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Performance of pulse trawling compared to conventional beam trawling

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Summary

A series of nine fishing trips with on board observers were carried out on MFV UK153 (PT1) and two beam trawlers (BT1, BT2) of comparative engine power and size to appraise the performance of pulse beam v.s. conventional tickler chain beam trawls. Five comparative trips, carried out in the period between October 2005 and March 2006, were analysed for catch rates of marketable plaice (*Pleuronectes platessa* L.) and sole (*Solea vulgaris* L.), undersized plaice and sole and benthic fauna. The pulse trawl caught significantly less landings, *i.e.* 68% of the landings of a conventional beam trawler. This was mainly caused by smaller catches of sole, and plaice. A lower discard rate was not found for plaice, but it was for sole. The result for plaice is contrary to earlier experiments on FRV "Tridens" with both gear types towed simultaneously. Benthos (sandstar (*Astropecten irregularis* L.), common starfish (*Asterias rubens* L.), and swimming crab (*Liocarcinus holsatus* L.)) were caught in significantly smaller numbers, which is in line with the results found in previous studies. The comparison of physical condition classes of sole and plaice showed variable results with a tendency of lower damage for the pulse trawl.

The main conclusions from this study are:

1. Landings of plaice and sole are significantly lower in the pulse trawl when compared to the conventional beam trawl.
2. There was no significant difference in the catch rates of undersized (discard) plaice between the pulse trawl and the conventional trawl.
3. In the pulse trawl, the catch rates of undersized (discard) sole were significantly lower than in the conventional beam trawl.
4. The catch rates of benthic fauna (nrs/hr of *Astropecten irregularis*, *Asterias rubens,* and *Liocarcinus holsatus*) were significantly lower in the pulse trawl compared to the conventional beam trawl.
5. There are indications that undersized plaice are damaged to a lesser degree in the pulse trawl and will survive better in the pulse trawl. Based on previous research, these results would indicate a survival rate of plaice in the pulse trawl that is twice as high as in a conventional beam trawl. But since the method of determining damage to fish by visual observation is subjective, this conclusion should be treated with caution.

1. Introduction

Beam trawling for flatfish is an efficient fishing method, but it requires a high level of energy input, due to the high gear drag and towing speeds, and affects benthic fauna (De Groot and Lindeboom, 1998). This has led to research on alternatives, such as electrical stimulation, initially aimed at reducing gear drag and fuel consumption (Agricola, 1985). Prototype gears were developed for shrimps and flatfish fisheries, but until the present day a commercial application did not emerge; (Van Marlen and De Haan, 1988; Van Marlen *et al.*, 1997). Fishing with electricity was banned in the European Union (EU) in 1988. The reason for this was fear of increasing catch efficiency in a time when the discrepancy between the state of the resources and the ever-increasing fishing effort became problematic. In the late 1990s the development of beam trawling with electrical stimulation was continued, but now the focus was on reducing ecosystem effects (Van Marlen *et al.*, 2001a).

RIVO became involved in an existing bilateral cooperation between a private company (Verburg-Holland Ltd.), the Dutch Fishermen's Federation and the Ministry of Agriculture, Nature Management and Food Quality in 1998. A series of trials were conducted onboard FRV "Tridens" on a 7 m prototype electrified beam trawl, called 'pulse' trawl, resulting in sole (*Solea vulgaris* L.) catches matching those of conventional tickler chain beam trawls, plaice catches being reduced by some 50%, and benthos catches reduced by 40%. These results stimulated further work. Extended trials were carried out in October-November 1999 (Van Marlen *et al.*, 1999; Van Marlen *et al.*, 2000).

A study on differences between a conventional 7 m tickler chain gear and the 7 m prototype electrical gear in direct mortality of invertebrates living on and in the sea bed was conducted in June 2000 onboard FRV "Tridens" and RV "Zirfaea". Benthos samples were taken from the Oyster grounds prior to fishing, and from trawl tracks caused by the two gear types. The direct mortality calculated from densities in these samples was lower for an assembly of 15 taxa for the pulse trawl, indicating the potential of electric fishing to reduce effects on benthic communities (Van Marlen *et al.*, 2001).

After these experiments it was decided to develop a prototype for 12 m beam length, being the most common value in the Dutch fleet. Technical trials with the new prototype were carried out in November-December 2001 onboard FRV "Tridens", and were continued in 2002 and 2003, resulting in catch rates for sole and plaice equaling those of conventional 12 m beam trawls.

Recently the bycatch and discarding of undersized fish, particularly plaice (*Pleuronectes platessa* L.) gained attention. Comparative studies were undertaken in 2005 on FRV "Tridens" on the differences in catches and on differences in survival of undersized sole and plaice between a 12 m pulse beam trawl and a conventional 12 m tickler chain beam trawl (Van Marlen *et al.*, 2005a, b).

In the fall of 2004 it was concluded that the 12 m prototype was technically ready for a series of long-term trials on a commercial fishing vessel. The MFV UK153 (further named PT1) was outfitted with a complete system of two pulse trawls and cable winches. The performance of this vessel in terms of catches was monitored and compared to that of fishing boats fishing with two conventional beam trawls in a number of weeks.

This report describes the results of comparisons of the catching performance of MFV PT1 with two beam trawlers fishing with conventional tickler chain beam trawls. The report focuses on the catch rates of landings, discards and benthic fauna. The economic issues will be dealt with in a separate report.

2. Materials and methods

2.1 Vessels and trips

The PT1 was outfitted with a complete system of two pulse trawls and winches with feeding cables (Figure 6 - Figure 9). Commercial beam trawlers from the same fishing harbour of similar size, and engine power were selected to fish simultaneously with conventional 12 m beam trawls in order to compare their performance. Characteristics of these boats are listed in the table below (Table 1).

Nine trips in total were undertaken. The first four trips were used to monitor catches and experiment with the setting of the pulse field and with the towing speed of the vessel. The latter five trips were used to make actual comparisons with a second vessel (Table 14). The fishing grounds were in the North Sea, on the Dutch Continental Shelf. The vessels fished where possible in the same area during the same week (Figure 1 - Figure 5).

Table 1: Vessels used and main particulars

Vessel ID	Year built	Loa	GT	kW
BT1	2003	39.67	418	1471
BT2	1993	42.36	501	1467
PT1	1998	42.40	508	1471

2.2 Gears

The 12 m pulse trawls were developed by company Verburg-Holland Ltd. of Colijnsplaat, The Netherlands (See Figure 9).

2.3 Data sampling protocol

2.3.1 Communication between the two vessels

In order to obtain sets of comparable data it was tried to take samples of hauls fished as much as possible on the same time and at the same location. This required intensive radio communication between the two boats. The differing towing speeds (~5.5 kts for the pulse trawl, and ~6.4 kts for the conventional type), and the normal operation of the accompanying beam trawlers caused limits to this requirement.

2.3.2 Estimating the volume of the total catch

The total volume of the catch in both gears was estimated in three different ways:

- By estimating the total number of baskets in both fish bins on deck including large debris and stones.
- By estimating the total number of baskets in both fish bins on deck with subtraction of large debris and stones.
- By measurement, using specially constructed compartments with a known volume that were filled and emptied subsequently, this only measured the amount of discards. It is then increased with the estimated amount of landings.

In most cases the third option was taken as the total catch volume in number of baskets.

2.3.3 Method of taking discard samples

Samples of undersized fish and benthos were taken by filling buckets from the conveyor belt(s) behind the fish processing line at differing intervals and discharging these in one basket, thus ensuring a representation of the entire catch (Figure 8). Usually the catch of one net was taken, being the side processed by the crew first. On the PT1 this was mostly the port side net, but in cases where the pulse field did not function well or was deliberately switched off the other net was taken.

The contents of the sample basket were tipped over on a sorting table, where for every species the sample was split in a reasonable number to count and measure (>50 individuals per species). Of all fish species the length was measured, the benthos (*e.g.* starfish (*Asterias rubens* L.), sandstar (*Astropecten irregularis* L.), sea mice (*Aphrodite* L.), swimming crabs (*Liocarcinus holsatus* L.), etc.) were only counted. The splitting of the samples often resulted in differing sampling ratios per species. The numbers of discards measured were raised to the total catch by multiplying the numbers with the ratio of the total catch volume / sampled volume.

2.3.4 Method of taking landings samples

The landings where sorted out by the crew of the vessel and when a haul was completely finished a part of the landings of sole, cod and plaice was measured. This was done by using the estimated weight of the total landings and of the sample, again resulting in a ratio. Numbers of landings measured were raised to the total catch by multiplying numbers measured with this ratio.

2.3.5 Number of hauls sampled

One or two hauls were skipped at night, the rest were sampled for discards. For landings only a part of these hauls was sampled. The last couple of hauls were mostly not sampled as the crew needed time and space to clean the deck and processing line (Table 15).

2.3.6 Monitoring fish damage classes

The first two hauls heaved in after 1000 hrs and 1500 hrs were taken to determine the damage categories of plaice in the catch, and after this processed as the other hauls according to Van Beek *et al.*, 1990, see Table 2. The fish were rinsed and their condition judged by eye.

Table 2: Classification of physical condition according to Van Beek *et al.*, 1990.

Class	Characteristics
A	Lively, no visible damage, scale loss or skin damage
B	Less lively, some scratches and scale loss. Skin to 20% damaged, some red spots on the lower side
C	Lethargic fish. Several scratches and spots without scales. Skin to 50% damaged, larger red spots on the lower side
D	Lethargic fish, head coloured red. Many scratches and spots without scales. Skin >50% damaged, many red spots and haemorrhages on the lower side

2.3.7 Data input, data checks and data storage

The data were recorded onboard on paper sheets and put in the computer using data input program Billie Turf™, as much as possible during the trip and when needed at the laboratory. This program generates data files that were checked and put in the RIVO-database.

At the end of each trip auction slips were provided from which CPUE in kg/hr was calculated, based on the total duration of all the hauls during the trip (Table 16 - Table 20). The weights in these tables give figures for stripped fish stored on ice in the various market grades defined by the auction, as well as the total sums for each species.

In addition there were sheets in Microsoft Excel™ with haul based estimates of catch weights filled in by the skippers for the major components of landings consisting of: 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. These were estimated values, but nevertheless they supplied insight in the haul-to-haul variation, particularly for plaice and sole. These values were corrected by haul with the total weight found in the auction for each of the list of catch components given above by multiplying with a factor (sum of estimated weight in each haul)/total auction weight.

A third source of information came from hauls for which landings (and discards) were sampled. Catch weights were calculated from measured lengths using weight-length keys. These hauls supplied data on the length-frequencies for the various catch components.

2.4 Data analysis

2.4.1 Routines developed in SAS

A number of routines were developed in SAS to process data from the input level to datasets suitable for statistical analysis. The skippers filled in data sheets in Microsoft Excel™ ensuring a common format. Similarly the data from auction slips were converted to datasets giving for each species category: plaice, sole, dab, turbot, brill, cod, whiting, *Nephrops* and other the total weight landed per trip.

2.4.2 Choice of comparative hauls

During the trials it was tried to keep the two vessels relatively close together, but due to the higher towing speed of the vessel fishing with the conventional beam trawls the distance between the boats could not be kept equal.

As the vessels started from different ports, it took some time to meet during which fishing already begun, and often one of the vessels fished a bit longer at the end of a trip. All hauls for which both vessels were not really fishing together, either before or after comparative hauls were deleted. Then hauls were put together for which their starting and ending times were within 90 min (with the majority 60 min), and hauls distinctly in different locations, mostly at the end of a trip, when both vessels were working their way towards their ports of landing were deleted. This resulted in a set of 175 paired hauls.

2.4.3 Statistical model used

The SAS-procedure GENMOD was used to analyse the effect of different variables on the variance of LpUE or log(LpUE), landings per unit of effort, kg/hr.

For haul-based data initially a model of type:

$$\text{Log(LpUE)}_i = \text{gear} + \text{day}_i + \text{position}_i$$

with: i = haul number
gear = pulse or conventional
day_i = day of the haul i
position_i = position (longitude) of haul i

was run, revealing that in most cases the explanatory variables ‘day’ and ‘position’ did not contribute to a significant contribution to the variance, and could therefore be deleted from the model, leaving:

$$\text{Log(LpUE)} = \text{gear}$$

A similar model was also applied to the auction data, but not log-transformed, *i.e.*:

Total LpUE = gear

2.4.4 Analysis of Variance

To analyse the variance in catches (landings, discards, benthic fauna) we used a generalized linear model. A similar model was used for plaice and sole discards, plaice and sole landings and for the benthic fauna species *Astropecten irregularis*, *Asterias rubens*, and *Liocarcinus holsatus*. For plaice and sole discards, both the total numbers and the total weight per species caught per haul were used as dependent variables. For the benthic fauna, the total numbers per species per haul were used. The following general model was used:

$C \sim T_i + A_j + D + G_k + (T_i \times G_k)) + (A_j \times G_k) + (D \times G_k)$,

Where C (numbers or weight per hour fishing) is the catch (discards) or landings, T is the trip number (factor, 1-5), A is the area (4 areas), D is the depth and G is the gear type (pulse beam trawl, conventional beam trawl). The terms (T x G), (A x G) and (D x G) are interaction terms that allow the effect of gear to vary with trip, area and depth. If a term did not contribute significantly to the explanation of variance ($p > 0.10$) it was removed from the model.

The areas were constructed based on combined ICES rectangles:

- Area 1: 33/F4, 33/F3, 34/F4, 34/F3
- Area 2: 34/F2, 35/F2, 35/F3, 36/F2, 36/F3
- Area 3: 35/F4, 35/F5, 36/F4, 36/F5
- Area 4: 37/F4, 37/F5, 38/F4, 38/F5

For each model, the assumption that the data were normally distributed was tested using a Wilk-Shapiro test. If data were not normally distributed, as was the case for sole discards numbers and weight (all trips) and all benthic catches, log-transformed catches were used as the dependent.

Least squares (LS) means were computed for the effect of gear (pulse, beam trawl) and differences of the means were compared and statistically tested. In effect, the LS means present the balanced mean value for each gear over all trips, areas and depths sampled.

In all five trips, the plaice discards were sampled in a similar manner, but for sole, the methods differed in trip 1 and 2 from trips 3-5. In the first two trips, it proved that our methods did not result in accurate estimates because the low catch rate of sole discards (in comparison with plaice) did not allow for sub-sampling. Therefore, we decided not to sub-sample and to count and measure all sole being caught in trips 3-5. In the analysis of catch rates of sole discards, we therefore omitted trips 1 and 2 because they did not result in reliable data of sole discards.

3. Results

3.1 Effect on composition of target fish species in the catch

3.1.1 Effect on landings based on auction data

Except for the first trip, the pulse trawls caught considerably less landings, about 60-70% of that of the conventional trawls. When lumped together (gear test 6) the overall ratio is 68% (Table 3). These data were consistent with the views expressed by the skipper and the crew on MFV PT1.

Table 3: Overall landings LpUE comparison

Gear test	Trip	Pulse kg/hr	Conv kg/hr	Ratio
1	1	65.7	69.3	94.8%
2	2	57.8	87.8	65.8%
3	3	86.2	145.7	59.2%
4	4	50.2	75.5	66.5%
5	5	61.2	87.4	70.0%
6	1 to 5	64.6	95.4	67.7%

3.1.2 Effect on summed landings of single species based on auction data

The differences between the pulse trawl and conventional beam trawl were substantial for various species (Table 16 - Table 21). It appeared that the pulse trawl performed best for turbot and brill with ratios ranging from 78% to 131% of the conventional landings, while cod landings were considerably lower, between 15% and 60% of that of the beam trawl (Table 21). A statistical test on these data revealed significant differences from beam trawls ($p \leq 0.05$) only for whiting and dab, but it should be borne in mind that the dataset contained only five observations of total landings, *i.e.* the five comparative trips (Annex A).

3.1.2.1 Effect of gear type on market grades based on auction data

Only in a few market categories a significant difference could be found between the pulse and the conventional gear type, *i.e.* for plaice cat5 where the pulse trawl caught more, sole cat2 with the pulse trawl catching less, turbot cat2 (more), and cod cat2 (less) and cat4 (more). All other differences were not statistically significant, but the number of observations was limited with five trips analysed (Table 4, Figure 10).

Table 4: Result of statistical tests on auction CPUE on effect of gear type, numbers are p-values, bold is significant, $p \leq 0.05$.

Species/cat	1	2	3	4	5	6
plaice	0.2436	0.2783	0.3722	0.0846	**< 0.0001**	-
sole	0.7169	**0.0019**	0.3122	0.7502	0.3047	-
dab	-	0.0915	-	-	-	-
turbot	0.6653	**0.0218**	0.9028	0.9096	0.8161	0.2544
brill	0.4184	0.8266	0.5669	0.9783	-	-
cod	0.3043	**0.0341**	0.2027	**0.0283**	0.0704	-
whiting	-	-	-	0.6967	-	-
Nephrops	-	0.5317	-	-	-	-
other	-	0.4684	-	-	-	-

3.1.2.2 Sole landings based on paired hauls

The analysis of haul-based data showed that for all trips, except no 1, the pulse trawl landed significantly less sole than the beam trawl, with ratios ranging from 66.1% to 93.1%. For the complete dataset of all five trips combined (gear test 6) the ratio pulse/conventional was 78.2% for sole landings (Table 5).

Table 5: Landings in kg/hr of sole based on paired hauls

Gear test	Vessels	Wk, year	No of hauls	CPUE in kg/hour mean PULSE	CON	PULSE/ CON	stdev PULSE	CON	p-value
1	PT1-BT2	41, 2005	34	19.30	20.74	93.1%	6.52	7.17	0.251
2	PT1-BT3	44, 2005	41	**17.52**	**21.74**	**80.6%**	**5.95**	**6.4**	**0.000**
3	PT1-BT1	05, 2006	35	**8.51**	**11.92**	**71.4%**	**2.76**	**3.94**	**0.000**
4	PT1-BT2	09, 2006	38	**7.93**	**11.66**	**68.0%**	**2.95**	**4.43**	**0.000**
5	PT1-BT1	11, 2006	27	**10.33**	**15.62**	**66.1%**	**2.86**	**3.03**	**0.000**
6	PT1-Both	All	175	**12.87**	**16.45**	**78.2%**	**6.64**	**6.87**	**0.000**

3.1.2.3 Plaice landings based on paired hauls

Similarly the plaice landings fell behind for the pulse trawl, with ratios ranging from 52.8% to 89.5% of beam trawl landings. For the complete dataset of all five trips combined (gear test 6) the ratio pulse/conventional was 64.5% (Table 6).

Table 6: Landings in kg/hr of plaice landings based on paired hauls

Gear test	Vessels	Wk, year	No of hauls	CPUE in kg/hour mean PULSE	CON	PULSE/ CON	stdev PULSE	CON	p-value
1	PT1-BT2	41, 2005	34	**25.56**	**28.56**	**89.5%**	**13.8**	**8.97**	**0.047**
2	PT1-BT3	44, 2005	41	**24.69**	**46.79**	**52.8%**	**10.91**	**15.37**	**0.000**
3	PT1-BT1	05, 2006	35	**56.02**	**93.43**	**60.0%**	**23.17**	**25.56**	**0.000**
4	PT1-BT2	09, 2006	38	**21.66**	**29.85**	**72.6%**	**13.64**	**11.18**	**0.000**
5	PT1-BT1	11, 2006	27	**20.09**	**28.87**	**69.6%**	**5.84**	**6.61**	**0.000**
6	PT1-Both	All	175	**29.76**	**46.13**	**64.5%**	**19.75**	**29.07**	**0.000**

3.1.3 Effect on discards of plaice and sole

In these analyses no significant difference was found in the number or in the weight of the plaice discards between both gear types (Table 7, Table 23). On average, the pulse trawl and beam trawl caught 68 and 67 kg/hr of undersized plaice respectively.

The pulse trawl caught significantly less undersized sole than the conventional beam trawl (1.4 kg/hr in comparison with 1.8 kg/hr for the beam trawl). For this analysis, only data of the last three trips were used because only in these trips numbers of discarded sole were counted accurately (in these trips all sole were measured as explained in the methods section).

Figure 12 and Figure 14 present the average discards per trip for sole and plaice.

Table 7: Discard rates of plaice and sole, results analysis of variance. Legend: +++: P<0.01, n.s.: 0.10 < P.

Species	Unit	Obs	Comparison of means			R^2
	W/N	(hauls)	Average Pulse	Average Control	Difference significance	
Sole (trip 3 t/m5) <24	N	182	14.6 /hr	19.4 /hr	+++	0.47
	W	182	1.4 kg/hr	1.8 kg/hr	+++	0.49
Plaice (all trips) <27	N	324	997 /hr	948 / hr	n.s.	0.47
	W	324	68.1 kg/hr	66.9 kg/hr	n.s.	0.40

3.1.4 Length-frequency (LF) distributions

LF-distributions were made for CPUE (numbers/hr) per trip, gear, species and length class. The raised numbers per haul are used to calculate a mean by trip. The vertical dashed line is the minimum landing size for the specific species (Figure 11 - Figure 14).

In the discard graphs for sole the problem with the first two trips as discussed before is clearly visible. The numbers are much higher, caused by multiplying with sampling ratios. In the graphs of the first two trips the number of discards between 20 and 23 cm are lower in the conventional beam trawl. This was caused by differences in what was considered discards by the different crews. In the last three trips the discards follow the same pattern for both vessels, with somewhat higher values in the smaller length classes for the conventional beam trawl. Also visible in the discards graphs is the effect of high-grading fish larger than the minimum landing size. The landings graphs clearly show that the tickler chain beam trawl caught more. These numbers however are based on fewer observations than in the case of discards, because a smaller number of hauls is sampled for landings.

For plaice in all the trips a sampling ratio is used and the graphs show thus more plaice discards in the last three trips. The pattern shown for the discards is almost the same for both gear types; on one trip the pulse trawl caught a bit more, on another trip the conventional beam trawl.

3.2 Effect on catches of benthic invertebrates

3.2.1 Effect on benthos catch in numbers

The main benthos species caught were: sandstar (*Astropecten irregularis* L.), common starfish (*Asterias rubens* L.), and swimming crab (*Liocarcinus holsatus* L.). These were caught in almost all hauls. The analysis of variance for these species shows that the pulse trawl caught significantly less numbers of these species (Table 8, Table 23). On average, catch rates of sandstar in the pulse trawl were 24% of that in the conventional beam trawl and of common starfish 75% and of swimming crab 53%.

Table 8: Discard rates of benthic fauna, results analysis of variance. Legend: +++: *P* <0.01, ++: 0.01≤ *P* < 0.05.

Species	Obs	Comparison of means			R^2
	(hauls)	Average Pulse	Average Control	Difference significance	
Sandstar	202	344 /hr	1428 /hr	+++	0.50
Common starfish	294	511 /hr	679 /hr	++	0.34
Swimming crab	303	2117 /hr	3969 /hr	+++	0.51

With regards to the benthos species there was special interest for quahogs (*Arctica islandica* L.) and prickly cockles (*Acanthocardia echinata* L.). These species are slow growing and have a low recruitment, because of this they are threatened by fishing methods disturbing the sea bed. These species however only sporadically occurred in the catch; therefore it was not possible to use them in an analysis. As an illustration, table 9 presents the catch rates of both species per trip.

Table 9: Average catch rates (numbers/hr) per trip and gear type for benthic fauna.

Trip	Gear	Sandstar	Common starfish	Swimming crab	Quahogs	Prickly cockles
1	conv	532	392	2921	0	23
	pulse	335	354	883	0	7
2	conv	15	273	1995	0	2
	pulse	7	101	1084	0	0
3	conv	5169	1436	4708	0	62
	pulse	1070	731	2629	0	1
4	conv	31739	2144	5705	0	17
	pulse	1700	1691	3509	0	11
5	conv	5327	1589	8133	20	82
	pulse	675	1274	4902	2	4
	Average conv	**8621**	**1181**	**4705**	**4**	**38**
	Average pulse	**705**	**753**	**2397**	**0**	**4**

3.3 Effect on damage classes

The extent of damage of plaice fluctuated with higher percentages class A (in good shape) and lower C for the pulse trawl, but unclear results in class B and D (severely damaged). Regarding the mean percentages there were more fish in class A, about comparable numbers in B, and less fish in C and D in the pulse trawl (Table 22). When using these means with the survival rates found in 2005 for the categories A, and B+C, the survival of undersized plaice in the catch after 192 hrs of observation of a pulse trawl is nearly doubled to 28% (

Table 10, Van Marlen *et al.*, 2005b).

Table 10: Estimated survival of plaice based on experiments in 2005

Species	**plaice**			
Gear	PULSE		CONVENTIONAL	
Category	% in catch	% survival	% in catch	% survival
A	36.22%	13.61%	6.49%	1.84%
B+C	51.40%	14.47%	73.51%	13.04%
D	12.38%	0%	20.00%	0%
% overall survival in catch		**28.09%**		**14.88%**

4. Discussion

4.1 Comparison with FRV "Tridens" results

The comparison of a 12 m pulse trawl and its conventional counterpart in 2004 and 2005 resulted in catch differences of: -4.8% in kg/hr landings, +22.1% in marketable sole, -16.7% in undersized sole, -16.6% in marketable plaice, and -18.1% in undersized plaice (Table 11). These results are different from the results obtained in the current study: -35.5% plaice in kg/hr landings, -21.6% in sole landings, but no difference in plaice discards (+1.8%). The reduction in undersized sole (-22.2%) and in benthic fauna (-51.1% in numbers) are, however, in line with the previous results.

Table 11: CPUE of pulse beam trawl (PULSE) and conventional tickler chain beam trawl (CONV) for the complete data set, with mean, stdev and p-value for various catch categories. Boldface values are significant ($p \leq 0.05$).

Category	number of hauls	CPUE in kg/hr Mean		stdev		p-value	
		PULSE	CONV	PULSE	CONV		PULSE/ CONV
total weight	67	**185.94**	**245.69**	**106.56**	**182.37**	**0.000**	**75.7%**
Landings	67	**44.67**	**46.90**	**13.41**	**15.42**	**0.019**	**95.2%**
discard fish	67	**85.91**	**100.25**	**54.94**	**63.97**	**0.000**	**85.7%**
Benthos	67	**100.58**	**134.17**	**69.97**	**105.52**	**0.008**	**75.0%**
sole > MLS	67	**12.78**	**10.47**	**5.15**	**4.47**	**0.000**	**122.1%**
sole < MLS	67	1.79	2.15	1.24	1.5	0.074	83.3%
plaice > MLS	67	**25.79**	**30.94**	**13.09**	**16.23**	**0.000**	**83.4%**
plaice < MLS	67	**34.09**	**41.63**	**24.7**	**32.33**	**0.022**	**81.9%**
quahogs	67	1.64	1.00	2.04	0.92	0.687	164.0%
prickly cockles	67	**0.59**	**51.52**	**19.83**	**61.46**	**0.000**	**19.8%**

Source: RIVO Report C043b/05, Table 4

4.2 Possible causes for the discrepancy

The percentages presented in Table 11 were obtained with both gears being towed at 5.5 kts. In the comparison presented here both vessels were fishing at their normal operating speeds, *i.e.* ~5.5 kts for the pulse beam trawls and ~6.5 kts for the conventional beam trawls. Higher towing speed cause larger CPUEs, as more ground is covered per unit of time. If this was the only reason, the same effect should be visible in all the species. This is not the case for plaice discards or for landings of brill and turbot.

To find out the effect of speed on the sole and plaice catch, CPUE (kg/hr) was also determined per mile fished (kg/nm), using records of towing speed or distance covered per haul. For sole the significance in differences seemed to disappear, while for plaice this happened only in two of the five trips. A declining trend with time in the ratio pulse/conventional for both (particularly) sole and plaice also emerged from the data (Table 12 and Table 13), a finding consistent with the opinion of the skipper and crew.

Table 12: Landings in kg/mile of sole based on paired hauls

Gear test	Vessels	Wk, year	No of hauls	CPUE in kg/mile mean PULSE	CON	PULSE/ CON	stdev PULSE	CON	p-value
1	PT1-BT2	41, 2005	34	**3.65**	**2.98**	**122.5%**	**1.24**	**1.04**	**0.006**
2	PT1-BT2	44, 2005	41	3.44	3.08	111.7%	1.19	0.85	0.063
3	PT1-BT1	05, 2006	35	1.60	1.80	88.9%	0.54	0.62	0.136
4	PT1-BT2	09, 2006	38	1.53	1.72	89.0%	0.56	0.65	0.143
5	PT1-BT1	11, 2006	27	**1.98**	**2.65**	**74.7%**	**0.55**	**0.51**	**0.000**
6	PT1-Both	All	175	2.47	2.44	101.2%	1.29	0.96	0.418

Table 13: Landings in kg/mile of plaice based on paired hauls

Gear test	Vessels	Wk, year	No of hauls	CPUE in kg/mile mean PULSE	CON	PULSE/ CON	stdev PULSE	CON	p-value
1	PT1-BT2	41, 2005	34	4.85	4.10	118.3%	2.66	1.32	0.309
2	PT1-BT2	44, 2005	41	**4.85**	**6.67**	**72.7%**	**2.13**	**2.18**	**0.000**
3	PT1-BT1	05, 2006	35	**10.48**	**14.03**	**74.7%**	**4.29**	**4.01**	**0.000**
4	PT1-BT2	09, 2006	38	4.18	4.44	94.1%	2.61	1.83	0.126
5	PT1-BT1	11, 2006	27	**3.86**	**4.88**	**79.1%**	**1.12**	**1.06**	**0.000**
6	PT1-Both	All	175	**5.68**	**6.88**	**82.6%**	**3.68**	**4.38**	**0.000**

Other possible causes for discrepancy are differences in the gears used in both projects. First there were differences in the prototype used on FRV "Tridens" and the pulse trawls used on MFV PT1, second the conventional beam trawls used on MFV BT1 and MFV BT2 may not have been completely similar. As no further details on nets and pulse gears were given we cannot judge this. To avoid disturbing effects of different codend mesh sizes, it was decided to use four newly purchased identical codends on the two vessels during comparative trips, but as the skipper of BT2 was sceptical about the efficiency of these codends, they were not used on trip 5.

4.3 Effect on damage classes

The hypothesis concerning survival of discard fish is that the pulse trawl would catch less debris and benthos and that this would positively effect the damage done to the fish species and would increase the survival rate of the fish. The method of classification however is subjective and depends on judgement of the person classifying the damage. These persons differed per trip, causing variability in results. The condition of the fish also depends on handling on board and the lay-out of the processing line, which differed per ship. Taking fish from the conveyor belt does not exclusively show the effect of the pulse or conventional beam trawl, but includes effects caused by processing as well. In spite of these caveats the results show, not statistically tested, more lightly damaged fish in the discards of the pulse trawl. When using the average percentages with the survival rates found in 2005, the percentage survival of plaice in the catch can be substantially higher, meaning a smaller impact on the plaice population by fishing with pulse trawl, because there is no difference in the number of plaice discards. This is a finding justifying further study.

4.4 Methods used

The data were collected onboard commercial vessels carrying out their normal fishing operation. The way of sampling fish depended on the methods used on board for processing the fish. These methods usually differ slightly between vessels. The experimental procedures were refined several times to enhance standardisation. In addition, the crew on board of the vessels sometimes high-graded landings (discarding fish that larger than the minimum landing size). On board of every ship this happened in a different way. To rule out this effect on the discard levels of undersized fish, only data from discarded fish smaller than the minimum landing size was used for the analyses of variance in discard catches.

4.5 Views expressed by the fishermen

During the trials there was ample time between hauls to talk to the skipper and the crew members of the PT1. The report they gave was that initially in the summer of 2004 the pulse trawls fished relatively well with gross earnings not too far behind the vessels fishing with conventional tickler chain beam trawls. Over time the performance deteriorated, in spite of regular checks of the net and the electronics. The causes were not really found. It could have been a temperature effect or a gradual change in the performance of the system, although the electronic measurements displayed onboard did not reveal any substantial decrease. The general attitude turned from very positive to a more sceptical view. The savings in fuel were noticeable and much appreciated given the high prices of fuel oil, but doubts expressed whether the losses in target species could be compensated by this. A conclusive view was that the catching performance on sole and plaice will have to be improved for the system to become an economically viable alternative (*personal communication B. van Marlen with skipper and crew, trip 5, 13-16 March 2006*).

5. Conclusions

The main conclusions from this study are:

1. The landings of plaice and sole are significantly lower in the pulse trawl when compared to the conventional beam trawl. Both the auction data as the haul-based data showed a reduction of LpUE of particularly sole and plaice, contrary to the findings of earlier paired experiments onboard FRV “Tridens”. Over all species landed, the pulse trawl about 68% in kg/hr.
2. There was no significant difference in the catch rates of undersized (discard) plaice between the pulse trawl and the conventional trawl.
3. In the pulse trawl, the catch rates of undersized (discard) sole were significantly lower than in the conventional beam trawl.
4. Catch rates of benthic fauna (nrs/hr *Astropecten irregularis*, *Asterias rubens,* and *Liocarcinus holsatus*) were significantly lower in the pulse trawl compared to the conventional beam trawl.
5. There are indications that undersized plaice are damaged to a lesser degree in the pulse trawl and will survive better in the pulse trawl. Based on previous research, these results would indicate a survival rate of plaice in the pulse trawl that is twice as high as in a conventional beam trawl. But since the method of determining damage to fish by visual observation is subjective, this conclusion should be treated with caution.

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7. List of references

Agricola, J.B, 1985. Experiments on electrical stimulation of flatfish in beamtrawling during 1984. ICES CM 1985/B:36.

Beek, F.A. van, Leeuwen, P.I. van, and Rijnsdorp, A.D., 1990. On the survival of plaice and sole discards in the otter-trawl and beam-trawl fisheries in the North Sea. Netherlands Journal of Sea Research 26 (1): 151-160.

Lindeboom, H.J. and De Groot, S.J. (*editors*), 1998. IMPACT-II, The Effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems. NIOZ Report 1998-1, RIVO-DLO Report C003/98

Marlen, B. van, and Haan, D. de, 1988. Elektrische stimulering van platvis (verleden, heden en toekomst). RIVO rapport TO 88-06, *(In Dutch).*

Marlen, B. van, 1997. Alternative stimulation in fisheries. Final Report EU-project AIR3-CT94-1850, June 1997

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, 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, Bergman, M.J.N., Groenewold, S., and Fonds, M., 2001b. Research on diminishing impact in demersal trawling – The experiments in The Netherlands, ICES CM 2001/R:09

Marlen, B. van, Ybema, M.S., Kraayenoord, A., Vries, M. de en Rink, G., 2005a. 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., Lambooij, E., Kals, J., Veldman, M. and Gerritzen, M.A., 2005b. 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

Smaal, A.C., and Brummelhuis, E., 2005. Explorative study of the impact of an electric fishing field on macrobenthos. RIVO report: C089b/05. December 2005.

Stralen, M.R. van, 2005. The pulse trawl - Developing alternative fishing gear for flatfish fisheries using an electrical stimulus - A summary. MarinX report 2005.26.

8. Tables

Table 14: Overview of comparative fishing trips with two vessels operating in the same week

Trip	Week, year	Dates	Vessels: pulse conventional	# of hauls	# of sampled hauls (discards)	# of sampled hauls (landings)
1	41, 2005	10/10/2005-14/10/2005	PT1	43	37	10
		11/10/2005-14/10/2005	BT2	42	39	16
2	44, 2005	31/10/2005-04/11/2005	PT1	41	30	9
		31/10/2005-04/11/2005	BT2	43	34	28
3	5, 2006	30/01/2006-03/02/2006	PT1	41	32	22
		30/01/2006-04/02/2006	BT1	48	36	36
4	9, 2006	27/02/2006-03/03/2006	PT1	38	31	16
		27/02/2006-03/03/2006	BT2	44	34	34
5	11, 2006	13/03/2006-16/03/2006	PT1	30	22	22
		13/03/2006-17/03/2006	BT1	48	31	31

Table 15: Summary of numbers of hauls sampled and numbers of plaice (PLE), sole (SOL) and benthos in samples

trip	ship	category	# sampled hauls	# unsampled hauls	# of PLE sampled	# of SOL sampled	# of benthos sampled
1	PT1	discards	37	6	1989	227	6237
		landings	10		277	525	
	BT2	discards	39	3	1535	58	3711
		landings	16		208	523	
2	PT1	discards	30	11	940	111	1232
		landings	9		139	230	
	BT2	discards	34	9	1611	90	3414
		landings	28		393	683	
3	PT1	discards	32	9	2448	974	3748
		landings	22		495	506	
	BT1	discards	36	12	1740	1160	3716
		landings	36		3286	3037	
4	PT1	discards	31	7	2309	399	1807
		landings	16		345	325	
	BT2	discards	34	10	1647	515	2588
		landings	34		1402	3019	
5	PT1	discards	22	8	1345	796	1845
		landings	22		647	465	
	BT1	discards	31	12	1268	1544	2991
		landings	31		2701	2620	

Table 16: Auction data of gear test 1 (trip 1)

CPUE in kg/hour

species	cat1	cat2	cat3	cat4	cat5	cat6	total
PLE	1.85	3.86	6.81	6.58	7.53		**26.63**
SOL	0.35	1.36	3.39	6.04	6.90		**18.04**
DAB		3.76					**3.76**
TUR	0.37	0.44	0.47	1.62	2.63	0.48	**6.01**
BLL	0.45	0.96	0.28				**1.69**
COD	0.13	0.54	0.96	0.09	0.14		**1.86**
WHG							
NEP							
VAR							**7.66**
						total	**65.65**
PLE	2.56	5.70	7.57	13.61			**29.44**
SOL	0.58	3.25	3.89	5.25	8.66		**21.63**
DAB		4.28					**4.28**
TUR	0.15	0.26	0.61	1.58	2.70	0.67	**5.97**
BLL	0.32	0.97	0.29				**1.59**
COD			0.17	0.12	0.20	0.13	**0.61**
WHG							
NEP							
VAR							**5.75**
						total	**69.27**
Ratio of CPUE P/C in kg/hour							
PLE	**72.3%**	**67.7%**	**90.0%**	**48.4%**			**90.5%**
SOL	**61.4%**	**41.7%**	**87.0%**	**115.1%**	**79.7%**		**83.4%**
DAB		**88.0%**					**88.0%**
TUR	**238.0%**	**170.4%**	**76.8%**	**102.6%**	**97.4%**	**72.6%**	**100.6%**
BLL	**140.0%**	**98.2%**	**96.1%**				**106.3%**
COD			**574.1%**	**81.9%**	**69.1%**	**0.0%**	**303.3%**
WHG							
NEP							
VAR							**133.2%**
						total	**94.8%**

Table 17: Auction data of gear test 2 (trip 2)

CPUE in kg/hour

species	**cat1**	**cat2**	**cat3**	**cat4**	**cat5**	**cat6**	**total**
PLE	0.91	3.78	5.64	13.62			**23.95**
SOL	0.33	1.94	3.46	5.84	5.63		**17.21**
DAB		4.96					**4.96**
TUR	0.12	0.23	0.32	1.19	1.24	0.72	**3.82**
BLL	0.06	0.95	0.23				**1.24**
COD			0.10		0.07		**0.17**
WHG							
NEP							
VAR							**6.41**
						total	**57.76**
PLE	2.38	7.18	10.09	26.04			**45.68**
SOL	0.51	3.57	3.94	6.23	7.64		**21.89**
DAB		4.70					**4.70**
TUR	0.22	0.07	0.56	1.17	1.65	1.25	**4.92**
BLL	0.16	1.15	0.17				**1.48**
COD	0.17				0.13		**0.30**
WHG				0.12			**0.12**
NEP							
VAR							**8.67**
						total	**87.76**
Ratio of CPUE P/C in kg/hour							
PLE	**38.1%**	**52.7%**	**55.9%**	**52.3%**			**52.4%**
SOL	**65.5%**	**54.4%**	**87.8%**	**93.9%**	**73.7%**		**78.6%**
DAB		**105.7%**					**105.7%**
TUR	**54.1%**	**325.8%**	**57.9%**	**101.9%**	**75.4%**	**57.2%**	**77.6%**
BLL	**36.7%**	**83.1%**	**130.3%**				**83.6%**
COD	**0.0%**				**56.1%**		**55.4%**
WHG				**0.0%**			**0.0%**
NEP							
VAR							**73.9%**
						total	**65.8%**

Table 18: Auction data of gear test 3 (trip 3)

CPUE in kg/hour

species	cat1	cat2	cat3	cat4	cat5	cat6	total
PLE	3.01	13.44	20.78	14.46			**51.68**
SOL	1.09	2.64	2.33	1.81	1.14		**9.01**
DAB		7.13					**7.13**
TUR	0.32	0.38	0.52	0.76	0.69	0.57	**3.24**
BLL	0.34	0.45	0.05				**0.84**
COD	0.32	0.27	0.91	0.11			**1.62**
WHG				0.11			**0.11**
NEP		0.32					**0.32**
VAR							**12.25**
						total	**86.20**
PLE	5.69	25.95	33.53	29.65			**94.82**
SOL	1.40	3.99	2.18	2.35	2.72		**12.64**
DAB		14.43					**14.43**
TUR	0.31	0.29	0.35	0.74	0.76	0.48	**2.93**
BLL	0.33	0.30	0.04				**0.67**
COD	0.37	1.03	2.01	0.81	0.31		**4.53**
WHG	0.26						**0.26**
NEP		0.29					**0.29**
VAR							**15.14**
						total	**145.70**

Ratio of CPUE P/C in kg/hour

PLE	**52.8%**	**51.8%**	**62.0%**	**48.8%**			**54.5%**
SOL	**78.1%**	**66.1%**	**107.0%**	**76.7%**	**41.9%**		**71.2%**
DAB		**49.4%**					**49.4%**
TUR	**105.0%**	**133.1%**	**147.4%**	**102.9%**	**90.8%**	**118.1%**	**110.8%**
BLL	**102.9%**	**152.8%**	**120.6%**				**125.9%**
COD	**85.7%**	**26.4%**	**45.5%**	**13.2%**	**0.0%**		**35.7%**
WHG	**0.0%**						**41.7%**
NEP		**112.3%**					**112.3%**
VAR							**80.9%**
						total	**59.2%**

Table 19: Auction data of gear test 4 (trip 4)

CPUE in kg/hour

species	cat1	cat2	cat3	cat4	cat5	cat6	total
PLE	1.29	3.30	7.27	9.19			**21.05**
SOL	1.45	2.30	1.70	1.76	0.62		**7.83**
DAB		5.34					**5.34**
TUR	0.08	0.32	0.37	0.31	0.32	0.62	**2.01**
BLL	0.33	0.28	0.08				**0.69**
COD	0.46	0.27	0.28	0.10			**1.11**
WHG							
NEP							
VAR							**12.15**
						total	**50.19**

PLE	1.61	6.87	11.79	9.16			**29.42**
SOL	1.50	3.16	2.82	2.25	2.25		**11.99**
DAB		8.34					**8.34**
TUR	0.10	0.15	0.28	0.42	0.42	0.87	**2.23**
BLL	0.39	0.34	0.17				**0.90**
COD	0.95	0.58	1.10	0.40	0.18		**3.21**
WHG				0.08			**0.08**
NEP							
VAR							**19.34**
						total	**75.51**

Ratio of CPUE P/C in kg/hour

PLE	**80.2%**	**48.1%**	**61.6%**	**100.4%**			**71.6%**
SOL	**96.7%**	**72.7%**	**60.1%**	**78.1%**	**27.7%**		**65.3%**
DAB		**64.1%**					**64.1%**
TUR	**73.5%**	**212.1%**	**133.3%**	**73.5%**	**76.6%**	**72.1%**	**90.3%**
BLL	**84.4%**	**83.7%**	**44.1%**				**76.4%**
COD	**48.4%**	**46.3%**	**25.5%**	**25.2%**	**0.0%**		**34.5%**
WHG							**0.0%**
NEP							
VAR							**62.8%**
						total	**66.5%**

Table 20: Auction data of gear test 5 (trip 5)

CPUE in kg/hour

species	cat1	cat2	cat3	cat4	cat5	cat6	total
PLE	1.65	3.45	6.24	8.62			**19.96**
SOL	1.80	3.51	2.68	1.50	0.47		**9.95**
DAB		5.24					**5.24**
TUR		0.20	0.33	0.68	0.40	0.47	**2.08**
BLL	0.10	0.13	0.28	0.03			**0.55**
COD	0.13	0.22	0.28				**0.63**
WHG							
NEP							
VAR		22.75					**22.75**
						total	**61.17**

PLE	1.42	5.90	8.87	11.75			**27.94**
SOL	1.75	4.36	3.09	2.97	3.33		**15.50**
DAB		17.78					**17.78**
TUR	0.16	0.03	0.16	0.83	0.46	0.46	**2.11**
BLL	0.43	0.31	0.03				**0.77**
COD	0.32	0.45	0.76	0.74	0.35		**2.62**
WHG				0.23			**0.23**
NEP		0.31					**0.31**
VAR		20.17					**20.17**
						total	**87.42**

Ratio of CPUE P/C in kg/hour

PLE	**116.3%**	**58.4%**	**70.3%**	**73.4%**			**71.4%**
SOL	**103.0%**	**80.5%**	**86.6%**	**50.5%**	**14.0%**		**64.2%**
DAB		**29.5%**					**29.5%**
TUR	**0.0%**	**587.5%**	**209.8%**	**82.5%**	**86.0%**	**100.3%**	**98.7%**
BLL	**23.2%**	**43.5%**	**832.3%**				**71.3%**
COD	**42.0%**	**47.7%**	**37.3%**	**0.0%**	**0.0%**		**24.2%**
WHG				**0.0%**			**0.0%**
NEP		**0.0%**					**0.0%**
VAR		**112.8%**					**112.8%**
						total	**70.0%**

Table 21: Auction data of gear test 6 (all five trips combined)

CPUE in kg/hour

species	cat1	cat2	cat3	cat4	cat5	cat6	total
PLE	1.75	5.73	9.57	10.62	1.63		**29.30**
SOL	0.95	2.28	2.73	3.53	3.14		**12.63**
DAB		5.29					**5.29**
TUR	0.19	0.32	0.41	0.94	1.11	0.58	**3.54**
BLL	0.27	0.59	0.18	0.01			**1.04**
COD	0.21	0.26	0.52	0.06	0.05		**1.11**
WHG				0.02			**0.02**
NEP		0.07					**0.07**
VAR		3.49					**11.60**
						total	**64.59**
PLE	2.83	10.92	15.13	18.49			**47.38**
SOL	1.17	3.69	3.14	3.73	4.77		**16.49**
DAB		10.20					**10.20**
TUR	0.19	0.16	0.39	0.93	1.15	0.74	**3.55**
BLL	0.33	0.59	0.14				**1.06**
COD	0.37	0.44	0.86	0.43	0.24	0.02	**2.37**
WHG	0.06			0.08			**0.14**
NEP		0.13					**0.13**
VAR		4.04					**14.04**
						total	**95.36**
Ratio of CPUE P/C in kg/hour							
PLE	**61.9%**	**52.4%**	**63.2%**	**57.4%**			**61.9%**
SOL	**81.3%**	**61.7%**	**86.9%**	**94.7%**	**66.0%**		**76.6%**
DAB		**51.8%**					**51.8%**
TUR	**98.0%**	**198.3%**	**106.0%**	**101.0%**	**96.4%**	**78.3%**	**99.6%**
BLL	**80.8%**	**98.8%**	**131.4%**				**97.9%**
COD	**56.7%**	**59.5%**	**60.9%**	**14.7%**	**19.3%**	**0.0%**	**46.7%**
WHG	**0.0%**			**27.4%**			**16.1%**
NEP		**54.3%**					**54.3%**
VAR		**86.5%**					**82.6%**
						total	**67.7%**

Table 22: Mean percentage per trip per hour of the raised number of fishes in each physical condition class

Trip	Ship	# of hauls	A	B	C	D
1	PT1	7	28%	0%	1%	70%
	BT2	6	9%	20%	34%	37%
2	PT1	6	11%	39%	31%	19%
	BT2	8	9%	32%	45%	14%
3	PT1	7	34%	59%	6%	2%
	BT1	5	6%	47%	28%	19%
4	PT1	7	63%	34%	3%	0%
	BT2	7	9%	39%	30%	23%
5	PT1	5	33%	52%	9%	7%
	BT1	5	2%	57%	27%	14%
all	**PT1**	**32**	**36%**	**44%**	**8%**	**12%**
	other	**31**	**6%**	**43%**	**30%**	**20%**

Table 23: Results of the analysis of variance

Category/Species	Unit	Obs	Comparison of means			R^2	Significance of terms						
	W/N	(hauls)	Average Pulse	Average Control	Difference significance		T_i	A_j	D	G_k	T_i x G_k	A_j x G_k	D xG_k
Landings													
Plaice	W	361	29	44	+++	0.70	+++	+++	+++	+++	+++	+++	n.s.
Sole	W	369	12	16	+++	0.49	+++	++	n.s.	+++	n.s.	n.s.	n.s.
Discards													
Sole (trip 3 t/m5) <24	N	182	14.6	19.4	+++	0.47	+++	+++	+	+++	+++	n.s.	+++
	W	182	1.4	1.8	+++	0.49	+++	+	+	+++	+++	n.s.	+++
Plaice <27	N	324	997	948	n.s.	0.47	+++	+++	+++	n.s	n.s	n.s	n.s
	W	324	68.1	66.9	n.s.	0.40	+++	+++	+++	n.s.	++	n.s	n.s
Benthic fauna													
Astropecten irregularis	N[1]	202	344	1428	+++	0.50	+++	+++	++	+++	n.s.	n.s.	n.s.
Asterias rubens	N[1]	294	511	679	++	0.34	+++	+++	++	++	n.s.	n.s.	n.s.
Liocarcinus holsatus	N[1]	303	2117	3969	+++	0.51	+++	+++	+++	+++	+++	n.s.	+

Legend: +++: $P<0.01$, ++: ≤ 0.01 $P < 0.05$, +: $0.05 \leq P < 0.10$., n.s.: $0.10 \leq P$.

9. Figures

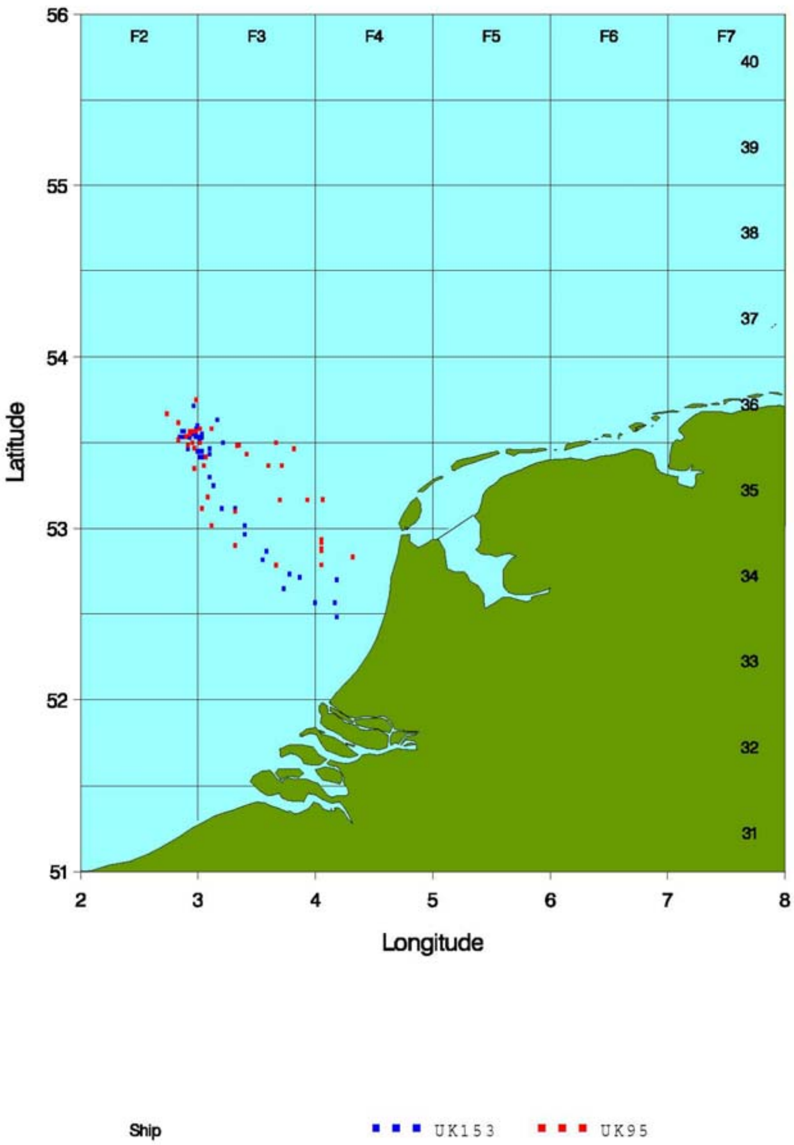

Figure 1: Positions fished during trip 1 PT1 and BT2, week 41, 2005

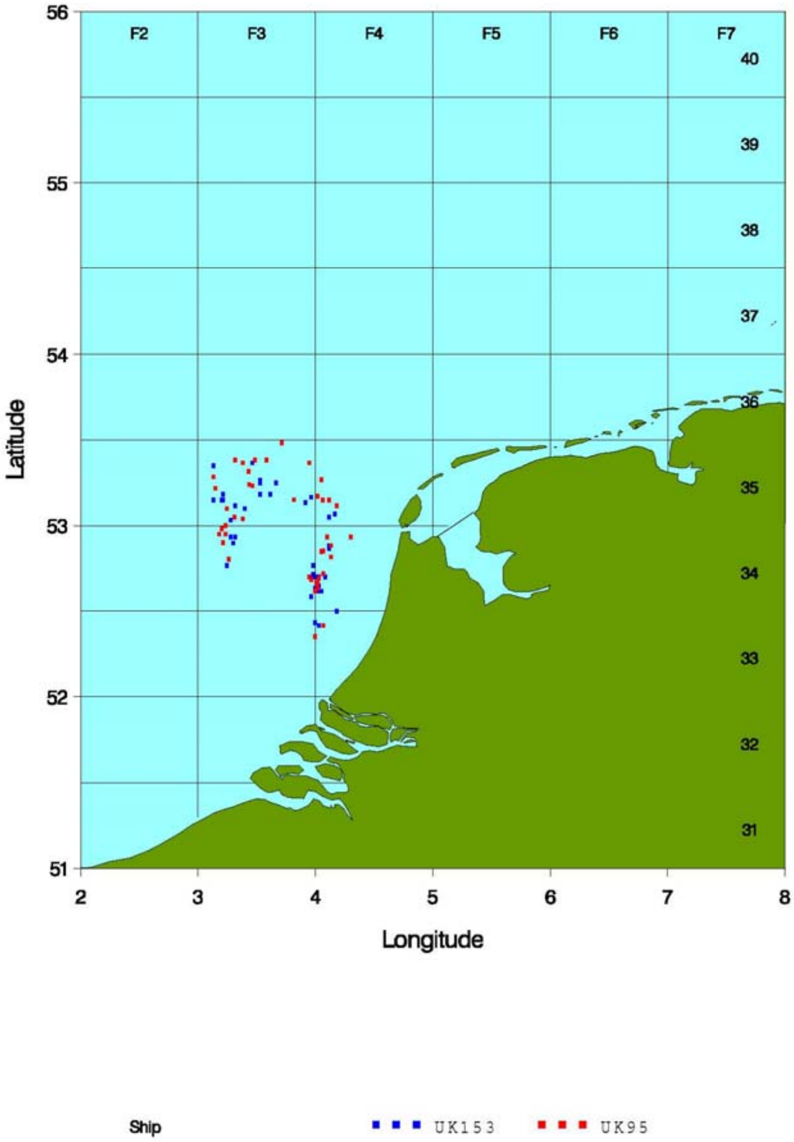

Figure 2: Positions fished during trip 2 PT1 and BT2, week 44, 2005

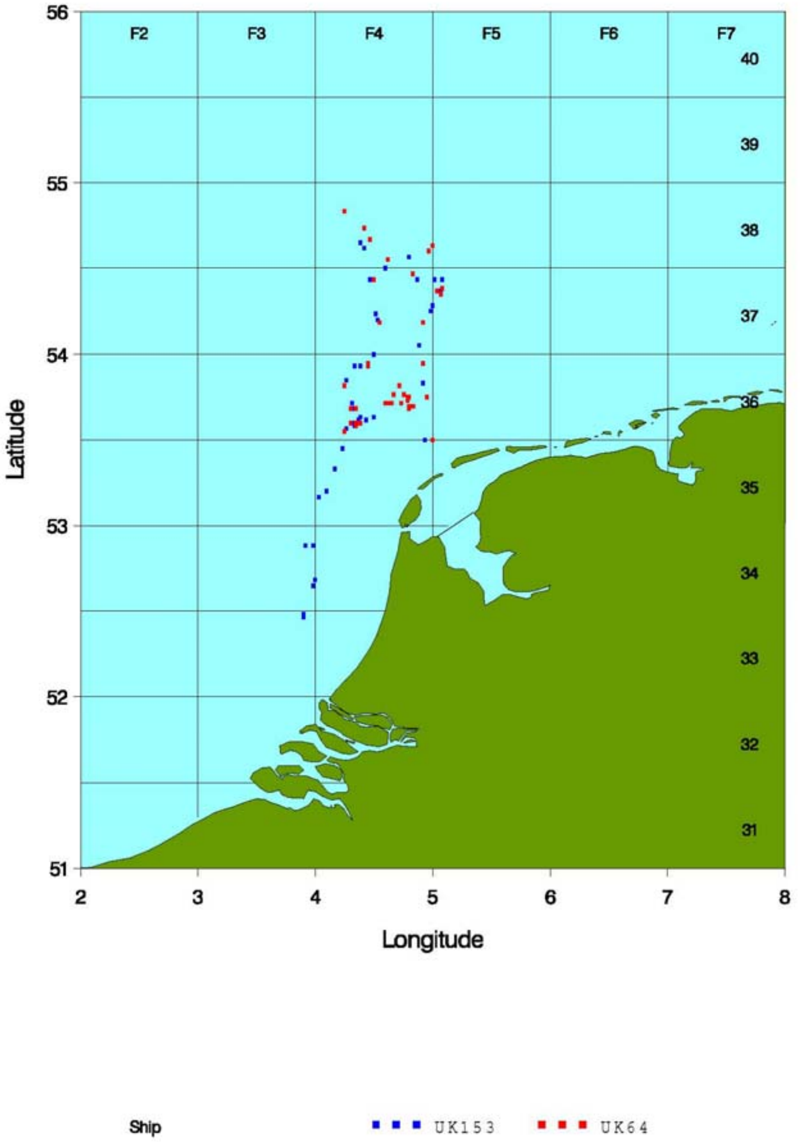

Figure 3: Positions fished during trip 3 PT1 and BT1, week 5, 2006

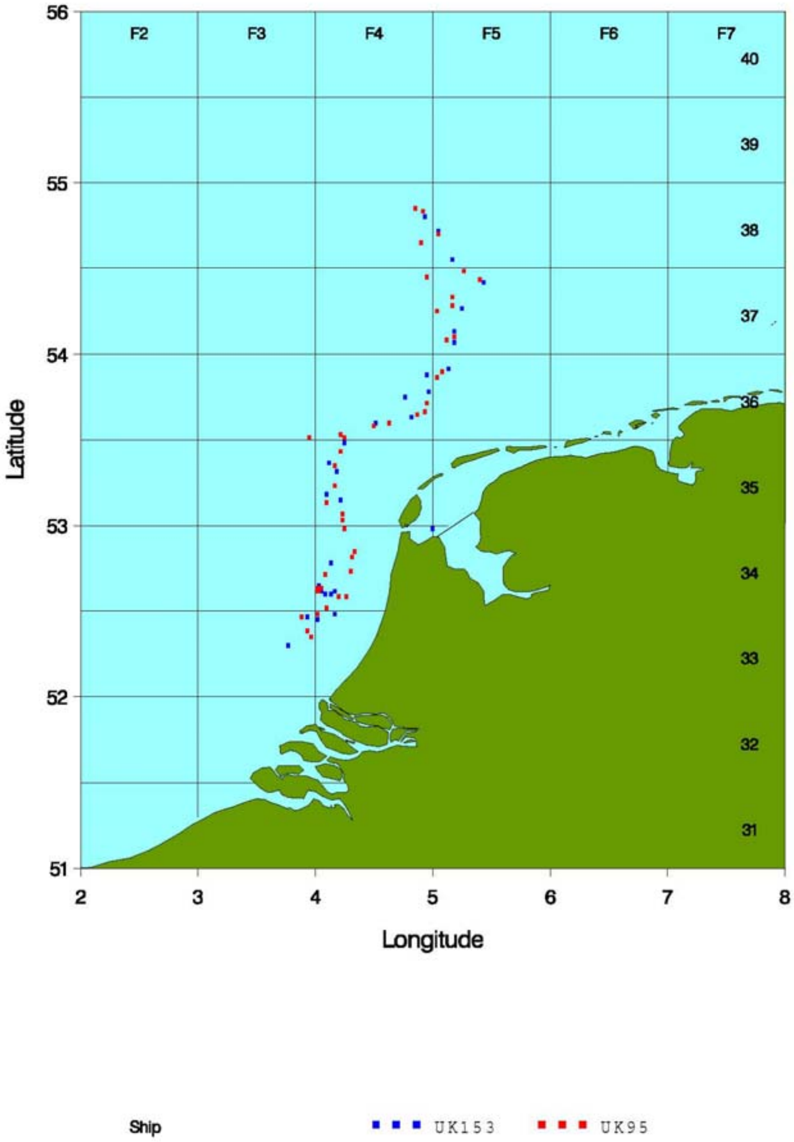

Figure 4: Positions fished during trip 4 PT1 and BT2, week 9, 2006

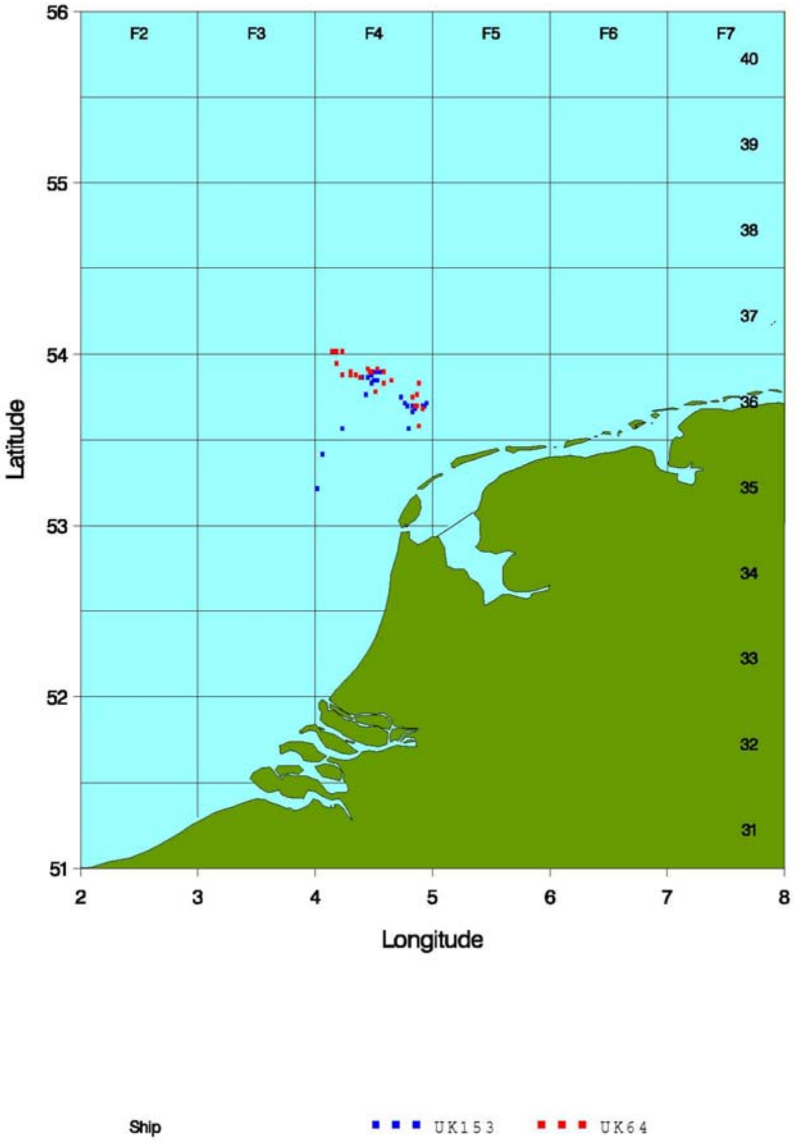

Figure 5: Positions fished during trip 5 PT1 and BT1, week 11, 2006

Figure 6: MFV UK153 (PT1) in port of IJmuiden, rear view with cable winches

Figure 7: Deck bins onboard PT1

Figure 8: Fish processing line onboard PT1

Figure 9: 12 m pulse beam trawls used on PT1

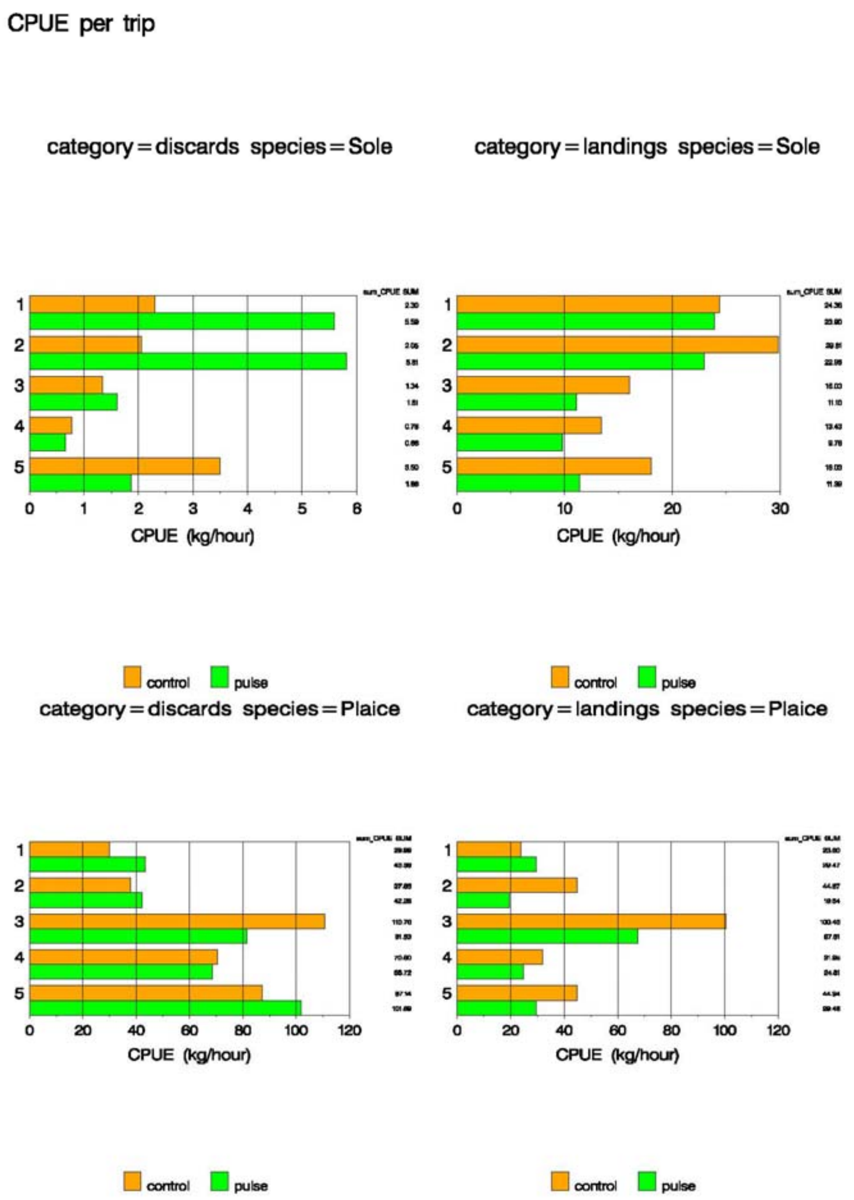

Figure 10: CPUE per trip for sole and plaice

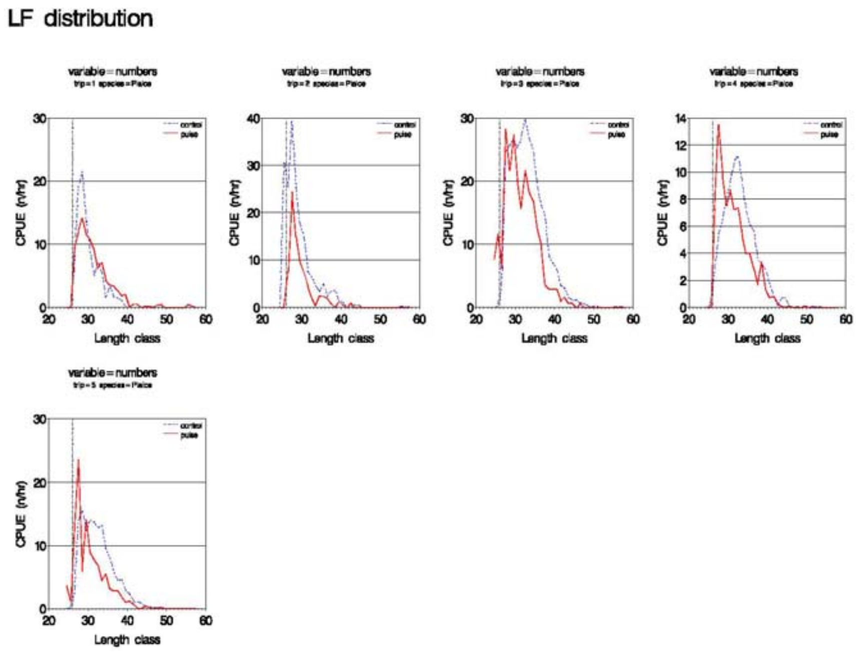

Figure 11: Length-frequency distributions per trip for plaice landings

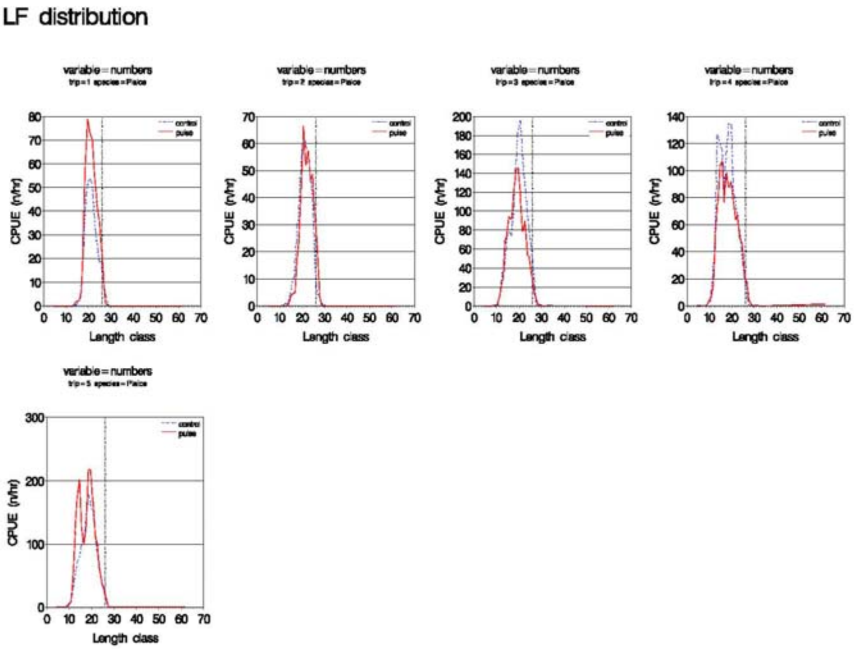

Figure 12: Length-frequency distributions per trip for plaice discards

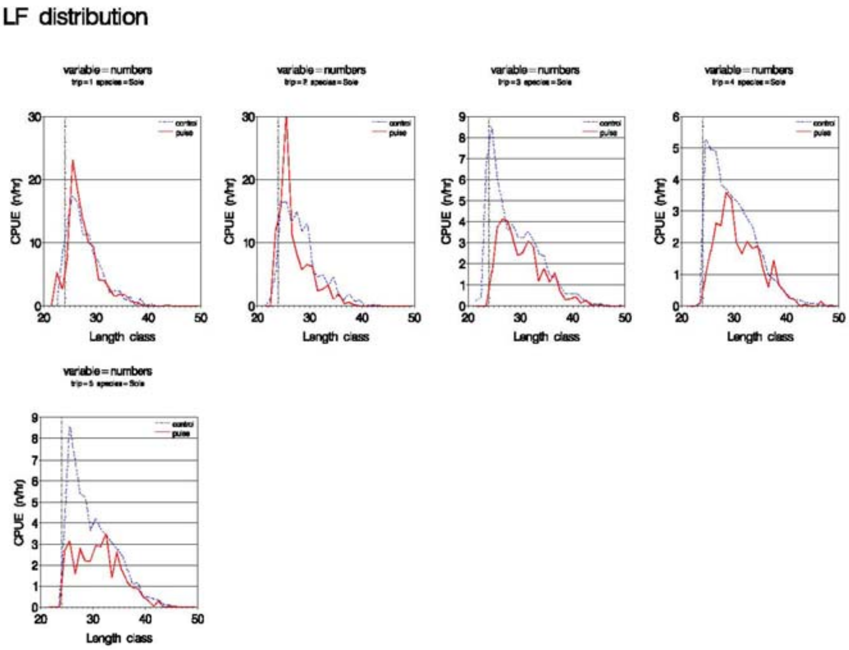

Figure 13: Length-frequency distributions per trip for sole landings

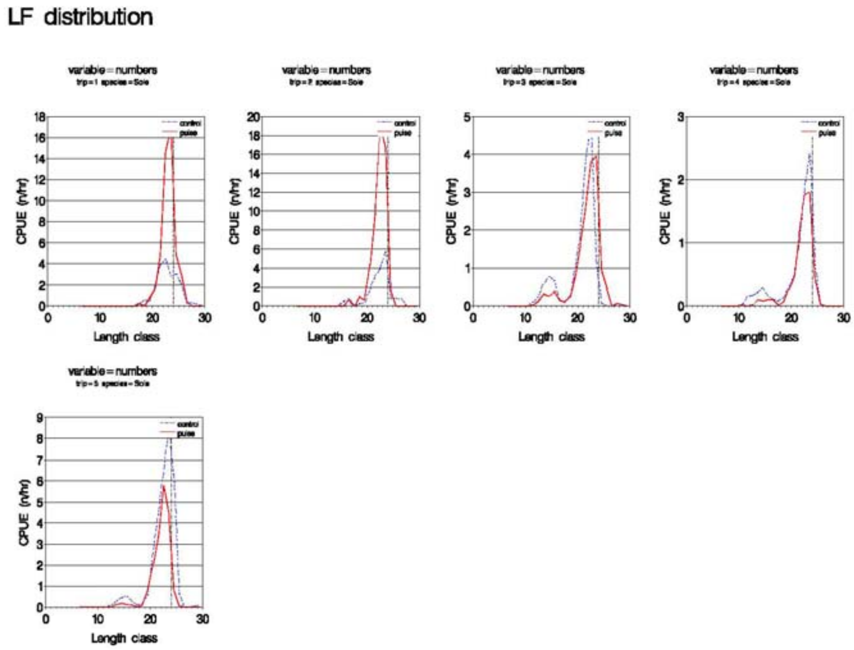

Figure 14: Length-frequency distributions per trip for sole discards

10. Annexes

10.1 Annex A: SAS GENMOD-output analyses CPUE with auction data

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                           The GENMOD Procedure

                             Model Information

                  Data Set              WORK.ALL_AUCTION_CPUE_SOL
                  Distribution                             Normal
                  Link Function                          Identity
                  Dependent Variable                     tot_CPUE


                      Number of Observations Read          10
                      Number of Observations Used          10


                          Class Level Information

                          Class      Levels    Values

                          GEAR            2    Conv Puls


                      Criteria For Assessing Goodness Of Fit

               Criterion                 DF           Value        Value/DF

               Deviance                   8        184.7376         23.0922
               Scaled Deviance            8          8.0000          1.0000
               Pearson Chi-Square         8        184.7376         23.0922
               Scaled Pearson X2          8          8.0000          1.0000
               Log Likelihood                      -28.8869


          Algorithm converged.


                         Analysis Of Parameter Estimates

                                    Standard     Wald 95% Confidence       Chi-
Parameter          DF     Estimate       Error           Limits            Square    Pr > ChiSq

Intercept           1      12.4086      2.1491      8.1965     16.6206      33.34        <.0001
GEAR       Conv     1       4.3216      3.0392     -1.6352     10.2784       2.02        0.1550
GEAR       Puls     0       0.0000      0.0000      0.0000      0.0000        .            .
Scale               0       4.8054      0.0000      4.8054      4.8054

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.


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                           The GENMOD Procedure
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Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.2857	0.5930

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	231.4285						
GEAR	184.7376	1	8	2.02	0.1928	2.02	0.1550

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
GEAR	1	8	2.02	0.1928	2.02	0.1550

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The GENMOD Procedure

Model Information

Data Set	WORK.ALL_AUCTION_CPUE_PLE
Distribution	Normal
Link Function	Identity
Dependent Variable	tot_CPUE

Number of Observations Read	10
Number of Observations Used	10

Class Level Information

Class	Levels	Values
GEAR	2	Conv Puls

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	8	3946.7930	493.3491
Scaled Deviance	8	8.0000	1.0000
Pearson Chi-Square	8	3946.7930	493.3491
Scaled Pearson X2	8	8.0000	1.0000
Log Likelihood		-44.1955	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits	Chi-Square	Pr > ChiSq

Intercept		1	28.6553	9.9333	9.1865	48.1242	8.32	0.0039
GEAR	Conv	1	16.8061	14.0478	-10.7270	44.3392	1.43	0.2316
GEAR	Puls	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		0	22.2115	0.0000	22.2115	22.2115		

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

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The GENMOD Procedure

Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.2857	0.5930

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	4652.9067						
GEAR	3946.7930	1	8	1.43	0.2658	1.43	0.2316

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
GEAR	1	8	1.43	0.2658	1.43	0.2316

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The GENMOD Procedure

Model Information

Data Set	WORK.ALL_AUCTION_CPUE_DAB
Distribution	Normal
Link Function	Identity
Dependent Variable	tot_CPUE

Number of Observations Read	10
Number of Observations Used	10

Class Level Information

Class	Levels	Values
GEAR	2	Conv Puls

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF

Deviance	8	149.6001	18.7000
Scaled Deviance	8	8.0000	1.0000
Pearson Chi-Square	8	149.6001	18.7000
Scaled Pearson X2	8	8.0000	1.0000
Log Likelihood		-27.8320	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	5.2882	1.9339	1.4978	9.0786	7.48	0.0062
GEAR	Conv	1	4.6160	2.7350	-0.7444	9.9764	2.85	0.0915
GEAR	Puls	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		0	4.3244	0.0000	4.3244	4.3244		

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

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The GENMOD Procedure

Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.2857	0.5930

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	202.8688						
GEAR	149.6001	1	8	2.85	0.1299	2.85	0.0915

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
GEAR	1	8	2.85	0.1299	2.85	0.0915

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The GENMOD Procedure

Model Information

Data Set	WORK.ALL_AUCTION_CPUE_TUR
Distribution	Normal
Link Function	Identity
Dependent Variable	tot_CPUE

Number of Observations Read 10

Number of Observations Used 10

Class Level Information

Class	Levels	Values
GEAR	2	Conv Puls

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	8	22.5331	2.8166
Scaled Deviance	8	8.0000	1.0000
Pearson Chi-Square	8	22.5331	2.8166
Scaled Pearson X2	8	8.0000	1.0000
Log Likelihood		-18.3671	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	3.4324	0.7506	1.9613	4.9034	20.91	<.0001
GEAR	Conv	1	0.1974	1.0614	-1.8830	2.2778	0.03	0.8525
GEAR	Puls	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		0	1.6783	0.0000	1.6783	1.6783		

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

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The GENMOD Procedure

Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.2857	0.5930

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	22.6306						
GEAR	22.5331	1	8	0.03	0.8571	0.03	0.8525

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
GEAR	1	8	0.03	0.8571	0.03	0.8525

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The GENMOD Procedure

Model Information

Data Set	WORK.ALL_AUCTION_CPUE_BLL
Distribution	Normal
Link Function	Identity
Dependent Variable	tot_CPUE

Number of Observations Read	10
Number of Observations Used	10

Class Level Information

Class	Levels	Values
GEAR	2	Conv Puls

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	8	1.5719	0.1965
Scaled Deviance	8	8.0000	1.0000
Pearson Chi-Square	8	1.5719	0.1965
Scaled Pearson X2	8	8.0000	1.0000
Log Likelihood		-5.0535	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	1.0019	0.1982	0.6133	1.3904	25.54	<.0001
GEAR	Conv	1	0.0810	0.2803	-0.4685	0.6305	0.08	0.7726
GEAR	Puls	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		0	0.4433	0.0000	0.4433	0.4433		

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

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The GENMOD Procedure

Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.2857	0.5930

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	1.5883						
GEAR	1.5719	1	8	0.08	0.7800	0.08	0.7726

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
GEAR	1	8	0.08	0.7800	0.08	0.7726

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The GENMOD Procedure

Model Information

Data Set	WORK.ALL_AUCTION_CPUE_WHG
Distribution	Normal
Link Function	Identity
Dependent Variable	tot_CPUE

Number of Observations Read	10
Number of Observations Used	10

Class Level Information

Class	Levels	Values
GEAR	2	Conv Puls

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	8	0.0537	0.0067
Scaled Deviance	8	8.0000	1.0000
Pearson Chi-Square	8	0.0537	0.0067
Scaled Pearson X2	8	8.0000	1.0000
Log Likelihood		11.8267	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	0.0214	0.0367	-0.0504	0.0932	0.34	0.5595
GEAR	Conv	1	0.1145	0.0518	0.0130	0.2161	4.88	0.0271
GEAR	Puls	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		0	0.0820	0.0000	0.0820	0.0820		

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

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The GENMOD Procedure

Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.2857	0.5930

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	0.0865						
GEAR	0.0537	1	8	4.88	0.0581	4.88	0.0271

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
GEAR	1	8	4.88	0.0581	4.88	0.0271

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The GENMOD Procedure

Model Information

Data Set	WORK.ALL_AUCTION_CPUE_COD
Distribution	Normal
Link Function	Identity
Dependent Variable	tot_CPUE

Number of Observations Read	10
Number of Observations Used	10

Class Level Information

Class	Levels	Values
GEAR	2	Conv Puls

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	8	14.6795	1.8349
Scaled Deviance	8	8.0000	1.0000
Pearson Chi-Square	8	14.6795	1.8349
Scaled Pearson X2	8	8.0000	1.0000
Log Likelihood		-16.2244	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	1.0778	0.6058	-0.1095	2.2651	3.17	0.0752
GEAR	Conv	1	1.1781	0.8567	-0.5010	2.8573	1.89	0.1691
GEAR	Puls	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		0	1.3546	0.0000	1.3546	1.3546		

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

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The GENMOD Procedure

Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.2857	0.5930

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	18.1494						
GEAR	14.6795	1	8	1.89	0.2064	1.89	0.1691

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
GEAR	1	8	1.89	0.2064	1.89	0.1691

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The GENMOD Procedure

Model Information

Data Set	WORK.ALL_AUCTION_CPUE_NEP
Distribution	Normal
Link Function	Identity
Dependent Variable	tot_CPUE

Number of Observations Read	10
Number of Observations Used	10

Class Level Information

Class	Levels	Values
GEAR	2	Conv Puls

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	8	0.1876	0.0234
Scaled Deviance	8	8.0000	1.0000
Pearson Chi-Square	8	0.1876	0.0234
Scaled Pearson X2	8	8.0000	1.0000
Log Likelihood		5.5764	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	0.0642	0.0685	-0.0700	0.1984	0.88	0.3488
GEAR	Conv	1	0.0542	0.0968	-0.1356	0.2440	0.31	0.5759
GEAR	Puls	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		0	0.1531	0.0000	0.1531	0.1531		

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

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The GENMOD Procedure

Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.2857	0.5930

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	0.1949						
GEAR	0.1876	1	8	0.31	0.5912	0.31	0.5759

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
GEAR	1	8	0.31	0.5912	0.31	0.5759

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The GENMOD Procedure

Model Information

Data Set WORK.ALL_AUCTION_CPUE_VAR

Distribution	Normal
Link Function	Identity
Dependent Variable	tot_CPUE

Number of Observations Read	10
Number of Observations Used	10

Class Level Information

Class	Levels	Values
GEAR	2	Conv Puls

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	8	329.7127	41.2141
Scaled Deviance	8	8.0000	1.0000
Pearson Chi-Square	8	329.7127	41.2141
Scaled Pearson X2	8	8.0000	1.0000
Log Likelihood		-31.7833	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	12.2435	2.8710	6.6164	17.8706	18.19	<.0001
GEAR	Conv	1	1.5718	4.0603	-6.3862	9.5297	0.15	0.6987
GEAR	Puls	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		0	6.4198	0.0000	6.4198	6.4198		

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

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The GENMOD Procedure

Lagrange Multiplier Statistics

Parameter	Chi-Square	Pr > ChiSq
Scale	0.2857	0.5930

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	335.8891						
GEAR	329.7127	1	8	0.15	0.7088	0.15	0.6987

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
GEAR	1	8	0.15	0.7088	0.15	0.6987

10.2 Annex B: SAS GLM-output analyses CPUE based on 175 pairs of hauls

Comment [h1]: Bob zijn dit de uitdraaien van jou analyses? Want dan is het enige verschil tussen dit en wat rob/ik hebben gedaan dat wij diepte hebben meegenomen en alle data hebben gebruikt. Wat weinig uit zal maken omdat je toch geen analyse doet op gepaarde waarnemingen.

Analysis for data : b_SOL 153

The GLM Procedure

Class Level Information

Class	Levels	Values
geartest	1	6
area	4	1 2 3 4
GEAR	2	Conv Puls

Number of Observations Read 350
Number of Observations Used 349

Analysis for data : b_SOL 154

The GLM Procedure

Dependent Variable: kg_hour

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	6448.28328	1612.07082	53.05	<.0001
Error	344	10452.63254	30.38556		
Corrected Total	348	16900.91582			

R-Square	Coeff Var	Root MSE	kg_hour Mean
0.381535	37.52453	5.512310	14.68988

Source	DF	Type I SS	Mean Square	F Value	Pr > F
geartest	0	0.000000	.	.	.
area	3	5223.596946	1741.198982	57.30	<.0001
GEAR	1	1224.686333	1224.686333	40.30	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
geartest	0	0.000000	.	.	.
area	3	5359.873816	1786.624605	58.80	<.0001
GEAR	1	1224.686333	1224.686333	40.30	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		6.66804996 B	0.83370413	8.00	<.0001
geartest	6	0.00000000 B	.	.	.
area	1	8.71320005 B	1.00678345	8.65	<.0001
area	2	10.89834908 B	0.96486363	11.30	<.0001
area	3	3.57663967 B	0.91748410	3.90	0.0001
area	4	0.00000000 B	.	.	.
GEAR	Conv	3.75269878 B	0.59110535	6.35	<.0001
GEAR	Puls	0.00000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

Analysis for data : b_SOL 155

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

GEAR	kg_hour LSMEAN	H0:LSMean1=LSMean2 Pr > |t|
Conv	16.2177959	<.0001
Puls	12.4650972	

GEAR	kg_hour LSMEAN	95% Confidence Limits	
Conv	16.217796	15.367564	17.068028
Puls	12.465097	11.621207	13.308987

Least Squares Means for Effect GEAR

i	j	Difference Between Means	Simultaneous 95% Confidence Limits for LSMean(i)-LSMean(j)	
1	2	3.752699	2.590063	4.915335

Analysis for data : b_SOL 156

The UNIVARIATE Procedure
Variable: res

Moments

N	349	Sum Weights	349
Mean	0	Sum Observations	0
Std Deviation	5.48053833	Variance	30.0363004
Skewness	1.02634179	Kurtosis	2.49948894
Uncorrected SS	10452.6325	Corrected SS	10452.6325
Coeff Variation	.	Std Error Mean	0.29336649

Basic Statistical Measures

Location		Variability	
Mean	0.00000	Std Deviation	5.48054
Median	-0.40143	Variance	30.03630
Mode	0.55580	Range	38.98549
		Interquartile Range	5.84105

Tests for Location: Mu0=0

Test	-Statistic-		—p Value—	
Student's t	t	0	Pr > ltl	1.0000
Sign	M	-11.5	Pr >= lMl	0.2389
Signed Rank	S	-2821.5	Pr >= lSl	0.1349

Tests for Normality

Test	–Statistic–		—p Value—	
Shapiro-Wilk	W	0.94127	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.101988	Pr > D	<0.0100
Cramer-von Mises	W-Sq	0.752976	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	4.706972	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	27.548895
99%	16.028584
95%	10.750522
90%	5.876296
75% Q3	2.401548
50% Median	-0.401425
25% Q1	-3.439505
10%	-6.609794
5%	-8.018127
1%	-10.477253
0% Min	-11.436600

Analysis for data : b_SOL 157

The UNIVARIATE Procedure
Variable: res

Extreme Observations

----Lowest----		----Highest----	
Value	Obs	Value	Obs
-11.4366	268	16.0064	296
-10.8642	50	16.0286	51
-10.6292	234	16.6387	58
-10.4773	329	16.9511	33
-10.4773	318	27.5489	75

Missing Values

Missing Value	Count	---Percent Of--- All Obs	Missing Obs
.	1	0.29	100.00

```
          Histogram                 #  Boxplot
  27+*                              1     *
    .
    .
    .
    .
    .**                             4     0
    .***                            6     0
    .***                            5     0
    .***                            6     |
    .**                             4     |
    .****                           7     |
    .*************                 26     |
    .*******************           38  +-----+
    .*********************************  66  |  +  |
    .************************************  72  *-----*
    .**********************        43  +-----+
    .****************              31     |
    .***********                   22     |
    .******                        11     |
 -11+****                           7     |
     ----+----+----+----+----+----+----+-
     * may represent up to 2 counts
```

Analysis for data : b_SOL 158

The UNIVARIATE Procedure
Variable: res

```
                Normal Probability Plot
  27+                                        *
    |
    |
    |
```

```
    |
    |                        ****
    |                      ***
    |                     **  ++++
    |                    ** +++
    |                    *+++
    |                  ++**
    |                ++****
    |              ++*****
    |            +******
    |          ******
    |        ****+
    |      *****
    |    *****+
    |  ****++
 -11+*** *++
     +--+--+--+--+--+--+--+--+--+--+
       -2    -1     0    +1    +2
```

Analysis for data : b_PLE 159

The GLM Procedure

Class Level Information

Class	Levels	Values
geartest	1	6
area	4	1 2 3 4
GEAR	2	Conv Puls

Number of Observations Read 350
Number of Observations Used 349

Analysis for data : b_PLE 160

The GLM Procedure

Dependent Variable: kg_hour

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	47228.8078	11807.2019	21.30	<.0001
Error	344	190692.2008	554.3378		
Corrected Total	348	237921.0086			

R-Square	Coeff Var	Root MSE	kg_hour Mean
0.198506	61.95270	23.54438	38.00380

Source	DF	Type I SS	Mean Square	F Value	Pr > F
geartest	0	0.00000	.	.	.
area	3	25526.08056	8508.69352	15.35	<.0001
GEAR	1	21702.72723	21702.72723	39.15	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
geartest	0	0.00000	.	.	.
area	3	24037.10373	8012.36791	14.45	<.0001
GEAR	1	21702.72723	21702.72723	39.15	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		43.74303934 B	3.56094755	12.28	<.0001
geartest	6	0.00000000 B	.	.	.
area	1	-20.32662601 B	4.30021027	-4.73	<.0001
area	2	-22.81078438 B	4.12116081	-5.54	<.0001
area	3	-8.45266739 B	3.91879160	-2.16	0.0317
area	4	0.00000000 B	.	.	.
GEAR	Conv	15.79750228 B	2.52475078	6.26	<.0001
GEAR	Puls	0.00000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

Analysis for data : b_PLE 161

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

GEAR	kg_hour LSMEAN	H0:LSMean1=LSMean2 Pr > |t|
Conv	46.6430222	<.0001
Puls	30.8455199	

GEAR	kg_hour LSMEAN	95% Confidence Limits	
Conv	46.643022	43.011480	50.274564
Puls	30.845520	27.241067	34.449973

Least Squares Means for Effect GEAR

i	j	Difference Between Means	Simultaneous 95% Confidence Limits for LSMean(i)-LSMean(j)	
1	2	15.797502	10.831608	20.763396

Analysis for data : b_PLE 162

The UNIVARIATE Procedure
Variable: res

Moments

N	349	Sum Weights	349
Mean	0	Sum Observations	0
Std Deviation	23.4086756	Variance	547.966094
Skewness	1.3399275	Kurtosis	2.03639028
Uncorrected SS	190692.201	Corrected SS	190692.201
Coeff Variation	.	Std Error Mean	1.25303768

Basic Statistical Measures

Location		Variability	
Mean	0.0000	Std Deviation	23.40868
Median	-5.0192	Variance	547.96609
Mode	-17.0741	Range	141.33230
		Interquartile Range	23.89360

Tests for Location: Mu0=0

Test	-Statistic-		—p Value—	
Student's t	t	0	Pr > |t|	1.0000
Sign	M	-48.5	Pr >= |M|	<.0001
Signed Rank	S	-5404.5	Pr >= |S|	0.0040

Tests for Normality

Test	–Statistic–		—p Value—	
Shapiro-Wilk	W	0.896027	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.148421	Pr > D	<0.0100
Cramer-von Mises	W-Sq	2.005985	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	11.32167	Pr > A-Sq	<0.0050

Quantiles (Definition 5)

Quantile	Estimate
100% Max	102.64292
99%	70.99246
95%	50.64574
90%	37.65114
75% Q3	9.14881
50% Median	-5.01921
25% Q1	-14.74478
10%	-23.69743
5%	-28.49912
1%	-35.96966

0% Min -38.68938

Analysis for data : b_PLE 163

The UNIVARIATE Procedure
Variable: res

Extreme Observations

----Lowest----		----Highest----	
Value	Obs	Value	Obs
-38.6894	136	64.9561	209
-36.9518	186	70.9925	212
-35.9706	163	80.3833	242
-35.9697	176	91.3392	232
-35.4459	127	102.6429	261

Missing Values

Missing Value	Count	---Percent Of--- All Obs	Missing Obs
.	1	0.29	100.00

```
                 Histogram                       #  Boxplot
   105+*                                         1     *
      .*                                         1     *
      .*                                         1     0
      .*                                         1     0
      .***                                       5     0
      .******                                   11     0
      .******                                   11     0
    35+******                                   11     |
      .********                                 16     |
      .*************                            26     |
      .*********************                    42  +--+--+
      .**********************************************  92  *-----*
      .*******************************************     86  +-----+
      .***************                          30     |
   -35+********                                 15     |
       ----+----+----+----+----+----+----+----+-
       * may represent up to 2 counts
```

Analysis for data : b_PLE 164

The UNIVARIATE Procedure
Variable: res

```
                 Normal Probability Plot
   105+                                        *
      |                                      *
      |                                     *
```

```
   |                                    *
   |                                  ***
   |                               ****  ++++
   |                              *** ++++
 35+                               **++++
   |                          +***
   |                       ++****
   |                   ++++****
   |                 +********
   |            *********
   |        *******++
-35+********+++++
    +—+—+—+—+—+—+—+—+—+—+
      -2     -1      0     +1     +2
```