion of fish retained in the test net (=test/(test+control) vs. length for <u>sole</u> (value 0.5 means both gears catch equal numbers, the solid line gives the mean, and the grey band gives the 95% confidence limit)

TX36 caught fewer small sole than GO4, while for TX68 there is much uncertainty both for small and large fish. TX36 appears to catch fewer small and more large sole, but again the conclusion is debatable, die to the wide confidence bands (Figure 4-20).

Dab



TX36 vs. GO4 | TX68 vs. GO4 | TX36 vs. TX68

Figure 4-21: Proportion of fish retained in the test net (=test/(test+control) vs. length for <u>dab</u> (value 0.5 means both gears catch equal numbers, the solid line gives the mean, and the grey band gives the 95% confidence limit)

The dab results are similar in trend as the sole results, with higher uncertainty (Figure 4-21).

Spinal damage of cod

On GO4 48 cod were filleted and photographed, with only one fish showing a haemorrhage near the spine in the tail section, but no fracture was seen (Appendix D: Table 8-1; Appendix E: Figure 8-1).

A total of 27 fish were studied on TX36. In 2 individuals spinal fracture was seen, which means 7.4%. For TX68 these were respectively 18 fish with 2 fractures, thus 11.1% (Appendix D: Table 8-2 and Table 8-3; Appendix E: Figure 8-2 and Figure 8-4). It was notable that spinal fractures appeared both in juvenile and in marketable fish.

The digital pictures show frequent haemorrhages in cod for the pulse trawls and occasionally a fracture of the spine. This was not the case for the GO4 where cod where photographed later in week 42.

Spinal damage of whiting

On TX36 and TX68 whiting was studied too. Of a total of 47 individuals only one fish on TX36 showed spinal fracture, a percentage of 2.1%. This injury may have been caused by the electrical stimulus or by mechanical forces during haul-back and discharge on deck. This fish was 32 cm long while longer fish did not show any damage (Appendix D: Table 8-4). The filleted fish did hardly show any haemorrhages (Appendix E: Figure 8-3). On TX68 a total of 10 individuals were taken from the catch and filleted, but not photographed. These fish showed no fractures or other damages (See Appendix A for TX68).

5. Discussion

As mentioned earlier in quite a number of hauls undersized fish was scored as landings (cat = ‘l’) and marketable fish as discards (cat = ‘d’). This can be a result of sorting errors by the crew. As we are interested in the differences between gear types (pulse vs. conventional) we corrected these scores in the analysis.

More hauls were sampled on GO4 than on both pulse trawl vessels and also more frequently both plaice and sole from the same haul. The mean CPUE (kg/h) calculated from sampled hauls deviated for various species considerably from the CPUEs raised to total trip duration, especially for low number of observations (hauls) in which these species were found. This means that the sampling procedure did not produce reliable results in all cases. The length-dependent analyses also showed that confidence bands were often wide indicating that the number of fish measured was low. This means that the results should be interpreted more in terms of giving a trend than producing absolute comparative data. In future catch comparisons one should ensure that more fish are sampled and measured to enhance statistical validity.

When comparing the capture efficiency of fishing gears one should accurately document technical and constructional details. Differences in catch are caused by many factors. Apart from the mesh size in the cod-ends, the ground rope construction and the netting used play an important role as well. The nets deployed on TX36 were very different than the usual beam trawl nets with the square front and double aft parts. We did not investigate these differences in great detail and the questions remains whether the results may have been affected by the gear differences other than the differences in stimulation. We cancelled any adverse effect from differences in mesh size by making all cod-ends from the same bale of netting. This does not exclude any other effects in gear differences completely, but as mesh size is one of the most determining variables other effects would have likely been small.

When measuring and comparing fish from several gears often numbers at length are found in one of them, but not in one of the others. Some researchers suggest to set these missing fish at zero catch. There may be a suit of reasons for fish not appearing in a sample: they may not have been on the grounds at all in range of a particular net to be caught, as fish distribution is often patchy, they may have been on the grounds, but out of reach of the net, they may have escaped from the gear, or they may have missed to be taken in a sample. Diurnal differences in behaviour may cause fish to stay out of reach, e.g. cod and whiting are usually caught mostly during the night. This problem turned out to be largest for less abundant species such as: brill, turbot, whiting and cod. We often found low numbers of hauls for these species in our data. We chose here to not set missing values at zero, and use the data as they emerged to avoid creating a dataset suggesting outcomes that were not really existing. This does mean, however, that our conclusions are most valid for the most abundant species such as plaice, sole and dab, and more uncertain for the other species brill, turbot, whiting, and cod.

When we compared the results with trials conducted in 2006 in which five trips of MFV UK153, fishing with pulse trawls with five trips with conventional beam trawls (van Marlen et al., 2006), we found, that the total landings in kg/h, based on the auction data, were in the same order of magnitude for the pulse trawl vessels in our present experiment. In 2006 we found in total landings for the pulse trawl vessel some 68% (ranging from 60-70%, with one outlier of 95%), whilst here the results were: 58% for the TX36 and 63% for the TX68. The catch efficiencies for sole and plaice seemed to have been raised somewhat. Now we found for sole some 84% for the TX36 and 87% for the TX68, then the CPUEs varied between 66-93% (78% for all trips taken together). For plaice these values were: 71% for the TX36 and 72% for the TX68 %, compared to 53-90% (65% for all trips taken together) in 2006. In our recent experiments we also did see a significant reduction in the CPUE of undersized sole in comparison with GO4, based on sampled hauls, for TX36, but not for TX68, whilst the CPUEs for undersized plaice were now significantly lower for both pulse trawl vessels and this was not the case in 2006.

The CPUEs of benthos (in #/h) were 73% (TX36, ns) and 50% (TX68, s) for the sampled hauls, compared to that of the GO4. The catch comparison of pulse and conventional beam trawls onboard FRV "Tridens" resulted in 75% (in kg/h) for the pulse trawl (van Marlen et al., 2005). In 2006 three benthic species were analysed in detail: sandstar (*Astropecten irregularis* L.), common starfish (*Asterias rubens* L.), and swimming crab (*Liocarcinus holsatus* L.), which gave catch rates of respectively: 24%, 75% and 53% (in #/h) for the pulse trawl (van Marlen et al., 2006). Now we found for these species: sandstar: no reported catches, starfish: 52% (TX36) en 63% (TX68), and swimming crab: 64% (TX36) en 75% (TX68). The catches of starfish seemed somewhat declined, and those of swimming crab increased, but this conclusion could not be back-up with a statistical test with only one trip in the present dataset.

Pulse trawls are continuously improved, *e.g.* the DELMECO-group offer a wing-shaped beam instead of the usual cylindrical in their new versions, but with two trawl shoes per side contrary to the pulse wing. This means that our conclusions should be restricted to the technical state of the gears as they were tested in May 2011. On the other hand, when pulse stimulation remains unchanged we may not expect great differences with the results produced here.

The ICES advice calls for ensuring unlimited growth in capture efficiency of pulse trawls and a proper control and enforcement regime while enhancing sustainable development in fisheries. In the Netherlands a special task group on control and enforcement issue was established, with representatives of the Dutch fishing industry, pulse trawl producers, the Directorate of fisheries of the Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL&I), researchers of IMARES and the General Inspection Service (AID) to address these issues. This group is currently working out additional technical requirements and requirements on electrical power, voltage used and possibly other important electro-technical variables, and explores the idea of certification of pulse trawls. The results of this study will be used in the discussions of this group. In addition the wish was expressed for further monitoring of catches, by-catches and pulse system variables onboard commercial pulse trawl vessels.

6. Conclusions

In Net Revenue the pulse trawl vessels (TX36 and TX68) fishing with pulse trawls in the version of May 2011 were much more efficient (55-84% higher) than the vessel with conventional beam trawls (GO4), mainly due to their lower fuel consumption (46-60% lower).

The vessels fishing with pulse trawls caught fewer of the main target species (65-69%), but also less fish discards (30-50%) and fewer benthic species (48-73%) than the vessel fishing with conventional beam trawls in this period and on these fishing grounds. Cod catches were very low and smaller catches (19-42%) than for the conventional beam trawl could only be proven for marketable sizes in kg/h in both pulse trawls.

For plaice and dab the differences were statistically significant, but not for brill, turbot, and cod. Both pulse trawl vessels did not show any significant differences in main target species when compared with each other. TX68 caught clearly less marketable sole, but not fewer undersized fish than GO4. TX36 did catch fewer discard sole than GO4, but this was not the case for marketable sizes. TX36 did catch fewer juvenile sole and dab than TX68. Catches of brill and turbot were so small that statistical evidence of differences was hardly found. The only significant difference was for small turbot on TX36. Both pulse trawl vessels caught clearly less undersized and marketable whiting than GO4.

Spinal fractures in cod did occur in the catches of the pulse trawl vessels in both undersized and marketable fish, but the rate was low at 7-11%. There were hardly any spinal fractures in whiting.

There was a reasonable correlation between CPUEs found from the auction data and the sampled hauls for the most abundant species, such as plaice and sole. For less abundant species the results do not match very well, and care should be taken to increase the sampling rate in future comparative fishing studies.

7. Acknowledgements

The authors are indebted to the Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL&I) for financially supporting this study, and to the skippers and crew of MFV "Jan van Toon" TX36, MFV "Vertrouwen" TX68, MFV "George Johannes Klazina" GO4, MFV "Dirkje" TH10 and MFV "Buis" OD17 for their fine cooperation. In addition we wish to thank F.J. Quirijns of IMARES for constructional criticism.

8. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

Rapport C122b/11
Project Number: 430.1301.401

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: F.J. Quirijns (M.Sc.)
Researcher

Signature:

Date: 22/11/2011

Approved: T.P. Bult (Ph.D.)
Head Fisheries Department

Signature:

Date: 22/11/2011

Appendix A. Cruise reports

Cruise report TX36

Ship (incl. address)	TX-36 “Jan van Toon” Vis Vis Ltd. Wulkpad 2 1794-BK Oosterend, Netherlands Tel.: +31 222-318651		
Year, month, week	2011, May, week 19	Trip number	
Scientists	Evert van Barneveld (IMARES) Eddy Buyvoets (ILVO)		
Port of departure, date, time	Oudeschild 8-5-2011 22:00 h		
Port of arrival, date, time	IJmuiden 13-5-2011 05:00 h		
Gear, mesh size, tickler chains	Pulse Wing HFK, width 12 m 8 cm mesh in cod-end		
Totale catch by species	See auction list		
Number of hauls	45		
Number of hauls sampled (discards, landings)	33 hauls discards sampled 33 hauls landings sampled		
Weather	Monday to Wednesday very fine weather (wind B 2) Thursday more wind (B 4)		
Comments	One time during the week (during haul 33 after which this haul was restarted) there was a malfunctioning of the pulse wing with replacement of a pulse module.		

Cruise report TX68

Ship (incl. address)	TX68 "Vertrouwen" Cor Daalder email: cordaalder@gmail.com Cor Bremerstraat 4 Tel: +31 6 1338 6264 1794 AX Oosterend Texel, Netherlands		
Year, month, week	2011, May, week 19	Trip number	
Scientists	J.A.M. Wiegerinck (IMARES) Christian van den Berghe (ILVO)		
Port of departure, date, time	Oudeschild, Sunday 8 May 2011 at 22.30 h		
Port of arrival, date, time	Den Helder, Friday 13 May 2011 at 05.00 h		
Gear, mesh size, tickler chains	Pulse trawl (Delmeco), width 12 m, mesh size 80 mm, no tickler chains Electrode length (from wing to groundrope): 6 m. Main engine power 1488 hp (on propeller 1250-1300 hp) Electrical power: 6 kW 1st mesh size measurement was done on previous Friday in the net loft (80 mm) 2nd mesh size measurement was done after last haul trek (10 readings with Omega-meter on each side) resulting in the following averages: Port side: 83.6 mm Starboard side: 83.9 mm		
Totale catch by species	See auction list		
Number of hauls	48		
Number of hauls sampled (discards, landings)	33		
Weather	Fine weather, calm see		
Comments	Big cod, larger than 50 cm showed little damage. Some haemorrhages and a few broken spines (see tables on cod observations and photos). Whiting (some 10 filleted) showed no damage (no photos were taken).		

Cruise report GO4

Ship (incl. address)	GO4 "George Johannes Klazina" 't Mannetje & Zn Bernardstraat 33 3248 AC Melissant, Netherlands		
Year, month, week	2011, May, week 19	Trip number	
Scientists	E. van Os-Koomen (IMARES) K. Vanhalst (ILVO)		
Port of departure, date, time	Scheveningen, 09-05-2011 at 01.30 h		
Port of arrival, date, time	Scheveningen, 13-05-2011 at 01.00 h		
Gear, mesh size, tickler chains	Conventional beam trawl 80 mm mesh in cod-end 12 tickler chains		
Totale catch by species	Sole - 1291 kg Plaice - 2565 kg Turbot - 263 kg Brill - 147 kg Seabass - 94 kg Cod - 134 kg Tub gurnard - 1322 kg Horse mackerel - 95 kg Red Mullet - 75 kg Dab - 250 kg Whiting - 201 kg Flounder - 120 kg		
Number of hauls	45		
Number of hauls sampled (discards, landings)	33		
Weather	Fine		
Comments	None		

Appendix B. Trawl lists of the three vessels

ship	gear	meshsize	haul	year	month	week	day	tset	thaul	duration	poslat	poslon	depth	winddir	windforc
GO4	BT12	80	1	2011	5	19	9	03:15	05:15	120	52.11	3.56	23	135	2
GO4	BT12	80	2	2011	5	19	9	05:40	07:40	120	52.19	3.38	25	180	2
GO4	BT12	80	3	2011	5	19	9	08:15	09:45	90	52.32	3.4	29	180	2
GO4	BT12	80	4	2011	5	19	9	10:00	11:30	90	52.3	3.38	30	180	2
GO4	BT12	80	5	2011	5	19	9	11:45	13:15	90	52.27	3.36	27	180	2
GO4	BT12	80	6	2011	5	19	9	13:45	15:15	90	52.21	3.36	27	180	2
GO4	BT12	80	7	2011	5	19	9	15:30	17:00	90	52.19	3.23	28	180	2
GO4	BT12	80	8	2011	5	19	9	17:20	18:50	90	52.15	3.05	36	180	2
GO4	BT12	80	9	2011	5	19	9	19:10	20:40	90	52.06	2.59	36	180	2
GO4	BT12	80	10	2011	5	19	9	21:00	22:30	90	52.04	2.57	36	180	2
GO4	BT12	80	11	2011	5	19	9	23:15	00:45	90	52	3.06	36	180	2
GO4	BT12	80	12	2011	5	19	10	01:00	03:00	120	52	3.05	34	180	2
GO4	BT12	80	13	2011	5	19	10	03:15	05:15	120	52	3.03	32	180	2
GO4	BT12	80	14	2011	5	19	10	05:30	07:30	120	51.58	3.03	32	180	2
GO4	BT12	80	15	2011	5	19	10	08:00	09:30	90	51.58	3.03	32	180	2
GO4	BT12	80	16	2011	5	19	10	09:50	11:20	90	52.01	3.05	32	180	2
GO4	BT12	80	17	2011	5	19	10	12:00	13:30	90	52.13	3.13	32	180	2
GO4	BT12	80	18	2011	5	19	10	13:50	15:20	90	52.18	3.13	32	180	2
GO4	BT12	80	19	2011	5	19	10	14:45	16:15	90	52.16	3.34	25	180	2
GO4	BT12	80	20	2011	5	19	10	17:35	19:05	90	52.17	3.43	24	180	2
GO4	BT12	80	21	2011	5	19	10	19:20	20:50	90	52.27	3.49	24	180	2
GO4	BT12	80	22	2011	5	19	10	21:10	22:40	90	52.29	3.5	24	180	2
GO4	BT12	80	23	2011	5	19	10	23:30	01:30	120	52.27	3.5	24	180	2
GO4	BT12	80	24	2011	5	19	11	01:45	03:45	120	52.24	3.44	24	180	2
GO4	BT12	80	25	2011	5	19	11	04:00	06:00	120	52.24	3.42	24	180	2
GO4	BT12	80	26	2011	5	19	11	06:20	08:20	120	52.23	3.43	24	180	2
GO4	BT12	80	27	2011	5	19	11	08:45	10:15	90	52.22	3.44	24	180	2
GO4	BT12	80	28	2011	5	19	11	10:30	12:00	90	52.29	3.51	24	180	2
GO4	BT12	80	29	2011	5	19	11	12:25	13:55	90	52.39	3.59	24	180	2
GO4	BT12	80	30	2011	5	19	11	14:15	15:45	90	52.39	3.59	24	180	2
GO4	BT12	80	31	2011	5	19	11	15:45	17:15	90	52.49	3.57	24	180	2

ship	gear	meshsize	haul	year	month	week	day	tset	thaul	duration	poslat	poslon	depth	winddir	windforc
GO4	BT12	80	32	2011	5	19	11	18:05	19:35	90	52.5	4.08	21	225	2
GO4	BT12	80	33	2011	5	19	11	19:50	21:20	90	52.45	4.03	21	225	2
GO4	BT12	80	34	2011	5	19	11	22:00	23:30	90	52.33	4.1	21	225	2
GO4	BT12	80	35	2011	5	19	12	00:00	02:00	120	52.34	4.1	21	225	2
GO4	BT12	80	36	2011	5	19	12	02:30	04:30	120	52.34	4.07	20	225	2
GO4	BT12	80	37	2011	5	19	12	04:50	06:50	120	52.23	3.59	22	225	2
GO4	BT12	80	38	2011	5	19	12	07:10	08:40	90	52.27	3.58	22	225	2
GO4	BT12	80	39	2011	5	19	12	09:00	10:30	90	52.21	3.56	21	225	2
GO4	BT12	80	40	2011	5	19	12	11:00	12:30	90	52.21	4.02	21	315	2
GO4	BT12	80	41	2011	5	19	12	12:45	14:15	90	52.2	4.03	20	315	2
GO4	BT12	80	42	2011	5	19	12	14:40	16:10	90	52.22	3.59	21	315	3
GO4	BT12	80	43	2011	5	19	12	16:30	18:00	90	52.2	4.02	21	270	4
GO4	BT12	80	44	2011	5	19	12	18:15	19:45	90	52.22	4.01	21	270	4
GO4	BT12	80	45	2011	5	19	12	20:00	21:30	90	52.23	4.01	21	270	4
TX36	BT12e1	80	1	2011	5	19	9	01:15	03:40	145	52.52	4.13	24	135	2
TX36	BT12e1	80	2	2011	5	19	9	03:50	06:00	130	52.45	3.48	22	180	2
TX36	BT12e1	80	3	2011	5	19	9	06:20	07:55	95	52.37	3.45	25	180	2
TX36	BT12e1	80	4	2011	5	19	9	08:00	09:50	110	52.31	3.34	24	180	2
TX36	BT12e1	80	5	2011	5	19	9	10:00	11:30	90	52.32	3.36	27	180	2
TX36	BT12e1	80	6	2011	5	19	9	11:45	13:15	90	52.3	3.38	24	180	2
TX36	BT12e1	80	7	2011	5	19	9	13:30	15:00	90	52.22	3.4	25	180	2
TX36	BT12e1	80	8	2011	5	19	9	15:10	16:50	100	52.21	3.27	30	180	2
TX36	BT12e1	80	9	2011	5	19	9	17:00	18:25	85	52.2	3.14	32	180	2
TX36	BT12e1	80	10	2011	5	19	9	18:45	20:30	105	52.14	3.05	36	180	2
TX36	BT12e1	80	11	2011	5	19	9	20:40	22:10	90	52.04	2.56	38	180	2
TX36	BT12e1	80	12	2011	5	19	9	22:25	23:55	90	52	3.08	25	180	2
TX36	BT12e1	80	13	2011	5	19	10	00:10	02:05	115	52.05	2.56	24	180	2
TX36	BT12e1	80	14	2011	5	19	10	02:15	04:05	110	51.59	3.05	26	180	2
TX36	BT12e1	80	15	2011	5	19	10	04:15	06:10	115	51.57	3.05	25	180	2
TX36	BT12e1	80	16	2011	5	19	10	06:20	08:10	110	51.55	3.03	26	180	2
TX36	BT12e1	80	17	2011	5	19	10	08:20	09:45	85	51.55	3.03	28	180	2
TX36	BT12e1	80	18	2011	5	19	10	10:00	11:35	95	52.03	3.06	30	180	2
TX36	BT12e1	80	19	2011	5	19	10	11:45	13:25	100	52.11	3.1	33	180	2
TX36	BT12e1	80	20	2011	5	19	10	13:40	15:20	100	52.17	3.19	24	180	2

ship	gear	meshsize	haul	year	month	week	day	tset	thaul	duration	poslat	poslon	depth	winddir	windforc
TX36	BT12e1	80	21	2011	5	19	10	15:30	17:05	95	52.17	3.44	21	180	2
TX36	BT12e1	80	22	2011	5	19	10	17:25	19:10	105	52.17	3.44	21	180	2
TX36	BT12e1	80	23	2011	5	19	10	19:20	21:05	105	52.21	3.5	23	180	2
TX36	BT12e1	80	24	2011	5	19	10	21:15	23:10	115	52.29	3.54	22	180	2
TX36	BT12e1	80	25	2011	5	19	10	23:20	01:25	125	52.27	3.49	23	180	2
TX36	BT12e1	80	26	2011	5	19	11	01:40	03:35	115	52.23	3.5	23	180	2
TX36	BT12e1	80	27	2011	5	19	11	03:45	05:50	125	52.25	3.48	23	180	2
TX36	BT12e1	80	28	2011	5	19	11	06:20	08:05	105	52.24	3.43	24	180	2
TX36	BT12e1	80	29	2011	5	19	11	08:20	10:05	105	52.19	3.47	24	180	2
TX36	BT12e1	80	30	2011	5	19	11	10:20	12:10	110	52.28	3.48	23	180	2
TX36	BT12e1	80	31	2011	5	19	11	12:35	14:10	95	52.37	3.58	22	180	2
TX36	BT12e1	80	32	2011	5	19	11	14:20	16:00	100	52.45	4.04	23	225	2
TX36	BT12e1	80	33	2011	5	19	11	17:50	19:50	120	52.53	4.04	22	225	2
TX36	BT12e1	80	34	2011	5	19	11	20:05	21:45	100	52.51	4.09	22	225	2
TX36	BT12e1	80	35	2011	5	19	11	21:55	23:45	110	52.45	4.05	22	225	2
TX36	BT12e1	80	36	2011	5	19	11	23:55	01:55	120	52.36	4.07	22	225	2
TX36	BT12e1	80	37	2011	5	19	12	02:05	04:15	130	52.36	4.03	23	225	2
TX36	BT12e1	80	38	2011	5	19	12	04:25	06:30	125	52.3	3.59	20	225	2
TX36	BT12e1	80	39	2011	5	19	12	06:40	08:40	120	52.26	4.02	22	225	2
TX36	BT12e1	80	40	2011	5	19	12	08:50	10:40	110	52.26	4.02	21	315	2
TX36	BT12e1	80	41	2011	5	19	12	10:55	12:30	95	52.23	4.05	22	315	2
TX36	BT12e1	80	42	2011	5	19	12	12:40	14:20	100	52.24	3.55	22	315	3
TX36	BT12e1	80	43	2011	5	19	12	14:30	15:55	85	52.19	4.05	18	270	4
TX36	BT12e1	80	44	2011	5	19	12	16:05	17:50	105	52.27	3.55	21	270	4
TX36	BT12e1	80	45	2011	5	19	12	18:05	19:50	105	52.21	4.03	18	270	4
TX68	BT12e2	80	1	2011	5	19	9	02:00	03:45	105	52.5	4.07	22	270	1
TX68	BT12e2	80	2	2011	5	19	9	04:00	06:00	120	52.43	3.55	23	270	1
TX68	BT12e2	80	3	2011	5	19	9	06:15	07:45	90	52.36	3.41	25	270	1
TX68	BT12e2	80	4	2011	5	19	9	08:00	09:45	105	52.32	3.37	28	270	1
TX68	BT12e2	80	5	2011	5	19	9	10:00	11:30	90	52.3	3.36	28	270	1
TX68	BT12e2	80	6	2011	5	19	9	11:45	13:15	90	52.28	3.37	28	270	1
TX68	BT12e2	80	7	2011	5	19	9	13:30	15:00	90	52.24	3.38	27	270	1
TX68	BT12e2	80	8	2011	5	19	9	15:10	16:45	95	52.22	3.27	28	270	1
TX68	BT12e2	80	9	2011	5	19	9	17:05	18:35	90	52.2	3.13	30	270	1

ship	gear	meshsize	haul	year	month	week	day	tset	thaul	duration	poslat	poslon	depth	winddir	windforc
TX68	BT12e2	80	10	2011	5	19	9	18:50	20:20	90	52.14	3.03	32	270	1
TX68	BT12e2	80	11	2011	5	19	9	20:35	22:10	95	52.08	2.56	30	270	1
TX68	BT12e2	80	12	2011	5	19	9	22:20	23:50	90	52.05	2.54	30	270	1
TX68	BT12e2	80	13	2011	5	19	10	00:05	01:50	105	52	3.05	30	270	1
TX68	BT12e2	80	14	2011	5	19	10	02:05	03:55	110	51.58	3.08	30	270	1
TX68	BT12e2	80	15	2011	5	19	10	04:10	06:00	110	51.56	3.07	30	270	1
TX68	BT12e2	80	16	2011	5	19	10	06:15	07:55	100	51.55	3.03	30	225	1
TX68	BT12e2	80	17	2011	5	19	10	08:10	09:45	95	51.55	3.02	30	135	1
TX68	BT12e2	80	18	2011	5	19	10	09:55	11:30	95	51.02	3.05	30	135	1
TX68	BT12e2	80	19	2011	5	19	10	11:45	13:15	90	52.09	3.11	30	135	1
TX68	BT12e2	80	20	2011	5	19	10	13:30	15:10	100	52.17	3.18	28	135	1
TX68	BT12e2	80	21	2011	5	19	10	15:35	17:10	95	52.18	3.3	26	135	1
TX68	BT12e2	80	22	2011	5	19	10	17:25	19:00	95	52.17	3.43	24	135	1
TX68	BT12e2	80	23	2011	5	19	10	19:15	21:00	105	52.2	3.49	23	135	1
TX68	BT12e2	80	24	2011	5	19	10	21:20	23:10	110	52.29	3.53	23	135	1
TX68	BT12e2	80	25	2011	5	19	10	23:25	01:15	110	52.27	3.53	23	135	1
TX68	BT12e2	80	26	2011	5	19	11	01:30	03:20	110	52.23	3.48	24	135	1
TX68	BT12e2	80	27	2011	5	19	11	03:40	05:40	120	52.21	3.5	24	135	1
TX68	BT12e2	80	28	2011	5	19	11	05:55	07:45	110	52.21	3.49	24	135	1
TX68	BT12e2	80	29	2011	5	19	11	08:05	10:00	115	52.22	3.4	24	135	1
TX68	BT12e2	80	30	2011	5	19	11	10:15	12:10	115	52.27	3.48	24	225	1
TX68	BT12e2	80	31	2011	5	19	11	12:25	14:00	95	52.36	3.55	23	270	1
TX68	BT12e2	80	32	2011	5	19	11	14:15	16:00	105	52.42	3.58	23	270	1
TX68	BT12e2	80	33	2011	5	19	11	16:20	18:00	100	52.51	4	24	270	1
TX68	BT12e2	80	34	2011	5	19	11	18:10	19:55	105	52.57	4.06	24	270	1
TX68	BT12e2	80	35	2011	5	19	11	20:05	21:40	95	52.51	4.08	23	270	1
TX68	BT12e2	80	36	2011	5	19	11	21:55	23:40	105	52.45	4.05	23	270	1
TX68	BT12e2	80	37	2011	5	19	12	23:55	01:55	120	52.37	4.01	24	270	1
TX68	BT12e2	80	38	2011	5	19	12	02:10	04:10	120	52.36	4.03	23	270	1
TX68	BT12e2	80	39	2011	5	19	12	04:25	06:30	125	52.28	4.06	22	270	1
TX68	BT12e2	80	40	2011	5	19	12	06:50	08:40	110	52.26	4.02	24	270	1
TX68	BT12e2	80	41	2011	5	19	12	08:55	10:30	95	52.25	4	23	270	2
TX68	BT12e2	80	42	2011	5	19	12	10:50	12:20	90	52.23	4.01	24	270	2
TX68	BT12e2	80	43	2011	5	19	12	12:35	14:05	90	52.24	3.55	23	270	2

ship	gear	meshsize	haul	year	month	week	day	tset	thaul	duration	poslat	poslon	depth	winddir	windforc
TX68	BT12e2	80	44	2011	5	19	12	14:20	15:50	90	52.21	4.02	24	270	2
TX68	BT12e2	80	45	2011	5	19	12	16:05	17:40	95	52.23	3.55	24	270	2
TX68	BT12e2	80	46	2011	5	19	12	17:55	19:35	100	52.23	4.01	23	270	2
TX68	BT12e2	80	47	2011	5	19	12	19:50	21:30	100	52.23	3.59	24	225	2
TX68	BT12e2	80	48	2011	5	19	12	21:50	23:50	120	52.24	4	24	225	2

Appendix C. Auction lists of the three vessels

ship	harbour	type	year	month	day	species	cat1	cat2	cat3	cat4	cat5	cat6	tot
GO4	Scheveningen	auction	2011	5	13	**PLE**	258	507	640	1160			**2565**
GO4	Scheveningen	auction	2011	5	13	**SOL**	155	239	238	364	295		**1291**
GO4	Scheveningen	auction	2011	5	13	**DAB**		250					**250**
GO4	Scheveningen	auction	2011	5	13	**TUR**	39	20	22	22	61	99	**263**
GO4	Scheveningen	auction	2011	5	13	**BLL**	37	87	23				**147**
GO4	Scheveningen	auction	2011	5	13	**COD**		35	36	43	20		**134**
GO4	Scheveningen	auction	2011	5	13	**WHG**				201			**201**
GO4	Scheveningen	auction	2011	5	13	**NEP**							**0**
GO4	Scheveningen	auction	2011	5	13	**VAR**	1769						**1769**
													6620

ship	harbour	type	year	month	day	species	cat1	cat2	cat3	cat4	cat5	cat6	tot
TX36	IJmuiden	auction	2011	5	13	**PLE**	138	356	525	946			**1965**
TX36	IJmuiden	auction	2011	5	13	**SOL**	150	268	198	328	236		**1180**
TX36	IJmuiden	auction	2011	5	13	**DAB**		200					**200**
TX36	IJmuiden	auction	2011	5	13	**TUR**	29	21	28	32	55	78	**243**
TX36	IJmuiden	auction	2011	5	13	**BLL**	2	53	84	26			**165**
TX36	IJmuiden	auction	2011	5	13	**COD**	0	9	30	14	8		**61**
TX36	IJmuiden	auction	2011	5	13	**WHG**	4.4	2.2	0.5	0.0	0.0		**7.0**
TX36	IJmuiden	auction	2011	5	13	**NEP**							**0**
TX36	IJmuiden	auction	2011	5	13	**VAR**	16	104	56	573	34	44	**827**
													4648

ship	harbour	type	year	month	day	species	cat1	cat2	cat3	cat4	cat5	cat6	tot
TX68	Denhelder	auction	2011	5	13	**PLE**	121	379	493	1061			**2054**
TX68	Denhelder	auction	2011	5	13	**SOL**	153	279	237	336	249		**1254**
TX68	Denhelder	auction	2011	5	13	**DAB**		376					**376**
TX68	Denhelder	auction	2011	5	13	**TUR**	30	21	19	29	38	92	**229**
TX68	Denhelder	auction	2011	5	13	**BLL**	51	75	37				**163**
TX68	Denhelder	auction	2011	5	13	**COD**	0.0	2.7	21.4	4.4	0.0		**28.5**
TX68	Denhelder	auction	2011	5	13	**WHG**				105			**105**
TX68	Denhelder	auction	2011	5	13	**NEP**							**0**
TX68	Denhelder	auction	2011	5	13	**VAR**	29	128	642	98			**897**
													5107

Red numbers were reconstructed from the observation data on cod and whiting, and therefore not actually landed fish

Appendix D. Tables of observations on conditions of spine of filleted cod

Table 8-1: Observations of condition of spine of cod for GO4 catches (after trials in week 42, 2011)

No	Haul nr.	Length (cm)	spine fracture y/n	Comments (photos)	Score
1	n/a	39.3	n		0
2	n/a	40.6	n		0
3	n/a	41	n		0
4	n/a	41.4	n		0
5	n/a	45.1	n		0
6	n/a	45.9	n		0
7	n/a	43.5	n		0
8	n/a	40.1	n		0
9	n/a	43.1	n		0
10	n/a	43.6	n		0
11	n/a	39.5	n		0
12	n/a	40.1	n		0
13	n/a	57.9	n		0
14	n/a	45.6	n		0
15	n/a	57.8	n		0
16	n/a	52.4	n		0
17	n/a	47.6	n		0
18	n/a	56.6	n		0
19	n/a	51.3	n		0
20	n/a	58.5	n		0
21	n/a	57.1	n		0
22	n/a	55.3	n		0
23	n/a	61.7	n		0
24	n/a	67.2	n		0
25	n/a	57.2	n		0
26	n/a	59.3	n		0
27	n/a	556.8	n		0
28	n/a	67.1	n		0
29	n/a	64.6	n		0
30	n/a	66.4	n		0
31	n/a	76.2	n		0
32	n/a	62.4	n		0
33	n/a	67.3	n		0
34	n/a	63.1	n		0
35	n/a	63.4	n		0
36	n/a	71.2	n		0
37	n/a	59.4	n		0
38	n/a	67.3	n		0
39	n/a	64.3	n		0

No	Haul nr.	Length (cm)	spine fracture y/n	Comments (photos)	Score
40	n/a	55.2	n	Blood stain near the tail	0
41	n/a	58.8	n		0
42	n/a	64.2	n		0
43	n/a	62.8	n		0
44	n/a	57.2	n		0
45	n/a	63.3	n		0
46	n/a	61.3	n		0
47	n/a	82.3	n		0
48	n/a	81.1	n		0
				sum	**0**
				Spinal fracture in percentage	**7.4%**

Table 8-2: Observations of condition of spine of cod for TX36 catches

No	Haul nr.	Length (cm)	spine fracture y/n	Comments (photos)	Score
1	3	56	n	Lots of blood	0
2	3	62	n	Lots of blood	0
3	11	84	n		0
4	11	57	n		0
5	11	33	n		0
6	12	56	n		0
7	12	49	n		0
8	12	54	n		0
9	12	20	**y**		**1**
10	14	84	n		0
11	14	60	n		0
12	14	50	n		0
13	15	55	n		0
14	16	65	n		0
15	16	56	n		0
16	16	55	**y**		**1**
17	18	89	n		0
18	18	28	n		0
19	20	49	n		0
20	21	62	n		0
21	25	54	n		0
22	26	60	n		0
23	26	58	n		0
24	31	24	n		0
25	36	56	n		0

26	37	54	n		0
27	37	56	n		0
				sum	**2**
				Spinal fracture in percentage	**7.4%**

Table 8-3: Observations of condition of spine of cod for TX68 catches

No	Haul nr.	Length (cm)	spine fracture y/n	Comments (photos)	Score
1	9	57	n		0
2	9	59	n		0
3	9	23	n	Badly filleted/ haemorrhages on left side	0
4	10	22	n	haemorrhages on left side	0
5	10	73	n		0
6	11	56	n		0
7	12	56	n		0
8	12	52	n		0
9	17	48	n	haemorrhages (unclear)	0
10	18	23	**y**	haemorrhages	**1**
11	18	27	**y**	haemorrhages	**1**
12	18	28	n	haemorrhages	0
13	18	58	n		0
14	18	58	n		0
15	20	66	n		0
16	21	56	n		0
17	29	58	n	haemorrhages	0
18	40	56	n		0
				sum	**2**
				Spinal fracture in percentage	**11.1%**

Table 8-4: Observations of condition of spine of whiting for TX36 catches

No	Haul nr.	Length (cm)	spine fracture y/n	Comments (photos)	Score
1	27		n		0
2	27		n		0
3	28		n		0
4	28		n		0
5	28		n		0
6	28		n		0
7	28		n		0
8	29		n		0

No	Haul nr.	Length (cm)	spine fracture y/n	Comments (photos)	Score
9	29		n		0
10	29		n		0
11	29		n		0
12	29		n		0
13	29		n		0
14	29		n		0
15	29		n		0
16	30		n		0
17	30		n		0
18	30		n		0
19	30		n		0
20	30		n		0
21	30		n		0
22	30		n		0
23	30		n		0
24	30		n		0
25	31		n		0
26	31		n		0
27	31		n		0
28	31		n		0
29	31		n		0
30	31		n		0
31	31		n		0
32	31		n		0
33	31		n		0
34	32		n		0
35	32		**y**	photo 134 + 135 = 1 fish	**1**
36	32		n		0
37	32		n		0
38	32		n		0
39	32		n		0
40	32		n		0
41	32		n		0
42	33		n		0
43	34		n		0
44	35		n		0
45	35		n		0
46	36		n		0
47	38		n		0
			sum		**1**
			Spinal fracture in percentage		**2.1%**

Appendix E. Digital photographs of filleted cod

GO4 Cod (week 42, 2011 <u>after</u> the trials)


FISH 16 GO 4
FISH 17 GO 4
FISH 18 GO 4
FISH 19 GO 4
FISH 20 GO 4
FISH 21 GO 4
FISH 22 GO 4
FISH 23 GO 4
FISH 24 GO 4
FISH 25 GO 4
FISH 26 GO 4
FISH 27 GO 4
FISH 28 GO 4
FISH 29 GO 4
FISH 30 GO 4


FISH 31
GO 4

FISH 32
GO 4

FISH 33
GO 4

FISH 34
GO 4

FISH 35
GO 4

FISH 36
GO 4

FISH 37
GO 4

FISH 38
GO 4

FISH 39
GO 4

FISH 40
GO 4

FISH 41
GO 4

FISH 42
GO 4

FISH 43
GO 4

FISH 44
GO 4

FISH 45
GO 4

Figure 8-1: Digital photographs of filleted cod GO4

TX36 Cod


T15 55cm

T16 65cm

T16 56cm

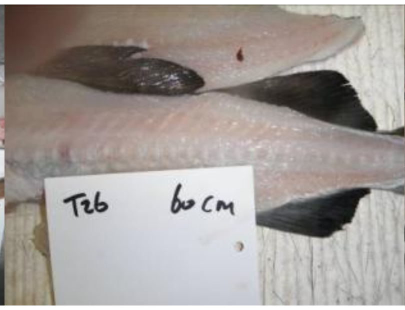
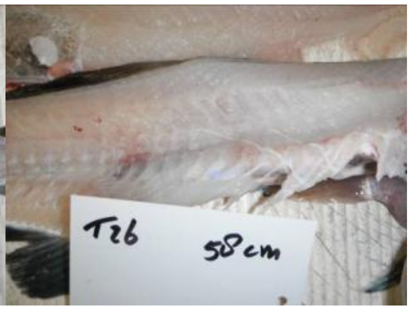
T16 55cm


T18 28 cm

T20 49 cm

T21 62

T22 30 cm


T26 60 cm

T26 58cm

T31 24cm

T31 24cm

T36 56cm

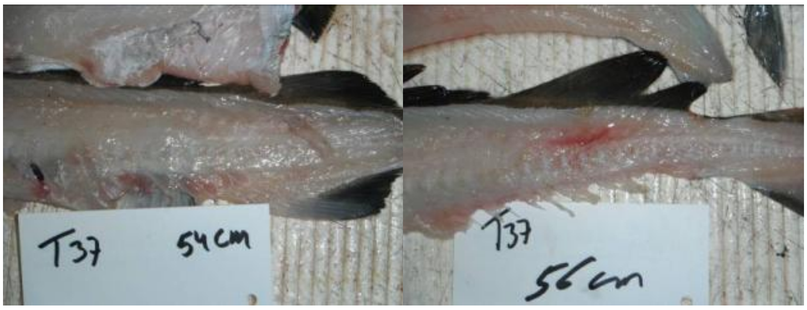


Figure 8-2: Digital photographs of filleted cod TX36

TX36 Whiting


28 cm

28 cm

28 cm

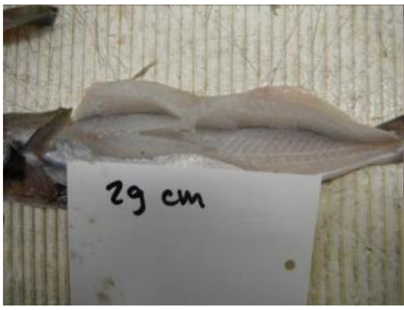
29 cm

29 cm

29 cm

29 cm

29 cm

29 cm

29 cm

29 cm

30 cm

30 cm

30 cm

30 cm


30 cm
30 cm
30 cm
30 cm
30 cm
31 cm
31 cm
31 cm
31 cm
31 cm
31 cm
31 cm
31 cm
31 cm
32 cm

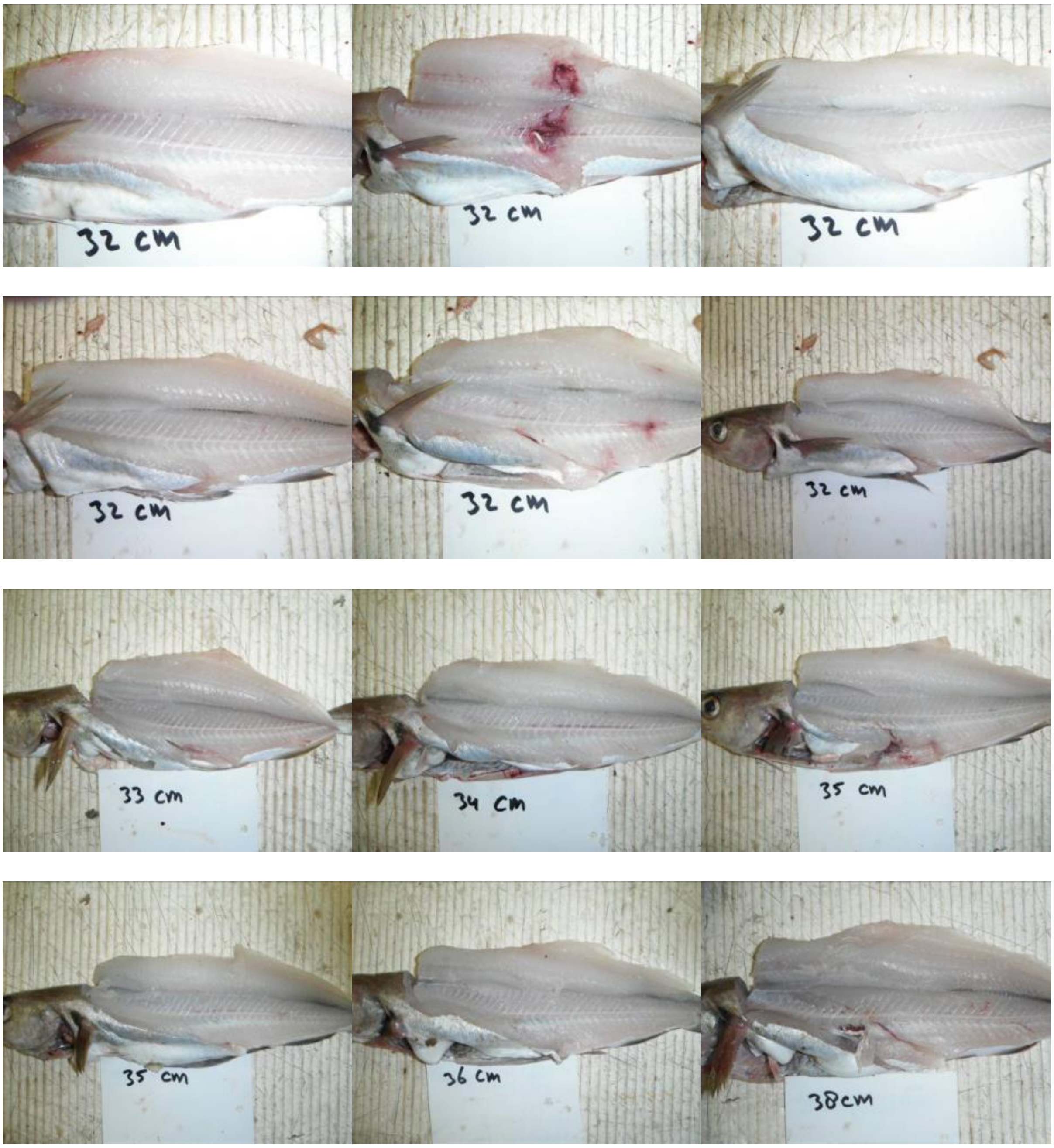


Figure 8-3: Digital photographs of filleted whiting TX36

TX68 Cod

Figure 8-4: Digital photographs of filleted cod TX68

Appendix F. Raising procedures

From: van Helmond and van Overzee, 2008:

Table I. Explanation of the abbreviations used in the formulas this Appendix.

	explanation	**sub-script**	**explanation**
n	sampled number	l	length
N	total number	h	haul
w	sampled weight		hour
		o	
W	total weight	t	trip
v	sampled discards volume	p	period
V	total discards volume	y	year
u	sampled duration	s	species
U	total duration	f	fleet
wt	sampled landings weight		
WT	total landings weight		
e	sampled fleet effort in number of trips		
E	total fleet effort in number of trips		
T	Number of trips		
DN	total discard number		
LN	total landings number		
CN	total catch number (landings and discards combined)		

Raising discards per trip

The sampled number per length and haul were raised per species to total number per length and haul

$$DN_{l,h,s} = \frac{V_h}{v_h} Dn_{l,h,s}$$

where $DN_{l,h,s}$ is the total number discarded at length (l) in haul (h) for species (s), V_h is total volume of haul (h), v_h is sampled volume of haul (h) and $Dn_{l,h,s}$ sampled number discarded at length (l) in haul (h) for species (s).

The total number discarded at length per haul and species was summed over the sampled hauls to obtain the total sampled number discarded at length (l) for species (s) over all sampled hauls (h). The total number discarded ($DN_{l,t,s}$) at length (l) per trip (t) and species (s) was calculated by multiplying the total number discarded ($DN_{l,h,s}$) over all sampled hauls with the ratio of total trip duration (U_t) and duration of all sampled hauls (Σu_h):

$$DN_{l,t,s} = \frac{U_t}{\sum u_h} \sum_{h=i}^{h} DN_{l,h,s}$$

The number discarded at length per hour and species ($DN_{l,o,t,s}$) was calculated by dividing the total number at length per trip ($DN_{l,t,s}$) by total trip duration *(U_t)*.

$$DN_{l,o,t,s} = \frac{DN_{l,t,s}}{U_t}$$

The obtained number discarded at length per hour ($DN_{l,o,t,s}$) was summed over length to obtain the number discarded per hour ($DN_{o,t,s}$):

$$DN_{o,t,s} = \sum_{l=i} DN_{l,o,t,s}$$

Discarded weight per hour per species at length was calculated using length-weight relationships:

$$DW_{l,o,t,s} = \sum_{l} \left(\frac{DN_{l,o,t,s} * A_s * l^{Bs}}{U_t} \right)$$

where $DW_{l,o,t,s}$ is the weight per length, per hour and per species, $DN_{l,o,t,s}$ is the number discarded at length, per hour and per species and A_s and B_s species specific constants.

Raising landings per trip

The sampled number landed at length per haul and species ($Ln_{l,h,s}$) were summed over all sampled hauls (*h)* to calculate the sampled number at length for the trip ($n_{l,t,s}$). The total number landed at length for the entire trip ($LN_{l,t,s}$) was calculated by multiplying the sampled number at length for the trip ($Ln_{l,t,s}$) with the ratio of total trip weight obtained from auction or VIRIS data ($WT_{t,s}$) to sampled landings weight of the trip ($wt_{t,s}$):

$$LN_{l,t,s} = \frac{WT_{t,s}}{wt_{t,s}} \left(\sum_{h=i}^{h} Ln_{l,h,s} \right)$$

Number landed at length per hour per species ($LN_{l,o,t,s}$) was calculated by dividing total number landed at length per trip ($LN_{l,t,s}$) by the trip duration *(U_t).*

$$LN_{l,o,t,s} = \frac{LN_{l,t,s}}{U_t}$$

The obtained total number at length per hour ($LN_{l,o,t,s}$) was summed to calculate number per hour per species ($LN_{o,t,s}$):

$$LN_{o,t,s} = \sum_{l=i} LN_{l,o,t,s}$$

Total landings weight per hour ($LW_{o,t,s}$) was calculated per species by dividing total landings weight ($WT_{t,s}$) per species by total trip duration (U_t).

$$LW_{o,t,s} = \frac{WT_{t,s}}{U_t}$$

Numbers at length, per quarter and year

The number of discards and landings ($CN_{l,o,p,s}$) at length per hour was calculated per quarter/year by summing the number landings or discards at length per hour per trip ($CN_{l,o,t,s}$) over all trips in that period (p) and then dividing this by the total number of trips *(U_t)* in this period:

$$CN_{l,o,p,s} = (\sum_p CN_{l,o,t,s}) / \sum_p U_t$$

Total numbers discards or landings ($CN_{o,p,s}$) were calculated by summing over length. Trips were excluded from calculation numbers per hour per period if landings were not measured during a trip, but auction records existed for this species.

$$CN_{o,p,s} = \sum_{l=i} CN_{l,o,p,s}$$

Numbers at age, per quarter and year

The age structure of both plaice and sole discard and landings was calculated by distribution of numbers at length over age groups using age-length-keys (ALK). The number landed and discarded ($CN_{l,a,t,s}$) at length and age per trip and species was calculated by distribution of the proportion *($f_{l,a}$)* of fish at length (l) with age (a) over the number ($CN_{l,t,s}$) at length per trip and species. Because $f_{l,a}$ is dependent on the period, ALK were taken from discards and market samples from the quarter were discards were sampled.

$$CN_{l,a,t,s} = f_{l,a} * CN_{l,t,s}$$

The number landed and discarded ($CN_{a,t,s}$) at age per trip and species was calculated by multiplying the number landed and discarded ($CN_{l,a,t,s}$) at length and age per trip and species over length:

$$CN_{a,t,s} = \sum_{l=i} CN_{l,a,t,s}$$

The number of discards and landings ($CN_{a,o,p,s}$) at age per hour was calculated per quarter/year by summing the number of landings or discards at age per hour per trip ($CN_{a,o,t,s}$) over all trips in that period (p) and then dividing this by the total number of trips *(U_t)* in this period:

$$CN_{a,o,p,s} = (\sum_p CN_{a,o,t,s}) / \sum_p U_t$$

Numbers at age, per quarter and year per fleet

Total landings en discards ($CN_{a,p,s,f}$) at age per quarter/year were calculated for the entire fleet by multiplying the total numbers of discards and landings ($N_{a,p,s}$) at age per quarter/year with the ratio effort of the entire fleet ($E_{p,f}$) per quarter/year measured in Hpeffort (proportion fishing duration per day multiplied with engine power) to the effort of the sampled part of the fleet in Hpeffort per quarter ($e_{p,f}$).

$$CN_{a,p,s,f} = \frac{E_{p,f}}{e_{p,f}} CN_{a,p,s}$$

Trips were excluded from calculation numbers per hour per period if landings were not measured during a trip, but auction records existed for this species.