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Report

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Explorative study of the impact of an electric fishing field on macrobenthos

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Summary

Research into possible effects of pulse stimulation on benthic organisms was carried out by the Centre for Shellfish Research of the Netherlands Institute for Fisheries Research (RIVO), commissioned by the Ministry of Agriculture, Nature Management and Food Quality, Directorate of Fisheries.

Questions addressed were:

1. Do the electrical stimuli lead to immediate or secondary responses in individuals of benthic species tested under laboratory circumstances?
2. Can such responses be extrapolated to the population level?

A number of benthic species from several taxonomic groups were exposed to electrical stimuli. To test the tolerance of these animals the voltage was taken twice as high and the duration eight times as high as in the pulse trawl in fishing practice. A number of animals was exposed to these high stimuli once (Group 1), others were exposed three times (Group 2), and a control group (Group 0) was handled equally but not exposed.

Reactions were observed during exposure and after exposure. The condition of the animals was observed for three weeks consecutively, and the survival rates determined at the end of this period.

Crustaceans react at exposure by stiffening, and shellfish by closing their shell, while sea snails withdraw partially or completely in their housing. No direct reaction was seen in echinoderms and worms.

There was no difference in immediate response between exposed and non-exposed animals, except in prawn which remained inactive for some time after exposure, but when activated by touch reacted immediately.

In shellfish normally living in the sediment there was no difference in settlement behaviour in the exposed groups and the controls. There was no also noticeable effect on filtration rates of mussels and cockles. The survival rate of exposed and non-exposed (one or three times) animals was not affected.

The doses used here were 16 to 48 times higher than used in the pulse trawl in fishing practice. As exposure to these stronger stimuli did not reveal any noticeable long-term effect, it is unlikely that there will be any harmful effect of pulse trawling *in situ* on the range of species studied here.

Introduction

The results of research into possible effects of pulse stimulation on benthic organisms are presented in this report. The study was carried out by the Centre for Shellfish Research of the Netherlands Institute for Fisheries Research (RIVO), commissioned by the Ministry of Agriculture, Nature Management and Food Quality, Directorate of Fisheries.

Questions addressed were:

3. Do the electrical stimuli lead to immediate or secondary responses in individuals of benthic species tested under laboratory circumstances?
4. Can such responses be extrapolated to the population level?

The research presented is of exploratory nature. Test animals from various taxonomic groups (molluscs, echinoderms, crustaceans, worms) were collected and subjected to electrical stimuli, comparable to those generated by a pulse beam trawl in an experimental set-up. To explore the limits the pulse voltage and duration were higher than usually generated in the current prototype pulse beam trawl. Behavioural responses were monitored prior and after exposure and compared with a control group not subjected to these stimuli. In addition the survival over a period of three weeks was observed. Other variables under study were settlement inside the sediment (shellfish) and filtration (mussels and cockles).

Acknowledgements

The authors are indebted to Mr. M. van Stralen for constructive criticism on the experimental methodology and on the report. We also like to thank the company Verburg-Holland Ltd. for enabling use of their test equipment, and B. van Marlen for translation in English.

Materials and methods

Pulse trawl

In this fishing gear flatfish are chased out of the sediment by electrical pulses rather than mechanical stimuli generated by an array of tickler chains. The prototype pulse trawl has been developed by the company Verburg-Holland Ltd. of Colijnsplaat, The Netherlands. The detailed characteristics of the pulses are not published for reasons of protecting industrial property rights.

Electric stimuli

Fishing gears do not frequently affect the same exact location. Therefore the duration of the stimuli is chosen at 10 s. It is estimated that the exposure time of animals in the fishing condition will be around 1.2 s (*personal communication* M. van Stralen). The duration of stimuli is taken eight times the interval used in the pulse trawl, with a voltage twice as high to test the tolerance of the test animals. The animals were exposed in three subsequent days, resulting in a dose 16 to 48 times as high as normally used in the pulse trawl. The sea water temperature varied between 10-12 ˚C. The trials were conducted in November 2004.

Test animals

A range of species commonly found in the North Sea was chosen, such as:

Molluscs:	mussel, cockle, razor clam, prickly cockle, Arctic cockle, whelk and netted dog whelk.
Echinoderms:	common starfish, sea urchin, serpent star en common brittle star.
Crustaceans:	swimming crab and common shore crab, prawn, Canadian lobster, and helmet crab.
Worms:	rag-worm and sea mouse.

The lobsters are Canadian lobsters bought from a merchant. The razor clams where collected by a commercial fisher and the rag-worms where obtained from a hatchery.

The other species were collected during regular surveys and sea trips taking place in this period.

The animals were collected in October/November 2004 and placed in a tank fed with continuously running sea water at CSO Yerseke to acclimatise to the laboratory conditions.

Three groups were distinguished, namely:

Group 0: Control group. This group was subjected to the same handling procedures as Group 1, without exposure to the electrical stimuli.

Group 1: Group exposed to electric stimuli for 10 s.

Group 2: Group exposed to electric stimuli for 10 s per day over three consecutive days.

Due to the low numbers available, most animals were used for Group 1 and Group 0. Group 2 consisted of two individuals for each species (Table 1).

Experimental set-up

The test set-up of Verburg-Holland Ltd. consists of a Plexiglas aquarium of 2 m length and a pulse generator. Two plate electrodes are placed in the reservoir at a distance of 1 m. The animals were put in small plastic baskets to avoid protective effects of the sediment when digging in or the housing in which they were placed (Figure 1).

Both animals of the control group and the test groups were placed in the aquarium at equal distances between the electrodes. During generation of the electrical pulses, the controls were removed and put in another tank. The responses were recorded on video. The exposure lasted for 10 s. Video recordings were also made in the following period of 30 minutes after exposure.

The animals were placed in separate reservoirs continuously fed with running sea after exposure. Their condition was checked three times a week and dead specimen removed. After a period of three weeks the remaining numbers were counted to determine the rate of survival.

A characteristic of importance for shell fish living in the sea bed is the speed of settlement ('digging-in') in the sediment. Therefore the experiment was repeated with a special group of cockles.

For filter-feeders the filtration activity is measured per group of five individuals in percentage particles filtered in the range of 4 to 11 µm.

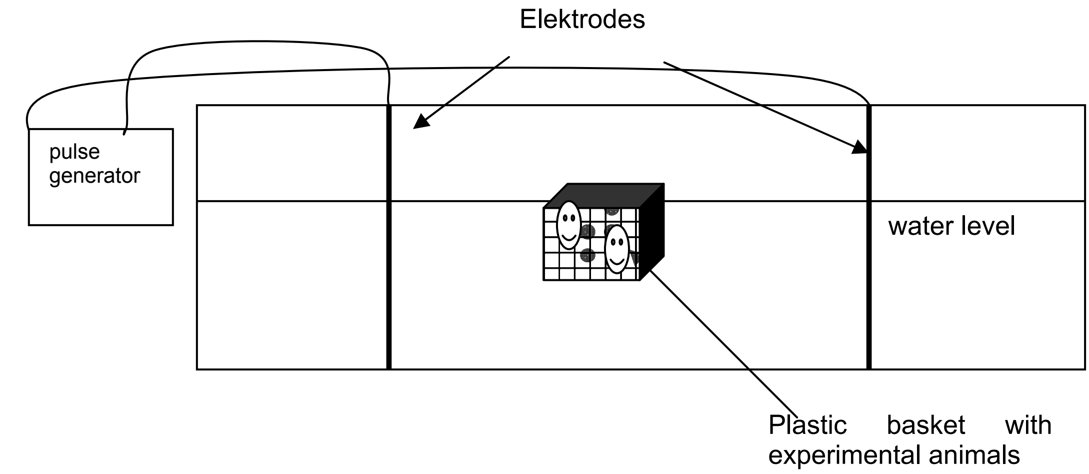

Figure 1: Experimental set-up

Results

Reactions during and after exposure

Observations were done during and after exposure to the electric pulses. Crustaceans react by stiffening under exposure, while shellfish close their shell, snails withdraw (partially or completely) in their housing. No reaction was seen in echinoderms and worms.

A response after exposure was only observed in prawns. They remained inactive during approximately 1 min., but moved immediately when touched.

Table 1: Reactions observed during and after exposure to electric field

Species	Reaction during stimuli	Reaction after stimuli
crustaceans		
helmet crab	Stiffened	Direct recovery
(swimming)crab	Stiffened	Idem
Shrimp (Crangon crangon L.)	Jumping (initial closure of shell), Stiffened and leg vibrating	Idem
hermit crab	Stiffened, withdrawal in housing	Idem
prawn	Jumping ((initial closure of shell), then stiffening	Remain stiffened for one minute, after which movements were regained. When touched immediate movement.
echinoderms		
common starfish	No response observed	No response
sea-urchin	Idem	Idem
common brittle star	Idem	Idem
serpent star	Idem	Idem
worms		
rag-worm	No response	No response
sea mouse	Idem	Idem
molluscs		
razor clam	Closure of shell, foot not completely retracted	Shell re-opens, direct recovery
prickly cockle	Closure of shell	Idem
cockle	Closure of shell	Idem
whelk	(partial) withdrawal in housing	Normal movements, direct recovery
netted dog whelk	(partial) withdrawal in housing	Idem

Type of response and survival rate

There were no significant differences in response between Group 0 (controls), Group 1 (10 s exposure, once), and Group 2 (10 s repeated exposure over 3 days). There were only two individuals per species available in Group 2, and there was no difference in survival between this group and Control Group 0.

Dead individuals were removed during intermediate checks. The count of rag-worms and common starfish did not correspond with initial numbers, indicating that some individuals did find a chance to escape from the basket, or even out of the tank itself. These were assumed to be survivors in such a good condition they managed to escape, as dead specimen could even be located days later (Table 2 and 6).

There was no significant difference in survival rate of all animals taken together between the control Group 0, the total survival rate being 88%, and Group 1, survival rate 87%. For Group 3 these rates were somewhat lower, *i.e.* 72% compared to 85%. This was caused by the mortality of razor clams and helmet crab. The razor clams did not settle in the sediment rendering them more vulnerable, while for helmet crab the mortality was also high in the control group (Table 2)

Table 2: Survival of Group 0 (controls) and Group 1 (one time exposed), after three weeks of monitoring

Exposed 1X		# of survivors control		# of survivors exposed		Survival rate	
Taxonomic group		initially	after 3 wks	initially	after 3 wks	Group 0	Group 1
crustaceans	(swimming)crab	10	9	10	9	90%	90%
crustaceans	Canadian lobster	3	3	3	3	100%	100%
crustaceans	helmet crab	7	3	7	3	43%	43%
crustaceans	hermit crab	10	8	10	9	80%	90%
crustaceans	prawn	10	10	10	10	100%	100%
shellfish	Norway cockle	2	1	2	2	50%	100%
shellfish	Norway cockle	10	8	10	8	80%	80%
shellfish	cockle	11	11	11	11	100%	100%
shellfish	cockle	38	38	38	38	100%	100%
shellfish	razor clam	10	7	10	7	70%	70%
shellfish	mussel	15	15	15	15	100%	100%
shellfish	netted dog whelk	10	9	10	10	90%	100%
shellfish	whelk	7	6	7	5	86%	71%
echinoderms	common brittle star	10	10	10	10	100%	100%
echinoderms	serpent star	10	7	10	7	70%	70%
echinoderms	sea-urchin	19	19	19	16	100%	84%
echinoderms	common starfish	13	13	13	13	100%	100%
worms	rag-worm	10	9	10	8	90%	80%
worms	sea mouse	10	4	10	3	40%	30%
crustaceans		40	33	40	34	83%	85%
shellfish		103	95	103	96	92%	93%
echinoderms		52	49	52	46	94%	88%
worms		20	13	20	11	65%	55%
total # animals		215	190	215	187	88%	87%

Table 3: Survival of Group 2 (three times exposed), after three weeks of monitoring

Exposed (3 times)	# of survivors		Survival rate
Time of recording	initially	after 3 wks	Group 2
(swimming)crab	2	2	100%
helmet crab	2	0	0%
hermit crab	2	2	100%
prickly cockle	1	1	100%
cockle	2	2	100%
razor clam	2	0	0%
netted dog whelk	2	2	100%
common brittle star	2	2	100%
serpent star	2	2	100%
sea-urchin	2	1	50%
common starfish	2	2	100%
rag-worm	2	1	50%
sea mouse	2	1	50%
crustaceans	6	4	67%
shellfish	7	5	71%
echinoderms	8	7	88%
worms	4	2	50%
total # animals	25	18	72%
3 x exposed			73%
Other species	Before	After	Survival
polished crab	3	0	0%
Norway lobster	1	1	100%
long-legged spider crab	1	1	100%
trough shells	1	1	100%
Sand star	2	2	100%
rock eel	2	2	100%
bull rout	1	1	100%
Total	11	8	73%

Burrowing in the sediment

Table 4 gives the numbers of animals burrowed in the sea bed. In the first trial a major percentage of cockles in the control group had burrowed, while in the group exposed to the electric field the rate was lower than 50%. These cockles came from a group of animals kept for several weeks in a tank without a sediment layer, which may have caused this difference. In a repeated trial with cockles collected on the same day there was no difference in settlement behaviour between the control group and treated animals, with a larger proportion in both groups digging in.

The other two shellfish species did not show any difference. Two individuals in the exposed group of razor clams were observed to burrow partly, but these two did not survive after a few days, and examination revealed that the shells of these animals were damaged during the catching process.

In mussels there was no difference in attachment to the sediment using byssus thread.

Table 4: Burrowing of shellfish

Group	#	Burrowed after 1 hr	after 2-3 hrs	the next day
control cockles (0)	11	8	9	11
exposed cockles (1)	11	3	4	11
control cockles (0)	38	18	26	38
exposed cockles (1)	38	19	30	38
control razor clams (0)	10	10	No observation	10
expose razor clams(1)	10	8	No observation	10, of which 2 likely
control prickly cockle (0)	10	No observation	No observation	9
exposed prickly cockle (1)	10	No observation	No observation	9
control Norway cockle (0)	2	No observation	No observation	2
exposed Norway cockle (1)	2	No observation	No observation	2

Filtration

The percentage of filtered particles was in the same order of magnitude for the exposed and unexposed animals. There was no significant difference between the control group and exposed mussels and cockles.

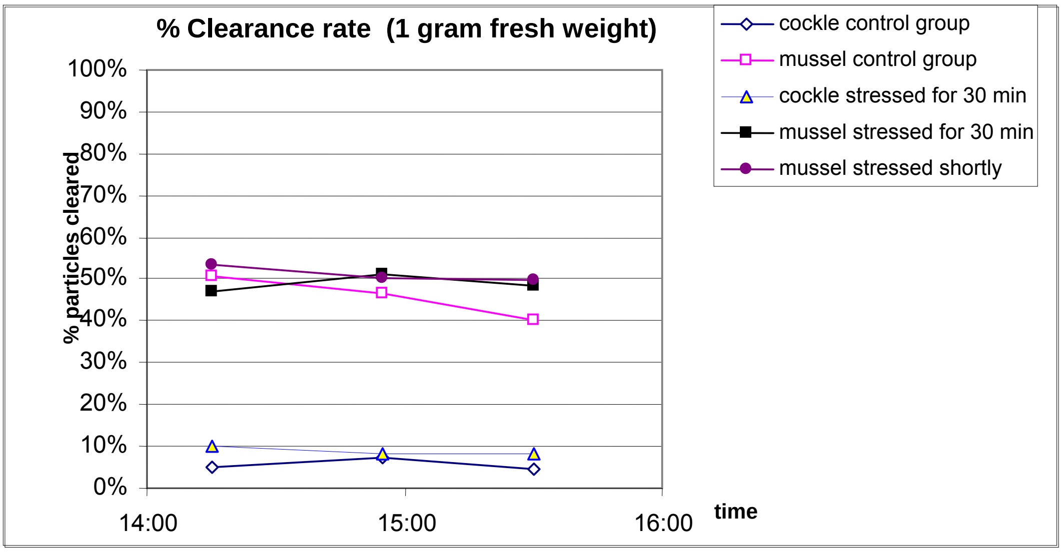

Figure 2: **Filtration rates of stressed and control cockles and mussels.**

Discussion

Experimental conditions

The exposure was done with a voltage twice as high and for a period of eight times as long as in the pulse trawl. These exposures were repeated for a number of test animals during three succesive days. This resulted in an exposure between 16 and 48 times higher than in practice in a single passage of the pulse trawl *in situ*. This choice for a higher dose was deliberately done to simulate multiple passages of a pulse trawl. When such high doses would not cause a noticeable effect, it is less likely that effects will occur in the actual circumstances *in situ*.

Group 2 exposed three times consisted of two individuals per species. These animals were also subjected to handling, which may have caused additional stress. Nevertheless, their behaviour was not noticeably different from the control group, and no signs of deterioration of their condition could be observed. In species for which mortality occurred this was also observed in the control group.

Two species showed noticeable results, *i.e.* common starfish and rag-worm. A number of them seemed to have disappeared in the final count. Their mortality was monitored during the trial, but without counting all individuals to avoid additional stress. It is likely that a number of common starfish managed to escape from the basin, as dead specimen could still be recognised after a considerable time, and were not found at the intermediate check points.

In rag-worms the final count revealed that from the control group 1 individual was recorded dead and 1 missing. From the exposed group 2 two individuals were counted dead and 5 were missing at the end.

Behaviour

A direct effect on behaviour was seen in crustaceans and molluscs with the stimuli used. A typical reaction of crustaceans was stiffening. Shell fish reacted by closing their shell and snails withdraw partially in their housing. Recovery occurred directly after exposure and after that no further reaction was observed, except in prawn. These animals remained inactive for about one minute after exposure to the stimuli, after which any mechanical touch activated these animals immediately. Echinoderms and worms showed no response at all. The speed at which the shellfish in this experiment dug in the sediment did not seem to be affected by the electric stimuli, nor was there any noticeable effect on filtration activity. In cockles the conditions under which these animals are kept seemed to influence their reaction. When kept in a tank without a sand layer fewer individuals dug in after exposure than in the control group. This may indicate an effect of cumulative stress caused by the lack of possibility to settle in sediment, and the added stress due to exposure.

Survival

There was no effect on the survival rates, which were of equal magnitude for both the control group and the exposed groups.

Conclusions

The exposure to the relative strong stimuli did not evoke irreversible effects on the species under investigation. Some species did show direct behavioural responses, but these ceased when the exposure was terminated. There was no additional mortality after three weeks of observation.

The results indicated that using the pulse trawl would not evoke any lasting effects on the population level *in situ* in the species and age groups tested here.

This research of exploratory nature did not reveal noticeable effects of the relatively high dose levels used on the species tested in our study. These species were chosen as representative for the species composition in the North Sea and their potential vulnerability to electric fields. Rare species or species difficult to keep at laboratory conditions were not investigated. Nor were the tests carried out under *in situ* circumstances. Monitoring species exposed to electric stimuli *in situ* is recommended when more certainty on effects would be required.

Annex A

Table 5: Survival in Group 0 (controls) and Group 1 (1 time exposed).

Species	Group	#	Treatment 30/11/2004	Treatment 1/12/2004	Final count 23-dec-04	Total dead	Escaped?
mussel	0	15			15	0	0
mussel	1	15		exposed	15	0	0
Canadian lobster	0	3			3	0	0
Canadian lobster	1	3		exposed	3	0	0
sea-urchin	0	19			19	0	0
sea-urchin	1	19	exposed		16	3	0
common starfish	0	13			5	0	8
common starfish	1	13	exposed		3	0	10
razor clam	0	10			7	3	0
razor clam	1	10	exposed		7	3	0
(swimming)crab	0	10			9	1	0
(swimming)crab	1	10	exposed		9	1	0
whelk	0	7			6	1	0
whelk	1	7	exposed		5	2	0
sea mouse	0	10			4	6	0
sea mouse	1	10	exposed		3	7	0
hermit crab	0	10			8	2	0
hermit crab	1	10	exposed		9	1	0
netted dog whelk	0	10			9	1	0
netted dog whelk	1	10	exposed		10	0	0
prawn	0	10			10	0	0
prawn	1	10	exposed		9	0	1
rag-worm	0	10			8	1	1
rag-worm	1	10	exposed		3	2	5
serpent star	0	10			7	3	0
serpent star	1	10	exposed		7	3	0
common brittle star	0	10			10	0	0
common brittle star	1	10	exposed		10	0	0
prickly cockle	0	10			8	2	0
prickly cockle	1	10	exposed		8	2	0
Norway cockle	0	2			1	1	0
Norway cockle	1	2	exposed		2	0	0
helmet crab	0	7			3	4	0
helmet crab	1	7		exposed	3	4	0
cockle	0	11			11	0	0
cockle	1	11		exposed	11	0	0
cockle	0	38			38	0	0
cockle	1	38		6-12-exposed	38	0	0

Comment: some common starfish have likely escaped from the tank. In it is less clear in rag-worms whether they escaped, because they quickly become unrecognizable or disappear due to scavenging.

Table 6: Survival in Group 2 (3 times exposed).

Species	#	Treatment 29/11/2004	Treatment 30/11/2004	Treatment 1/12/2004	Final count 23-dec-04	Total dead	Escaped?
helmet crab	2	exposed	exposed	exposed	0	2	0
common starfish	2	exposed	exposed	exposed	2	0	0
sea-urchin	2	exposed	exposed	exposed	1	1	0
hermit crab	2	exposed	exposed	exposed	2	0	0
sea mouse	2	exposed	exposed	exposed	1	1	0
razor clam	2*	exposed	exposed	exposed	0	2	0
prawn	2**	exposed	exposed	exposed	0	1	1
(swimming)crab	2	exposed	exposed	exposed	2	0	0
rag-worm	2	exposed	exposed	exposed	1	1	0
common brittle star	2	exposed	exposed	exposed	2	0	0
serpent star	2	exposed	exposed	exposed	2	0	0
netted dog whelk	2	exposed	exposed	exposed	2	0	0
prickly cockle	1	exposed	exposed	exposed	1	0	0
cockle	2	exposed	exposed	exposed	2	0	0

Comments: *1 rasor was dead on 1/12/2004 and was removed, so exposed once.
** 1 prawn escaped on 1/12/2004

Table 7: Latin names

English name	Latin name
Norway cockle	*Laevicardium crassum*
Canadian lobster	*Homarus americanus*
polished crab	*Thia scutellata*
Norway lobster	*Nephrops norvegicus*
long-legged spider crab	Macropodia sp.
trough shell	*Spisula subtruncata*
Sand star	*Astropecten irregularis*
rock eel	*Pholis gunnellus*
bull rout	*Myoxocephalus scorpius*
crab	*,Carsinus maenas*
swimming crab	Portunidae sp.
Whelk	*Buccinum undatum*
cockle	*Cerastoderma edu.e*
common brittle star	*Ophiothrix fragilis*
common starfish	*Asterias rubens*
helmet crab	*Corystes cassivelaunus*
hermit crab	*Pagarus bernhardus*
Mussel	*Mitylus edulis*
netted dog whelk	*Nassarius* sp.
prawn	Dendrobranchiata
prickly cockle	*Acantocardia echinata*
rag-worm	*Nereis virens*
razor clam	*Ensis* sp.
sea mouse	*Aphrodite aculeata*
sea-urchin	*Echinus* sp
serpent star	*Ophiura* sp