THE APPLICATION OF ELECTRICAL STIMULATION IN FISHERIES

G.P. Boonstra

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ABSTRACT
This paper gives a short description of applications of electrical stimulation and attraction in fisheries with special reference to beam trawls. No great emphasis is laid on the electro-technical and biological aspects of the different reactions as those have been described in great detail by many authors.

A short description of the basic experiments with a low-powered pulse generator for the stimulation of shrimp and flatfish in the Netherlands is given.

The main points of the paper are:

a. The effort which is being made to introduce low-powered pulse generators in the beam-trawl fishery in the Netherlands.

b. The difficulty in making this final step from research to application as it means the adaptation of an existing fishing technique to electrical stimulation and not the adaptation of electrical stimulation to an existing fishing technique.

1 RESEARCH AND APPLICATION

1.1 Basic research
Electrical fishing is not a novelty. A bibliography published in April 1960 gives a list of 600 publications (Meyer-Waarden and Halsband 1960). Since then many more papers have been published. Some of these date back to the turn of the century while an important part of the basic work was done in the 1920's and 30's.

In the past modern electronic components have given a great stimulus to technical research in the field of electrical fishing. Nowadays it is possible to switch very high currents at high frequencies and with very fast rise times. Much research has been done too, on the mechanisms which cause the different reactions. Most authors describe the different reactions as related to the voltage per unit distance in the water, V/m or V/cm, one of the most important reactions being the forced swimming towards the anode, which is called anodic attraction or 'galvanotaxis'. This reaction is very marked with DC. When the conductivity of the water becomes too high for pure DC equipment, pulsating currents, mostly capacitor discharges, are a good alternative. Capacitor discharges with frequencies in the range of 30 to 100 Hz are reported to evoke anodic attraction in most species, although the optimum frequency is different for various species.

1.2 Fresh water fisheries
DC and pulsed DC equipment is known to be widely used in many countries as sampling tools and on a commercial scale in dipnet fishing.

Another application in fresh water is an electrified 'dragnet' which is towed by one or two vessels. It is known to be commercially used in some East European countries. In the German Federal Republic and in the Netherlands it is used on an experimental scale. In the Netherlands it has been developed into a sampling gear for eels, which catches almost exclusively eels by reducing the vertical net opening to almost nothing and by stimulating the eels out of the bottom by means of electrical impulses. This is done with a beam-trawl which makes it possible to lower the head rope. The author of this paper has no knowledge of any extensive use of electricity in combination with towed nets in fresh water except for the examples mentioned.

1.3 Fish screens
Another use of electricity which has a worldwide application is fish screens, which are either used for keeping fish out of water inlets of electric power plants and factories or for guiding fish. Fish screens are powered by low frequency pulses, mostly quartersine waves, because the idea is not to attract or narcotise the fish but to scare them off.

1.4 Sea fisheries
1.4.1 Research with high-power pulse generators
As sea fisheries are practised on a much larger scale than fresh water fisheries, the interest in applying electricity to sea fisheries is very great indeed. The problems, however, are magnified in about the same order because of the high conductivity of sea water, which is on the average about 500 times higher than the conductivity of fresh water.

The use of DC, therefore, is impossible because of the excessive power demands. A solution is the use of pulsed DC which has a strong physiological effect on fish and a mean power consumption which is much lower than with DC.

The mean power consumption is dependent on the duty cycle which is the relation between power on during time t and total time T. This relation is thus dependent on pulse length and pulse frequency. Although pulsating current is the only means of applying electricity to sea fisheries it does not mean that the electric power needed to influence fish in sea water is negligible. Kreutzer gives a formula to find the effective distance from the electrodes under certain conditions (Kreutzer 1954). His conclusion is that fish can be caught by means of electricity on a commercial scale with a power source of 200 kW. Recent research in the United States is being done with a 120 kW pulse generator by the Pascagoula Laboratory of the Southeast Fisheries Center (U.S. Department of Commerce) for the electrification of a 30-foot midwater trawl. Fisheries scientist in France (Kurc) also uses a pulse generator with a power consumption in the same order of magnitude.

It is obvious that the problems involved in working with pulse generators with a mean power consumption of 100—200 kW are still great.

The voltage used by the U.S. scientists is from 500 to 1200 volts, while the peak current must be thousands of amperes.

The reason for the use of those high voltages is to get a field strength in the range of 20 to 30 V/m in the middle of the field for effective electrotaxis. Because of the rapid breakdown of the field near the electrodes this aim is difficult to achieve. The cable winch, sliprings, cables, transformers and electrodes have to be of a very special design. Moreover, there is the problem of smoothing the surge on the power source during the pulse period. It appears to be very difficult to introduce this system on commercial fishing vessels as long as the existing fishing methods are effective, and in otter trawling both the modern midwater trawl and also the high opening bottom trawls are very efficient fishing tools indeed.

It has been suggested (Stewart 1971) to use other approaches than stunning to increase the effectiveness of capture of the nets by using the herding effect. The author of this paper would like to suggest this approach for fishing on stony grounds. If those grounds were fished with a midwater trawl fitted with a netsonde, the groundrope could be kept just off the stones.

If electrodes were trailed from the groundrope or from a false groundrope rigged in front of the proper groundrope, the fish would be scared from between the stones and be caught. This would probably have the same effect as an attracting anode in the net mouth but the power consumption would certainly be much lower.
1.4.2 Fish pumps and electrified hooks

An application of electricity which is used in commercial fishing is the electrified fish pump. This is used on a large scale for emptying the bunt in menhaden purse-seining. The rigging of the electrodes and additional gear is difficult. The end of the suction hose is fitted with the anode of an electric fishing system. The fish is forced to swim towards the anode and is then pumped up. This system is reported to be used without a net in combination with light attraction in the kilka fisheries in the Caspian Sea and the saury fishery in the Sea of Okhotsk (Nikonorev 1964). This application is not possible for all schooling species as not all of them are in the same way attracted by light, but hover in the twilight zone. A successful experiment with an electrified fish pump without a net is reported by Dethloff (1969). This system, however, is not known to be used commercially. Some use seems to have been found for electrified hooks in the tuna fisheries.

1.4.3 Problems in application

The examples show that in many promising-looking experiments there is a long difficult way between research and practical application. McRae and French gave a summing-up of the five major problems to be overcome in the application of electricity for the catch of ground fish and this should also apply to pelagic fish (McRae and French 1965). The five points are:

1. To supply the electric current required to produce the desired effect upon fish.
2. To transform the current into the most efficient and effective form and type to catch the fish.
3. To transport the current from the ship to the net (where it will be used) without exorbitant loss.
4. To overcome or eliminate the effect of electrolysis upon the electrodes.
5. To provide rugged and practical equipment components necessary to withstand use aboard ship and severe treatment during fishing operations.

Stewart formulates the problems in the same way (Stewart 1971).

2 DIFFERENCE BETWEEN OTTER TRAWLS AND BEAM TRAWLS

It should at this stage be explained that there is a real difference between electrical fishing with an otter trawl, either bottom or midwater, and a beam trawl. With an otter trawl, the rigging of the electrodes and additional gear is difficult because the trawl is not a stable platform. The electrodes should therefore be attached directly or indirectly to the headline and/or the groundrope. They should not interfere with the operational configuration of the trawl. The field strength in the middle of the net mouth must have a certain minimum value and, as already mentioned, the rapid decay of the field caused by polarisation and the non-uniformity of the field makes it necessary to use very high voltages. As the power increases with the square of the voltage, a 10-fold increase in voltage increases the power demand 100-fold. Modern midwater trawls for high-powered trawlers have a net opening of more than 1000 m². It seems unlikely that a pulse generator can be developed to be used on such a huge net. Efforts to use pulse generators in combination with midwater trawling are directed therefore at much smaller nets, and even then the problems are great.

Although bottom-trawls are not as large as midwater trawls, high-powered pulse generators are still needed for effective electrotaxis. To evoke the first (flight) reaction in bottom dwelling species appears to be much simpler and good results have been reported by American scientists (Seidel 1969) in the shrimp fisheries in the Gulf of Mexico. The pulse generators used in those experiments were low-powered and the electric ticklers were running over the bottom more or less parallel to the groundrope. With a beam trawl it appears to be simpler to realise a commercial introduction after, of course, one has first found the right values for the electrical stimuli for the species one wants to catch.

The advantages of a beam trawl are:

a. It is a stable platform and the rigging of an electrode array and pulse generator does not influence the operation of the trawl.
b. The area over which the field has to be effective is much smaller than for an otter trawl. This area is the part of the seabottom in front of the groundrope (± 30 m²), wide enough to influence the fish at a certain fishing speed.
c. The electrode array consists preferably of a number of electrodes (6—10) alternately positive and negative and running in the towing direction. With this kind of array, with the electrodes rather close together, it is easier to get sufficient field strength halfway between the electrodes than with large electrodes spaced far apart.
d. The beam trawl is used to catch bottom dwelling species and the reaction which is needed to catch them is not taxis or narcosis but (if possible) a flight reaction, stimulating them out of the bottom.

3 RESEARCH IN THE NETHERLANDS

3.1 Objectives

As the Fisheries Research Department in the Netherlands is too small to cope with the problems of high-power pulse generators, it was nevertheless felt that something useful might be done for a new kind of fishing which is practised on a large scale by Dutch fishermen, i.e. beam trawling.

Beam trawling is practised for shrimps and flatfish. The shrimp trawlers do not use tickler chains and are relatively low-powered, c. 150—250 hp. The flatfish trawlers fish with tickler chains and the engines of those vessels are up to 2000 hp. This kind of fishing is very efficient but the gear which is dragged over the bottom is very heavy. To give an example: a new beam trawler, recently commissioned, has a main engine of 1200 hp. Each of the two beam gears has a weight of 5300 kg which is distributed as follows:

- Beam: 1000 kg
- Trawl heads: 1300 kg
- Tickler chains: 2300 kg
- Net: 700 kg

When the research on electrical fishing was started there were two objectives.

a. Opening the possibility of electric shrimp fishing in daylight and increasing the selectivity of the shrimp trawl by saving young and valuable flatfish.

b. Fishing for sole and other flatfish with light electrical ticklers instead of the heavy tickler chains and thus reducing the weight of the gear and the propulsive power needed to tow the gear.

3.2 Shrimp

3.2.1 Basis

For the research on shrimp the basis was the excellent work done in the United States (Klima 1968). Although the species there are different from the species along the Dutch coast the experimental pulse generator (Figure 1) which was developed was expected to have sufficient flexibility to give the information needed for the electrical stimulation of shrimp (Crangon Crangon L.).

The research was started in the aquaria of the Fisheries Laboratory in IJmuiden. After successful conclusion of this first step the need was felt for observation of the reaction of shrimp in an environment as close to their natural habitat as possible (Boonstra—de Groot 1970). This was done in an oyster basin with sandy bottom and well stocked with shrimps. The water level in the basin could be regulated with sluices dependent on the tide (Figure 2, photo by S. J. de Groot). Observations were made from the side. The results confirmed the American results. Shrimps reacted favorably to electrical
stimuli. On the average it took a completely burrowed shrimp three pulses to jump high enough to be caught with a pulse frequency of 5 Hz and an optimum pulse duration of 0.2 milliseconds.

Figure 1. Experimental pulse generator PG 6820

Figure 2. Oyster basin where second-stage experiments were carried out

3.2.2 Comparative fishing with research vessels
The next step was comparative fishing with small research vessels in the estuary of the Scheldt river in the south and the Waddensee in the north. The fishing was carried out with a 3-metre beam gear on either side, one side fitted with electrical ticklers and the other side without. Originally the ticklers were rigged parallel to the ground rope. This not only made them vulnerable to damage but in areas with bottom vegetation the electrodes got so draped that a 'blanket' was formed on the bottom preventing the shrimps from jumping. The electrodes were then rigged in the towing direction which made them less vulnerable. The problem then, especially with a small trawl, is to let the electrodes touch the ground. This was done by attaching them to a steel wire between the trawl heads just off the bottom. Although this system had a negative effect on the catch when there was no power on the electrodes, the results with the power on were quite good.

The pulse generator used on the comparative fishing trials with the 3-metre beam trawl was the experimental pulse generator PG 6820. The pulses were led to the electrode-array via two cables of 25 mm². On a commercial vessel with 8- or 9-metre trawls this system could not be maintained because of the deterioration of the pulse form over the long cables.

Figure 3. Pulse generator and electrode array on beam gear (1973)

Figure 4. Pulse generator PG 7317 (Principle)

Figure 5. Pulse generator PG 7317 (Lay-out)

3.2.3 Comparative fishing on commercial vessel in 1973
In August and September 1973 a series of experiments were carried out on a commercial shrimp trawler with a propulsive
power of 250 hp. The vessel fished with two 9-metre beam trawls. The starboard gear was fitted with the pulse generator and electrodes (Figure 3). The power supply cable was paid out and hauled by hand during this series of experiments. The catch was sorted with a rotating shrimp sieve, which sorts into three categories:

- **consumption-sized shrimp**
- **undersized shrimp**
- **fish and benthos**

### Results

The results of this series of experiments are shown in Figure 6. The 43 tows represent a total fishing time of 1227 minutes and a catch of 1337 kg (electric side = E) and 1058 kg (non-electric side = N). For those 43 tows E : N = 1.26 : 1.

The 18 tows in column 2 are clear water tows and represent a fishing time of 507 minutes and a catch relation E : N = 1.43 : 1. As there was quite a bit of sprat in the consumption shrimp the relation between E and N was in fact better. For six tows with a fishing time of 173 minutes the catch was therefore cooked separately and after cooking the relation was E : N = 2.34 : 1.

The by-catch was not influenced unfavorably but was in fact a little better, 51 plaice over 27 cm length per fishing hour on the E side against 44 on the N side.

![Figure 7. Electrode rigging (1974)](image)

### 3.2.4 Experiments in 1974

Although the fishing in 1973 was done on a commercial vessel and the results were encouraging, they were not good enough to stimulate adoption in the shrimp fleet, because the electrode system was too vulnerable (Figure 3). A four-month series of trials was started in May 1974 using the same vessel as in 1973.

The electrode rigging was changed and the system which is used at present is shown in Figures 7 and 8. The electrodes are made of copper aerial-wire woven through a light chain (4 kg/m). The chain is used to keep the electrodes hard on the ground. The only material which wears out is the aerial wire, but this will be replaced by stainless steel.

The power supply is now led via a self-tensioning netsonde winch with a cable capacity of 500 metres and a drive motor of 110 V DC 3 HP (Figure 9). Instead of a netsonde cable a 4-core Niplas cable of 200 metres length is now used with a breaking strength of 380 kgf. In two months of use this cable has not given any trouble, but for future use a special cable has been ordered.

### Discussion of results

Taken at their face value the results seem good enough to introduce the system in the shrimp fleet. There are, however, still a few unknown factors.

- **Selectivity**

  The selectivity aspect which was mentioned as one of the objectives will be given more attention from now on because it will be one of the main arguments before or against introduction of the system in the shrimp fleet.

  During the current experiments the bobbins and ground rope of both trawls have been rigged in exactly the same way. The results seem to indicate that the electrified trawl does not catch more juvenile sole and plaice than the non-electrified one. It should, however, preferably be less.
The juvenile sole and plaice which come out of the rotating shrimp sieve together with the consumption shrimp are definitely lost because they go right into the cooking kettle. On the two other outlets of the sieve they have a good chance of survival. As those species are very valuable they should be saved as much as possible.

On the vessel, where the current experiments are carried out, a further decrease in fishing speed is not very well possible. Both the vessel and the gear are designed for a certain fishing speed and low-speed fishing can only be carried out with a very smooth sea. Moreover, there is the matter of the by-catch which is sometimes up to 50% of the value of the catch. With a low fishing speed a comparison between both nets would not be fair, but only a comparison with another vessel over a long period would be of any value. It is impossible to evaluate all factors which influence the introduction of a new fishing technique during research trips, even if they are made on a commercial vessel. Even the most impressive conclusions of a fisheries scientist do not convince the fisherman before he has seen one of his colleagues make more money than he does.

3.3 Flatfish
3.3.1 Basic research
The stimulation of flatfish by means of electrical ticklers has been a subject of study in the Netherlands for a number of years (Figure 10). Basic research has given the following data as necessary for the stimulation of sole and other flatfish.

- Pulse length for a capacitor discharge pulse 0-7 milliseconds
- Field strength 10 V/m
- Pulse frequency 30—50 Hz
- Pulse frequency interruption ½ Hz (1 second on — 1 second off).

Originally the research on shrimp and flatfish went on a parallel course.

3.3.2 Expected benefits
After the basic research was done, priority was given to the shrimp fisheries because the number of shrimp vessels has declined drastically during the last few years and the shrimp stock was supposed to be able to withstand more intensive fishing. Moreover, the flatfish beam trawlers did very well at that time. At present, this situation has changed drastically. Although the fleet of Dutch beam trawlers is the most modern in the world there are two important factors which have an adverse influence on their profitability.

- a. Very poor catches, especially of sole.
- b. The high cost of fuel and other materials.

Under the present conditions, stimulation by means of electrical ticklers would mean a considerable saving in the cost of fuel, tickler chains and other materials.
In the previously-mentioned example of the 1200 hp beam trawler the tickler chains make up 2300 kg of the total weight of 5300 kg. If the pulse generator and electric ticklers made up a weight of 300 kg (a very reasonable estimate) and the trawl heads and beam were reduced in weight too, the total reduction in weight could be at least 50%.

The reduction in resistance would be 22%, as 44% of the resistance of a beam trawl is bottom-friction resistance (de Boer, 1969).

For the same fishing speed this would mean a reduction in fuel consumption of 25% or Dfl. 62,500.- a year. Chains have to be renewed about seven times a year. With the present cost of steel this is yearly about Dfl. 30,000.

This, of course, is an over-simplification, because the full impact of an introduction of electric stimulation cannot be comprehended.

The matter is far too complex.

To give an example:

The fishing speed of the most modern beam trawlers is up to seven knots (3.5 m/sec). It would not be possible to maintain this fishing speed because the stimulation time for the fish in the electric field would be too short.

A vessel of 400—500 hp with a fishing speed of approximately 3.5 knots using electrical ticklers.

3.3.3 Results

The results obtained so far in comparative fishing were obtained with small-scale experiments only. The results in Figure 11 are for comparative fishing with 3-metre beam trawls. There are, however, more positive indications of the possibility for electrical stimulation of flatfish.

The results obtained with plaice in the shrimp experiments, which are described in this paper, point in that direction.

Dr. Peter Stewart from the Marine Laboratory in Aberdeen, Scotland, is engaged in experiments with electrical stimulation of flatfish and has personally observed the fish reactions by diving (Stewart, 1974). The reactions were positive and were obtained with volleys of pulses.

3.3.4 Biological interest

The author of this paper cannot give a very well-founded view as to the difference in effect on the bottom fauna when chain ticklers or electrical ticklers are used.

Under the auspices of the I.C.E.S. the Netherlands have been urged to study the effect of the heavy chains on the sea bottom.

Investigations so far have not pointed to any serious lasting damage, although there is a certain short-term damage to bottom organisms (de Groot-Apeldoorn, 1971).

Some biologists expressed the fear that electrical fishing would be even more effective than fishing with tickler chains.

This fear appears to be unfounded because there are a number of safeguards which are inherent to the system:

a. Selectivity of orientation towards the electrodes. Maximum stimulation is obtained with a fish at right-angles with the electrodes, minimum stimulation with a fish parallel to the electrodes.

b. Selectivity of size. A large fish of the same species reacts sooner to an electric field than a small one.

c. A random distribution, both in orientation and of the place of the fish within the field (the field strength being non-uniform), would ensure a certain selectivity, providing that the field is not saturated (Stewart, 1974).

d. Electrical fishing will have to be a more 'gentle' type of fishing. Low fishing speed is imperative to give the fish time to react. Because of this more gentle type of fishing (slower and lighter), the survival chances of the escaping fish will, in the author's view, be much higher.

3.3.5 Interest from the side of the fishermen

On the part of the fishermen an increasing interest is shown in the experiments.

Anything that might decrease the exploitation cost is looked at with interest.

One enterprising skipper has already bought his own pulse generator and is experimenting with the aid of the Institute for Fishery Investigations. Although his main interest is electrical eel-fishing along the coast, the results obtained in the same area with shrimp and sole are very valuable to the Institute.

3.3.6 Next step in research

Based on the specifications given on a previous page, a pulse generator is now being built especially for flatfish stimulation. The total discharge capacity is 11,000 μF.

Maximum discharge voltage 60 V

Maximum pulse frequency 50 Hz

Average power delivered to the electrodes at 30 Hz with 60 V and maximum discharge capacity = ¼ CV²f = 600 W

With an efficiency of 0.2 the power source will have to be 3 kW

A long series of tests with a vessel of 400 to 500 hp using electrical ticklers on one side and chain ticklers on the other is planned for 1975. Those tests should start to give some serious answers to the possibility of electrical fishing on flatfish. The present research on a shrimp vessel is in fact an etude for the more important flatfish fishery.
4 FINAL REMARKS

The five major problems as given by McRae and French have, at least for the low-powered pulse generators, been overcome. Once the basic studies are done, the most important steps to be taken are:

- Bring the system to the fisherman and let him judge as to the usefulness for commercial fishing.
- Listen to him on such matters as rigging of instruments and electrodes to his gear and on matters of fishing technique.
- Choose for your research a skipper and a crew who show a real interest in what is going on.
- Try to close the gap between scientific research and practical application.

REFERENCES


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No great emphasis is laid on the electro-technical and biological aspects of the different reactions as those have been described in great detail by many authors.

A short description of the basic experiments with a low-powered pulse generator for the stimulation of shrimp and flatfish in the Netherlands is given.

The main points of the paper are:

1. The effort which is being made to introduce low-powered pulse generators in the beam-trawl fishery in the Netherlands.
2. The difficulty in making this final step from research to application as it means the adaptation of an existing fishing technique to electrical stimulation and not the adaptation of electrical stimulation to an existing fishing technique.

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It should at this stage be explained that there is a real difference between electrical fishing with an otter trawl, either bottom or midwater, and a beam trawl. With an otter trawl, the rigging of the electrodes and additional gear is difficult because the trawl is not a stable platform. The electrodes should therefore be attached directly or indirectly to the headline and/or the groundrope. They should not interfere with the operational configuration of the trawl. The field strength in the middle of the net mouth must have a certain minimum value and, as already mentioned, the rapid decay of the field caused by polarisation and the non-uniformity of the field makes it necessary to use very high voltages. As the power increases with the square of the voltage, a 10-fold increase in voltage increases the power demand 100-fold. Modern midwater trawls for high-powered trawlers have a net opening of more than 1000 m². It seems unlikely that a pulse generator can be developed to be used on such a huge net.

Efforts to use pulse generators in combination with midwater trawling are directed therefore at much smaller nets, and even then the problems are great.

Although bottom-trawls are not as large as midwater trawls, high-powered pulse generators are still needed for effective electrotaxis. To evoke the first (flight) reaction in bottom dwelling species appears to be much simpler and good results have been reported by American scientists (Seidel 1969) in the shrimp fisheries off the coast of Mexico. The pulse generators used in those experiments were low-powered and the electric ticklers were running over the bottom more or less parallel to the groundrope. With a beam trawl it appears to be simpler to realise a commercial introduction after, of course, one has first found the right values for the electrical stimuli for the species one wants to catch.

The advantages of a beam trawl are:

a. It is a stable platform and the rigging of an electrode array and pulse generator does not influence the operation of the trawl.

b. The area over which the field has to be effective is much smaller than for an otter trawl. This area is the part of the seabottom in front of the groundrope (± 30 m²), wide enough to influence the fish at a certain fishing speed.

c. The electrode array consists preferably of a number of electrodes (6-10) alternately positive and negative and running in the towing direction. With this kind of array, with the electrodes rather close together, it is easier to get sufficient field strength halfway between the electrodes than with large electrodes spaced far apart.

d. The beam trawl is used to catch bottom dwelling species and the reaction which is needed to catch them is not taxis or narcosis but (if possible) a flight reaction, stimulating them out of the bottom.

3 RESEARCH IN THE NETHERLANDS

3.1 Objectives
As the Fisheries Research Department in the Netherlands is too small to cope with the problems of high-power pulse generators, it was nevertheless felt that something useful might be done for a kind of fishing which is practiced on a large scale by Dutch fishermen, i.e. beam trawling. Beam trawling is practised for shrimps and flatfish. The shrimp trawlers do not use tickler chains and are relatively low-powered, c. 150-250 hp. The flatfish trawlers fish with tickler chains and the engines of those vessels are up to 2000 hp. This kind of fishing is very efficient but the gear which is dragged over the bottom is very heavy. To give an example: a new beam trawler, recently commissioned, has a main engine of 1200 hp. Each of the two beam gears has a weight of 5300 kg which is distributed as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam</td>
<td>1000</td>
</tr>
<tr>
<td>Trawl heads</td>
<td>1300</td>
</tr>
<tr>
<td>Tickler chains</td>
<td>2300</td>
</tr>
<tr>
<td>Net</td>
<td>700</td>
</tr>
</tbody>
</table>

When the research on electrical fishing was started there were two objectives.

a. Opening the possibility of electric shrimp fishing in daylight and increasing the selectivity of the shrimp trawl by saving young and valuable flatfish.

b. Fishing for sole and other flatfish with light electrical ticklers instead of the heavy tickler chains and thus reducing the weight of the gear and the propulsive power needed to tow the gear.

3.2 Shrimp

3.2.1 Basis
For the research on shrimp the basis was the excellent work done in the United States (Klima 1968). Although the species there are different from the species along the Dutch coast the experimental pulse generator (Figure 1) which was developed was expected to have sufficient flexibility to give the information needed for the electrical stimulation of shrimp (Crangon Crangon L.).

The research was started in the aquaria of the Fisheries Laboratory in IJMUIDEN. After successful conclusion of this first step the need was felt for observation of the reaction of shrimp in an environment as close to their natural habitat as possible (Boonstra - de Groot 1970). This was done in an oyster basin with sandy bottom and well stocked with shrimps. The water level in the basin could be regulated with sluices dependent on the tide (Figure 2, photo by S. J. de Groot). Observations were made from the side. The results confirmed the American results. Shrimps reacted favorably to electrical
stimuli. On the average it took a completely burrowed shrimp three pulses to jump high enough to be caught with a pulse frequency of 5 Hz and an optimum pulse duration of 0.2 milliseconds.

Rather than opting for a system which improves the pulse form it was decided to develop a pulse generator which could be rigged on the beam trawl with very short cables to the electrode array and only the power supply cable between the vessel and the pulse generator (Figure 3). This pulse generator (Figures 4 and 5) can deliver 60 V pulses into a load of 50 milli-ohm with a pulse length of 0.2 milliseconds. The pulse repetition rate is variable between 1 and 50 Hz.

3.2.2 Comparative fishing with research vessels
The next step was comparative fishing with small research vessels in the estuary of the Scheldt river in the south and the Waddensee in the north. The fishing was carried out with a 3-metre beam gear on either side, one side fitted with electrical ticklers and the other side without. Originally the ticklers were rigged parallel to the ground rope. This not only made them vulnerable to damage but in areas with bottom vegetation the electrodes got so draped that a 'blanket' was formed on the bottom preventing the shrimps from jumping. The electrodes were then rigged in the towing direction which made them less vulnerable. The problem then, especially with a small trawl, is to let the electrodes touch the ground. This was done by attaching them to a steel wire between the trawl heads just off the bottom. Although this system had a negative effect on the catch when there was no power on the electrodes, the results with the power on were quite good.

The pulse generator used on the comparative fishing trials with the 3-metre beam trawl was the experimental pulse generator PG 6820.

The pulses were led to the electrode-array via two cables of 25 mm². On a commercial vessel with 8- or 9-metre trawls this system could not be maintained because of the deterioration of the pulse form over the long cables.

3.2.3 Comparative fishing on commercial vessel in 1973
In August and September 1973 a series of experiments were carried out on a commercial shrimp trawler with a propulsive
power of 250 hp. The vessel fished with two 9-metre beam trawls. The starboard gear was fitted with the pulse generator and electrodes (Figure 3). The power supply cable was paid out and hauled by hand during this series of experiments. The catch was sorted with a rotating shrimp sieve, which sorts into three categories: 

a. consumption-sized shrimp
b. undersized shrimp
c. fish and benthos

Results
The results of this series of experiments are shown in Figure 6. The 43 tows represent a total fishing time of 1227 minutes and a catch of 1337 kg (electric side = E) and 1058 kg (non-electric side = N). For those 43 tows E : N = 1.26 : 1. The 18 tows in column 2 are clear water tows and represent a fishing time of 507 minutes and a catch relation E : N = 1.43 : 1. As there was quite a bit of sprat in the consumption shrimp the relation between E and N was in fact better. For six tows with a fishing time of 173 minutes the catch was therefore cooked separately and after cooking the relation was E : N = 2.34 : 1. The by-catch was not influenced unfavorably but was in fact a bit better, 51 plaice over 27 cm length per fishing hour on the E side against 44 on the N side.

3.2.4 Experiments in 1974
Although the fishing in 1973 was done on a commercial vessel and the results were encouraging, they were not good enough to stimulate adoption in the shrimp fleet, because the electrode system was too vulnerable (Figure 3). A four-month series of trials was started in May 1974 using the same vessel as in 1973. The electrode rigging was changed and the system which is used at present is shown in Figures 7 and 8. The electrodes are made of copper aerial-wire woven through a light chain (4 kg/m). The chain is used to keep the electrodes hard on the ground. The only material which wears out is the aerial wire, but this will be replaced by stainless steel. The power supply is now led via a self-tensioning netsonde winch with a cable capacity of 500 metres and a drive motor of 110 V DC 3 HP (Figure 9). Instead of a netsonde cable a 4-core Niplas cable of 200 metres length is now used with a breaking strength of 380 kgf. In two months of use this cable has not given any trouble, but for future use a special cable has been ordered.

Results
Although the experiments are only halfway at the moment when this paper is written, some preliminary information is already available.

a. Average increase in shrimp catch 30%
b. Increase in catch in clear water over 100%
c. Increase in catch of plaice 20%
d. Reliability of the system: very good. The first breakdown of a component occurred after 250 hours of fishing.

The above-mentioned results were obtained with:

a. Resistance between the electrodes 100 milli-ohm
b. Discharge capacity 3500 μF
c. Pulse frequency 5 Hz
d. Peak voltage delivered to the electrodes 80 V (slightly overloaded)
e. Voltage measured in the middle of the electrode array 35 V/m
f. Average power taken from the AC source 225 W.

Discussion of results
Taken at their face value the results seem good enough to introduce the system in the shrimp fleet. There are, however, still a few unknown factors.

a. Selectivity
The selectivity aspect which was mentioned as one of the objectives will be given more attention from now on because it will be one of the main arguments before or against introduction of the system in the shrimp fleet. During the current experiments the bobbin and ground rope of both trawls have been rigged in exactly the same way. The results seem to indicate that the electrified trawl does not catch more juvenile sole and plaice than the non-electrified one. It should, however, preferably be less.
The juvenile sole and plaice which come out of the rotating shrimp sieve together with the consumption shrimp are definitely lost because they go right into the cooking kettle. On the two other outlets of the sieve they have a good chance of survival. As these species are very valuable they should be saved as much as possible.

On the vessel, where the current experiments are carried out, a further decrease in fishing speed is not very well possible. Both the vessel and the gear are designed for a certain fishing speed and low-speed fishing can only be carried out with a very smooth sea. Moreover, there is the matter of the by-catch which is sometimes up to 50% of the value of the catch.

With a low fishing speed a comparison between both nets would not be fair, but only a comparison with another vessel over a long period would be of any value. It is impossible to evaluate all factors which influence the introduction of a new fishing technique during research trips, even if they are made on a commercial vessel.

Even the most impressive conclusions of a fisheries scientist do not convince the fisherman before he has seen one of his colleagues make more money than he does.

3.3 Flatfish

3.3.1 Basic research

The stimulation of flatfish by means of electrical ticklers has been a subject of study in the Netherlands for a number of years (Figure 10). Basic research has given the following data as necessary for the stimulation of sole and other flatfish.

- Pulse length for a capacitor discharge pulse 0.7 milliseconds
- Field strength 10 V/m
- Pulse frequency 30–50 Hz
- Pulse frequency interruption ½ Hz (1 second on – 1 second off).

Originally the research on shrimp and flatfish went on a parallel course.

3.3.2 Expected benefits

After the basic research was done, priority was given to the shrimp fisheries because the number of shrimp vessels has declined drastically during the last few years and the shrimp stock was supposed to be able to withstand more intensive fishing.

Moreover, the flatfish beam trawlers did very well at that time. At present, this situation has changed drastically. Although the fleet of Dutch beam trawlers is the most modern in the world there are two important factors which have an adverse influence on their profitability.

- Very poor catches, especially of sole.
- The high cost of fuel and other materials.

Under the present conditions, stimulation by means of electrical ticklers would mean a considerable saving in the cost of fuel, tickler chains and other materials.
In the previously-mentioned example of the 1200 hp beam trawler, the tickler chains made up 2300 kg of the total weight of 5300 kg. If the pulse generator and electric ticklers made up a weight of 300 kg (a very reasonable estimate) and the trawl heads and beam were reduced in weight too, the total reduction in weight could be at least 50%.

The reduction in resistance would be 22%, as 44% of the resistance of a beam trawl is bottom-friction resistance (de Boer, 1969).

For the same fishing speed this would mean a reduction in fuel consumption of 25% or Dfl. 62,500.- a year. Chains have to be renewed about seven times a year. With the present cost of steel this is yearly about Dfl. 30,000.-.

This is, of course, an over-simplification, because the full impact of an introduction of electric stimulation cannot be comprehended. The matter is far too complex.

To give an example:

The fishing speed of the most modern beam trawlers is up to seven knots (3.5 m/sec). It would not be possible to maintain this fishing speed because the stimulation time for the fish in the electric field would be too short.

A simple reduction of the weight of the gear and fishing with the same speed, even if it was four knots, would not be possible, because the gear would not keep to the bottom but, in the words of a fishing skipper, 'it would catch seagulls instead of soles'.

Many more examples could be mentioned, but the final comparison will have to be:

The most modern unit of the fleet with an engine of 2000 hp and a fishing speed of seven knots using chains against:

A vessel of 400- 500 hp with a fishing speed of approximately 3.5 knots using electrical ticklers.

3.3.3 Results

The results obtained so far in comparative fishing were obtained with small-scale experiments only. The results in Figure 11 are for comparative fishing with 3-metre beam trawls. There are, however, more positive indications of the possibility for electric stimulation of flatfish. The results obtained with place in the shrimp experiments, which are described in this paper, point in that direction.

Dr. Peter Stewart from the Marine Laboratory in Aberdeen, Scotland, is engaged in experiments with electrical stimulation of flatfish and has personally observed the fish reactions by diving (Stewart, 1974). The reactions were positive and were obtained with volleys of pulses.

3.3.4 Biological interest

The author of this paper cannot give a very well-founded view as to the difference in effect on the bottom fauna when chain ticklers or electrical ticklers are used.

Under the auspices of the I.C.E.S. the Netherlands have been urged to study the effect of the heavy chains on the sea bottom.

Investigations so far have not pointed to any serious lasting damage, although there is a certain short-term damage to bottom organisms (de Groot—Apeldoorn, 1971).

Some biologists express the fear that electrical fishing would be even more effective than fishing with tickler chains. This fear appears to be unfounded because there are a number of safeguards which are inherent to the system:

a. Selectivity of orientation towards the electrodes. Maximum stimulation is obtained with a fish at right-angles with the electrodes, minimum stimulation with a fish parallel to the electrodes.

b. Selectivity of size. A large fish of the same species reacts sooner to an electric field than a small one.

c. A random distribution, both in orientation and of the place of the fish within the field (the field strength being non-uniform), would ensure a certain selectivity, providing that the field is not saturated (Stewart, 1974).

d. Electrical fishing will have to be a more 'gentle' type of fishing. Low fishing speed is imperative to give the fish time to react. Because of this more gentle type of fishing (slower and lighter), the survival chances of the escaping fish will, in the author's view, be much higher.

3.3.5 Interest from the side of the fishermen

On the part of the fishermen an increasing interest is shown in the experiments. Anything that might decrease the exploitation cost is looked at with interest.

One enterprising skipper has already bought his own pulse generator and is experimenting with the aid of the Institute for Fishery Investigations. Although his main interest is electrical eel-fishing along the coast, the results obtained in the same area with shrimp and sole are very valuable to the Institute.

3.3.6 Next step in research

Based on the specifications given on a previous page, a pulse generator is now being built especially for flatfish stimulation. The total discharge capacity is 11,000 μF.

Maximum discharge voltage 60 V

Maximum pulse frequency 50 Hz

Average power delivered to the electrodes at 30 Hz with 60 V and maximum discharge capacity of 11,000 μF is 600 W.

With an efficiency of 0.2 the power source will have to be 3 kW.

A long series of tests with a vessel of 400 to 500 hp using electrical ticklers on one side and chain ticklers on the other is planned for 1975. Those tests should start to give some serious answers to the possibility of electrical fishing on flatfish. The present research on a shrimp vessel is in fact an etude for the more important flatfish fishery.
4 FINAL REMARKS

The five major problems as given by McRae and French have, at least for the low-powered pulse generators, been overcome. Once the basic studies are done, the most important steps to be taken are:

- Bring the system to the fisherman and let him judge as to the usefulness for commercial fishing.
- Listen to him on such matters as rigging of instruments and electrodes to his gear and on matters of fishing technique.
- Choose for your research a skipper and a crew who show a real interest in what is going on.
- Try to close the gap between scientific research and practical application.

REFERENCES


