# Electrofishing: exploring the safety range of electrical pulses for marine species and its potential for further innovation

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In traditional beam trawl fisheries, a gear comprising tickler chains, chain matrices or bobbin ropes is dragged over the seafloor to startle and catch flatfish or shrimp. These heavy fishing have well-known disadvantages such as seabed disturbance, fuel consumption and high by-catches. Pulse trawling is the most promising alternative for conventional beam trawling at this moment. In these electrotrawls, the mechanical stimulation by tickler chains, chain matrices or bobbins is (partly) replaced by electric stimulation, resulting in a less intensive drag and subsequently decreased seabed disturbance and fuel consumption. Additionally, the electric pulses generated by electrodes affect the target species more selectively, thus reducing by-catch. The nearly 100 vessels that have adopted this technique at this moment can be divided into two pulse types as a function of the target species. The first type constituting the vast majority of pulse vessels targets flatfish, particularly Dover sole (*Solea solea* L.), by using a bipolar pulse of 60-80 Hz. This stimulus induced a cramp response in the sole's muscle, which makes it bend in a U-form and prevents it from escaping, resulting in increased catch efficiency. A minority of vessels target brown shrimp (*Crangon crangon* L.) by outfitting their boat with electrotrawls that produce a unipolar startle pulse of 5 Hz. These pulses force shrimp to flip their tail 5 times a second, which makes them jump out of the sediment in the water column. This allows the fishermen to catch them more selectively with less by-catch, also in clear water conditions. However, despite the promising opportunities, several concerns about negative effects of electric pulses on survival, behaviour and reproduction of target and non-target species need to be addressed (ICES recommendations, 2009), which led to the general aim of this thesis. **Chapter 1** elaborates on the history and development of the use of electric pulses in trawls, as well on possible side-effects, emphasizing the areas meriting further investigation. The consequential specific aims of the thesis may be found in **Chapter 2**, and include the investigation of possible side-effects of electric pulses on adult invertebrates (**Chapter 3 & 4**), flatfish (**Chapter 5**) and roundfish (**Chapter 5, 6 & 7**) as well as testing new applications of pulse stimulation improving the selectivity (**Chapter 8**).

The first major gap in knowledge was the effect of electric pulses on marine benthic invertebrates. This was addressed in **Chapter 3**, presenting the results of experiments performed with brown shrimp (*Crangon crangon* L.) and ragworm (*Alita virens* S.) as model species for crustaceans and polychaetes, respectively. These animals were exposed to a homogenously distributed electric field with varying values of frequency, electric field strength, pulse polarity, pulse shape, pulse duration and exposure time to determine the range of safe pulse parameter settings and evaluate the effect of the pulses already being used on commercial electrotrawls. Behaviour during and shortly after exposure, 14 day (14-d) mortality rates, gross and histological examination were used to evaluate possible effects. No significant increase in mortality or injuries was encountered for either species within the range of pulse parameters tested. In contrast, examination of the hepatopancreas of shrimp exposed to the highest field strength revealed a significantly higher severity of an intranuclear bacilliform virus (IBV) infection. The obtained results hence were promising, but indirect effects, in particular on shrimp, as well as an increased impact of repetitive exposure under commercial conditions were still a major concern.

Therefore, brown shrimp were exposed 20 times in 4 days using commercial electrodes and pulse settings to catch shrimp (shrimp startle pulse) or sole (sole cramp pulse) and monitored for 14 days post first exposure (**Chapter 4**). Additionally to the previous experiment, also the size, egg loss, moulting and the degree of IBV infection were evaluated and compared between non-stressed non-exposed shrimp (control group 1) and shrimp exposed to electrodes without electric stimulus (control group 2) and as well as shrimp exposed to mechanical stimuli. In this study, no effect of electric stimulation on the degree of IBV infection was found. The survival of shrimp repetitively exposed to electric pulses did not significantly differ from those that were repetitively mechanically stimulated. However, the lowest survival was observed for the sole cramp pulse, and was significantly lower than second control group displaying the highest survival. On the other hand, the mechanic stimulated shrimp demonstrated the lowest percentage of moults compared to all other treatments, significantly lower than the second control group in which the highest percentage of moults was noted. Additionally, the mechanically stimulated shrimp that died during the experiment had a significantly larger size compared to the surviving individuals. Although negative impact of repetitive electric exposures on shrimp could not be ruled out, these results demonstrate that any impairing effects should be balanced against the harmful impact of the conventional trawls.

Despite being the major target species of beam trawls, no research investigating the effect of electric pulses on flatfish was reported so far. Dover sole (*Solea solea* L.), was therefore used as model species and exposed to over 40 different homogenously distributed electric fields with varying pulse parameters (**Chapter 5**). Fish behaviour during and shortly after exposure, 14-d post exposure mortality rates, as well as gross and histological examination was used to evaluate possible effects. Sole showed an escape response below a frequency of 20 Hz and a cramp reaction above 40 Hz, immediately followed by post-exposure escape behaviour. No mortality was observed and histological examination did not reveal any abnormalities, indicating the absence of irreversible lesions as a direct consequence of exposure to electric pulses in sole.

Atlantic cod (*Gadus morhua* L.) exposed in the same homogenous experimental set-up (**Chapter 5**), showed similar reactions during exposure. However, immediately after exposure to high electric loads, this gadoid round fish showed tonic-clonic epileptiform reactions. Moreover, one cod developed a spinal injury, which confirmed observations of cod with paravertebral bleedings in published laboratory and field research. Further research (**Chapter 6**) revealed that these epileptiform seizures were not observed when cod was exposed near electrotrawls' wire-shaped electrodes (heterogenous electric field) generating commercial cramp pulses, and may thus be promoted by the homogenous set-up with plate-shaped electrodes. The heterogenous set-up with cod aimed to investigate the variability in occurrence of electric-induced injuries in cod, by exposing wild cod and cultured cod from two different farms to the pulse used by electrotrawls targeting sole. Gross and radiographic examination revealed spinal injuries in 0-5% of fish when exposed near the electrodes. This contrasts with other studies showing incidences varying between 0 and 70% under the same experimental settings, demonstrating a fish-effect rather than a pulse (setting) effect. Analysis of the size, somatic weight, muscularity, number of vertebral bodies and vertebral mineral contents of cod of different origin did not reveal any (co-)decisive physiological nor morphological parameter for exhibiting vulnerability to electric pulses. However, some clues such as the impact of breeding-conditions definitely warrant further research.

Subsequently, we aimed to assess the vulnerability of another roundfish, sea bass (*Dicentrachus labrax* L.), and compare its susceptibility for spinal injuries with that of gadoid roundfish such as cod and whiting (*Merlangius merlangus* L.) (**Chapter 7**). Therefore, sea bass were divided in 2 groups based on the size of the animals and exposed near commercial electrodes the same way as cod (Chapter 6). The behaviour during and after exposure was comparable to that of cod, but no epileptic seizures were induced in this heterogenous set-up. Further gross, radiographic and histologic examination did not demonstrate lesions, suggesting that bass is a less sensitive gadoid roundfish species. As a consequence, sea bass is not to be used as an alternative model species for all roundfish, and it is recommended to include other parameters besides anatomy of the musculature when examining the effect of electric pulses in future research.

The last study (**Chapter 8**) focussed on a possible new application of electric pulses, aiming in (further) improving the selectivity of beam and pulse trawl gears. Firstly, the conventional benthos release panels (BRP) were improved. These BRPs are known to release large amounts of benthos and debris which facilitate the sorting process as well as to reduce the catch of undersized fish. However, unacceptable losses of commercial sole and damage to the BRP as a consequence of slack between the round net and square panel hampers a successful introduction in commercial beam trawl fisheries. To eliminate these drawbacks, the BRPs were inserted in square nets and the selectivity for BRPs square mesh size of 150 mm, 200 mm and 240 mm was assessed. Secondly, an electric cramp stimulus was implemented on the BRP to eliminate the loss of commercial sole. The first modification successfully eliminated the bag formation and subsequent damage while benthos and undersized fish were released in significant quantities. The results of the second innovation suggest that larger than 25 cm was retained, without negatively affecting the release of benthos and most undersized commercial fish. Although further research using smaller mesh sizes or optimized electric stimuli to achieve retention of all commercial sole is warranted, this study clearly demonstrates the promising potential of electric stimuli for further innovation.

Finally, an overall discussion of the scientific results and future research perspectives are provided in **Chapter 9**. The laboratory findings and implications for the field are reviewed, subsequently focusing on the estimated total impact of electrotrawls and elaborating on further innovations that may be created.