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The development of an electrified shrimp-trawl in the Netherlands

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The first results of trials with an electrified Dutch beam trawl for shrimp (*Crangon crangon* L.) fishing are reported. An electrified beam trawl catches about 116% more commercial sized shrimp and 81% more undersized shrimp. By using this type of gear it is hoped that the destruction of immature fish, especially flatfish, by the shrimp fishing fleet will be reduced.

Introduction

In studying the possibilities of increasing the efficiency and selectivity of the shrimp-trawl (beam trawl), our attention fell upon the research work carried out in the United States on the development of an electrified shrimp-trawl (Pease, 1967; Pease and Seidel, 1967; Klima, 1968; Seidel, 1969). The species they investigated were the American pink shrimp (*Penaeus duorarum* Burkenroad) and the American brown shrimp (*P. aztecus* Ives). Our commercially important shrimp is the European brown shrimp (*Crangon crangon* L.), a much smaller species. Shrimps in our waters are caught during the night as well as during the day. The fact that they are also caught during the day-time finds its origin in the turbidity of the coastal waters, with strong tides (Waddensea). In clear water, as for example along the coast during the winter, day catches are very poor. The reason is that a high light intensity inhibits the activity of the shrimp.

Shrimps burrow into the bottom during the day-time, especially in clear water (Fuss and Ogren, 1966; Hughes, 1968; Dornheim, 1969). As there is now a trend for the shrimp fishermen to move out of the turbid Waddensea into the deeper and clearer off-shore North Sea water and the Sylt area, an electrified shrimp-trawl might make it possible to fish during the whole 24 h period with success. The introduction of this electrified shrimp-trawl may also reduce the destruction of immature flat fish, such as sole and plaice, by fishing with the ground rope off the bottom, thus giving the flatfish more chance to evade the net.

Material and methods

Preliminary experiments were carried out in a former oyster basin in the Scheldt estuary to establish the optimum electrical characteristics. The dimensions of the basin, near the village of Yerseke, were $30 \times 10 \times 1{\cdot}5$ m. The water level could be regulated by a system of sluices in combination with the tide (salinity 28‰). The basin was heavily stocked with shrimps caught in the estuary. For the experiments we used an electrode array mounted in a frame of 2×2 m. The distance between the electrodes was 35 cm and they were alternatively positive and negative. Later, experiments were carried out on board research vessels equipped for double rigged beam trawling in the Scheldt estuary and Dutch Wadden Sea. The fishing speed was between 1·0–1·8 m/s. The trawling direction was with the tide. Depths varied between 2·5–20 m. The time between shooting and hauling was 15 min. Three-metre beam trawls were used. This type of trawling is ideal for comparative fishing, as it is possible to fish simultaneously with two identical gears rigged in the same manner. Initially both trawls were equipped with electric ticklers (electrodes) running parallel to the groundrope (Fig. 1).

However, only one trawl, either port- or starboard-gear, was connected to the pulse generator during the experiments. The ticklers were fitted so that they were separated by a distance of 40 cm along the midline of the trawl and by a distance of 25 cm towards the wings. This rig was changed into one with the electrodes in line with the towing direction as to reduce the mechanical resistance (see Figs. 2

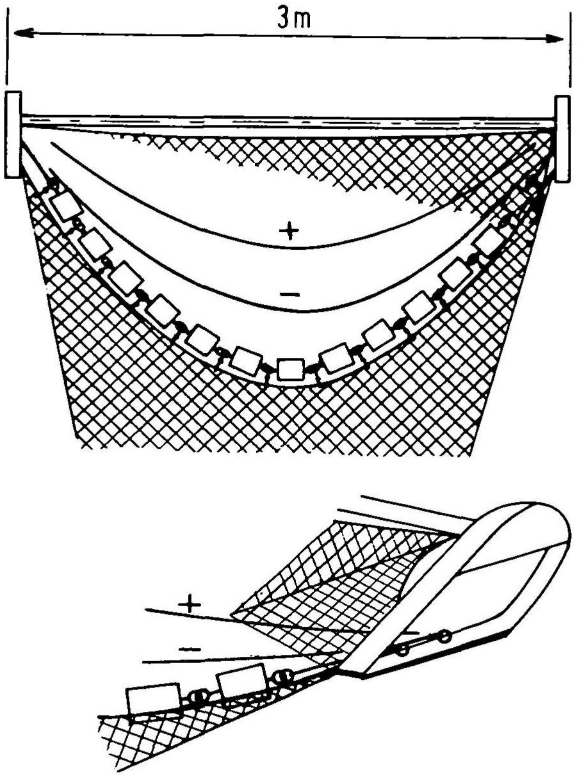

Figure 1. The rig of the shrimp beam trawl with electrodes parallel with the groundrope.

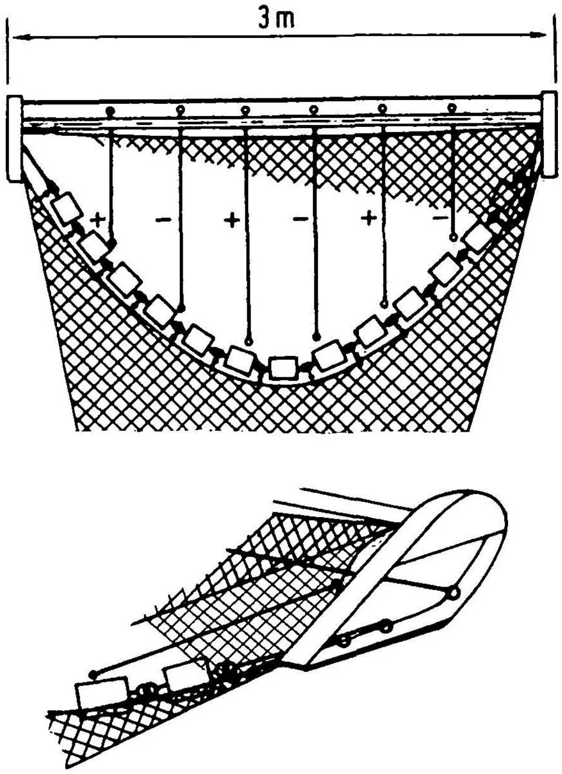

Figure 2. The rig of the shrimp beam trawl with electrodes in line with the direction of tow.

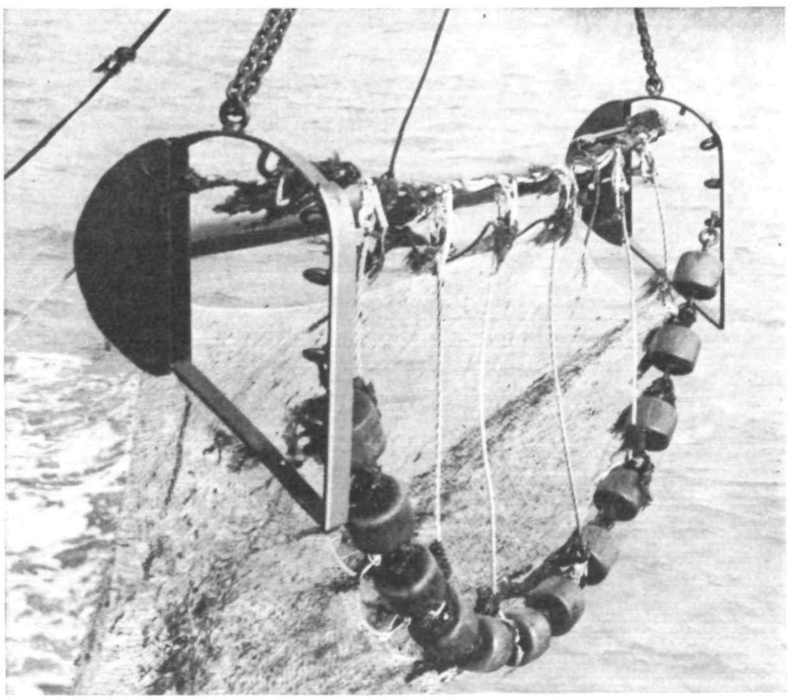

Figure 3. A 3 m shrimp beam trawl rigged for electrical fishing. (Photograph, S. J. de Groot.)

and 3). The electrodes consisted of three strands of steel wire covered by polyamide for strengthening and three strands of copper wire, with a total diameter of 12 mm.

The pulse generator (P.G. 6820) was made to our specifications by Radio Holland N.V., Amsterdam. The peak voltage can be regulated in steps between 2·5 and 60 V. The pulse frequency can be regulated continuously between 1 and 50 Hz. A facility to interrupt the pulse cycle was added later. The pulse cycle can be interrupted at a frequency of 0·5 to 10 Hz. The discharge capacitors have a total capacity of 9520 uF to be regulated in steps, viz. 2×34, 9×68 and 13×680 uF. The total number of discharge capacitors is 1400. They are of a very high quality and can withstand a short circuit. The discharge capacitors are quickly charged by four electrolytic buffer capacitors of 10 mF each. The discharge capacitors are switched on and off by silicon controlled rectifiers, which are activated by the pulse frequency switching unit (Fig. 4).

The discharge time has a maximum of 6 ms and the charging time is from 14 to 994 ms depending on the pulse repetition rate (14 ms at 50 Hz and 994 ms at 1 Hz). The electrical resistance of the electrode array was estimated to be about 0·1 ohm for a commercial trawl (9 m), which was in agreement with the American findings (Seidel, 1969).

Because the results given in Table 2 are partly influenced by another pulse generator which was especially developed for sole, a short description of this pulse generator will also be given. This pulse generator was built to our specifications by the Technical and Physical Engineering Research Service

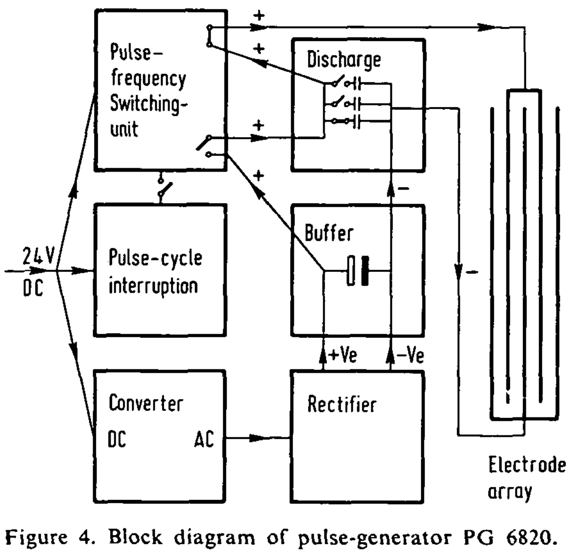

Figure 4. Block diagram of pulse-generator PG 6820.

(TFDL) of the Department of Agriculture and Fisheries in Wageningen. The pulse generator and power supply are housed in a watertight container which was tested for a pressure of 10 atm. The container can be mounted on the beam of the trawl. The supply is from 24 V nickel-cadmium batteries which have a capacity of 15 Ah and can be recharged. The output is a square pulse with a length of 0·55 ms. The pulse frequency is 50 Hz, and the pulse cycle is interrupted at a frequency of 0·5 Hz. The pulse voltage is 10 V. The minimum resistance of the electrode is reckoned to be 0·1 ohm and with this resistance the batteries can be used for 6 h. When the TFDL pulse generator was used, the non-electric gear was compensated with a weight equal to that of the pulse generator.

In the last series of experiments the catch was sorted out by a rotating shrimp sieve (Boddeke, 1971) which has three sorting categories:

1. Undersized shrimp;
2. Commercial sized shrimp;
3. By-catch (fish, benthos and debris).

Results

The optimum pulse length (RC) derived from the experiments in the oyster basin, is about 0·2 ms although the shrimps still react with pulses of 0·1 ms. A burrowed shrimp in sandy bottom will, as a rule, become visible after the first pulse, emerge completely after the next one, and will jump at the third pulse. This seems to be the minimum number of pulses required to make a completely burrowed shrimp jump high enough, about 20 cm, to be caught by the net. However, this will only be the case when the pulse frequency does not exceed 5 Hz. The fact that not all of the shrimps present between the electrodes jump after the first three pulses, may be due to the orientation of the shrimp in the electric field. The reaction time was established by counting the number of pulses needed to make the shrimp jump at a known number of pulses per second. Although the pulse shape differed from a capacitor discharge shape because of the long cables (50 m) between pulse generator and electrode array, this did not influence the reactions (De Groot and Boonstra, 1970). The hight of the initial jump was estimated to be about 10–20 cm. However, by means of additional swimming shrimps often reached the surface (bottom to surface about 60 cm, as observed in the experiments in the oyster basin).

Regarding our field experiments, the results of our latest trials on board the Research Vessel "Stern" in the Dutch Wadden Sea, are given in Tables 1 and

Table 1. The catch (in litres per haul) of undersized (<54 mm) and commercial sized brown shrimp (*Crangon crangon*) in electrified and normal beam trawls. Hauls in which the net was heavily fouled with sea lettuce are indicated with an asterisk

Experiment number	Haul number	Electrified beam trawl		Normal beam trawl	
		Undersized	Commercial	Undersized	Commercial
2	10	4·5	2·0	3·0	1·5
	11	7·5	2·5	2·0	0·1
4	16*	7·0	1·0	4·5	0·5
	17*	2·0	0·5	1·0	0·1
	18*	4·5	0·5	1·5	0·5
	19*	2·5	0·5	1·0	0·5
5	20	1·0	0·8	0·5	0·8
	21	3·0	1·0	1·5	0·3
	22	4·0	3·5	6·0	3·0
	24	3·0	3·0	2·5	1·0
	25	1·5	0·2	1·5	0·1
	26	1·0	0·2	0·5	0·1
	27*	0·3	0·8	0·5	0·5
	28	11·0	8·0	7·0	6·0
	29	9.5	10·0	5·0	5·0
	30	12·0	10·0	6·0	6·0
	31	8·0	6·0	3·5	4·0
	32	6·0	3·0	6·0	2·5
	33	13·0	11·0	5·0	4·5
	34	20·0	13·0	12·5	6·0
	35	15·0	11·0	10·0	6·0
	36	7·0	8·0	4·0	5·0
	37	5·0	2·0	3·0	1·3
	38	10·0	12·0	6·0	6·0
	39	6·0	7·0	2·5	2·0
	40	7·0	1·5	2·5	0·3
6	41*	9·0	6·5	4·0	3·0
	42*	6·0	0·8	2·5	0·5
	43*	12·0	4·5	5·5	1·5
	44	5·5	3·0	2·0	0·8
	45	4·0	1·8	1·5	0·3
	46*	6·0	2·0	2·5	0·5
	47*	9·0	2·0	1·3	0·2
	48	10·0	3·0	5·5	2·2
	49*	1·3	0·2	0·1	0·1
	50	7·0	7·0	3·0	1·5
	52	15·0	10·0	8·0	4·0
	53	11·0	6·0	4·0	2·0
	54	8·0	4·0	4·0	2·0
7	57	10·0	10·0	11·0	8·0
	58	9·0	8·0	5·0	4·0
	59	3·5	3·0	3·0	1·5
	60	4·0	4·0	3·0	3·0
	61	7·0	5·5	4·5	3·0
	62*	2·0	1·0	2·0	1·0
	63	4·0	3·5	3·0	2·0
	64	6·0	2·5	2·5	1·0
	65	7·0	2·5	3·0	0·8
	67	3·0	0·8	0·1	0·1
	71	2·0	2·5	5·0	1·0
	72	9·0	8·0	5·0	2·0
	73	10·0	7·0	1·0	0·3
	74	5·0	3·0	3·0	1·0
	75	5·0	3·0	2·0	1·0
	76	3·0	4·0	2·0	1·5
	77	3·0	0·2	1·0	0·1
	78	1·0	0·5	1·0	0·5
	79	3·0	4·0	2·0	1·5
	80	1·8	3·0	2·0	1·0
	81*	3·0	3·0	3·0	1·5
	82	1·5	0·5	0·8	0·1
	83	4·0	3·0	2·1	1·8
	84	4·0	3·0	1·5	0·8

2. During these experiments the water temperature was about 16·5°C, and the conductivity about 12 mS. Weather conditions were good throughout the period 6–22 September 1971. The effect of the electrified ticklers can clearly be seen in Table 1 and confirm earlier experiments not reported here.

The details for each shrimp haul are given in Table 1. If the net was heavily fouled with sea lettuce (*Ulva lactuca*) this was noted. Several hauls are left out of this table as the net was damaged or the pulse generator was out of order. Data on by-catch are not given but will be reported later. The experiments 1 and 3 were carried out with electric parameters suitable for sole stimulation. However, the summarized results of these two experiments are incorporated in Table 2 as they also show a difference in the catch of shrimp with and without electric stimulation. In experiment 5 the ticklers of the port gear emitted pulses with characteristics for shrimp stimulation, and the ticklers of the starboard gear those for sole stimulation. As Table 2 deals with shrimp, the starboard side was considered to be non-electrified.

The average catch of 63 shrimp hauls (experiments 2, 4, 5, 6 and 7) was 10·2 litres with an electrified trawl, as against 5·2 l with the control trawl. The average catch of the electrical side can be divided in 6·1 l undersized shrimp and 4·1 l commercial sized shrimp (shrimp with a length above 54 mm), as against 3·3 l and 1·9 l on the control side. This means that for the experiments described, the electrified beam trawl caught 116% more commercial sized shrimps and 81% more undersized shrimps. In experiments 2, 4, 5 and 6 (39 hauls) there was hardly any difference in the catch ratio between commercial and undersized shrimps for the electrified and normal trawl: 1:1·75 for the normal trawl, 1:1·63 for the electrified trawl. In experiment 7 (24 hauls) this ratio improved in favour of the commercial sized shrimp. 1:1·77 for the normal trawl, 1:19 for the electrified trawl.

In experiments 2, 4, 5 and 6 the pulse frequency was kept constant at 5 Hz, whilst in experiment 7 the pulse frequency was varied over a wide range, between 7 and 50 Hz, with an average of 24 Hz. The improvement in the ratio between commercial sized and undersized shrimps with a higher pulse repetition rate needs further investigating as it appears contradictory to the normal reaction as observed in the oyster basin.

Discussion

The results confirm that the reaction to electricity of the European brown shrimp is quite similar to the reaction observed in the American pink and brown shrimp (Pease, 1967; Pease and Seidel, 1967; Klima, 1968; Seidel, 1969). The optimum pulse length in the experiments was established as being 0·2 ms which is in agreement with that of 0·14 ms found for the American pink shrimp (Kessler, 1965). The pulse frequency, 5 Hz, is also quite in accordance with that used by Klima. The voltage between the electrodes in our field experiments was 60 V.

The turbidity of the water plays an important role in the activity cycle of the shrimp. A high turbidity and a lower light intensity will cause a burrowed shrimp to come out of the sand even during the day-time (Hughes, 1968; Dornheim, 1969). These conditions prevail especially in the Wadden Sea where shrimps are actually caught in commercial quantities during the day-time. Our most recent series of experiments show an increase in catch with electrified ticklers during the day. No experiments have been carried out during the night. This will be a field for further study.

At this time the requirements for a commercial

Table 2. The total catches (in litres) of brown shrimps *Crangon crangon* taken in experiments 1–7 to show the difference between the performance of the electrified (E) and normal (N) beam trawl

Experiment number	Number of hauls	Total shrimp catch in l Undersized		Commercial		Total shrimp catch of the electrified trawl as a percentage of the total catch of the normal trawl	
		E	N	E	N	Undersized	Commercial
1	8	65·5	59·5	3·3	2·8	110	118
2	2	12	5	4·5	1·6	240	281
3	4	5·6	4·5	0·6	0·5	124	120
4	4	16	8	2·5	1·6	200	156
5	20	143	86	110	60	166	183
6	13	103	44	50·7	18·3	236	277
7	24	109	68	91	38·3	160	238

pulse generator based on the principle of capacitor discharge is as follows:

resistance between the electrodes 0·1 ohm; CR time 0·2 ms; discharge capacity 2 mF; pulse frequency 5 Hz; voltage 60 V; and power delivered to the electrodes 18 W.

It is still a point for discussion as to whether a pulse generator, to meet this specification, should be developed with the power supply on board and fed by a cable or complete with power supply mounted on the gear.

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