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Preliminary assessment of the reduction of the ecological and environmental impacts of the tickler chain beam trawls by pulse trawls in the North Sea fishery for sole and plaice

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Preliminary assessment of the reduction of the ecological and environmental impacts of the tickler chain beam trawls by pulse trawls in the North Sea fishery for sole and plaice

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Introduction

This report provides a preliminary assessment of the potential contribution of pulse fishing to the sustainable exploitation of flatfish with a reduced environmental and ecological impact as compared to the traditional beam trawl fishery with tickler chains. The report is commissioned by the Dutch ministry of Agriculture, Nature and Food Quality (LNV) after the decision by the EP to ban pulse trawling.

The assessment evaluates the scientific knowledge on the relative impact of both fishing methods on a number of environmental, ecological, and fisheries management criteria, and evaluates the strength of the scientific evidence and its uncertainty. The assessment is based on the review and synthesis of the scientific knowledge by ICES WGELECTRA in January 2017 (ICES, 2017b) and additional information that has become available in 2017 (Desender, 2018; van der Reijden et al., 2017; Polet et al., 2017).

In addition, the Bloom document (Bloom, 2018) on pulse fishing, which was presented to the members of the European parliament in early January 2018, is reviewed.

Assessment

The pulse trawl is an alternative fishing method that can replace the tickler chain beam trawl targeting flatfish in the North Sea. The pulse trawl is particularly selective for sole. To assess whether the pulse trawl is an innovation that improves the sustainability of the flatfish fisheries, a number of criteria needs to be assessed (Table 1). The criteria chosen are based on the concerns expressed by stakeholders on possible adverse effects of pulse fishing on the marine environment and on the general concerns about the adverse effect of bottom trawls (Kraan et al., 2015; Kaiser et al., 2016). For each criterion, the scientific literature is reviewed for evidence that the pulse trawl has a lower, similar or higher environmental impact. The strength of the evidence is assessed as proven, indicative or inferred. The uncertainty is scored as low, medium and high taking account of the relevance of the

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evidence for the sometimes wider criterion. For example, for the criterion 'marine organisms' experimental studies showing no adverse effect on one species will score a medium uncertainty.

Table 1 presents the score card summarising the assessment of the scientific evidence for the different criteria. Below the results are summarised.

Catch comparison experiments show that the pulse gear is more selective in catching sole relative to plaice and other bottom dwelling fish species (van Marlen et al., 2014). Ongoing research provided evidence that the pulse trawl has a higher catch rate for sole, but a lower catch rate for plaice than the tickler chain trawl. The available studies of the size selectivity have not resulted in a clear answer whether pulse trawling reduces the catch efficiency of smaller fish (ICES, 2017b). Nevertheless, the improved species selectivity is expected to result in a reduction in discarding because of the lower catch efficiency of other species relative to sole.

The increase in catch efficiency of sole does not increase the risk of overfishing because the fishing pressure is controlled by the catch quota management. However, increased catch efficiency can lead to a competitive advantage on local fishing grounds that are used by different fisheries (Sys et al., 2016).

In the southern North Sea there has been a relative increase in pulse trawling as compared to beam trawling in the past. Whether this may influence thee spawning-stock biomass (SSB) of the eastern Channel sole stock is unknown. The SSB of North Sea sole has increased since 2007 and has been estimated at above MSY $B_{trigger}$ since 2012. The SSB of eastern Channel sole has been fluctuating between Blim and MSY $B_{trigger}$ (ICES, 2017d; ICES, 2017e).

The lower fuel consumption and the increased catch efficiency for sole have substantially improved the economic profitability of the pulse trawl vessels. Pulse stimulation allows fishers to reduce the towing speed. In combination with the lower weight of the gear, this leads to a reduction in the fuel use and CO2 emission of 46% (Turenhout et al., 2016), a reduction in the surface area of the seafloor that is trawled (Polet et al., 2017), and a reduction in the wear of the trawl nets and corresponding pollution. Besides, the replacement of tickler chains with electrodes will reduce the disturbance of the sea floor. The penetration of the gear was estimated to decrease from 4.0 cm (beam trawl with tickler chains) to 1.8 cm (pulse trawl) (Depestele et al., 2018). The reduced footprint and penetration depth results in a reduction of the impact on the benthic ecosystem in terms of the biomass of the benthos as well as the community composition (Polet et al., 2017), which will reduce the impact on the functions of the benthic ecosystem such as the bio-turbation and bio-irrigation. The effect of electrical stimulation on the bio-geochemical processes in the sediment is currently being investigated.

Catching leads to the mortality of the marketable fish that are landed. Fish that are caught in trawls but thrown back to sea (discards), or fish that escape through the meshes, may incur injuries and may die. The severity of the damage caused is related to the towing duration, towing speed, catch composition and type of gear used. Pulse fishing imposes less damage of species in the net because of the lower towing speed, lower volume caught and cleaner catch composition. Flatfish caught in commercial pulse trawls have fewer skin lesions and show a better vitality score (Uhlmann et al., 2016). The survival experiments carried out so far show a substantial survival in flatfish discards (sole, plaice, turbot and brill) and in thornback ray (van der Reijden et al., 2017; Molenaar et al., in prep). The survival of sole and

plaice discards is higher than the survival reported for the traditional tickler chain beam trawl fishery in the Netherlands (van Beek et al., 1990).

The major concerns about pulse fishing is the fear that exposure to an electrical stimulus may cause unwanted side-effects and mortality of flatfish, roundfish, cartilage fish or invertebrate species (Kraan et al., 2015). Laboratory experiments have confirmed that injuries may occur in some species (de Haan et al., 2016; Soetaert et al., 2016b), although the vast majority of animals experienced no adverse effects during or after exposure to electrical pulses (Soetaert, 2015; Desender, 2018).

So far, no side-effects were observed in flatfish. Sole was exposed to a wide range of electrical stimuli, exceeding the intensities used in the field, showing that none of the soles showed injuries or mortality (Soetaert et al., 2016a). Another study exposing over 100 dab near the electrodes of the pulse used in the sole fishery did not induce harm (de Haan et al., 2015). No injuries were observed in plaice exposed to the pulse stimulus used in the fisheries for brown shrimp (Desender et al., 2016).

Roundfish on the other hand have proven to be more vulnerable, especially gadoid species. Spinal fractures have been observed in cod, both at sea and in laboratory experiments (de Haan et al., 2016; van Marlen et al., 2014; Soetaert et al., 2016b). Other species such as seabass and flatfish do not show these spinal injuries (Soetaert, 2015; Desender et al., 2016; Soetaert et al., 2016a). Given the observed proportion of fractured roundfish (cod 9%; whiting 2%: van Marlen et al., 2014) and the small proportion of these species in the total catch, the number of injured fish in the total catch is likely to be very small. The injuries in marketable fish will affect the value of the fish but will not have adverse ecological effects as these will be landed anyway. For undersized fish, fractures may contribute to the mortality imposed by the catch process. To assess the possible adverse effect, it is important to know whether body size has an effect on the sensitivity. This is currently being investigated.

Pulse stimulation may disturb the sensory system of fish species that make use of electrical stimuli to detect their prey, such as sharks and rays. In a tank experiment, it was found that the capability of catsharks to detect electric prey was not affected by exposure to a commercial pulse stimulus (Desender et al., 2017).

The few exposure experiments carried out so far have not indicated any major adverse effect of electrical pulses on invertebrate species, including brown shrimps, despite repetitive exposures of high intensities (Soetaert et al., 2015; Soetaert et al., 2016c).

Review of the critique of Bloom

A review of the critique by Bloom (2018) against the available scientific evidence is given in Table 2. The Bloom document criticises a number of topics ranging from ecological, fisheries management, governance, legal and political aspects. Table 2 compares all paragraphs of the Bloom document in one column with the relevant factual information focussing on the environmental, ecological and fisheries management aspects in another column. Some of the points raised by Bloom reflect their opinion about industrial and small-scale fisheries. These topics are not reviewed as these opinions are more related to values, objectives in and trade-offs of fisheries governance, than to facts related to pulse fishing. The political and governance related topics are not reviewed as they are beyond the scope of this report.

Conclusion.

Based on the current scientific knowledge available to date, the sustainability score card (Table 1) shows an improvement of most of the criteria. The clear negative effects are related to the injuries caused by pulse stimulation in cod and whiting. On the socio-economic side, the increase in competition between the pulse and other fleets on local fishing grounds is a negative effect for the non-pulse fishers.

The severity of the injuries caused by pulse stimulation appear to be restricted to gadoid roundfish and can be explained by the biomechanical overload of the spinal column. Because no negative effects were found for flatfish, which comprise the bulk of the catch, sharks and invertebrates, the percentage of the total catch that is injured by the electrical stimulation will be small. The incidence rate of lesions caused by the pulse stimulus are likely to be small relative to the incidence rate of lesions caused in the catch process of the tickler chain beam trawl, although the latter has not been investigated in depth. Additionally, a clear reduction in bottom impact, discard rates and fuel consumption has been shown.

The review of the Bloom document shows that their conclusions about the devastating effects of pulse fishing on the marine environment cannot be substantiated scientifically.

The preliminary conclusion can be drawn that based on the available scientific evidence available to date there is no support that pulse trawling will have serious ecological impacts, although a number of important questions are currently under investigation. The ongoing research will critically test this preliminary conclusion by investigating a broader range of fish species (and sizes) and benthic invertebrates, developing a bio-mechanistic understanding of how electrical stimulation cause injuries, and study the effect of electrical and mechanical stimulation on geochemical processes in the benthic ecosystem. The results of these studies will be available for a full assessment in 2019.

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Justification

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The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

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Table 1. Preliminary assessment of the contribution of the pulse trawl to improve the sustainability of the sole trawl fisheries by reducing the adverse impact on the environment, benthic ecosystem and marine organisms, and the consequences for the sustainable management of commercial stocks and socio-economy. The colour code shows whether the pulse trawl is an improvement (green) or deterioration (red) compared to the tickler chain trawl. The intensity of the colour reflects the degree of support and uncertainty.

	Impact of pulse trawl relative to tickler chain trawl	Strength of support (1=proven; 2=indicative 3=inferred)	Uncertainty 1=low 2=medium 3=high	Comment	Source
Environment					
CO2 emissions	46% lower	1	1	Due to lower fuel consumption	Turenhout et al (2016)
Seafloor disturbance	~50% lower	1	1	Due to lower towing speed and reduced penetration in seabed	Polet et al (2017); Depestele et al (2016, 2018)
Pollution	Reduced	3	1	Due to lower towing speed and lighter gear the wear of the gear is reduced	
Benthic ecosystem					
Impact on benthic biomass	~50% lower	1	2	Due to lower towing speed and reduced penetration in seabed the mortality of mechanical disturbance is reduced	Polet et al (2017); Depestele et al (2016, 2018)
Ecosystem functions	improved	2	2	Logical consequence from the above	
Marine organisms					
Fractures / haemorrhages due to	Increased	1	1	In cod (9%) and whiting (2%) but not	Van Marlen et al. (2014); De Haan et al (2016); Soetaert et al (2016a, 2016b)

	Impact of pulse trawl relative to tickler chain trawl	Strength of support (1=proven; 2=indicative 3=inferred)	Uncertainty 1=low 2=medium 3=high	Comment	Source
electrical pulse				in flatfish. The incidence rate is un-certain (small sample size) Cod, whiting relative small proportion of total catch	
Fractures / haemorrhages due to catch process	reduced	2	2	Lower towing speed and cleaner catch	Uhlman et al (2016)
Skin lesions / scale loss	reduced	2	2	Lower towing speed and cleaner catch	Uhlman et al (2016); Molenaar et al (in prep); van Beek et al (1990)
Discard survival	improved	1	1	Lower towing speed and cleaner catch. Only in roundfish pulse may increase mortality due to spinal fractures (uncertain)	Van der Reijden et al (2017); Molenaar et al (in prep)
Development and growth eggs and larvae	No or small adverse effect	2	2	Experiments with cod and sole	Desender et al. (2017b); Desender (2018)
Mortality of invertebrates	No, or small adverse effect	2	2	Few experiments	Soetaert et al (2015, 2016c)
Behaviour	No effect	2	2	catshark	Desender et al (2017a)
Management of commercial stocks					
Species selectivity	More sole	1	1	Increased catch rate of sole relative to other	ICES (2017b)

	Impact of pulse trawl relative to tickler chain trawl	Strength of support (1=proven; 2=indicative 3=inferred)	Uncertainty 1=low 2=medium 3=high	Comment	Source
				species	
Size selectivity	No effect on size selectivity	2	2	Conflicting evidence from comparative fishing trials	ICES (2017b)
Discards (fish)	Reduction in discards relative per kg sole	3	3	Inferred from higher selectivity of sole	
Discards (benthos)	Substantial reduction	1	1		ICES (2017b)
Risk of overfishing	No effect	1	1	TAC restrict fishing effort NSea flatfish fisheries	ICES (2017d, 2017e)
Socio-economic					
Competition with other fishing fleets	increase	1	1	If fishers exploit the same grounds.	Sys et al (2015); Rijnsdorp et al (2008)

Table 2. Review of the critique of Bloom (2018) on the impact of pulse trawling.

#	Bloom	Scientific evidence
1	Electric 'pulse' fishing is a technological trick which halves fuel consumption, so that a fleet of otherwise cash-strapped fishing units can be kept in operation. Under the guise of "experimental fishing" a whole fleet in the Netherlands has been converted to a fishing method that is banned in Europe (and elsewhere in the world). Several million euros of public money have been allocated to equipping Dutch vessels with electric 'pulse' trawls, with the complicity of the public authorities.	Fuel consumption is reduced by 46% (Turenhout et al., 2016) All pulse trawl vessels collaborate in a research project where the landings of the main commercial fish species are recorded per tow to study the small scale dynamics of their distribution and exploitation of local fishing grounds. This will provide better understanding of the interactions between vessels on a local fishing ground. A total of 84 licenses have been issued in the Netherlands (Haasnoot et al., 2016) of which 79 are currently (pers comm LNV) used: - 22 under a derogation under Annex III (4) of Council Regulation (EC) No. 41/2006 allowing 5% of the beam trawler fleet by Member States fishing in ICES zones IVc and IVb to use the pulse trawl on a restricted basis, provided that attempts were made to address the concerns expressed by ICES; - 20 vessels based on Article 43,850/1998, which is a regulation for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms; - 42 temporary licenses in the context of the landing obligation to explore in technological innovations to reduce discarding. According to information obtained from the ministry of LNV, subsidies were given to the 1st four vessels to 40% of the investment with a maximum of €176,000 per vessel. 3.8 million Euros of EMFF have been committed for research projects on the ecological effects of pulse trawling in the fishery for sole and brown shrimps.
2	Reducing costs in a situation of chronic overexploitation is a seductive argument to convince European fishers to equip their vessels with electrodes. Unfortunately, this fishing method is so effective that above all, it promises to accelerate the exhaustion of marine resources and ruin the fishing sector in the medium term.	The pulse vessels target North Sea sole which is exploited according to the MSY target (ICES, 2017). Hence, the total fishing effort of the pulse trawlers is restricted by the annual quota.
3	Accepting electric 'pulse' fishing is an admission of failure: it recognizes that there are no longer	This is an opinion.

#	Bloom	Scientific evidence
	enough fish for fishers to fill their nets without recourse to increasingly sophisticated and effective technology. There is an urgent need to understand the risk associated with the mermaid's song of industrialists, and to say no to the desertification of the ocean, the disappearance of small-scale fishing and the collapse of a whole economic sector	Concerning research of the risk of pulse fishing, the effect has been the subject of scientific research projects including two PhDs at the University of Gent (Soetaert, 2014; Desender, 2018), two PhDs (since 2016) at the Netherlands Institute of Sea Research and Wageningen University, and a number of specific research projects (https://www.pulsefishing.eu/research-agenda)
4	Electric fishing has been prohibited in Europe since 1998, alongside other destructive fishing methods "including the use of explosives, poisonous or stupefying substances", for the "conservation of fishery resources through [...] the protection of juveniles [...]".[1]	Fishing with electricity is prohibited. Based on scientific information that the innovation could improve the selectivity and reduce the fuel cost, the EU has allowed a number of fishers to test the technique (Haasnoot et al., 2016).
5	China, which used it in the 90s, banned it in 2000[2] because of its serious harmful effects for biodiversity.[3] Hong Kong had already banned it in 1999[4] because of its damaging consequences:[5] "Electric fishing harms or even kills most fish, including fish fry and other marine life. Such methods of fishing have a longterm deleterious effect on fisheries resources and the marine ecosystem".	[3: Yu et al. 2007] shows that electric fishing increased the efficiency and resulted in an overexploitation of the stock, which was the reason to ban the technique. Except for the effect on the target species that was related to the overfishing of the stock, the paper does not provide evidence for serious harmful effects for biodiversity. In the North Sea, the fishing effort, and hence the collateral damage to the ecosystem, is controlled by the TAC set for the target species (sole and plaice). The TAC also restricts the collateral damage of the fishery to the ecosystem
6	In Vietnam, "electric impulses and toxics to exploit aquatic resources is an act of exterminating the resources, damaging the ecology and polluting the habitat of aquatic resources",[6] and electric fishing was banned in 1996 [7]. Brazil, the United States and Uruguay have also banned electric fishing to "prevent habitat degradation" [8] The list of countries that have banned electric fishing is long, as seen below.	Not reviewed
7	Despite the proven destructiveness of electric fishing and against the advice of the Scientific, Technical and Economic Committee for Fisheries (STECF),[9] the European Commission and Council have authorized granting exemptions to use electric current in the southern part of the North Sea since late 2006.[10] In 2013, the 1998 Regulation was amended to include this principle of exemptions in the law (thus allowing Member States to equip up to 5% of their beam trawl fleets with electrodes), [11] but the Commission and Council have allowed further licences beyond the legal framework (see point 8).[12]	Bloom does not provide proof for the ‘destructiveness’ of pulse fishing. The serious concerns related to pulse fishing are being investigated at present. The ICES advice in 2006 (ICES, 2006b; ICES, 2006a)was cautiously positive: despite clear benefits to benthic species and habitats and clear gains in fuel efficiency, concern was raised about potential spinal damage to cod, potential effects on invertebrates and effects on electric sensory systems of elasmobranchs. STECF concluded in 2006 (STECF, 2006) Although the development of this technology should not be halted, there are a number of issues

#	Bloom	Scientific evidence
		that need to be resolved before any derogation can be granted (p. 6). The EU nevertheless introduced a derogation (under Annex III (4) of Council Regulation (EC) No. 41/2006) and further licences were arranged under other parts of legislation (see #1) ICES observes (ICES, 2016) that 84 licences have now been issued to use pulse trawl in the Netherlands for scientific research and data collection purposes. This is well in excess of the 5% limit included in the original legislation. The increases in the number of licences issued were agreed at EU level in 2010 and 2014. ICES has no basis to conclude whether this level is appropriate or not, although it would seem over and above levels that would normally be associated with scientific research. ICES advises not to generalize from the results of the research carried out to date to allow expansion of the use of the pulse trawl outside the current area and fisheries allowed for in the current legislation. Conventional beam trawling has significant and well demonstrated negative ecosystem impacts. If properly understood and adequately controlled, electric pulse stimulation may offer a more ecologically benign alternative and could reduce fishing mortality on non-target species. However, it is unclear whether the current legislative framework is sufficient to avoid the deployment of systems that are potentially harmful for some marine ecosystem components (e.g. cod). While the systems currently used do not appear to have major negative impacts, ICES considers that the existing regulatory framework is not sufficient to prevent the introduction of potentially damaging systems.
8	The European Commission has thus caved in to lobbying from the Dutch fishing industry, whose trawl fleet has been teetering on the edge of bankruptcy since fuel prices rose in 2007 [13]. The economic model of the beam trawl fleet is extremely vulnerable, because of its structural dependency on fuel. Rather than questioning an inevitably doomed fishing method because of its unacceptable environmental impact and excessive fuel consumption, the Dutch have stubbornly pursued high-impact fishing methods rather than converting to more sustainable gears. → The Dutch fishing industry now wants electric 'pulse' fishing to be considered a 'conventional' fishing method so that it can be	The economic performance of the Dutch demersal fleet in 2006 had been negative for the 5th year in a row. The rising oil price, lower fish quota, lower value of quota as well as growing societal critique on the ecological effects of beam trawling, resulted in the foundation of the ‘Task force sustainable north sea fisheries’ in 2005. The task force wrote an advice for the Dutch government on how to deal with these threats to the sector (van Balsfoort et al., 2006). They advised (amongst others) a Fisheries Innovation Platform (VIP) to steer innovations as well as study groups to stimulate fishers to share knowledge and empower them to innovate towards more sustainable fisheries. The pulse has been one of the innovations which have

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	widely authorized without requiring special authorizations.	been taken up by the fleet, as well as a shift to twinrig and flyshoot fishing; improved cooperation within the sector; improved entrepreneurship in family businesses (in total 130 VIP projects were undertaken).
9	The electric current used, a 'pulsed bipolar current', is identical to that used by Tasers© (electroshock weapons) [14]. This type of current causes such violent, uncontrolled convulsions that 50 to 70% of large cods are left with a fractured spine and internal bleeding after the shock [15].	The 50 to 70% is not representative of the injuries in the pulse fisheries. [15] refers to a tank experiment where cod was exposed just next to the conductor at a maximum strength (worst case). A 2nd tank experiment showed a lower fracture rate (3/170 cod; Soetaert et al., 2016a). A 3rd tank experiment showed a spinal fracture in 1/26 cod (Soetaert et al., 2016b) The published evidence from samples collected on board pulse vessels indicates 9% injuries (4/45) in cod and 2% (1/57) in whiting (van Marlen et al., 2014).
10	Electricity can also weaken the immune system of worms and common shrimp, and increase their sensitivity to pathogens [16]. And this is just the tip of the iceberg, because we know nothing about the effect of the electric current on eggs, juvenile growth, fish reproduction, plankton or electro-sensitive species such as rays and sharks.	[16] could not find any adverse effects for lugworms, but found an indication of a negative effect on the immune system of shrimps. In a follow up experiment, however, exposing the shrimp 20 times instead of one, no effect on the immune system was found, indicating that this was most probably coincidence (Soetaert et al., 2016). Desender et al (2016) did an experiment with electro-sensitive catsharks showing that the food detection ability was not affected. Desender et al (2017) exposed eggs and larvae of cod to pulse stimulus. No adverse effects were found in 6 out of the 8 developmental stages studied. The eggs were exposed to a worst case exposure that only occur in a narrow zone next to the conductor. No effects were observed in a follow up experiment with sole eggs (Desender, 2018). A research project is currently conducted to develop the mechanistic understanding how electrical pulses may adversely affect marine life. Such a mechanistic basis is required to assess the effects on the wide diversity of life forms in the sea.
11	The research conducted so far by the Dutch has essentially focused on the economic performance of vessels, but electric 'pulse' fishing poses a systemic problem of unprecedented severity: its extreme efficacy inexorably empties the ocean. Small-scale and recreational fishers denounce a fishing method that turns European waters into a "graveyard" and a "garbage dump".[17]	In Belgium two PhD-projects were dedicated to the ecological effects of the flatfish pulse (Soetaert, 2015) and the shrimp pulse (Desender (2018). Research conducted by the Dutch on pulse fishing is reported in three peer reviewed publications and numerous reports (www.pulsefishing.eu). Peer reviewed publications studied the catch composition and selectivity (van Marlen et al., 2014), injuries in cod (de Haan et al., 2016) and discard survival (van der Reijden et al., 2017).

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		The concerns about the adverse effects of pulse fishing has shaped the Dutch research agenda which is focussed on the biological and ecological effects (https://www.pulsefishing.eu/research-agenda) The statement of fishers that the fishing grounds of pulse trawlers are a graveyard are most likely related to the accumulation of discarded fish on a local fishing ground which is being exploited for a period of days. This phenomenon is not specific for pulse trawls but will also occur in other fisheries which produce discards such as flatfish beam trawl, otter trawls targeting roundfish or nephrops (Uhlmann et al., 2014) and static gears (Depestele et al., 2014).
12	Electric 'pulse' fishing reduces the impact on habitats compared to 'regular' beam trawls, but still has harmful impacts on both habitats and marine life. Electric trawls are still bottom trawls: they are dragged along the bottom and impact marine habitats. In fact, it is reported that the electrodes still penetrate into the sediment and that the trawl shoe goes six centimeters down the sediment. See Baarseen et al. (2015)	The FP7-project BENTHIS has studied the mechanical impact (penetration depth, sediment resuspension, sediment mixing) of the tickler chain trawls and pulse trawls. The results show that the penetration of the pulse trawl in the sea bed is reduced. Penetration depth was estimated at 4.0 cm for the tickler chain trawl and 1.8 cm for the pulse trawl (Depestele et al., 2016; Depestele et al., in prep). Application of the newly developed trawling impact methodology, which was taken up by ICES in 2017 (ICES, 2017a), shows that the benthic impact of the pulse trawl vessels is reduced by 50% as compared to the impact using tickler chain beam trawls (Polet et al., 2018) Almost all beam trawl vessels have replaced the shoes plus beam by a foil, i.e. without trawl shoes.
13	Furthermore, electric 'pulse' trawlers are not selective at all. For 100kg of fish caught, 50–70kg are discarded (including plaice, dab and soles) (Cappell et al. 2016; Baarsseen et al., 2015) In comparison, sole netters discard only 6kg of fish per 100kg of fish caught (Kelleher, 2005)	The trawl fishery for sole has a high bycatch rate because of the use of a 80mm mesh size required to retain the slender sole. Since the catch efficiency of sole in the pulse trawl is increased relative to other species, the bycatch of the other species in the pulse trawl will be lower. Van Marlen et al (2014) reported a lower catch rate of undersized flatfish in the pulse, but this result has not been corroborated in further studies (ICES, 2017b). Although netters may have a lower bycatch of fish species, they may have other bycatch such as marine mammals such as harbour porpoises (Hall et al., 2000). Sole trammel netters along the Belgium coast were shown to have fish bycatch rates of 22% in weight (Depestele et al., 2012). Further, it is doubtful whether the sole TAC in the North Sea can be harvested by netters only.
14	Survival rates were measured for several	From research on survivability we know that:

#	Bloom	Scientific evidence
	discarded species and were very low, especially for undersized specimens: 15% for plaice, 29% for sole, and 16% for dab.(van der Reijden et al 2017)	survival rate of the bycatch in the commercial pulse fishery (plaice: 15%, sole 29%; van der Reijden et al., 2017) is higher than survival rates measured on board commercial (2 hr tows) beam trawlers in the 1970s and 1980s (plaice and sole <10%; van Beek et al., 1990). Uhlmann et al (2016) compared the reflexes of plaice and sole discards caught in the beam trawl and pulse trawl and showed that impairment of the reflexes was stronger in beam trawl discards than pulse trawl discards. Range of discard survival rates of other species as observed in 7 commercial trips is: Brill (0-35%), Turbot (18-62%), Thornback ray (40-81%) (Molenaar et in prep).
15	Since electric 'pulse' trawls are lighter than conventional trawls, they can operate in zones that were previously inaccessible, near the coasts. However, these areas are sometimes reproduction zones or nurseries for numerous marine species. Only low-impact, small-scale fisheries were operating there. This unfair and unreasonable competition is worrying, because it rings the death knell for small-scale fishing.	Pulse trawls can be used on softer grounds (Turenhout et al. 2016). Whether the impact on the marine environment is raised depends on the sensitivity of these habitats and its biota. This is part of the ongoing research impact assessment project.
16	Bled dry, French fishers are forced to redeploy their fishing effort in the Channel, so that they can continue their activities. They denounce an irresponsible fishing method with dangerous consequences for the whole ecosystem and the economic balance of the sector. UK fishers from Lowestoft are equally angry at the expansion of electric fishing. According to them, "going beyond 12 nautical miles is a waste of time. It's a graveyard". Same story in Belgium and the Netherlands: electric 'pulse' fishing threatens their very viability in the short term.	It is well known in fisheries science that different fishing gears may compete for the same fish (Rijnsdorp et al., 2008). As the catch rates are determined by the local densities, the introduction of a new and more efficient gear may adversely affect the catch opportunities of other gears (Sys et al., 2016). See reply #11 to statement of fishers that the fishing grounds of pulse trawlers are a graveyard
17	The current regulatory framework allows each Member State to equip a maximum of 5% of its beam trawl fleet. If the Netherlands were to comply with this legal limit, they would have 15 electric 'pulse' trawl licenses, not 84, as indicated by the European fleet register. According to Dutch researchers, there are now only 8 beam trawls fishing for sole without electricity in the Netherlands [24] → In October 2017, BLOOM filed a complaint to the European Commission against the Netherlands, for the illegal and unjustified allocation of exemptions. The Commission has not yet responded to this complaint.	See reply to #1 for the regulatory basis of the exemptions

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18	The massive increase in exemptions since 2012 is attributed first to experimentation [25], and second to the implementation of a "pilot project" [26]. Under the pretext of scientific research, a destructive fishing method is authorized against the recurrent advice of scientists. The European Commission is thus displaying complicity with a fishing practice that is as questionable as "scientific whaling". In 2015, the International Council for the Exploration of the Sea (ICES) acknowledged that "the issuing of 84 licences to carry out further scientific data collection is not in the spirit of the previous advice and that such a level of expansion is not justified from a scientific perspective. […] This is well in excess of the 5% limit included in the current legislation. At this level this is essentially permitting a commercial fishery under the guise of scientific research" [27]. → In total, there were over 100 electric 'pulse' trawlers operating in Europe in 2017: 84 in the Netherlands, 12 in the United Kingdom, 10 in Germany and 2 in Belgium. Most vessels conducting electric 'pulse' trawling in Europe are under Dutch ownership.	See reply to #1 for the regulatory basis of the exemptions Concerning the number of vessels required for research the vessels of the original 5% would have been sufficient to study the immediate ecological impact of the pulse trawl on marine organisms and the benthic ecosystem. To study the impact at the scale of the fleet, the 84 licenses allow us to collect the relevant information on the distribution and catch rates required to estimate the impact on the North Sea without the need to extrapolate from a sample of the fleet.
	As things currently stand, it is impossible to check the electric parameters used on the vessels and the current sent into the bottom of the ocean. ICES considers that "the existing regulatory framework is not sufficient to prevent the introduction of potentially damaging systems" [28]. Moreover, several fraudulent behaviors have been reported aboard electric 'pulse' trawlers, for example the use of netting below the legal size [29] or illegal fishing in zones with seasonal closures [30]. It is not just ecosystems that are put under strain by electric fishing: the situation has become explosive between European professionals, and between fishers and the authorities. Following the discovery of an infraction, three inspectors were even dragged through the water in the nets of an electric 'pulse' trawler [31] (the crew members were accused of attempted murder) [32].	The pulse trawls are restricted to the following maximum parameter values, in accordance with Regulation 850/1998, art 31 bis: - Power The maximum effective output power must not exceed 1kW per metre of beam length, measured between the connections of the electrodes and pulse modules. - Voltage (root mean square) The effective voltage between the electrodes is no more than 15 V - The vessel is equipped with an automatic computer management system which records the maximum power used per beam and the effective voltage between electrodes for at least the last 100 tows. It is not possible for non-authorised personnel to modify this automatic computer management system. The national and international fisheries inspection services control and enforce the fisheries legislation.

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19	Since August 2015 only, at least 5.7 million euros of public subsidies have been allocated to the development of the industrial electric 'pulse' fishing fleet in the Netherlands, including 3.8 million euros of European funding (67% of the total).33 These public subsidies have been abusively granted for 'research', 'innovation' and 'better practices'. European Institutions and Member States need to stop using public funds for ecologically and socially harmful fishing practices. Public decision-making has to be consistent with the objectives of the Common Fisheries Policy and must show greater vision, courage and ambition for the future of European fisheries. → The Netherlands have not uploaded the file on public subsidies allocated from 2007 to 2015 under the "European Fisheries Fund" (EFF). For this reason, it is impossible to calculate the total amount of subsidies allocated to electric 'pulse' fishing since the introduction of the exemptions.	Only the 1st four vessels were subsidised to 40% of the investment in a pulse system with a maximum investment of €176,000 per vessel, in accordance with the European Commission in 2008 (Haasnoot et al., 2015). According to information from the ministry LNV, none of the other pulse vessels received subsidy to invest in the pulse gear. 3,8 mln. Dutch EMFF budget has been committed to two research projects about pulse fisheries. One project is an impact assessment about pulse fisheries. This study will form a coherent project that aims to develop the fundamental knowledge on the effects of electricity on marine organism and the benthic ecosystem required to assess the ecological consequences of this new fishing method. Another project aims to study the selectivity gain that pulse technology can have in the shrimp fishing industry. The main value of pulse technology in the shrimp fishing industry is to reduce by-catches. In compliance with Commission Regulation (EC) No 498/2007, the EFF subsidies were always electronically published with the CAP subsidies in a publicly available database. This database contained the grants for the EFF per calendar year (for CAP payments per financial year). These databases stayed online for 2 years. Furthermore all completed pilot-projects are published (and still available) on the website “Europa om de Hoek” (https://www.europaomdehoek.nl/projecten/?page=3&map=&radius=&projectFund%5B0%5D=EVF&projectFund%5B1%5D=EVF).
20	A fishing method in total contradiction with our international commitments… As part of the Sustainable Development Goals adopted by the United Nations General Assembly in 2015, Europe committed to "end overfishing" and "destructive fishing practices" by 2020 (SDG 14.4).* The development and public funding of electric 'pulse' fishing is in total contradiction with these objectives …and with our regulatory objectives. The basic regulations of the Common Fisheries Policy adopted in 2013** set an objective for the European Union to restore fish stocks and end overfishing by 2020 at the latest. The "Marine Strategy Framework Directive" (2008/56/ EC) demands the "conservation of the marine ecosystems. This approach should include protected areas and	The objective of the EU to restore fish stocks and end overfishing by 2020 have been met for North Sea sole and plaice, the two main target species of the pulse trawl fishery. The spawning-stock biomass (SSB) of sole has increased since 2007 and has been estimated at above the maximal sustainable yield (MSY) reference since 2012. Fishing mortality (F) has declined since 1997 and is slightly above F_{MSY} in 2016. The spawning-stock biomass (SSB) of plaice is well above the MSY reference, and has markedly increased in the past ten years. Since 2009, fishing mortality (F) has been estimated at around F_{MSY} (ICES, 2017e; ICES, 2017c) The scientific studies carried out so far do not support that pulse trawling is a destructive fishing practice (ICES, 2017b). The evidence support the conclusion that pulse fishing contributes to a

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	should address all human activities that have an impact on the marine environment". * United Nations (2015) Sustainable Development Goals — Goal 14: conserve and sustainably use the oceans, seas and marine resources. Available at: www.un.org/sustainabledevelopment/oceans. ** Regulation (EU) No 1380/2013.	substantial reduction in the adverse ecological and environmental impacts although a number of topics warrant further investigation (this report).
21	A destructive technological race. Electricity is also used to catch shrimp. Besides the Dutch, Belgian fishers have also shown some interest in this technique, but it uses a 'unipolar' (as opposed to 'bipolar' for flatfish) pulsed current. Although unipolar current is less harmful than bipolar current, such a technological race will also result in an increased fishing effort and thus aggravate the overexploitation of common shrimp.* The German Thünen Institute considers that electric fishing may be a viable alternative, but its position is solely based on i) reduced fuel consumption and ii) lower impact on habitats relative to beam trawling, as well as iii) potential decreased bycatch, but again only in comparison with one of the most high impact fishing gears there is: beam trawls. Therefore, similarly to research carried out by the Dutch IMARES Institute, effects on the whole marine ecosystem and ripple down effect on fishing communities are not accounted for.** * ICES (2014) Request from Germany and the Netherlands on the potential need for a management of brown shrimp (Crangon crangon) in the North Sea. ICES Advice 2014, Book 6 — North Sea — 6.2.3.4 — Special request, Advice October 2014. 10 p. ** See their public position at: www.thuenen.de/en/of/projects/fisheries-and-survey-technology/pulsetrawl-for-shrimp-fishery.	Research of the Belgian fisheries institute has shown the potential to reduce the substantial bycatch in the fishery for brown shrimp, including juveniles of commercial species such as plaice and sole (Polet et al., 2005; Verschueren et al., 2014) The PhD project of Desender (2018) has provided no support for concern about adverse effect of electrical stimulation on marine organisms. The traditional shrimp beam trawl is in no way comparable to a tickler chain beam trawl used in the fishery for sole and other flatfish. The gear deploys a light ground rope with rollers and is expected to have a substantial lower impact on the benthos (Eigaard et al., 2016).