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Pulse trawl on flatfish as an alternative for beam trawl

The economic performance and the environmental impact of the innovative. Pulse trawl in comparison to the conventional Beam trawl

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***Abstract*—The cost effectiveness of the pulse trawl in comparison to the beam trawl on the basis of two periods of commercial trials of the pulse trawl, turns out to be rather positive. The economic performance of the pulse trawl can compete with comparable beam trawl. This is especially due to a decrease in oil consumption, which is a high cost for beam trawlers. Fuel consumption of the pulse trawl is some 45-50% lower than the beam trawl.**

Environmental costs are also lower. When it concerns discards, in the pulse trawl, the catch rates of undersized (discard) sole were significantly lower in 2006 than in the conventional beam trawl, and also catch rates of benthic fauna were significantly lower. However, in 2009 with the pulse trawl more sole in number and weights per unit of time was discarded and less plaice was discarded. There are indications that undersized plaice are damaged to a lesser degree in the pulse trawl and will survive better in the pulse trawl. Next to this the use of a pulse trawl generates less emission of CO2 than the use of a beam trawl.

The pulse trawl seems to be an alternative for beam trawlers that are mainly directed towards sole and plaice. Even sole catches are better but catches of plaice lack some behind. Some concern exists on the effects of pulse trawling on certain non target species which is subject of research at the moment.

I. THE ECONOMIC PERFORMANCE OF THE PULSE TRAWL IN COMPARISON TO THE CONVENTIONAL BEAM TRAWL

A. Introduction

The willingness of fishermen to adopt the pulse trawl will largely depend on the impact that the gear will have on their own economic performance. Gear that results in decrease of revenues below costs would not be accepted by any fisherman, while gear that enhances profitability will be readily adopted. Gear that results in lower levels of profitability than the current beam trawl would also not easily be voluntarily adopted. Compliance with any legislated gear restrictions would depend, at least in part, with the degree by which profits fell. It is therefore important to understand this impact when assessing the likelihood of adoption and compliance with any legislated requirement to use the pulse trawl.

This paragraph presents estimates of the economic impact of adoption of the pulse trawl (PT) from the perspective of the fisherman. It presents a measure of the financial profitability of an individual fisherman adopting PT, which can be compared with the profitability of using the Beam trawl (BT). For modifications to existing gear, this involves estimates of changes in the revenue and costs from using the gear. The impact on revenue is based on changes in catch rates and catch composition observed in the sea trials. In the case of the pulse trawl change in fuel consumption has a large impact on costs. Estimates of gear costs are derived based on the gear specifications. The economic results from the sea trials are applied to cost and earnings data collected from a sample of four similar vessels operating in the same fishery as the sea trial vessel (PT1), during the period 2004-2006. Next to this economic results of another pulse trawl vessel (PT2) in 2009 has been compared to the results of the same vessel (BTx) that operated in 2007 as a beam trawl vessel. Cost data collected from the sea trial vessel also provide an indication of the relevance of the derived cost per day to the alternative application of the gear. Catch and revenue information are based on the sea trials, however the pulse trawl that operated in the period 2004-2006, operated only in 2006 on a commercial basis. It is likely that the revenue information obtained from the sea trials may underestimate the revenue that could be achieved once fishers gained experience in the use of the gear. That is why the first three quarters of 2006 are considered to deliver reliable and valuable data, since ‘growing pains’ in the experimental phase were conquered. The fishermen of PT2 started in May 2009 with the commercial exploitation of the

pulse trawl, and data from the period 4 May till 2 October 2009 is compared to the data of BTx in the same period in 2007.

B. General setting of Dutch fishery

The Dutch fleet fishes its coastal waters (12 miles zone), the mid-distant waters (North Sea), and the high seas. The cutter fleet fish mainly for demersals, like sole, plaice, cod, whiting, and shrimps, and also pelagic fish, like herring. These North Sea stocks are joined with some of the European Union Member States bordering on the North Sea, namely Belgium, Germany, Great Britain, and Denmark, and to a certain extent with the non-Member States Norway, for plaice.

In 2005 the cutter fishery existed of 342 vessels of which 242 were beam trawlers (large beam trawlers and Euro cutters). Other vessels were: three otter trawlers, one round fish pair trawlers, one herring pair trawlers, 47 shrimp vessels and several other gear vessels (like twin rig, Danish seine and fixed net fishing for langoustines, red gurnard, red mullet, dab, plaice and sole). Next to this Dutch fishery consists of 15 high seas pelagic trawlers and 64 mussel vessels. Total engine power of the Dutch fleet is 332,000 HP. 2263 Fishermen find employment on the Dutch fleet (Taal et al 2006). The number of vessels in the active cutter fleet in 2009 decreased to 308 cutters while the total engine power declined by 36% to 268,000 HP (Taal et al. 2009).

In general the cutters are property of (extended) fishing families, on which father and sons complemented with other fishermen, work. Together they fish in a partnership in which the owner(s) bring in their vessel(s) and ITQs, while the other fishermen bring in their labour. Together they agree on a division of the revenues.

C. Beam trawl cutter fleet

The beam trawl cutter fleet consisted in 2005 of 102 large beam trawlers and 140 Euro cutters, also operating with a beam trawl, total 240 beam trawlers. Since then the number of large beam trawlers decreased to 80 and the number of Euro cutters (seasonally targeting flatfish) to 70 in 2008. Cutters fish the coastal waters (12 miles zone) and the mid-distant waters in the North Sea: Dogger Bank, German Bight, and north of Friesland. Deeper parts of the North Sea and parts with a lack of streams are seldom fished. “Although there are relatively few restrictions on the areas that can be fished by beam trawlers, the distribution of fishing activity is patchy on many scales (Rijnsdorp et al., 1998). For instance, more than half the North Sea is not fished by the beam trawl fleet and yet small areas in the south-eastern part are trawled more than 10 times per year (Rijnsdorp et al., 1998)”. The cutter fleet fishes mainly for demersals, like sole, plaice, cod, whiting, and shrimps, and also pelagic fish, like herring. Total engine power of the Dutch beam trawl fleet is estimated at a maximum of 181.000 HP. Revenues in the cutter fleet as a whole decreased in 2008 by 7% to € 252 million. The financial position of the cutter sector is rather bad since the year 2002 (Taal et al 2009).

D. The evolution of the fishing techniques in the Netherlands

Dutch fishermen used until the 1960’s the otter trawl to fish for flatfish. Fishermen from the Wadden sea imported the shrimp beam trawl from Germany. They improved the beam trawl and went for shrimp in the North Sea from 1950 on. Because results of this technique were very good, one tried to catch flatfish as well with some extra features added to the beam trawl. Before 1960 some fishermen that used the otter trawl switched over to beam trawling and from 1960 on the otter trawl became outmoded1.

The beam trawl became very popular and successful in Dutch flatfish fishery. Catches were high, however since introduction of the quota system fishermen have had to adapt learning not to fish as much as possible, but to fish within their ITQ limits. The beam trawl’s reputation changed for the worse a number of years ago. The technique is now considered to be environmentally unfriendly because the benthos is damaged by the trawling and it generates a lot of by catch. Some fishermen have already switched to twinrig, hydrorig, Danish seine, otter trawl (again) and fixed net fishing. A new technique, the pulse trawl, has been tested on an experimental basis. Two vessels have recently, respectively in 2006 and in 2009, been using this technique on a commercial basis and others would like to follow. Since the pulse trawl is using electric pulses to startle the flatfish and electric fishing is forbidden in Europe, every year a dispensation from this rule is needed. ICES is looking at the effects of the pulses on the ecosystem. Whether the pulse trawl will be allowed is still uncertain.

II. PULSE TRAWLING COMPARED TO BEAM TRAWLING

A. Two periods of comparison

In this presentation the performance of two pulse trawl vessels (PT1 and PT2) will be compared to the traditional beam trawl in two ways:

1) PT1 will be compared to four reference vessels (BT1, BT2, BT3 and BT4) and to the average of these BTs in 2006 (paragraph 2.2).

2) The performance of PT2 in 2009 will be compared to the performance of the same vessel that operated in 2007 as a beam trawl (paragraph 2.3).

B. Main characteristics of the pulse trawl vessel (PT1) and the four reference vessels (BT1-4) 2004-2006

The PT1 was built in 1998, has a length of 42.4 meter and an engine of 2000 HP. The PT1 will be compared with the average of the four reference beam trawl vessels. The average of the reference vessels differ slightly from the PT1 (see table 1).

1 Source: de Vleet, Ecomare.

TABLE I. CHARACTERISTICS OF THE VESSELS

	Characteristics of the vessels		
	PT1	***4 Reference Vessels***	***Difference in %***
Length	42,40	41,44	+2
GT	508	466	+9
HP	2000	2224	-10
Year hull	1998	1991	-7 Years
Year engine	1999	1995	-4 Years

C. Pulse trawling 2004-2006

During the period 2004-2006 the pulse trawl (PT1) was in its experimental phase, it had to overcome many growing pains. Various changes and improvements were made to the system and in 2004 and 2005 pulse trawling did not perform economically better than the beam trawlers. However, costs for PT1 were lower than of BTs due to a lower fuel consumption of 50%-60% next to high fuel prices. Savings were up to 300,000 € in 2005. Fuel costs for BTs increased in 2005. In this period the pulse trawl technique was not yet fully developed. In fact catches stayed behind the BT catches and as a consequence revenues were low, no profits were made, although fish prices were good.

Conventional beam trawling however has not been economical profitable for some years now. Costs are high; in 2005 the BT fleet (on average) suffered losses weekly. High costs are mainly caused by high fuel prices and the high fuel consumption of beam trawling. This is why an alternative to beam trawling is economically necessary. The costs of investing in pulse trawl gear are high (circa 400,000 €), however some enterprises are confident that revenues will improve and consequently investment in PT will become feasible. In the middle of 2006 PT1 started operating on a commercial base. The fishing enterprise using the pulse trawl gear, was allowed to rent the gear from the ministry that owns the pulse trawl gear.

D Pulse trawling on a commercial basis in 2006

In the third quarter of 2006 of the test phase of PT1 came to an end and the fishing enterprise continued using the alternative gear on a commercial base. If we compare the average revenues in the first three quarters of 2006 of PT1 with the third quarter of 2006 we see an increase in revenues.

TABLE II. REVENUES FOR FIRST THREE QUARTERS OF 2006

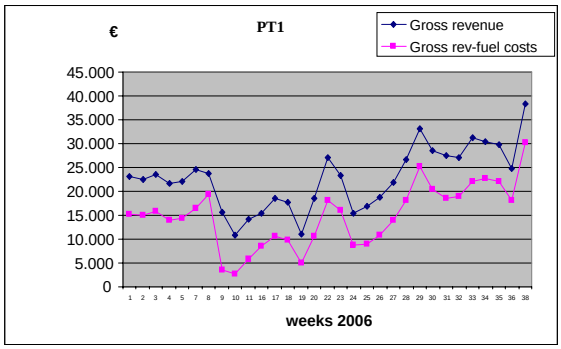
PT1	**Week 1 till 38 of 2006 (1 January till 30 September)**	
	Per day	***Per week***
Average revenues	5.772	23.087
Fuel costs	2.001	8.004
Revenue minus fuel costs	**3.771€**	**15.083€**

TABLE III. REVENUES 3RD QUARTER OF 2006: COMMERCIAL BASE

PT1	**Week 27 till 38 of 2006 (1 July till 30 September)**	
	Per day	***Per week***
Average revenues	7.264	29.057
Fuel costs	2.030	8.119
Revenue minus fuel costs	**5.234€**	**20.938€**

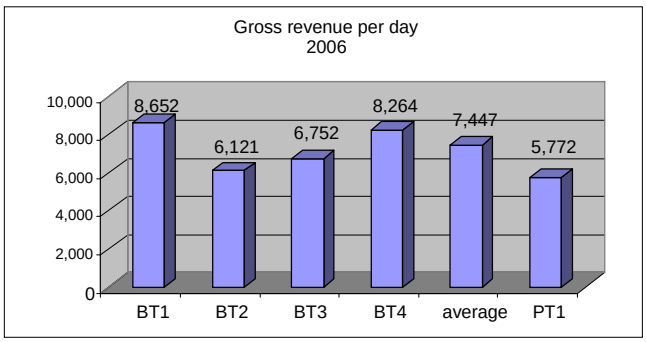
In the third quarter of 2006 no technical problems occurred. An increase in catches and revenues of 25%, without an increase in costs made PT1 a competitor of the reference vessels (see below). Profitability seems to be better in this period than average Dutch beam trawler, especially in the sole fishery.

FIGURE 1 GROSS REVENUE AND GROSS REVENUE MINUS FUEL COSTS FOR FIRST 3 QUARTERS OF 2006



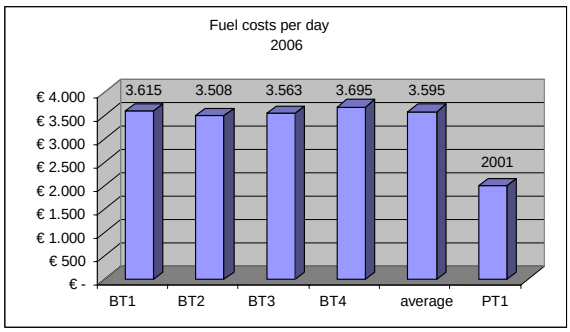
In next figures results of 2006 per day of PT1 compared to four reference BT vessels and average of the reference vessels are presented.

FIGURE 2 GROSS REVENUE PER DAY IN 2006



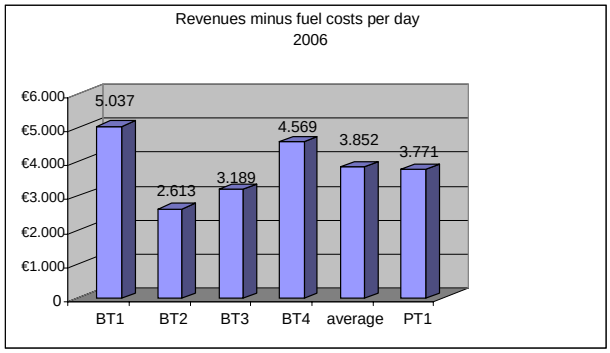
Catches and revenues of PT1 are lower than the BT reference vessels. Fuel costs, however are much lower for PT1.

FIGURE 3 FUEL COSTS PER DAY IN 2006



If revenues minus fuel costs per day in 2006 are calculated, it shows that PT1 can compete with beam trawlers.

FIGURE 4 REVENUES MINUS FUEL COSTS PER DAY IN 2006



In next graphs result of 2006 per week of PT1 compared to four reference BT vessels and average of the reference vessels are presented. Normally a week consists of 4 fishing days.

FIGURE 5 GROSS REVENUE PER WEEK IN 2006

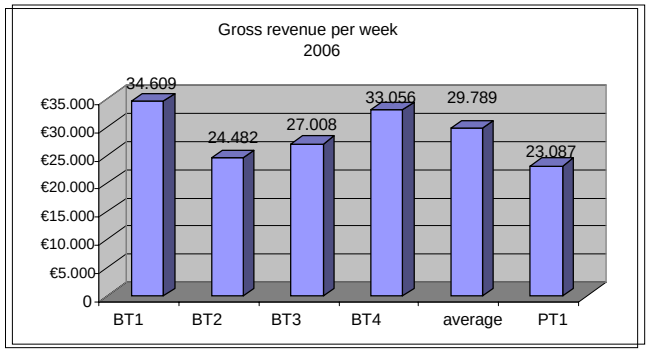


FIGURE 6 FUEL COSTS PER WEEK IN 2006

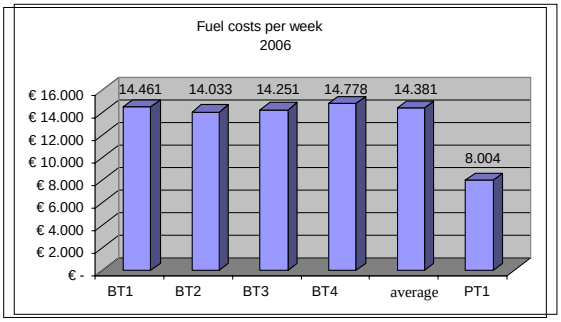
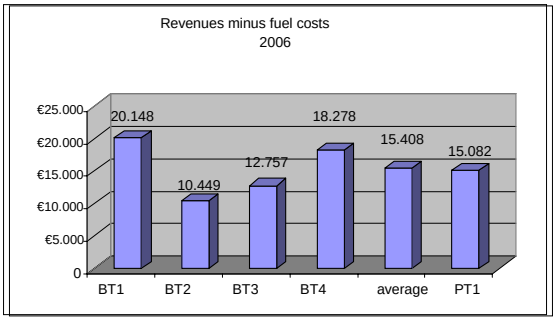


FIGURE 7 REVENUES MINUS FUEL COSTS PER WEEK IN 2006



E. Costs of the Pulse system 2004-2006

An indication of the purchasing costs of the pulse system of 12 meter of Verburg for one vessel.

An indication of the purchasing costs of the pulse system of 12 meter of Verburg for one vessel.

The system consists of the following parts:

On board system	€ 124.404,-
Underwater system	€ 215.354,-
Total selling price VAT excl.:	€ 339.758,-

Installation

System tests and on deck provision cable winches € 100.000,-

Total € 439.758,-

Per vessel costs may vary. For instance, if a vessel does not possess sufficient electrical power an extra generator would need to be installed, bigger vessels will have sufficient electrical power. Risks to the system are mainly external, such as; obstacles on the benthos, fishing in too deep waters, inexpert operation, improper speed.

Maximum yearly costs of operating a pulse trawl system will be globally presented in table 4:

TABLE IV. MAXIMUM YEARLY COSTS OF PT IN €

	Adaption vessel	***Purchase and costs***	***Total***
Depreciation	10.000	66..400	76.400
Interest	1.500	6.000	7.500
Maintenance and repair	0	80.500	80.500
Total	**11.500**	**152.500**	**164.000**

Minus: Saving of existing gear costs (circa 20%) -14.000

Extra costs per year subsidy excluded 150.000

In the following table it is assumed that gross revenue of PT1 is on the basis of the number of days at sea of the reference vessels (204 days at sea in 2005) 1.578.000€ then the net result of PT1 will be 56000 €.

TABLE V. NETT REVENUES IN €

	PT	***BT (av 2005)***
Gross revenue	1.578.000	1.578.000
Total costs, inc. labour	1.372.000	1.624.500
Result	206.000	-46.500

Extra costs pulse system 150.000 - 0

Nett result 56.000 - -46.500

Since under this assumption there is no lower level of profitability this could stimulate certain fishermen to adopt pulse trawling.

F. The main conclusions from the economic performance of PT1 in 2006

The main conclusions from the economic performance study 2006 are:

- Nett result is almost at the business economical neutral level
- PT1 is competitive with the reference vessels
- Profitability of PT better than of BT
- Fuel costs of PT is remarkably lower than of BT
- PT1 seems to be an alternative for BT that is mainly directed towards sole
- Catches of plaice lack behind
- Further development is necessary to improve results

G. Main characteristics of the pulse trawl vessel (PT2) 2009

In august 2007 the owner of PT1 sold the vessel and pulse trawling consequently ended at that time. However, pulse trawl fishing started again in the beginning of 2009. Another fishing enterprise started to fish with a different pulse trawl on a commercial base in the first week of May 2009. At that moment the fisherman did not have any experience with pulse fishery, before he used the beam trawl as fishing method to catch flatfish in the past thirty years.

The vessel BTx was built in 1993 as a beam trawler, it has a length of 41.15 meter and an engine of 2.000 HP. In 2008 the beam trawl BTx has been modified to a pulse trawl (PT2). Engine power has been limited to 1.300 HP. The results of PT2 in 2009 are compared to the results of the BTx in 2007. The year 2008 was not representative for this vessel because of a long stay in dock for maintenance and refit.

TABLE VI. CHARACTERISTICS OF THE VESSSEL PT1/BTX

Length	41,15
GT	438
HP	2.000 (maximised to 1.300 HP in 2008)
Year hull	1993
Year engine	1993

H. Pulse trawling on a commercial basis in 2009

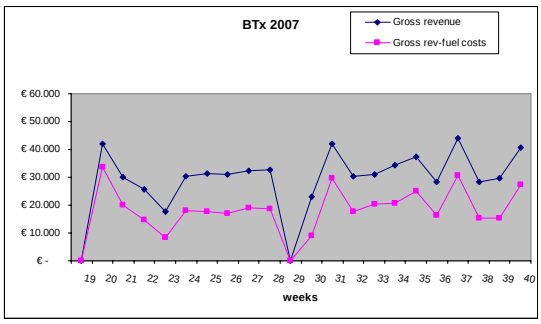
The vessel PT2 started fishing with pulse in the first week of May in 2009. If we compare the average revenues in the period May 4th till October 2nd (21 weeks) with the same period of the year 2007 we see an increase in revenues.

TABLE VII. REVENUES IN 2009 (21 WEEKS)

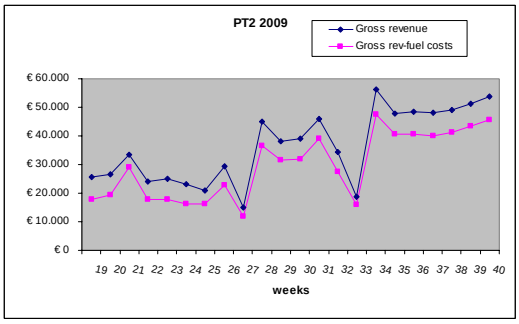
	Pulse trawl **Week 19 till 40 of 2009 (4 May till 2 October)**		Beam trawl **Week 19 till 40 of 2007 (4 May till 2 October)**	
	Per day	Per week	Per day	Per week
Average revenues	8.743	34.972	7.986	31.945
Fuel costs	1.498	5.993	3.182	12.730
Revenue minus fuel costs	**7.245€**	**28.979€**	**4.804€**	19.215€

During the 21 weeks period in 2009, several times technical problems occurred. Revenues could have been higher because of inefficient effort of the vessel. Effective hours of fishing were lower as a result of experiments done and also because of some cases of (small) damage of the gear. Particularly in week 27 and week 33 troubles caused low revenues. Despite mentioned problems, catches and revenues raised by 10% during the whole period. Fuel consumption decreased by approximately 45%. Profitability was much better in this period than in the year 2007.

FIGURE 8 GROSS REVENUE AND GROSS REVENUE MINUS FUEL COSTS IN 2007 AND 2009 WEEK 19-40 OF BTX

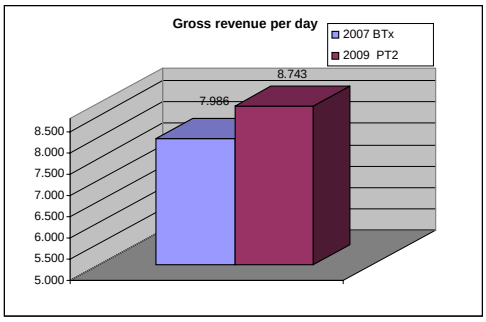


And of PT2:



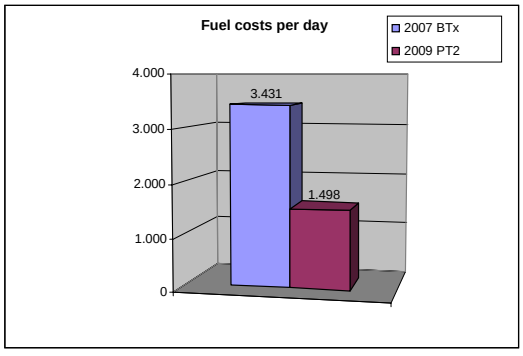
In the next figures results of 2009 per day of PT2 are compared to BTx per day in 2007.

FIGURE 9 GROSS REVENUE PER DAY IN 2007 AND 2009



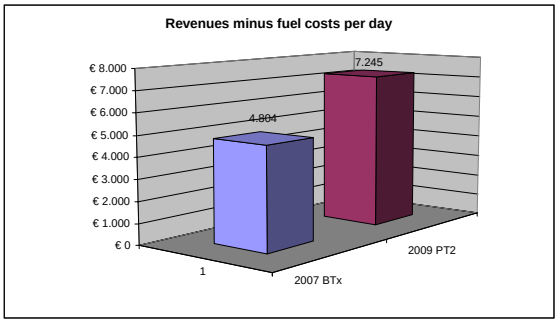
Revenues of PT2 were higher than with BTx while fuel costs were much lower for PT2.

FIGURE 10 FUEL COSTS PER DAY IN 2007 AND 2009



If revenues minus fuel costs per day in 2007 and 2009 are calculated, it shows that PT2 can compete with beam trawl.

FIGURE 11 REVENUE MINUS FUEL COSTS PER DAY IN 2007 AND 2009



In the next graphs results of 2007 and 2009 per week of PT2 and BTx vessels are presented. A week consists of 4 fishing days.

FIGURE 12 GROSS REVENUES PER WEEK IN 2007 AND 2009

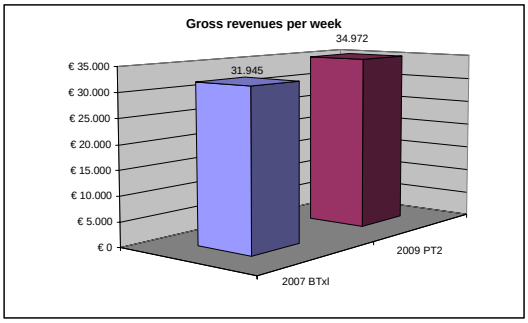


FIGURE 13 FUEL COSTS PER WEEK IN 2007 AND 2009

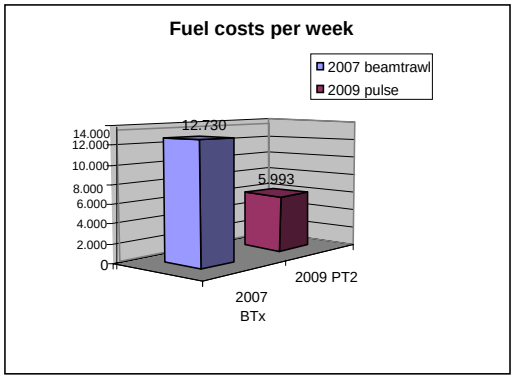
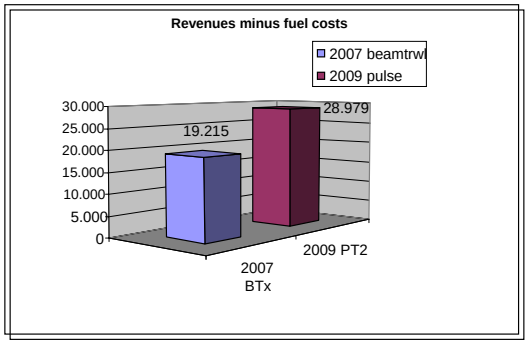


FIGURE 14 FUEL COSTS PER WEEK IN 2007 AND 2009



I. Costs of the Pulse system in 2009

An indication of the purchasing costs of the pulse system of 12 meter of Verburg for one vessel is assumed to be about the same as in 2006, namely € 439.758. Extra costs per year subsidy excluded will be 150.000 € (see par. 2.2.3)

In the following table it is assumed that gross revenue of PT2 will be € 1.790.000 on basis of the same number of days at sea (204 days in 2007). Taking into account all savings but also all extra costs for pulse, on balance total costs will decrease by € 200.000. The net result of PT2 will then be € 140.000, which means a substantial better performance compared to the year 2007 fishing with the beam trawl. It can be concluded that the vessel will operate much more profitable by using the pulse trawl rather than the beam trawl.

TABLE VIII. NETT REVENUES

(2007)	***PT2***	***BTx***
Gross revenue	1.790.000	1.722.000
Total costs, inc. labour *)	1.500.000	1.700.000
Result	**290.000**	**22.000**
Extra/less costs pulse system (balance)	150.000	0
Nett result	**140.000**	**22.000**

*) Total costs; fuel costs for PT 2 will be much lower compared to BTx, on the other hand labour costs will rather be higher. However, on balance, savings for PT2 will be positive substantially. This result should stimulate beam trawl fishermen to adopt pulse trawling.

J. The main conclusions from the economic performance of PT2 in 2009

The main conclusions from the economic performance study 2009 are:

- PT2 is competitive with BTx in 2007
- Nett result is better than in the year 2007
- Profitability of PT2 is better than of BT
- Fuel costs of PT in 2009 is circa 50% lower than of BTx in 2007
- PT2 is developed for sole fishery and is an alternative for BTx towards sole
- Catches of plaice lack somehow
- Further development is necessary to improve results, especially towards the catch of plaice

III. THE ENVIRONMENTAL IMPACT OF THE PULSE TRAWL IN COMPARISON TO THE CONVENTIONAL BEAM TRAWL

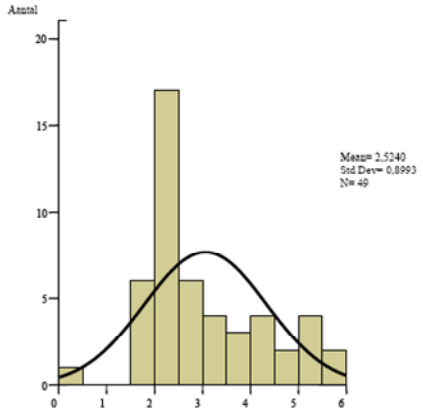
A. Fuel consumption

Fuel consumption of beam trawlers is very high, over 8000 litres a day. On average a beam trawler > 1501 HP consumes 1,5 million litres on a yearly basis.

Current high oil prices are a problem for conventional beam trawlers. Oil prices remain high and volatile making it necessary for BTs to consume oil efficiently. As a measure of fuel efficiency the following variable has been constructed by LEI (Taal et al, 2006): Fuel efficiency= value of the catch (in Euro)/fuel costs (in Euro).

Figure 3.1 shows the frequency distribution of the efficiency measure for fuel of 49 beam trawlers in 2005. On average the consumption of € 1.000 fuel yielded circa € 2.500 in catch revenues. A relatively high number of vessels have a low degree of efficiency in fuel consumption, fuel costs are relatively high with respect to the value of catch.

FIGURE 15 DISTRIBUTION MEASURE EFFICIENT FUEL CONSUMPTION OF BEAM TRAWLERS, 2005 (WEIGHTED WITH GROSS EVENUE)

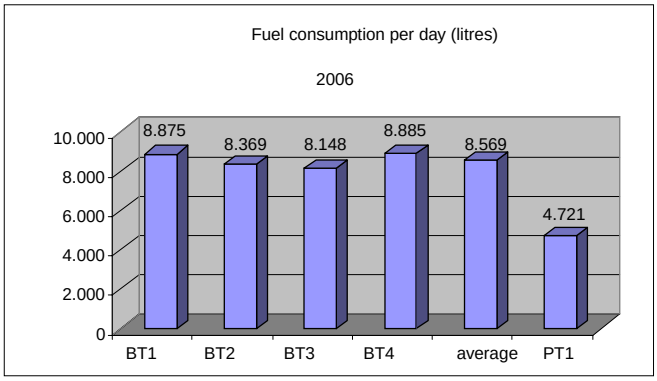


Vessels with >1501 HP are less fuel efficient than smaller beam trawlers. The pulse trawler consumes less fuel than a beam trawler.

B. Fuel consumption PT1 2006

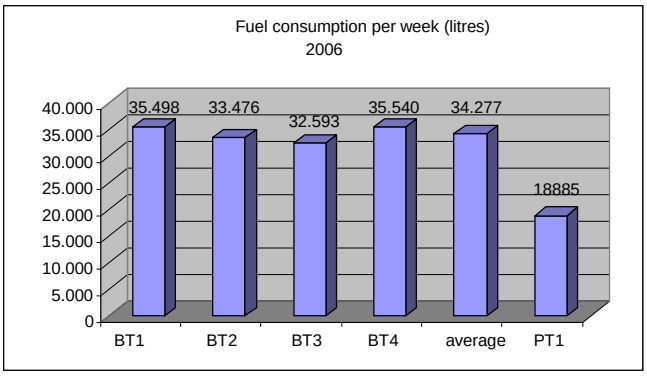
Fuel consumption of PT1 in 2006 is remarkably lower than the oil consumption of the four BTs:

FIGURE 16 FUEL CONSUMPTION PER DAY, BEAM TRAWLERS COMPARED TO PULSE TRAWL



FUEL CONSUMPTION PER WEEK:

FIGURE 17 FUEL CONSUMPTION PER WEEK, BEAM TRAWLERS COMPARED TO PULSE TRAWL

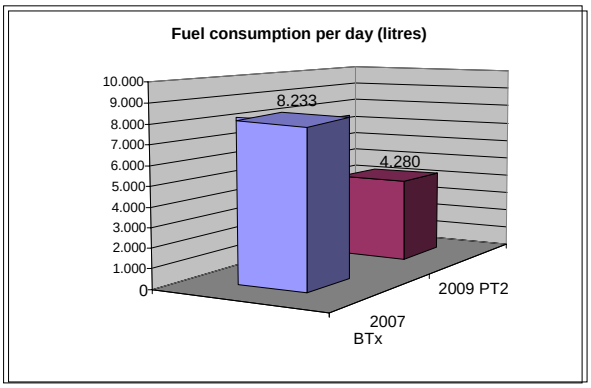


The use of PT1 generates consequently less emission of CO2 than the use of the beam trawls.

C. *Fuel consumption PT2 2009*

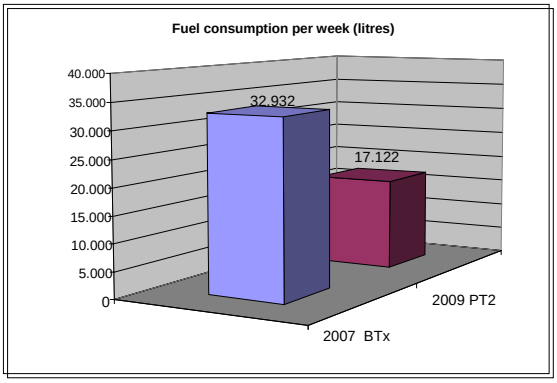
Also the fuel consumption of PT2 in 2009 is remarkably lower than the oil consumption of BTx:

FIGURE 18 FUEL CONSUMPTION PER DAY, BEAM TRAWL COMPARED TO PULSE TRAWL



Fuel consumption per week:

FIGURE 19 FUEL CONSUMPTION PER WEEK BEAM TRAWL COMPARED TO PULSE TRAWL



Fuel consumption of PT2 in 2009 is 45-50% lower than of BTx in 2007.

It can be concluded from the oil consumption of PT1 and PT2 that the use of a pulse trawl compared to the use of a beam trawl consequently has a positive effect on the emission of CO2.

D. *Change in catch composition, discards and benthos2*

A series of nine fishing trips with on board observers were carried out by IMARES on the same pulse trawl PT1 and two other beam trawlers (BTa, BTb) 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. It has to be taken into account that this IMARES research was conducted in a period previous to the period the pulse trawl operated on a commercial basis. In this period the pulse was not yet as developed as in the commercial period. The data of the economic performance section (above) is from the later period (3 quarters of 2006).

In paragraph 3.6 catch composition and discards of plaice and sole in 2009 from an IMARES survey onboard of PT2 will be presented (3.

TABLE IX. VESSELS USED AND MAIN PARTICULARS

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

2 This part is based on: Performance of pulse trawling compared to conventional beam trawling. B. van Marlen, R. Grift, O. van Keeken, M.S. Ybema, R. van Hal , IMARES, 2006

3 During four trips, IMARES observers were on board of PT.

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 10). These data were consistent with the views expressed by the skipper and the crew on PT1. (gross revenue PT/BTav= 77%)

TABLE X. 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%**

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. 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.

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.

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 11).

TABLE XI. LANDINGS IN KG/HR OF SOLE BASED ON PAIRED HAULS (PART I)

Gear test	Vessels	Wk, year	No of hauls	CPUE in kg/hour mean PULSE	CON
1	PT1-BT2	41, 2005	34	19.30	20.74
2	PT1-BT3	44, 2005	41	17.52	21.74
3	PT1-BT1	05, 2006	35	8.51	11.92
4	PT1-BT2	09, 2006	38	7.93	11.66
5	PT1-BT1	11, 2006	27	10.33	15.62
6	PT1-Both	All	175	12.87	16.45

TABLE XI LANDINGS IN KG/HR OF SOLE BASED ON PAIRED HAULS (PART II)

Gear test	PULSE/CON	Stdev PULSE	CON	p-value
1	93.1%	6.52	7.17	0.251
2	80.6%	5.95	6.4	0.000
3	71.4%	2.76	3.94	0.000
4	68.0%	2.95	4.43	0.000
5	66.1%	2.86	3.03	0.000
6	78.2%	6.64	6.87	0.000

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 12).

TABLE XII. LANDINGS IN KG/HR OF PLAICE LANDINGS BASED ON PAIRED HAULS (PART I)

Gear test	Vessels	Wk, year	No of hauls	CPUE in kg/hour mean PULSE	CON
1	PT1-BT2	41, 2005	34	25.56	28.56
2	PT1-BT3	44, 2005	41	24.69	46.79
3	PT1-BT1	05, 2006	35	56.02	93.43
4	PT1-BT2	09, 2006	38	21.66	29.85
5	PT1-BT1	11, 2006	27	20.09	28.87
6	PT1-Both	All	175	29.76	46.13

TABLE XII LANDINGS IN KG/HR OF PLAICE LANDINGS BASED ON PAIRED HAULS (PART II)

Gear test	PULSE/CON	Stdev PULSE	CON	p-value
1	89.5%	13.8	8.97	0.047
2	52.8%	10.91	15.37	0.000
3	60.0%	23.17	25.56	0.000
4	72.6%	13.64	11.18	0.000
5	69.6%	5.84	6.61	0.000
6	64.5%	19.75	29.07	0.000

E. 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. 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 from the last three trips were used because it was only in these trips that the numbers of discarded sole were counted accurately .

F. Impact on benthos

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. 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%.

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.

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% (Van Marlen et al., 2005b).

TABLE XIII. ESTIMATED SURVIVAL OF PLAICE ON EXPERIMENTS IN 2005

Species Gear Category	Plaice PULSE % in catch	% survival	CONVENTIONAL % 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%	

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 however72.6 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.

G. The main conclusions from the IMARES study from 2006

The main conclusions from the IMARES study from 2006 are:

1. The landings of plaice and sole were significantly lower in the pulse trawl when compared to the conventional beam trawl (in 2005/2006). 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 (fishing research vessel) “Tridens”. Over all species landed, the pulse trawl about 68% in kg/hr. (The economic performance study showed an improvement in landings.)

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.

H. Catch composition and discards of plaice and sole in 2009 (4

The catches in terms of landings and discards were monitored onboard PT2, fishing with two pulse trawls using the Verburg-Holland system during four weeks in June-August 2009. The average fishing speed was about 5 knots. The fishing area of the four trips was east of the coast of England and fishing depth was 36 m on average with a minimum depth of 20 m and a maximum depth of 46 m.

For this study the standard sampling procedure for the yearly monitoring of discards of conventional beam trawl fleet was applied (van Helmond and van Overzee, 2008). Sampled numbers of fish per haul were raised to numbers and weight per hour, for both discards and landings.

The four trips led to a total of 103 valid hauls for analysis, with a total fishing duration of 186 hours. The number of hauls per trip varied between 17 and 38.

The average number of plaice landed per hour was 58 or, in weight 19 kg plaice per hour. The average number of plaice discarded per hour was 164 or, in weight 18 kg plaice per hour. This resulted in an average discard percentage for plaice of 74% in numbers and 49% in weight.

The average number of sole landed per hour was 208 or, in weight 53 kg sole per hour. The average number of sole discarded per hour was 54 or, in weight 5 kg sole per hour. This resulted in an average discard percentage for sole of 21% in numbers and 9% in weight.

Comparing the landings with that of conventional beam trawl discard surveys in 2007 leads to the general impression that with the pulse trawl more sole was caught and less plaice than with conventional beam trawls. The range of numbers of plaice landed was 101 - 561 per hour on the conventional beam trawls monitored in 2007, whereas during with the pulse trawl between 14 – 106 numbers of plaice where landed per hour. The range of number of sole landed was 45 - 149 per hour on the conventional beam trawls that were monitored in 2007, whereas during with the pulse trawl between 142 – 259 numbers of sole where landed per hour.

The total discards per trip were within range of the discards per trip in earlier years. When compared with conventional beam trawls in previous years it seems that with the pulse trawl more sole in number and weights per unit of time was discarded and less plaice was discarded. However, the average discard percentages of as well plaice as sole for the pulse trawl of this study were within range with the average discard percentages of conventional beam trawls in 2005, 2006 and 2007 (van Keeken, 2006; van Helmond and van Overzee, 2007; van Helmond and van Overzee, 2008).

Data from 2009 was not yet available and year can have influence on the differences. Another important factor is the fishing area, just east of the coast of England, which probably in this case has influenced the catch composition and the fact that sole was more abundant in as well the landings as the discards. The comparison of pulse beam trawling vs. conventional beam trawling in 2006 showed that the pulse trawl caught less sole in kg per hour, i.e. 12.87 vs. 16.45 (ratio 78.2%), and fewer plaice, i.e. 29.76 vs. 46.13 kg per hour (ratio 64.5%), see van Marlen et al., 2006.

This study gives a general impression of the performance in terms of catches of fishing with a pulse trawl using the Verburg-Holland system. However it is recommended to conduct a comparative study on performance of a beam trawl and a pulse trawl, where the two vessels of similar size fish simultaneously. This is to exclude the effects of time and area of fishing.

IV. FUTURE

At the moment of writing just one vessel (PT2) was operating with the pulse trawl. It is expected that at least three other vessels will be equipped with pulse in the last quarter of the year 2009. These three vessels intend to combine pulse technology with SumWing gear instead of beam trawl gear.

It is expected to obtain higher prices for pulse trawl landings through labelling in the future.

Research is done on the effects of pulse trawling on cod, shark and ray and other benthic fauna. It is expected that results of the studies will be available in the end of 2009.

V. THE COST EFFECTIVENESS OF THE PULSE TRAWL IN COMPARISON TO THE BEAM TRAWL

The cost effectiveness of the pulse trawl in comparison to the beam trawl on the basis of two periods of commercial trials of the pulse trawl, turns out to be rather positive. The economic performance of the pulse trawl can compete with comparable beam trawls. This is especially due to a decrease in oil consumption, which is a high cost for beam trawlers. Fuel consumption of the pulse trawl is some 45-50% lower than the beam trawl.

4 Steenbergen, J. and Marlen, B. van, 2009. Landings and discards on the pulse trawler MFV “Vertrouwen” TX68 in 2009. IMARES Report C111/09, 20 pp.

Environmental costs are also lower. When it concerns discards, in the pulse trawl, the catch rates of undersized (discard) sole were significantly lower in 2006 than in the conventional beam trawl, and also catch rates of benthic fauna (nrs/hr Astropecten irregularis, Asterias rubens, and Liocarcinus holsatus) were significantly lower. However, in 2009 with the pulse trawl more sole in number and weights per unit of time was discarded and less plaice was discarded. There are indications that undersized plaice are damaged to a lesser degree in the pulse trawl and will survive better in the pulse trawl. Next to this the use of a pulse trawl generates less emission of CO2 than the use of a beam trawl.

The pulse trawl seems to be an alternative for beam trawlers that are mainly directed towards sole, even sole catches are better, catches of plaice lack behind. Some concern exists on the effects of pulse trawling on certain non target species.

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