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Research on diminishing impact in demersal trawling – The experiments in The Netherlands.

by

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Abstract

Recent research in beam trawling is directed to reducing impact on benthic infauna and epifauna and by-catches of non-target and juvenile target species, whilst remaining the catch levels of target species. This paper presents results obtained in The Netherlands of an EU-project aimed at reducing benthic trawlpath and catch mortality by 1) altering the design of the nets through drop out zones made of large meshes in the belly of the net, 2) modifying the rigging of the tickler chains, and 3) using alternative stimulation techniques. It is shown that drop-out zones in the lower panel of a beam trawl can be effective in reducing by-catches of benthic fauna, but the penalty is also a loss in marketable flatfish (sole, plaice, dab). Heavy benthic organisms (shellfish) seem to drop out of the gear. An alternative parabolic tickler chain arrangement did increase catches of flatfish and benthos, which was not the aim. Parallel chains seem to offer more potential in reducing benthos by-catches, particularly shellfish, but losses in commercial flatfish might occur. The replacement of tickler chains by an array of parallel electrodes caused a decrease in direct benthic mortality, but in the prototype used the catches of particularly plaice fell short in comparison with the conventional tickler chain type of beam trawl. It is recommended to pursuit further development of the electrotrawl.

1. Introduction

There is growing concern about the impact of fishing on marine eco-systems, particularly benthic fauna (Lindeboom and De Groot, 1998). Beam trawling being carried out with relatively heavy gears and with high towing speeds is often criticised in this respect. As a follow-up of these investigations this project aimed at finding potential gear modifications in demersal trawls mitigating such effects. The catch efficiencies of modified gears on commercial fish species and non-commercial by-catches were studied and compared with conventional gears. In addition the direct mortalities on benthic organisms retained in the cod-end and left behind in the path of the trawl were determined. The project was carried out in cooperation with research institutes in The Netherlands, Belgium, Germany, and Ireland. This report focuses on the research carried out by the Dutch partners in this project on the following beam trawl modifications:

1) Drop-out zones made of large meshes in the lower panel.
2) Alternative chain arrangements, parabolic or parallel chains.
3) Replacing tickler chains by electrical stimulation

2. Materials and Methods

2.1. Overview of trials

An overview of trials on all the different techniques investigated is given in Table 1, with the number of hauls in each period. Table 2 gives the details for each period and each experiment on the trawl configurations and the number of valid hauls.

2.2. Gears used

Particulars of the gears used on RV “Isis” are given in Table 3. These configurations are also depicted in Figure 1 and Figure 2.

Particulars of the gears with large meshed drop-out panels and with alternative chain arrangements used on RV “Tridens” are given in Table 3, Table 4, Table 5, Table 6, and Table 7. These configurations are also given in Figure 3, Figure 4, Figure 5, Figure 6, Figure 8 and Figure 9. The conventional tickler chain arrangement is depicted in Figure 7.

The prototype electrotrawl was developed by the private company Verburg-Holland of Colijnsplaat, The Netherlands and tested thoroughly in 1998 (Van Marlen *et al*., 1999). The gear used in 1999 differed from that used in 1998 in the sense that the array of electrodes was brought further aft by 3m in an attempt to improve the catches of plaice (Table 8 and Figure 12).

The net attached to the electrified beam (Figure 12) was designed by the company Bakker of Urk, The Netherlands (Figure 11). The cutting rate of the top panel is 1N1B and 1N2B. The conventional net was kept the same as in 1998. Both codends have a circumference of 120 meshes, a twine thickness of 2.5mm, are made of PES, and are double braided. The conventional 7m tickler chain beam trawl net is shown in Figure 10.

2.3. Data collection and analysis – catch comparison

2.3.1 Data recorded

The following data were recorded for each haul: haul number, date-time of shooting, date-time of heaving, shooting position, heaving position, towing speed, warp length, fishing ground, wind speed and wind direction, water depth.

2.3.2 Sampling procedure

Catches of both nets were sampled and measured according to RIVO's BTS-protocol. The catch of both nets is stored in fish bins on the working deck of the vessel and then fed on a conveyor belt in sequence during which the total weight is recorded. Fish of commercial

species and size of both the port and the starboard catches were sorted out. Sub-samples of the remaining catches were taken to determine the catch in weight and numbers of non-target and undersized fish and invertebrates. The size distribution (cm-below) and total weight was determined for each fish species. The total weight of benthos was also determined. The data was typed in using program Bessie Turf™. An experiment is defined as a series of hauls for which no changes in gear or rigging were made, but may cover more than one fishing ground.

Sampling of benthos in week 40 and week 41 (1999).
During sorting of the catch on the sorting belt larger and less abundant invertebrates were sorted out and their numbers and weight estimated for the whole catch (e.g. shellfish, whelks, edible crab, a.o.). Numbers and weight of smaller and abundant invertebrates, such as starfish, swimming crabs, hermits and seamouse, were estimated in subsamples of 1/4 or 1/16 of the catch, taken after proper mixing, and total numbers and weight in the whole catch were estimated accordingly.

Sampling of benthos in week 47 and week 48 (1999).
During week 47 and 48 of 1999 a more detailed data collection scheme was carried out for several species (quahog (*Arctica islandica* L.), whelk (*Buccinum undatum* L.), prickly cockle (*Acanthocardia echinata* L.)), where all individuals were taken from the conveyor belt, counted and weighted. In this case also the number of damaged animals was recorded. To calculate benthos weights the weight of by-catch fish was substracted from the total weight of baskets caught. For Hauls 8-25 and Hauls 26-46 all individuals of several species of interest were taken, and for other species individuals were taken from the sub-sampled basket. The weights were measured with the scale onboard, that is compensated for vessel motions.

2.3.3 Data analysis

The SAS™ (SAS Institute, Cary, NC, USA, 1992) statistical package was used to analyse the data in more detail. Files stored onboard were converted into a large SAS-datafile using a special programme called Bessie2Survey. A special SAS-routine was developed to extract the numbers per hour fishing and weights in kg per hour for the overall categories discards, landings, by-catch and undersized commercial fish, as well as more detailed data on (undersized and marketable) commercial species sole, plaice, dab, brill, turbot, whiting and cod in the way described below.

Length-weight relationships (Coull *et al*., 1989) were used to calculate the weight of fish and the weight measurements when avialable used as control.

The following categories were used in the analysis:

- Non-marketable or undersized commercial species:
  (sole (*Solea solea* L.), plaice (*Pleuronectes platessa* L.), dab (*Limanda limanda* L.), brill (*Scophthalmus rhombus* L.), turbot (*Psetta maxima* L.), whiting (*Merlangius merlangus* L.), cod (*Gadus morhua* L.), smaller than the minimum landing size.

- Marketable target species.
  Same species list as above, bigger than the minimum landing size.

- By-catch:
  (All non-commercial species among which: lesser weever (*Echiichthys vipera* L.), hooknose (*Agonus cataphractus* L.), dragonet (*Callionymus lyra* L.), scald fish (*Arnoglossus laterna* L.), solenette (*Buglossidium luteum* L.), tub gurnard (*Trigla lucerna* L.), grey gurnard (*Eutrigla gurnardus* L.), haddock (*Melanogrammus aeglefinus* L.), Atlantic mackerel (*Scomber scombrus* L.), horse mackerel, (*Trachurus trachurus* L.), bib (*Trisopterus luscus* L.), pilchard (*Sardina pilchardus* L.), flounder (*Platichthys flesus* L.), sandeel (*Ammodytus spp.* L.), spurdog (*Squalus acanthias* L.), shorthorn sculpin (*Myoxocephalus scorpius* L.), long rough dab (*Hippoglossoides platessoides* L.), lemon sole (*Microstomus kitt* W.), four bearded rockling (*Enchelyopus cimbrius* L.), poor cod (*Trisopterus minutus capelanus* L.), witch (*Glyptocephalus cynoglossus* L.) etc).

- Discards:
  All undersized commercial species plus all by-catch species.

- Landings:
  All marketable commercial species.

- Benthos:
  Major species caught: swimming crab (*Liocarcinus spp*. L.), masked crab (*Corystes cassivelaunus* L.), common starfish (*Asterias rubens* L.), starfish species, (*Astropecten irregularis* L.), brittle star (*Ophiura spp*. L.), hermit crab (*Pagurus bernhardus* L.), but in weight expressed including all other species found.

The minimum landing sizes used in these analyses are given in Table 9.

2.3.4 Analysis of differences in benthos catches between alternative gear and standard gear in October-December 1999

Since experimental trawling was carried out over larger areas with considerable differences in bottom structure and fauna composition, it was not practical to estimate mean densities with standard deviations of the different species over all hauls.

For an initial appreciation of differences in catch composition, irrespective of the occurrence of species in all catches, total numbers and weight of the different species were summed for all hauls (for each different week) and sums estimated for the alternative gear compared with sums for the standard gear.

In order to get an impression of the mean catch for different species in each gear, the geometric mean catches were estimated for those hauls that contained the species concerned. It does not make sense to compare mean catches for species of soft bottom communities (e.g. *Astropecten, Aphrodyte, Nephrops, Arctica,* etc) for hauls carried out in a sandy area where these species do not occur or where they are very scarce. Data on

numbers and weight in each haul were log-transformed and means of ln(n+1) were estimated in order to obtain the geometric mean catch as: (e^(mean ln(n+1))–1. For the different species the geometric means for catches with the alternative gear were compared with the geometric means of the standard gear, which gives another estimate of differences in catch composition.

Finally, for a proper analysis of significance of differences in catch composition observed, catch of each species in the alternative gear was divided by catch with the standard gear for all individual paired hauls. Once again, for the different species only those hauls were selected that contained the species concerned in appreciable numbers. Mean values were estimated (catch alternative gear / catch standard gear) and the standard error (S.E.) of the means (standard error = (t * Standard deviation) / V(n-1), where n is the number of hauls concerned and t is the value of t for p=0.025 two ways).

The standard error gives the 95% confidence intervals of the means, and values of (mean – S.E.) and (mean + S.E) are presented. If catches in the two different gears were similar, the relation (alternative / standard) should be 1.0. Differences from 1.0 indicate whether the alternative gear caught less (<1) or more (>1) than the standard gear and the 95% significance intervals indicates whether observed differences were statistically significant or not : if the means minus and plus standard error are both below or above 1.0, the observed difference is significant according to the t-test.

2.4. Catch efficiency for invertebrates and trawl path mortality

2.4.1 Sampling area

Figure 13 depicts the area chosen for this study, i.e. the Oyster Ground in the North Sea (between 54.13º - 54.17º N and 05.03º - 04.57º E). Next to being a representative fishing ground, the area had to fullfil two main conditions:

- homogenous (uniform) distribution of benthic fauna and minor environmental gradients within the study area,
- high abundance of megafaunal species that are well known from previous studies to give a clear response to trawling such as the sea potato (*Echinocardium cordatum*), various bivalves and the helmet crab (*Corystes cassivelaunus*).

2.4.2 Sampling design and equipment

Ten parallel strips on the sea bed were fished with standard and alternative Dutch and Belgian beam trawls from RV “Tridens”. The Dutch gears were: a 7m electrotrawl (TE2), a 7m standard beam trawl (TS4) and a 7m trawl with parallel chains (TL4); the Belgian gears were a 2*4m twin beam trawl with chain mats (CS), and the same with two escape windows inserted (CW2). The strips were about 2000m in length and some 30m in width. Depending on the with of the gear used (7m or 8m) the transects were fished either twelve times or ten times to ensure adequate coverage. Prior to fishing samples were taken from the sea bed using the triple-D sampler (t_0) from RV “Zirfaea”. Similar samples were taken 2 to 6 days after trawling (t_1), in order to enable fish and mobile epibenthos to scavenge on the organisms damaged or dislodged. These tracks were positioned close to (within 3 m) and parallel to the t_0-tracks (paired samples) in order to reduce bias caused by small-

scaled patchy distribution of species. The triple-D tracks were about 100m in length, depth 14cm, and taken from various positions along the transect. The dredge was equipped with a video to show the impact of the different types of trawls on the seabed. A 3m beam trawl was also used to sample fish and invertebrates from locations between the strips.

2.4.3 Data analysis

After fishing catches of fish and invertebrates were collected onboard RV "Tridens", and the length distribution measured of the first three hauls and the rest lumped together. The invertebrate catches from the first three hauls in two replicate strips were compared with the catches of 20 Triple-D samples (t_0) from the same strips. The catch efficiency of the trawls was expressed as percentage of the initial density estimated from the Triple-D catches. Direct mortality is calculated as percentage of the initial density in the trawled replicate strips. Box-Whisker plots of direct mortality of 15 abundant benthic species (fish and mobile epibenthos excluded) were made.

3. Results

3.1. Drop-out zones

3.1.1 "Isis" Experiments January 1999 (I9901)

The benthos results are summarised in Table 10. Table 11 gives the numbers/hr, kg/hour, ratio between modified gear and conventional gear in percentage and the p-value of the statistical test for both gears for the overall categories: fish discards, landings or marketable commercial fish, by-catch, undersized commercial fish added for the three experiments in this period. Table 12 and Table 13 give the same for the undersized commercial fish species and marketable commercial fish species separately (sole, plaice, dab, brill, turbot, whiting and cod).

There is no statistically significant difference between the two gears for the overall categories in all three experiments. The number and weight of fish discards did not drop for the modified nets, although adding more open meshes seem to bring the surplus down. The landings were somewhat smaller in numbers, but higher in weight for the modified net. No significant difference was detected for benthos in weight/hr for both standard gears in Experiments 1a and 1c. A significant difference however was found for benthos weights in Experiment 1b. A deeper analysis was also carried out of species composition. Only some reduction appears for *Echinocardium sp*., sea mouse (*Aphrodita aculeata L.)*, whelks (*Buccinum undatum L*.), the brittle star (*Ophiura L*.) and hermit crabs (*Pagurus bernhardus* L.), but the numbers were relatively small. For all the commercial species no difference was found in numbers or weight in Experiment 1a, apart from marketablelly sized brill. In Experiment 1b the standard gear caught significantly more undersized sole and plaice, but in dab no significant differences could be observed. Undersized cod were caught more in the modified gear, but the numbers were very low. The difference found for sole in Experiment 1b could not be confirmed in a statistical sense in Experiment 1c, nor was there any difference in plaice and dab.

3.1.2 "Tridens" Experiments March 1999 (T9903a)

The benthos catch in weight is again given in Table 10. Table 14 gives the numbers/hr, kg/hour, percentage difference and the p-value of the statistical test for the modified and the conventional gears for the overall categories for the four experiments in this period. Table 15, Table 16, and Table 17 give the same for the undersized and marketable commercial fish species.

For all experiments a statistically significant reduction in the weight of benthos catches was found. Contrary to the trials in January the discards were now lower in numbers and weight for the modified gear, in some cases even in a statistical sense. The same applies to the landings, although in Experiment 2d they reached a similar level. The by-catch seems to be reduced as well as the catch of undersized commercial species. The big meshes offer escape opportunities for sole, plaice, and dab, with reduced catches in numbers/hr and weight/hr in Experiment 2a. Adding a sheet of netting underneath in Experiment 2b did not seem to have a noticeable effect compared to Experiment 2a. Here too, a reduction was found for sole, plaice and dab in numbers and weight. Closing the three aftmost meshes did not improve the catch rates for the commercial flatfish species in Experiment 2c. Closing another four meshes (Experiment 2d) helps to reduce the losses in plaice and dab, but not in sole. For brill, turbot, whiting and cod the catches were relatively low and variable results emerged. The weight of benthos was reduced significantly in Experiment 2a, b, c, and 2d varying from 75% to 81%.

3.2. Alternative chain arrangements

3.2.1 "Tridens" Experiments March 1999 (T9903b)

The benthos catch in weight is again summarised in Table 10. The results of overall categories and commercial species are given in Table 18, Table 19 and Table 20.

The landings and the bycatch as well as the undersized commercial catch reached the same level or were higher in weight for the modified gear. The alternative chain arrangement generally caught equal or more flatfish, both in numbers/hr as in weight/hr, although the differences were, however, in most cases not significant. More small whiting seemed to be caught by the modified gear and the same quantity of cod. Benthos catches were equal or larger in kg for all experiments for the modified gear so the objective of reduction was not achieved. A more detailed investigation into separate species showed that shellfish (quahogs (*Arctica islandica L*.), prickly cockles (*Acanthocardia echinata L.)* and whelks (*Buccinum undatum L.))* were more effectively caught by the alternative chain configuration in Experiment 3a. A small increase in catches of quahogs (*Arctica islandica L*) and whelks (*Buccinum undatum L*.) was also found in Experiment 3b.

3.2.2 "Tridens" Experiments October 1999 (T9910)

The benthos catch in weight is again given in Table 10. The results of overall categories and commercial species are given in Table 21 and Table 22, and Table 23. The results of benthic discard analysis are presented in Table 24 and Table 25. Differences in catch composition of different types of trawls are shown as the relationship (alternative gear /

standard gear), both for total sums of different species in all catches, as well as for the geometric mean catches of the different species for hauls that contained these species. Statistical significance of differences is shown by the 95% confidence interval of mean values of the relation (alternative / standard) for paired hauls.

A significant reduction of 20%-25% was found for all marketablely sized commercial species for all three experiments. Discards were higher for the modified gear in Experiment 4a, and lower in Experiment 4b and 4c. By-catch was variable, sometimes higher, sometimes lower. Most noticeable is the reduction in sole catches for the modified gear, particularly the marketablely sized to about half of those of the conventional gear. The earlier experiments may give an overestimate of sole due to a discrepancy between the number of meshes around both codends (See Discussion). The cod-ends were checked and made as equal as possible, and the ends of ten pairs of chains were connected (Experiment 4c). The result was that the undersized sole catches of the modified net became even smaller (significant). The only striking difference in round fish was found in Experiment 4b for marketable whiting where the modified net caught significantly more. For all three experiments the reduction in benthos weight was noticeable, ranging from 30%-65%.

The results of analysis of benthic discards in week 40 (21 parallel chains) and week 41 (29 parallel chains) are presented in respectively Table 3.3.1.22 and Table 3.3.1.23. In general, the gears with parallel chains caught less molluscs and less infauna species such as Sandstars *(Astropecten),* but more Crustaceans. Due to the large variations in numbers, most differences were not statistically significant, but the lower catches in molluscs were highly significant (exept for the epibenthic active swimming queen scallop), while higher catches of swimming crabs in week 41 were also statistically significant. For the discard fish appeared that the alternative gears with parallel chains caught significantly less dabs *(Limanda)* and more whiting *(Merlangius).* Most remarkable was that the higher catches of crustaceans with parallel chains were also observed for Norway lobster *(Nephrops)*: the alternative gears caught about 1.5 times as many lobsters, although variation was such that the differences were not statistically significant.

A higher number of parallel tickler chains in week 41 (29 in stead of 21) did not result in marked differences with the results obtained in week 40. However, some differences became statistically significant, such as the lower catches of whelks in the alternative gear and the higher catches of swimming crabs.

3.2.3 “Tridens” Experiments June 2000 (T0006)

The benthos catch in weight is again given in Table 10. The results of overall categories and commercial species are given in Table 26, and Table 27.

Both gears performed quite similar in both experiments in all overall categories. The bycatch was only clearly different in Experiment 5a. Discards and landings might be slightly higher for the parallel chain gear, but more data is needed to confirm this statistically. Sole catches differed for the two nets with net ticklers only, casting doubt on the assumption of equal performance of the two unmodified nets. For all other species the

data do not allow statistical evidence however, as if significance occurred, it was found when both gears without net ticklers were compared. No statistical difference was found for the overall benthos weight for both experiments. In fact the numbers were remarkably similar.

3.3. Electrified beam trawl

3.3.1 "Tridens" Experiments April 1999 (T9904)

A total of 47 hauls was made, 1 at 2kn, 10 at 3 kn, 26 at 4 kn and 10 at 5kn towing speed. Table 28 gives the summarised data for sole and plaice converted per hour fishing as a function of towing speed. The electrotrawl seems particularly effective at low speeds compared to the conventional trawl. The standard deviations were of the same magnitude as the catches, thus for hard evidence more data would be needed.

3.3.2 "Tridens" Experiments November-December 1999 (T9911)

The benthos catch in weight is again given in Table 10. Direct mortality of invertebrates is given in Table 29. Table 30 gives the numbers/hr, kg/hour, percentage difference and the p-value of the statistical test for the modified and the conventional gears for the overall categories for the three experiments analysed for this period. Table 31 and Table 32 give the same for the undersized and marketable commercial fish species. Minor gear alterations were lumped together for Experiments 6a and 6b to create a suitable number of hauls. Experiment 6b differs in the sense that a winding of the groundrope was taken off. Experiment 6c gives the results of adding one tickler chain to the electrotrawl.

Discards were lower for the electrotrawl in Experiment 6a and 6b, but higher in Experiment 6c. Landings decreased for the electrotrawl with about 30% in numbers. In Experiment 6b and 6c the electrotrawl caught about 75% of the juvenile commercial species in numbers. More by-catch fish were caught over the range of experiments. Adding the tickler chain caused some 100% increase in numbers, although this was not reflected similarly in weight. The electrotrawl caught more juvenile sole than the conventional one. The extra tickler chain in Experiment 6c caused a significant increase in sole catches over the whole length range. The catches in marketable plaice were 40 to 60% of those of the conventional trawl. Fewer juveniles were caught, some 50%. More small whiting were caught with the tickler chain attached, but the effect of large whiting was unclear. The electrotrawl caught about 60% in benthos weight in Experiments 6a, and 6b. Adding a tickler chain caused this decrease to vanish (Experiment 6c).

The results of analysis of benthic discards obtained in week 47 (10 paired hauls) and week 48 (8 paired hauls) are presented in respectively Table 33 and Table 34. In general, the 7m beam trawl, with parallel electrified stimulation cables in stead of ordinary tickler chains, caught much less bentic invertebrates than the standard 7m beam trawl. Most differences were statistically significant, the overall catch of the electric beam trawl being about 45–55% of the standard trawl. Catches of electric beam trawl were particularly lower for "infauna" species (30-40% of catch with standard trawl), the difference was less for epibenthic species 65-75% of standard.

This pattern changed considerably after addition of one tickler chain to the array of electrified cables: the results of week 48 still show lower catches of infauna species such as molluscs and sandstar *(Astropecten),* but differences for epifauna species became less and not significant. After addition of only one tickler chain the overall catch of all invertebrates with the electric beam trawl increased from about 60% to about 80% of the catch with standard gear. Catches of some crustaceans, such as swimmimg crabs, hermit crabs and shrimp appear to be even slightly higher in the electric beam trawl, although differences were not statistically significant.

3.4. Catch efficiency and direct benthos mortality

3.4.1 Catch efficiencies

Table 35 gives the catch efficiencies for several species in the taxa molluscs, crustaceans, echinoderms and polychaetes for the five gears tested in June 2000.

All types of standard and alternative trawls caught only a small fraction of the invertebrate fauna. Highest catch efficiencies were found for epibenthic or shallow burrowing species like sandstar (up to 7%), seamouse (up to 9%), large bivalves (up to 8%) and for the Norway lobster (up to 6%). Catch efficiencies for more deeply burrowing species (*e.g*. sea potatoes, blunt gapers *Mya arenaria*), and small species (*e.g.* sea cucumbers, small bivalve species) was low (less than 0.3%) or even zero.

The electrical beam trawl as well as the longitudinal chain beam trawl caught less efficiently large bivalves (quahog, prickly cockle), seamouse, sandstar, and helmet crabs than the standard beam trawl. Yet, the electrical beam trawl with its limited penetration depth into the seabed showed higher catch efficiencies for larger crustaceans such as *Nephrops*, just alike the longitudinal chain beam trawl.

The catch efficiency of the window chain matrix beam trawl for most infaunal and epifaunal species *e.g.*, prickly cockle, sea mouse, hermit crab, helmet crab, Norway lobster, and sandstar was lower than that of the standard chain matrix.

3.4.2 Short term trawl path mortality of discard invertebrates

- **In all standard 7m and 12m trawls** invertebrate test species showed discard mortalities from 17% (edible crab) up to 80% (quahog). Hermits, prickly cockle, swimming crab and helmet crab showed intermediate discard mortalities (on average 28%, 39%, 43% and 65%, respectively).

- **In catches of the electrical beam trawl,** discard mortalities of helmet crabs and hermits (without shells) were significantly lower (reduced from 64 to 38-44%) than in catches of the standard gear.

- **In catches of the longitudinal chain beam trawl,** the discard mortality of swimming crab, *Nephrops* and quahog was significantly lower (reduced from 39-80% to 27-60%) than in catches of the standard gear.

- **The standard chain matrix and its window alternative** generated discard mortalities of invertebrates in the same order of magnitude.

- Fish caught **in standard and alternative gears** showed no significant differences in short term discard mortality, with the exception of dab showing lower mortality in window chain matrix trawls.

3.4.3 Direct mortality in the trawl path of invertebrates

The median, lower and upper quartiles (boxes) and whiskers are given in Box-Whisker plots of direct mortality of invertebrates for the three Dutch gears in Figure 14 and the two Belgian gears in Figure 15.

The median mortality of the 15 species under investigation caused by trawling with the various alternative gears were compared with median mortalities due to trawling with their standards.

- **electrical beam trawling** caused lower median mortalitiy (24%) than standard beam trawling (36%).

- **longitudinal chain beam trawling** caused a statistically significant higher median mortality (*i.e.* 53%) than standard beam trawling and also than electro beam trawling.

- **window chain matrix trawling** caused a lower median mortality (38%), although not significantly, than trawling with the standard chain matrix (47%).

4. Discussion

4.1 Drop-out zones in the lower panel of a beam trawl

A considerable reduction in benthos catches ranging from 20-25% in weight can be achieved with the drop-out zones in the lower panel of a beam trawl, but the penalty is a loss in commercial catches.

It appears that sole catches are most sensible to changes in the net design. Creating large meshes in the lower panel apparently offers more escape opportunities for sole, which results in a loss in marketable fish ranging from 25% to 35%. The fact that these fish often appear gilled in the meshes of a cod-end indicates that this species undertake vigorous escape attempts. A loss was also found for plaice and dab, be it to a smaller extent i.e. 15-30%. Adding a sheet of netting with the idea to reduce escape attempts did show some prospect in the “Isis”-experiments, but this was not confirmed in the “Tridens”-experiments later. The losses in flatfish could only be diminished when closing meshes, thus reducing the drop-out zone. However, the penalty is a loss in commercial catches.

A considerable reduction in benthos catches ranging from 20-25% in weight can be achieved with the drop-out zones in the lower panel of a beam trawl.

Especially the heavier shellfish seem to drop out through the panel, possibly sinking faster in the water flow. Additional research using underwater observation techniques may cast more light on this phenomenon.

4.2 Alternative chain arrangements

The parabolic chain arrangement resulted in higher catches of flatfish and benthos, contradictory to the objective. Apparently this creates a stronger stimulus on the sea bed, possibly due to smaller incidence angles of the chains compared to chains hung on the shoe plates as in the conventional beam trawl.

Parallel chains seem to diminish sole catches, whereas the effect on plaice is marginal, there seems to be potential in substantially reducing benthos catches. In the course of the experiments on parallel chains it was found, that there was a difference in circumference of the two codends. Activities were undertaken to limit the effect, by interchanging cod-ends and nets and carefully checking and where necessary replacing cod-ends. The experiments were lumped together to average these errors. It should be born in mind that the configuration used was a combination of parallel chains and net tickler hung in the conventional way. The trawl path mortality study revealed that this configuration caused the highest direct mortality of invertebrates. Apparently the combination of chains digging parallel and scraping the sea bed more or less horizontal is unfavourable. Further trials should be carried out with chains running parallel only.

4.3 Electrotrawl

The use of electrical stimulation in sea fisheries has been investigated thoroughly over the past decades, but has until now not led to an introduction in commercial fisheries (Van Marlen *et al*., 1997). The wish to diminish bottom contact renewed the interest in this technique.

Basic reponses of fish to electrical stimuli were described by McK.Bary, 1956. Three types were distinguished, i.e. minimum response, electrotaxis, and electronarcosis. The species investigated was Mugil auratus. The stimuli used here invoke reactions of the first type.

Stewart, 1975 showed that for a given field strength larger fish are subject to a greater potential difference from snout to tail. Although it was acknowledged at the time that the length dependency should be different for the various reaction types, direct underwater observations showed larger fish to elicit higher responses (Stewart, 1977). Based on these early experiments, it is often suggested, that electrical stimulation offers a potential for better size selectivity. The results of the tests reported here do not support this view. The electrotrawl caught about the same quantity of marketable sole, and certainly not fewer undersized.

Adding one tickler chain caused a clear increase in sole catches over the whole length range, but this was contradictory to the objective of reducing benthos mortality, and should not be encouraged.

In general about 50% of plaice were caught compared to the conventional gear. Bringing the electrode array further aft did not result in higher plaice catches, nor did the changes in the net design. An explanation for these differences was not found. It may be caused by morphological differences between the two species. Sole has a much more flexible spine and is able to curl in two directions, while plaice is more rigid.

5. Conclusions

5.1 Drop-out zones

A considerable reduction in benthos catches ranging from 20-25% in weight can be achieved with the drop-out zones, but the penalty is a loss in commercial catches, particularly sole, and to a lesser extent plaice and dab.

5.2 Alternative chain arrangements

The alternative arrangement with parabolic chains (TP1...3) caused higher catches of flatfish and benthos, contrary to the objective. The gear with parallel chains (and net ticklers) (TL1...4) caught substantially less sole, and marginally less plaice, but also significantly less benthos, and if sole catches could be enhanced this configuration might be promising, at least from the catch point of view. The final judgement for both came from the benthos mortality study. Here the parallel chains did result in a higher direct mortality of invertebrates in the trawl path then the conventional gear, thus rendering this option unacceptable in the form tested.

5.3 Electrotrawl

The catches of all commercial marketable sized species taken together reached between 50% and 80% of that of the conventional beam trawl. About 55% to 75% of undersized commercial species were caught, which would help to reduce discards.

There is no clear tendency in the by-catch of non-commercial species. In some cases the catches were lower, in other they were somewhat higher.

Benthos catches were about 60% in weight compared to the conventional trawl. Clearly fewer infauna species were caught. In some cases the comparison may have been biased by the different construction of the footrope of both gears, i.e. a single chain for the electrotrawl, and a much thicker rubber disc footrope for the conventional trawl. It was clear that adding one extra tickler chain to the electrotrawl caused the difference in favour of the electrotrawl to disappear.

The electrotrawl caught about the same quantity of sole or slightly more, and certainly not fewer undersized. Adding one tickler chain caused a clear increase in sole catches over the whole length range, but this was contradictory to the objective of diminishing the benthos catches.

In general about 50% of plaice were caught compared to the conventional gear. Bringing the electrode array further aft did not result in higher plaice catches, nor did the changes in the net design.

The electrotrawl performed well over the period of many weeks fishing. No major breakdowns were experienced, not even in moderate seas.

The electrotrawl caused the lowest catch efficiency and direct mortality of benthic invertebrates and is therefore from this point a view a very interesting alternative, justifying further research and development. Nevertheless, also the electrical beam trawl will cause damage to emergent epibenthos due to the ground rope. The combination of electrical stimulation and escape window might enhance the performance in terms of lower impact further.

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Table 1 ***Overview of trials***

Vessel	Subject	Beam width	Period	ID	# hauls (valid)
"Isis"	Drop-out zones	8m	January 1999	I9901	38 (36)
"Tridens"	Drop-out zones	12m	March 1999	T9903a	37 (35)
"Tridens"	Alternative chains	12m	March-April 1999	T9903b	36 (34)
"Tridens"	Alternative chains	12m	October 1999	T9910	72
"Tridens"	Alternative chains	7m	June 2000	T0006	13
"Tridens"	Electrical stimulation	7m	April 1999	T9904	47
"Tridens"	Electrical stimulation	7m	Nov-Dec 1999	T9911	55
"Tridens" "Zirfaea"	Trawl path mortality	7m, 8m	May-June 2000	T0005	40

Table 2 **Summary of experiments and configurations tested**

Trials	Exp	Comparison	Configuration	# hauls (valid)
Jan 1999	1a	TS2-TS2	standard	4
	1b	TS2-TD1	19 large meshes	18
	1c	TS2-TD2	19 meshes + sheet	14
Mar 1999	2a	TS3-TD3	19 large meshes	5
	2b	TS3-TD4	19 meshes + sheet	12
	2c	TS3-TD5	16 meshes + sheet	7
	2d	TS3-TD6	12 meshes + sheet	12
Mar-Apr '99	3a	TS3-TP1	25 cm spacing	13
	3b	TS3-TP2	40 cm spacing	17
	3c	TS3-TP3	25 cm spacing, centre chain - 35cm	5
Oct 1999	4a	TL1-TS3	21 chains, 50 cm spacing	19
	4b	TL2-TS3	29 chains, 35 cm spacing	42
	4c	TL3-TS3	29 chains, 35 cm spacing, ten pairs of chains connected	11
Jun 2000	5a	TS4-TS4	Both 7m gears with net ticklers only	3
	5b	TL4-TS4	Parallel chains on port gear	10
Apr 1999	1	TE1-TS4	7m E-trawl as 1998 at 2, 3, 4, 5 kn	47
Nov-Dec '99	6a	TE2-TS4	Modified net, electrodes 3m further aft. Various minor gear alterations	20
	6b	TE3-TS4	As TE2 with winding taken off groundrope. Various minor gear alterations	23
	6c	TE4-TS4	As TE3, with one tickler chain added.	9

TS = trawl standard; TD = trawl with drop-out meshes; TP = trawl with parabolic chains;
TL = trawl with parallel chains; TE = trawl electrified.

Table 3 ***Gear dimensions RV "Isis", large mesh trials January 1999***

Item	Standard net	Modified gears
beam length	8 m	8 m
headline length	7.8 m	7.8 m
gear weight	1500 kg	1500 kg
# ticklers	4	4
# net ticklers	4	4
shackle diameter	16 mm	16 mm
footrope length	19 m	19 m
	wings 2 x 7 m	vlerken 2 x 7 m
	rollers 5 m	rollers 5 m
footrope chain ø	18 mm	18 mm
codend depth in meshes	75 meshes	75 meshes
codend circumference	2 x 50 meshes	2 x 50 meshes
codend mesh size	75.3 mm	75.4 mm
codend material	PES, ø=2.5mm, double	PES, ø=2.5mm, double
TD1		19 meshes of 720 mm
TD2		19 meshes of 720 mm
		+ sheet netting : 115 x 80 meshes
		mesh size 120 mm
		material 19-71

Table 4 ***Gear dimensions RV "Tridens", large mesh trials March 1999.***

Item	Standard net	Modified gears
beam length	12 m	12 m
headline length	11.20 m	11.20 m
gear weight	5500 kg	5500 kg
# ticklers	10	10
# net ticklers	10	10
shackle diameter	24 mm	24 mm
footrope length	38 m	38 m
	wings 15 m	wings 15 m
	rollers 8 m	rollers 8 m
footrope chain ø	22 mm	22 mm
codend depth in meshes	70 meshes	70 meshes
codend circumference	150 mazen	150 meshes
codend mesh size	80 mm	80 mm
codend material	PES, ø=2.5mm, double	PES, ø=2.5mm, double
TD3		19 meshes of 500 mm
TD4		19 meshes of 500 mm
		+ sheet netting: x meshes
		mesh size 100 mm
		material 19-71MOD2
TD5		16 meshes of 500 mm
		+ sheet netting
TD6		12 meshes of 500 mm
		+ sheet netting

Table 5 ***Gear dimensions RV "Tridens", alternative chain trials March-April 1999.***

Item	Standard net	Modified gears
beam length	12 m	12 m
headline length	11.20 m	11.20 m
gear weight	5500 kg	5500 kg
# ticklers	10	10
# net ticklers	10	10
shackle diameter	24 mm	24 mm
footrope length	38 m	38 m
	wings 15 m	wings 15 m
	rollers 8 m	rollers 8 m
footrope chain ø	22 mm	22 mm
codend depth in meshes	70 meshes	70 meshes
codend circumference	150 mazen	150 meshes
codend mesh size	80 mm	80 mm
codend material	PES, ø=2.5mm, double	PES, ø=2.5mm, double
TP1		25 cm spacing
TP2		40 cm spacing
TP3		25 cm spacing
		centre chain - 35cm

Table 6 ***Gear dimensions RV "Tridens", alternative chain trials in October 1999.***

Item	Standard net	Modified gears
beam length	12 m	12 m
headline length	11.20 m	11.20 m
gear weight	5500 kg	5500 kg
# ticklers	10	10
# net ticklers	10	10
shackle diameter	24 mm	24 mm
footrope length	38 m	38 m
	wings 15 m, rollers 8 m	wings 15 m, rollers 8 m
footrope chain ø	22 mm	22 mm
codend depth in meshes	70 meshes	70 meshes
codend circumference	150 mazen	150 meshes
codend mesh size	80 mm	80 mm
codend material	PES, ø=2.5mm, double	PES, ø=2.5mm, double
TL1		21 parallel chains
TL2		29 parallel chains
TL3		29 parallel chains
		ten pairs connected

Table 7 ***Gear dimensions RV "Tridens", alternative chain trials in June 2000.***

Item	Standard net	Modified gear
beam width	6.4m	6.4m
length of footrope	6.4m	6.4m
weight in air (without net)	~2500kg	~3000kg
number of tickler chains	-	-
shackle diameter	-	-
number of net ticklers	7	7
shackle diameter	2x16mm	2x16mm
	5x14mm	5x14mm
length of groundrope	chain 24m	chain 24m
	rollers 4m	rollers 4m
footrope chain ø	18mm	18mm
length of fishing line	28m	28m
codend length	70 meshes	70 meshes
codend circumference	2x60 meshes	2x60 meshes
codend mesh size	80mm	80mm
codend material	PES, ø=2.5mm	PES, ø=2.5mm
	double	double
TL4		13 parallel chains
		40 cm apart
length of chains		9m(1x),
length of chains		8.5, 7.5 ,6.5 ,5 ,3.5 ,2m (2x)
total 75m*7kg/m		525kg

Table 8 ***Gear dimensions RV "Tridens", electrical stimulation trials in November 1999.***

Item	Standard net TS4	Electronet1 TE2	Electronet2 TE5
beam width	6.4m	6.9m	6.9m
length of footrope	6.4m	6.4m	6.4m
weight in air (without net)	3700kg	2600kg	2600kg
weight in water (without net)		1400kg	1400kg
number of tickler chains	9	(1)	-
shackle diameter	18mm	-	-
number of net ticklers	7	-	-
shackle diameter	2x16mm, 5x14mm	-	-
number of electrodes	-	13	13
electrode length	-	3m+3m	3m+3m
electrode distance	-	0.5m	0.5m
length of groundrope	chain 24m	chain 19m	chain 21.8m
	rollers 4m		11.4m,'teeth' 10.4m
footrope chain ø	18mm	18mm	18mm
length of fishing line	28m	22m	25.4m
width at electrodes in meshes	-	122x100	214x100
codend length	70 meshes	70 meshes	70 meshes
codend circumference	2x60 meshes	2x60 meshes	2x60 meshes
codend mesh size	80mm	80mm	80mm
codend material	PES, ø=2.5mm, db	PES, ø=2.5mm, db	PES, ø=2.5mm, db

Table 9 Minimum Landing Sizes (MLS) 1999.

(Source: EU Regulation Nr. 894/97 Technical measures, Annex II)

Species	**MLS in cm**
sole (*Solea solea* L.)	24
plaice (*Pleuronectes platessa* L.)	27
dab (*Limanda limanda* L.)	23
brill (*Scophthalmus rhombus* L.)	30
turbot (*Scophthalmus maximus* L.)	30
whiting (*Merlangius merlangus* L.)	23
cod (*Gadus morhua* L.)	35

Table 10 Benthos weight comparison

Exp.	# hauls	Weight in kg/hour			
		MOD	CON	MOD/CON %	t-test 95%
1b	18	67.5	78.7	85.80%	s
1c	14	33.4	34.5	96.80%	ns
2a	5	83.2	106.3	78.30%	s
2b	12	56.7	73.9	76.70%	s
2c	7	101.9	135.7	75.10%	s
2d	12	72.8	88.9	81.90%	s
3a	13	81.7	73.4	111.30%	s
3b	16	65.4	65.8	99.40%	ns
3c	5	174.7	166.7	104.80%	ns
4a	19	24.2	33.9	71.40%	s
4b	41	23.6	55.5	42.60%	s
4c	11	13.1	38.79	33.80%	s
5a	3	45.1	47.6	94.70%	ns
5b	10	109.9	105.5	104.20%	ns
6a	20	42.85	69.83	61.40%	s
6b	23	14.34	23.52	61.00%	s
6c	9	18.9	19.84	95.30%	ns

Table 11 ***Results in overall categories of large meshes trials "Isis", January 1999.***

l9901	**numbers/hour**					**kg/hour**			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
discards	1a	1651.25	1374.56	120.1%	0.44	103.92	90.09	115.4%	0.58
	1b	882.10	719.63	122.6%	0.46	68.66	47.07	145.9%	0.26
	1c	303.38	303.05	100.1%	0.99	22.56	21.85	103.2%	0.69
landings or	1a	57.11	60.10	95.0%	0.87	17.73	11.80	150.3%	0.55
>commercial	1b	66.81	67.74	98.6%	0.91	15.75	14.62	107.7%	0.50
	1c	41.06	42.83	95.9%	0.66	15.17	13.62	111.4%	0.25
bycatch	1a	33.92	26.43	128.3%	0.74	4.53	4.50	100.7%	0.98
	1b	266.39	69.93	380.9%	0.34	29.74	6.42	463.2%	0.22
	1c	34.68	28.73	120.7%	0.31	2.03	1.76	115.3%	0.41
<commercial	1a	1617.33	1348.13	120.0%	0.46	99.39	85.59	116.1%	0.59
	1b	615.71	649.71	94.8%	0.57	38.93	40.65	95.8%	0.69
	1c	268.70	274.31	98.0%	0.86	20.54	20.09	102.2%	0.82

Table 12 ***Results in commercial species of large meshes trials "Isis", January 1999.***

I9901	numbers/hour					kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<sole	1a	0.50	1.25	40.0%	0.07	0.06	0.09	66.7%	0.11
	1b	**2.77**	**3.71**	**74.7%**	**0.03**	**0.27**	**0.36**	**75.0%**	**0.02**
	1c	1.61	1.50	107.3%	0.80	0.16	0.16	100.0%	0.96
>sole	1a	3.24	2.37	136.7%	0.30	0.58	0.48	120.8%	0.40
	1b	8.05	8.81	91.4%	0.37	1.62	1.79	90.5%	0.33
	1c	8.04	8.81	91.3%	0.27	1.68	1.85	90.8%	0.37
<plaice	1a	580.92	707.73	82.1%	0.25	38.68	48.80	79.3%	0.22
	1b	266.01	263.06	101.1%	0.90	17.68	18.09	97.7%	0.84
	1c	163.41	147.01	111.2%	0.48	14.85	13.29	111.7%	0.32
>plaice	1a	9.60	11.10	86.5%	0.22	3.02	3.24	93.2%	0.26
	1b	16.37	19.49	84.0%	0.27	**5.03**	**6.58**	**76.4%**	**0.04**
	1c	24.37	24.73	98.5%	0.89	7.75	8.12	95.4%	0.64
<dab	1a	980.92	627.18	156.4%	0.31	58.61	36.26	161.6%	0.32
	1b	314.78	356.47	88.3%	0.32	19.88	21.14	94.0%	0.65
	1c	89.25	108.18	82.5%	0.17	5.26	6.26	84.0%	0.22
>dab	1a	35.91	43.89	81.8%	0.68	12.28	6.56	187.2%	0.54
	1b	32.71	28.72	113.9%	0.58	5.19	4.50	115.3%	0.53
	1c	6.68	6.39	104.5%	0.92	1.13	1.08	104.6%	0.91
<brill	1a	0.12	0.25	48.0%	0.80	0.05	0.02	250.0%	0.73
	1b	**0.00**	**0.03**	**0.0%**	**.**	**0.00**	**0.00**	**.**	**.**
	1c	**.**	**.**		**.**	**.**	**.**	**.**	**.**
>brill	1a	0.37	0.12	308.3%	0.50	**0.31**	**0.07**	**442.9%**	**0.05**
	1b	**0.00**	**0.03**	**0.0%**	**.**	**0.00**	**0.02**	**0.0%**	**.**
	1c	**0.04**	**0.18**	**22.2%**	**0.02**	0.06	0.22	27.3%	0.10
<turbot	1a	0.37	0.25	148.0%	0.50	0.10	0.07	142.9%	0.65
	1b	0.14	0.10	140.0%	0.64	0.04	0.02	200.0%	0.36
	1c	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**.**
>turbot	1a	0.50	0.00	**.**	0.30	0.32	0.00	**.**	0.22
	1b	0.28	0.17	164.7%	0.43	0.31	0.11	281.8%	0.17
	1c	0.15	0.11	136.4%	0.70	0.19	0.27	70.4%	0.79

Table 13 ***Results in commercial species of large meshes trials "Isis", January 1999 (continued).***

I9901	numbers/hour					kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<whiting	1a	53.62	11.22	477.9%	0.39	1.82	0.32	568.8%	0.39
	1b	31.56	26.05	121.2%	0.53	0.99	1.00	99.0%	0.98
	1c	14.09	17.32	81.4%	0.29	0.25	0.35	71.4%	0.09
>whiting	1a	7.23	2.00	361.5%	0.29	0.63	0.17	370.6%	0.32
	1b	8.60	10.09	85.2%	0.33	0.66	0.75	88.0%	0.45
	1c	0.26	1.65	15.8%	0.07	0.04	0.16	25.0%	0.12
<cod	1a	0.87	0.25	348.0%	0.24	0.08	0.02	400.0%	0.33
	1b	0.45	0.28	160.7%	0.32	0.05	0.03	166.7%	0.40
	1c	0.33	0.29	113.8%	0.80	0.03	0.04	75.0%	0.71
>cod	1a	0.25	0.62	40.3%	0.48	0.59	1.27	46.5%	0.48
	1b	0.80	0.42	190.5%	0.09	**2.94**	**0.87**	**337.9%**	**0.02**
	1c	1.54	0.95	162.1%	0.11	4.32	1.93	223.8%	0.09

Table 14 ***Results in overall categories of large meshes trials "Tridens", March 1999.***

T9903a		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
discards	2a	723.65	1033.95	70.0%	0.07	60.29	77.64	77.7%	0.08
	2b	**1204.89**	**1588.50**	**75.9%**	**0.02**	**87.28**	**116.63**	**74.8%**	**0.02**
	2c	1165.62	1622.76	71.8%	0.11	75.16	111.51	67.4%	0.07
	2d	1507.61	1767.06	85.3%	0.11	**97.89**	**126.68**	**77.3%**	**0.01**
landings or	2a	105.68	150.99	70.0%	0.18	29.80	45.82	65.0%	0.19
>commercial	2b	135.89	186.17	73.0%	0.17	36.89	46.54	79.3%	0.15
	2c	130.38	205.90	63.3%	0.12	33.10	47.69	69.4%	0.07
	2d	167.28	184.22	90.8%	0.50	43.75	44.83	97.6%	0.86
bycatch	2a	175.17	129.59	135.2%	0.17	**24.17**	**16.34**	**147.9%**	**0.01**
	2b	246.28	294.00	83.8%	0.25	27.34	33.17	82.4%	0.17
	2c	**137.43**	**233.33**	**58.9%**	**0.03**	10.22	20.72	49.3%	0.12
	2d	233.83	290.39	80.5%	0.13	**18.96**	**31.81**	**59.6%**	**0.02**
<commercial	2a	548.48	904.36	60.6%	0.05	**36.12**	**61.30**	**58.9%**	**0.04**
	2b	**958.61**	**1294.50**	**74.1%**	**0.01**	**59.94**	**83.46**	**71.8%**	**0.02**
	2c	1028.19	1389.43	74.0%	0.17	64.93	90.78	71.5%	0.08
	2d	1273.78	1476.67	86.3%	0.14	78.93	94.87	83.2%	0.06

Table 15 ***Results in commercial fish species of large meshes trials "Tridens", March 1999.***

T9903a		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<sole	2a	2.77	7.00	39.6%	0.06	**0.29**	**0.73**	**39.7%**	**0.05**
	2b	6.50	5.44	119.5%	0.42	0.64	0.54	118.5%	0.44
	2c	**10.29**	**13.62**	**75.6%**	**0.04**	**1.02**	**1.36**	**75.0%**	**0.03**
	2d	**7.94**	**13.33**	**59.6%**	**0.002**	**0.83**	**1.33**	**62.4%**	**0.002**
>sole	2a	**27.21**	**40.69**	**66.9%**	**0.01**	**5.98**	**9.10**	**65.7%**	**0.02**
	2b	**26.06**	**37.22**	**70.0%**	**0.000**	**5.60**	**8.46**	**66.2%**	**0.00**
	2c	**32.86**	**44.10**	**74.5%**	**0.04**	**7.19**	**9.82**	**73.2%**	**0.04**
	2d	**40.17**	**54.17**	**74.2%**	**0.000**	**9.00**	**11.50**	**78.3%**	**0.000**
<plaice	2a	65.26	209.38	31.2%	0.05	6.53	20.37	32.1%	0.06
	2b	179.94	242.11	74.3%	0.17	15.07	21.90	68.8%	0.10
	2c	**223.05**	**312.19**	**71.4%**	**0.01**	**18.66**	**24.22**	**77.0%**	**0.003**
	2d	318.89	339.17	94.0%	0.68	25.22	27.63	91.3%	0.54
>plaice	2a	28.93	38.44	75.3%	0.33	10.17	12.59	80.8%	0.25
	2b	**26.17**	**42.61**	**61.4%**	**0.05**	**8.77**	**13.68**	**64.1%**	**0.03**
	2c	21.81	34.48	63.3%	0.17	7.10	9.89	71.8%	0.14
	2d	32.39	27.11	119.5%	0.51	9.02	8.58	105.1%	0.79
<dab	2a	480.32	687.45	69.9%	0.14	29.25	40.09	73.0%	0.11
	2b	**771.56**	**1045.33**	**73.8%**	**0.01**	**44.20**	**60.95**	**72.5%**	**0.02**
	2c	783.24	1059.81	73.9%	0.23	44.85	64.87	69.1%	0.11
	2d	944.00	1124.00	84.0%	0.14	**52.64**	**65.85**	**79.9%**	**0.04**
>dab	2a	42.01	67.64	62.1%	0.32	7.14	12.33	57.9%	0.29
	2b	78.61	100.89	77.9%	0.48	13.01	16.30	79.8%	0.47
	2c	72.38	124.48	58.1%	0.23	12.27	22.40	54.8%	0.22
	2d	89.33	98.56	90.6%	0.62	14.80	15.90	93.1%	0.74

Table 16 ***Results in commercial fish species of large meshes trials "Tridens", March 1999 (continued).***

T9903a		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<brill	2a	0.00	0.00	.	.	0.00	0.00	0.0%	.
	2b	0.00	0.00	.	.	.	.	.	.
	2c	.	.	.	.	.	.	.	.
	2d	.	.	.	.	.	.	.	.
>brill	2a	0.13	0.26	50.0%	0.67	0.34	0.18	188.9%	0.74
	2b	0.22	0.22	100.0%	1.00	0.22	0.24	91.7%	0.91
	2c	**0.19**	**0.00**	.	.	0.13	0.00		0.06
	2d	0.06	0.06	100.0%	1.00	0.05	0.06	83.3%	0.95
<turbot	2a	0.13	0.13	100.0%	.	0.05	0.05	100.0%	.
	2b	**0.06**	**0.00**	.	.	**0.02**	**0.00**	.	.
	2c	0.19	0.38	50.0%	0.18	0.07	0.12	58.3%	0.28
	2d	0.56	0.17	329.4%	0.32	0.14	0.06	233.3%	0.32
>turbot	2a	**1.98**	**0.53**	**373.6%**	**0.004**	**3.11**	**0.59**	**527.1%**	**0.01**
	2b	0.83	0.78	106.4%	0.89	1.41	1.58	89.2%	0.86
	2c	0.38	0.86	44.2%	0.09	0.51	0.96	53.1%	0.21
	2d	1.28	0.89	143.8%	0.28	1.64	1.41	116.3%	0.62

Table 17 ***Results in commercial fish species of large meshes trials "Tridens", March 1999 (continued).***

T9903a		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<whiting	2a	0.00	0.13	0.0%	.	**0.00**	**0.01**	**0.0%**	.
	2b	0.50	1.50	33.3%	0.45	0.01	0.02	50.0%	0.12
	2c	11.43	3.05	374.8%	0.67	0.33	0.07	471.4%	0.64
	2d	2.39	0.00	.	0.49	0.10	0.00		0.48
>whiting	2a	4.36	1.19	366.4%	0.41	0.38	0.14	271.4%	0.44
	2b	1.17	2.22	52.7%	0.07	0.14	0.25	56.0%	0.14
	2c	0.95	0.29	327.6%	0.25	0.11	0.04	275.0%	0.31
	2d	0.78	1.06	73.6%	0.32	0.10	0.14	71.4%	0.26
<cod	2a	**0.00**	**0.26**	**0.0%**	.	**0.00**	**0.05**	**0.0%**	.
	2b	0.06	0.11	54.5%	0.67	0.01	0.04	25.0%	0.40
	2c	0.00	0.38	0.0%	0.30	0.00	0.13	0.0%	0.27
	2d	.	.	.	.	.	.	.	.
>cod	2a	1.06	2.25	47.1%	0.32	2.68	10.89	24.6%	0.17
	2b	2.83	2.22	127.5%	0.32	7.74	6.02	128.6%	0.30
	2c	1.81	1.71	105.8%	0.88	5.78	4.59	125.9%	0.56
	2d	3.28	2.39	137.2%	0.51	9.15	7.25	126.2%	0.61

Table 18 ***Results in overall categories of alternative chain arrangement trials "Tridens", March 1999.***

T9903b		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
discards	3a	**1422.83**	**1223.4**	**116.3%**	**0.018**	**104.38**	**89.75**	**116.3%**	**0.022**
	3b	1707.01	1646.98	103.6%	0.574	121.51	110.8	109.7%	0.093
	3c	1857.33	1834.53	101.2%	0.913	108.18	111.16	97.3%	0.849
landings or	3a	155.01	141.31	109.7%	0.335	36.88	35.64	103.5%	0.586
>commercial	3b	**120.49**	**151.88**	**79.3%**	**0.034**	50.32	32.71	153.8%	0.431
	3c	117.73	122.27	96.3%	0.903	35.09	35.73	98.2%	0.925
bycatch	3a	220.71	202.8	108.8%	0.527	28.75	27.4	104.9%	0.76
	3b	**384.72**	**321.08**	119.8%	**0.016**	**42.31**	**33.24**	**127.3%**	**0.005**
	3c	258.27	203.73	126.8%	0.212	20.88	15.34	136.1%	0.21
<commercial	3a	**1202.13**	**1020.6**	**117.8%**	**0.039**	**75.63**	**62.35**	**121.3%**	**0.026**
	3b	1322.3	1325.9	99.7%	0.97	79.2	77.56	102.1%	0.794
	3c	1599.07	1630.8	98.1%	0.858	87.3	95.82	91.1%	0.609

Table 19 ***Results in commercial fish species of alternative chain arrangement trials "Tridens", March 1999.***

T9903b		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<sole	3a	6.33	4.72	134.1%	0.265	0.65	0.51	127.5%	0.33
	3b	9.95	7.17	138.8%	0.066	1.02	0.73	139.7%	0.057
	3c	17.07	14.53	117.5%	0.745	1.71	1.46	117.1%	0.732
>sole	3a	**41.26**	**36.9**	**111.8%**	**0.029**	**9.13**	**8.01**	**114.0%**	**0.012**
	3b	39.77	41.07	96.8%	0.548	8.61	8.82	97.6%	0.66
	3c	59.2	55.2	107.2%	0.74	13.6	11.95	113.8%	0.606
<plaice	3a	124.7	95.9	130.0%	0.24	10.99	8.21	133.9%	0.233
	3b	341.93	304.43	112.3%	0.325	27.38	23.52	116.4%	0.199
	3c	520.4	539.73	96.4%	0.691	39.5	43.24	91.4%	0.589
>plaice	3a	21.85	24.65	88.6%	0.409	6.47	7.86	82.3%	0.063
	3b	31.5	31.47	100.1%	0.995	8.52	8.63	98.7%	0.927
	3c	27.73	24.4	113.6%	0.426	8.57	8.13	105.4%	0.619
<dab	3a	1068.5	918.73	116.3%	0.058	63.93	53.56	119.4%	0.058
	3b	953.8	1011.91	94.3%	0.449	50.48	53.22	94.9%	0.522
	3c	1043.73	1068	97.7%	0.897	45.8	50.95	89.9%	0.708
>dab	3a	88.43	76.23	116.0%	0.352	15.02	13.03	115.3%	0.319
	3b	**46.16**	**76.45**	**60.4%**	**0.023**	29.51	11.88	248.4%	0.439
	3c	25.6	37.07	69.1%	0.699	4.2	5.99	70.1%	0.676
<brill	3a	0	0	.	.	0	0	.	.
	3b	0	0	.	.	0	0	.	.
	3c	0	0	.	.	0	0	.	.
>brill	3a	0.26	0.21	123.8%	0.732	0.22	0.21	104.8%	0.942
	3b	0.04	0.16	25.0%	0.058	0.07	0.14	50.0%	0.226
	3c	**0**	**0.67**	0.0%	**0.038**	0	0.76	0.0%	0.124
<turbot	3a	**0**	**0.05**	0.0%	.	**0**	**0.02**	0.0%	.
	3b	0.12	0.08	150.0%	0.638	0.04	0.02	200.0%	0.503
	3c	0.27	0.27	100.0%	1	0.11	0.09	122.2%	0.904
>turbot	3a	0.52	0.52	100.0%	1	0.74	0.71	104.2%	0.948
	3b	1.02	0.63	161.9%	0.065	1.1	0.94	117.0%	0.703
	3c	0.8	0.8	100.0%	1	0.49	0.71	69.0%	0.631

Table 20 ***Results in commercial fish species of alternative chain arrangement trials "Tridens", March 1999 (continued).***

T9903b		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<whiting	3a	2.49	1.04	239.4%	0.751	0.03	0.01	300.0%	0.653
	3b	**16.34**	**2.23**	**732.7%**	**0.024**	**0.24**	**0.04**	**600.0%**	**0.035**
	3c	17.6	8.27	212.8%	0.461	0.18	0.08	225.0%	0.279
>whiting	3a	0.57	0.67	85.1%	0.645	0.08	0.1	80.0%	0.503
	3b	0.98	0.98	100.0%	1	0.13	0.13	100.0%	0.905
	3c	1.47	1.33	110.5%	0.374	0.2	0.18	111.1%	0.26
<cod	3a	0.1	0.16	62.5%	0.761	0.03	0.05	60.0%	0.656
	3b	0.16	0.08	200.0%	0.541	0.03	0.02	150.0%	0.716
	3c	.	.	.	.	.	.	.	.
>cod	3a	2.13	2.13	100.0%	1	5.23	5.7	91.8%	0.788
	3b	1.02	1.14	89.5%	0.699	2.38	2.17	109.7%	0.828
	3c	2.93	2.8	104.6%	0.854	8.03	8.01	100.2%	0.993

Table 21 ***Results in overall categories of alternative chain arrangement trials "Tridens", October 1999.***

T9910		**numbers/hour**				**kg/hour**			
category	exp	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
discards	4a	**24.75**	**16.96**	**145.9%**	**0.011**	**5.53**	**3.61**	**153.2%**	**0.003**
	4b	**22.93**	**35.35**	**64.9%**	**0**	**4.67**	**6.4**	**73.0%**	**0.001**
	4c	**9.85**	**16.78**	**58.7%**	**0.045**	2.36	2.66	88.7%	0.624
landings or	4a	**174.66**	**197.58**	**88.4%**	**0.039**	**48.46**	**54.66**	**88.7%**	**0.024**
>commercial	4b	**166.79**	**223.55**	**74.6%**	**0**	**43.16**	**56.28**	**76.7%**	**0**
	4c	**162.39**	**201.61**	**80.5%**	**0.009**	**42.81**	**51.6**	**83.0%**	**0.026**
bycatch	4a	**4.45**	**3.36**	**132.4%**	**0.014**	**2.26**	**1.4**	**161.4%**	**0.02**
	4b	8.38	11.16	75.1%	0.125	2.58	3.27	78.9%	0.161
	4c	1.01	1.13	89.4%	0.762	1.02	0.68	150.0%	0.286
<commercial	4a	**20.29**	**13.6**	**149.2%**	**0.021**	**3.26**	**2.21**	**147.5%**	**0.021**
	4b	**14.55**	**24.2**	**60.1%**	**0.001**	**2.09**	**3.13**	**66.8%**	**0.004**
	4c	**8.84**	**15.64**	**56.5%**	**0.041**	1.34	1.97	68.0%	0.137

Table 22 ***Results in commercial fish species of alternative chain arrangement trials "Tridens", October 1999.***

T9910		numbers/hour				kg/hour			
category	exp	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<sole	4a	**1.3**	**3.19**	**40.8%**	**0.023**	**0.15**	**0.36**	**41.7%**	**0.02**
	4b	**5.43**	**15.12**	**35.9%**	**0**	**0.58**	**1.64**	**35.4%**	**0**
	4c	**2.15**	**11.76**	**18.3%**	**0.009**	**0.24**	**1.3**	**18.5%**	**0.009**
>sole	4a	**22.36**	**31.83**	**70.2%**	**0.004**	**5.29**	**7.15**	**74.0%**	**0.009**
	4b	**49.92**	**93.65**	**53.3%**	**0**	**11.17**	**20.08**	**55.6%**	**0**
	4c	**54.45**	**101.13**	**53.8%**	**0**	**13.74**	**23.17**	**59.3%**	**0.001**
<plaice	4a	**17.32**	**8.69**	**199.3%**	**0.003**	**2.64**	**1.35**	**195.6%**	**0.003**
	4b	7.66	7.95	96.4%	0.878	1.17	1.21	96.7%	0.892
	4c	6.33	3.46	182.9%	0.29	0.98	0.53	184.9%	0.288
>plaice	4a	141.68	154.82	91.5%	0.169	**36.73**	**41.53**	**88.4%**	**0.021**
	4b	92.64	106.73	86.8%	0.041	24.12	28.6	84.3%	0.019
	4c	101.25	95.16	106.4%	0.486	24.83	24.33	102.1%	0.801
<dab	4a	0	0		0	0	0		0
	4b	0.33	0.17	194.1%	0.695	0.04	0.02	200.0%	0.699
	4c	0	0		0	0	0		0
>dab	4a	2.14	1.65	129.7%	0.275	0.46	0.39	117.9%	0.534
	4b	10.81	13.14	82.3%	0.13	2.54	2.92	87.0%	0.093
	4c	**1.01**	**0.36**	**280.6%**	**0.03**	**0.25**	**0.09**	**277.8%**	**0.023**
<brill	4a	**0**	**0.04**	**0.0%**	.	**0**	**0.01**	**0.0%**	.
	4b	0.06	0.1	60.0%	0.451	0.02	0.03	66.7%	0.38
	4c	0	0		0	0	0		0
>brill	4a	0.46	0.6	76.7%	0.484	0.47	0.74	63.5%	0.275
	4b	0.57	0.95	60.0%	0.017	0.45	0.75	60.0%	0.075
	4c	0.48	0.54	88.9%	0.859	0.47	0.51	92.2%	0.905
<turbot	4a	**0**	**0.04**	**0.0%**	.	**0**	**0.01**	**0.0%**	.
	4b	**0.02**	**0.03**	66.7%	0.667	**0.01**	**0.01**	1	0.693
	4c	0.06	0.06	100.0%	1	0.02	0.02	100.0%	0.962
>turbot	4a	1.26	1.19	105.9%	0.801	2.04	1.58	129.1%	0.359
	4b	2.19	2.23	98.2%	0.927	3.4	3.19	106.6%	0.729
	4c	0.78	1.19	65.5%	0.33	1.18	1.72	68.6%	0.506

Table 23 ***Results in commercial fish species of alternative chain arrangement trials "Tridens", October 1999 (continued).***

T9910		numbers/hour				kg/hour			
category	exp	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<whiting	4a	0	0		0	0	0		0
	4b	**0.06**	**0**		.	**0**	**0**		**0**
	4c	0	0		0	0	0		0
>whiting	4a	5.05	5.89	85.7%	0.474	0.63	0.72	87.5%	0.521
	4b	**10.27**	**6.65**	**154.4%**	**0.001**	**1.13**	**0.76**	**148.7%**	**0.001**
	4c	2.57	1.49	172.5%	0.064	0.32	0.19	168.4%	0.092
<cod	4a	1.68	1.65	101.8%	0.917	0.48	0.48	100.0%	0.981
	4b	0.98	0.83	118.1%	0.32	0.27	0.22	122.7%	0.34
	4c	0.3	0.36	83.3%	0.822	0.1	0.13	76.9%	0.808
>cod	4a	1.72	1.61	106.8%	0.733	2.85	2.55	111.8%	0.754
	4b	1.17	0.75	156.0%	0.164	1.51	0.75	201.3%	0.209
	4c	1.85	1.73	106.9%	0.824	2.02	1.58	127.8%	0.576

Table 24 *Composition of discards of 12m beam trawl with 21 parallel chains compared to standard 12m beam trawl with 20 ticklers.*

Week 40 - 1999 : 12 m bt.		NUMBERS			NUMBERS per haul				NUMBERS per haul				
P = 21 parallel tickler chains	n	SUM	SUM	**SUM**	Geometric means		**geom.**		Means from comparison of individual paired hauls				
S = standard 12 m beam trawl	hauls	P-net	S-net	**P / S**	P	S	**P/S**		**P/S**	S.E. (95 %)	mn-se	mn+se	t-test 95 %
Whelks *(Buccinum & Neptunea)*	10	1681	2115	**0.79**	13	27	**0.48**		**0.67**	0.38	0.30	1.05	
Quahog *(Arctica)*	18	103	1461	**0.07**	5	52	**0.07**		**0.09**	0.03	**0.06**	**0.11**	s
Cockle *(Acanthocardia)*	18	142	1796	**0.08**	6	78	**0.06**		**0.08**	0.03	**0.05**	**0.11**	s
Edible crab *(Cancer)*	19	57	59	**0.97**	3	3	**1.02**		**1.22**	0.31	0.91	1.52	
Masked crab *(Corystes)*	7	2446	1839	**1.33**	28	18	**1.25**		**2.43**	2.44	-0.02	4.87	
Norway lobster *(Nephrops)*	14	2355	1734	**1.36**	70	49	**1.41**		**1.86**	1.17	0.69	3.04	
Swimming crabs *(Liocarcinus)*	18	5606	3884	**1.44**	270	207	**1.21**		**1.43**	0.48	0.96	1.91	
Hermit crabs *(Pagurus)*	16	2180	3040	**0.72**	96	125	**0.64**		**1.12**	0.70	0.41	1.82	
Starfish *(Asterias)*	17	5978	4419	**1.35**	196	124	**1.44**	P>S	**1.68**	0.64	**1.04**	**2.32**	s
Sandstar *(Astropecten)*	14	67787	104347	**0.65**	809	1332	**0.59**		**0.85**	0.34	0.51	1.18	
Seamouse *(Aphrodyte)*	18	943	951	**0.99**	36	38	**0.94**		**1.54**	0.90	0.63	2.44	
ALL INVERTEBRATES	17	89278	125645	**0.71**	2543	3144	**0.81**		**0.89**	0.20	0.69	1.10	
INFAUNA species	17	75455	114242	**0.66**	1425	2109	**0.68**		**0.76**	0.19	**0.57**	**0.95**	s
EPIFAUNA species	17	13823	11403	**1.21**	679	592	**1.15**		**1.28**	0.32	0.97	1.60	
DISCARD FISH - numbers													
Plaice *(P. platessa)*	18	1259	1362	**0.92**	56	60	**0.96**		**1.27**	0.55	0.72	1.82	
Dab *(L. limanda)*	18	9357	13346	**0.70**	436	681	**0.64**		**0.70**	0.16	**0.54**	**0.85**	s
Whiting a.o. *(Merlangius* a.o.)	18	4549	2659	**1.71**	206	111	**1.86**	P>S	**2.65**	1.00	**1.64**	**3.65**	s
ALL DISCARD FISH	18	17348	19698	**0.88**	815	947	**0.85**		**0.87**	0.10	0.77	0.97	
DISCARDS WEIGHT (KG)		WEIGHT, KG			WEIGHT, KG / haul				WEIGHT, KG / haul				
Total Kg discards	19	1949	2416	**0.81**	104	127	**0.82**		**0.85**	0.11	**0.74**	**0.95**	sign.
Benthic invertebrates	17	655	917	**0.71**	29	39	**0.68**		**0.72**	0.14	**0.59**	**0.86**	sign.
Discard fish	18	1251	1241	**1.01**	66	65	**1.01**		**1.04**	0.15	0.89	1.19	
COMMERCIAL FISH													
Kg sole	19	144	200	**0.72**	7	10	**0.73**		**0.79**	0.17	**0.62**	**0.97**	sign.
Kg plaice	19	1036	1085	**0.95**	52	54	**0.96**		**1.00**	0.14	0.86	1.13	

Table 25 *Composition of discards of 12m beam trawl with 29 parallel chains compared to standard 12m beam trawl with 20 ticklers.*

Week 41 - 1999

P = 36 Parallel ticklerchains S = Standard 12 m beam trawl 17 paired hauls	Number hauls	SUM P-net	SUM S-net	**Sums P / S**	Geometric means P-net	S-net	**P / S**		P-net / S-net Mean values for individual paired hauls **P / S**	S.E. (95 %)	mn-se	mn+se	t-test 95 %
Species		TOTAL NUMBERS			NUMBERS per haul				NUMBERS				
Whelks a.o. *(Buccinum, Neptunea)*	15	294	582	**0.51**	5	12	**0.46**		**0.51**	0.11	**0.41**	**0.62**	s
Quahogs *(Arctica)*	15	107	615	**0.17**	4	31	**0.14**		**0.24**	0.19	**0.05**	**0.43**	s
Cockles *(Acanthocardia)*	16	84	570	**0.15**	4	28	**0.13**		**0.16**	0.06	**0.11**	**0.22**	s
Queen scallop *(Chlamys)*	10	79	86	**0.92**	2	3	**0.71**		**1.45**	1.26	0.19	2.71	
Edible crab *(Cancer)*	14	42	52	**0.81**	2	2	**0.86**		**1.06**	0.55	0.51	1.61	
Masked crab *(Corystes)*	11	105	181	**0.58**	10	14	**0.70**		**0.94**	0.79	0.16	1.71	
Norway lobster *(Nephrops)*	16	1417	1021	**1.39**	49	31	**1.58**		**1.95**	1.22	0.73	3.17	
Swimming crabs *(Liocarcinus)*	17	8422	5599	**1.50**	424	249	**1.70**	P > S	**1.91**	0.54	**1.37**	**2.45**	s
Hermit crabs *(Pagurus)*	17	972	1010	**0.96**	44	35	**1.24**		**2.35**	1.43	0.92	3.79	
Starfish *(Asterias)*	17	8446	5352	**1.58**	252	146	**1.73**		**2.12**	0.78	1.34	2.90	
Sandstar *(Astropecten)*	17	36890	42808	**0.86**	698	918	**0.76**		**0.82**	0.19	0.63	1.00	?
Seamouse *(Aphrodyte)*	16	326	428	**0.76**	17	17	**1.03**		**1.08**	0.37	0.71	1.45	
									P/S				
ALL INVERTEBRATES	17	57184	58304	**0.98**	2257	2274	**0.99**		**1.04**	0.16	0.88	1.20	
INFAUNA species	16	39223	46205	**0.85**	1191	1525	**0.78**		**0.83**	0.16	**0.66**	**0.99**	just
EPIFAUNA species	17	17961	12099	**1.48**	863	556	**1.55**	P > S	**1.67**	0.34	**1.32**	**2.01**	s
DISCARD FISH													
Plaice *(p.platessa)*	17	2712	2821	**0.96**	144	149	**0.97**		**1.01**	0.18	0.84	1.19	
Dabs *(L.limanda & Hippoglossoides)*	17	11085	14046	**0.79**	630	814	**0.77**		**0.80**	0.10	**0.69**	**0.90**	s
Whiting a.o. *(M.merlangius a.o.)*	17	3644	1923	**1.89**	181	88	**2.04**	P > S	**2.58**	1.04	**1.55**	**3.62**	s
ALL DISCARDFISH	17	19110	20751	**0.92**	1103	1209	**0.91**		**0.93**	0.09	0.84	1.02	
DISCARD WEIGHT, KG		WEIGHT, KG			WEIGHT, KG per haul				WEIGHT, KG : P/S				
Total Kg discards	17	1867	1845	**1.01**	108	107	**1.01**		**1.02**	0.08	0.94	1.10	
Benthic invertebrates	17	470	508	**0.93**	25	27	**0.93**		**0.97**	0.17	0.79	1.14	
Discard fish	17	1394	1320	**1.06**	81	77	**1.05**		**1.08**	0.12	0.96	1.20	

Table 26 ***Results in overall categories of alternative chain arrangement trials "Tridens", June 2000.***

T0006		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
discards	5a	438.89	420.22	104.4%	0.798	25.02	23.87	104.8%	0.691
	5b	745.22	669.51	111.3%	0.217	41.88	41.98	99.8%	0.974
landings or	5a	33.56	28.22	118.9%	0.316	6.66	6.23	106.9%	0.777
>commercial	5b	84.43	73.9	114.2%	0.189	14.67	13.39	109.6%	0.167
bycatch	5a	35.78	34.67	103.2%	0.875	**2.87**	**2.28**	**125.9%**	**0.021**
	5b	37.64	38.54	97.7%	0.929	2.79	2.59	107.7%	0.748
<commercial	5a	403.11	385.56	104.6%	0.795	22.15	21.59	102.6%	0.848
	5b	707.58	630.97	112.1%	0.172	39.09	39.4	99.2%	0.917

Table 27 ***Results in commercial fish species of alternative chain arrangement trials "Tridens", June 2000.***

T0006		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<sole	5a	**1.11**	**0.67**	**165.7%**	.	**0.12**	**0.07**	**171.4%**	.
	5b	2.29	1.44	159.0%	0.345	**0.24**	**0.09**	**266.7%**	**0.016**
>sole	5a	**10.22**	**6**	**170.3%**	**0.019**	**2.21**	**1.3**	**170.0%**	**0.009**
	5b	10.52	12.21	86.2%	0.417	2.5	3	83.3%	0.351
<plaice	5a	220.22	228	96.6%	0.89	12.52	12.47	100.4%	0.985
	5b	439.51	342.39	128.4%	0.241	25.05	23.49	106.6%	0.637
>plaice	5a	9.11	10	91.1%	0.787	2.07	2.36	87.7%	0.714
	5b	23.39	22.67	103.2%	0.749	5.7	5.34	106.7%	0.556
<dab	5a	177.78	151.78	117.1%	0.23	8.92	8.08	110.4%	0.408
	5b	247.62	276.13	89.7%	0.673	12.55	14.74	85.1%	0.541
>dab	5a	13.11	10.22	128.3%	0.238	2.2	1.88	117.0%	0.412
	5b	13.83	9.56	144.7%	0.479	2.2	1.71	128.7%	0.595
<brill	5a	1.78	2.22	80.2%	0.635	0.42	0.49	85.7%	0.737
	5b	0.96	1.62	59.3%	0.387	0.23	0.43	53.5%	0.301
>brill	5a								
	5b	0.12	0.12	100.0%	.	0.09	0.1	90.0%	0.298
<turbot	5a	0.22	1.11	19.8%	0.057	0.09	0.36	25.0%	0.081
	5b	0.54	0.42	128.6%	0.699	0.16	0.14	114.3%	0.831
>turbot	5a	0.22	0.44	50.0%	0.667	0.1	0.48	20.8%	0.413
	5b	0.84	0.36	233.3%	0.121	**0.9**	**0.32**	**281.3%**	**0.017**
<whiting	5a	**2**	**1.56**	**128.2%**	.	0.08	0.07	114.3%	0.56
	5b	16.3	8.48	192.2%	0.258	0.76	0.37	205.4%	0.238
>whiting	5a	0.89	1.33	66.9%	0.5	0.08	0.09	88.9%	0.733
	5b	35.66	28.92	123.3%	0.408	3.24	2.88	112.5%	0.574
<cod	5a	**0**	**0.22**	**0.0%**	.	**0**	**0.04**	**0.0%**	.
	5b	0.36	0.48	75.0%	0.611	0.09	0.13	69.2%	0.545
>cod	5a	**0**	**0.22**	**0.0%**	.	**0**	**0.11**	**0.0%**	.
	5b	0.06	0.06	100.0%	.	**0.04**	**0.03**	**133.3%**	.

Table 28 ***Effect of towing speed on sole and plaice of trials in April 1999.***

species	sole		plaice	
speed	**E nr/hr**	**C nr/hr**	**E nr/hr**	**C nr/hr**
3	**111.0**	**54.4**	**12.3**	**15.7**
4	**64.0**	**37.9**	**8.0**	**13.8**
5	**133.2**	**115.0**	**12.2**	**21.9**
speed	**E kg/hr**	**C kg/hr**	**E kg/hr**	**C kg/hr**
3	**17.3**	**9.1**	**3.4**	**4.9**
4	**10.6**	**6.8**	**2.4**	**4.1**
5	**21.6**	**19.2**	**3.7**	**7.2**

Table 29 ***Short term mortality of discard invertebrates during sorting on the conveyor belt.***

Gear type :		**CONVENTIONAL - 7m**			
Species:		hauls	total numbers	dead	**mortality %**
Masked crab	*Corystes*	3	199	127	**64**
Swimming crab	*Liocarcinus*	3	250	113	**45**
Hermit crab without shell	*Pagurus*	1	22	14	**64**
Hermit crab with shell	*Pagurus*	1	24	0	**0**
Edible crab	*Cancer*	16	35	6	**17**
Quahog	*Arctica*	6	15	12	**80**
Prickly cockle	*Acanthocardia*	11	210	68	**32**
Gear type :		**ELECTROTRAWL - 7m**			
Species:		hauls	total numbers	dead	**mortality %**
Masked crab	*Corystes*	3	204	90	**44**
Swimming crab	*Liocarcinus*	3	227	91	**40**
Hermit crab without shell	*Pagurus*	1	29	11	**38**
Hermit crab with shell	*Pagurus*	1	43	0	**0**
Edible crab	*Cancer*	10	24	6	**25**
Quahog	*Arctica*	8	19	13	**68**
Prickly cockle	*Acanthocardia*	9	83	34	**41**

Table 30 ***Results in overall categories of trials on electrical stimulation "Tridens", November-December1999.***

T9911		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
discards	6a	378.66	469.49	80.7%	0.113	**22.2**	**31.26**	**71.0%**	**0.026**
	6b	143.93	177.6	81.0%	0.135	**7.24**	**11.72**	**61.8%**	**0.024**
	6c	299.54	247.69	120.9%	0.375	13.1	18.58	70.5%	0.246
landings or	6a	**68.09**	**92.1**	**73.9%**	**0.021**	**16.35**	**20.98**	**77.9%**	**0.029**
>commercial	6b	**56.54**	**81.15**	**69.7%**	**0**	**13.43**	**21.61**	**62.1%**	**0**
	6c	54.86	57.3	95.7%	0.671	13.42	15.48	86.7%	0.183
bycatch	6a	67.57	55.17	122.5%	0.28	2.95	2.4	122.9%	0.609
	6b	31.78	24.83	128.0%	0.056	1.01	1.27	79.5%	0.173
	6c	**63.65**	**31.01**	**205.3%**	**0.009**	1.93	6.1	31.6%	0.28
<commercial	6a	311.09	414.32	75.1%	0.054	**19.26**	**28.86**	**66.7%**	**0.028**
	6b	112.15	152.77	73.4%	0.064	**6.23**	**10.45**	**59.6%**	**0.029**
	6c	235.89	216.68	108.9%	0.718	11.16	12.48	89.4%	0.602

Table 31 *Results in commercial species of trials on electrical stimulation "Tridens", November-December1999.*

T9911	numbers/hour					kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<sole	6a	**4.26**	**2.05**	**207.8%**	**0**	**0.44**	**0.22**	**200.0%**	**0.001**
	6b	**4.43**	**2.86**	**154.9%**	**0.01**	**0.43**	**0.28**	**153.6%**	**0.012**
	6c	**5.74**	**2.39**	**240.2%**	**0.001**	**0.54**	**0.25**	**216.0%**	**0.003**
>sole	6a	**27.06**	**23.04**	**117.4%**	**0.024**	6.22	5.48	113.5%	0.081
	6b	26.14	26.88	97.2%	0.652	6.06	6.48	93.5%	0.245
	6c	**35.49**	**22.98**	**154.4%**	**0.008**	**7.96**	**5.43**	**146.6%**	**0.019**
<plaice	6a	**109.77**	**214.24**	**51.2%**	**0.017**	**10.47**	**19.84**	**52.8%**	**0.021**
	6b	23.35	56.26	41.5%	0.058	**2.26**	**5.91**	**38.2%**	**0.039**
	6c	26.28	57.14	46.0%	0.191	2.35	5.05	46.5%	0.138
>plaice	6a	**30.97**	**51.77**	**59.8%**	**0.012**	**7.59**	**12.55**	**60.5%**	**0.007**
	6b	**19.31**	**43.53**	**44.4%**	**0**	**5.42**	**12.2**	**44.4%**	**0**
	6c	**16.62**	**28.11**	**59.1%**	**0**	**4.49**	**7.43**	**60.4%**	**0**
<dab	6a	185.49	177.5	104.5%	0.703	7.55	7.91	95.4%	0.683
	6b	66.1	83.76	78.9%	0.125	**2.83**	**3.85**	**73.5%**	**0.046**
	6c	190.09	152.16	124.9%	0.263	7.9	7.01	112.7%	0.378
>dab	6a	5.99	7.69	77.9%	0.503	0.89	1.21	73.6%	0.397
	6b	**3.44**	**7**	**49.1%**	**0.002**	**0.59**	**1.17**	**50.4%**	**0.001**
	6c	1.83	4.68	39.1%	0.249	0.3	0.73	41.1%	0.291
<brill	6a	0.35	0.32	109.4%	0.799	0.05	0.05	100.0%	0.932
	6b	**0**	**0.02**	**0.0%**	**.**	**0**	**0.01**	**0.0%**	**.**
	6c	**0.05**	**0**		**.**	**0.01**	**0**		**.**
>brill	6a	0.3	0.35	85.7%	0.748	0.32	0.3	106.7%	0.893
	6b	0.28	0.21	133.3%	0.394	0.26	0.19	136.8%	0.457
	6c	0.15	0.31	48.4%	0.363	0.16	0.35	45.7%	0.316
<turbot	6a	1.38	0.4	345.0%	0.279	**0.32**	**0.11**	290.9%	0.264
	6b	0.14	0.3	46.7%	0.251	0.04	0.09	44.4%	0.249
	6c	0.1	0.05	200.0%	0.5	0.04	0.02	200.0%	0.635
>turbot	6a	0.43	0.24	179.2%	0.205	0.74	0.27	274.1%	0.116
	6b	0.53	0.69	76.8%	0.362	0.5	0.97	51.5%	0.08
	6c	0.36	0.31	116.1%	0.818	0.48	0.39	123.1%	0.78

Table 32 ***Results in commercial species of trials on electrical stimulation "Tridens", November-December1999 (cont.)***

T9911		numbers/hour				kg/hour			
category	**exp**	**MOD**	**CON**	**MOD/CON**	**p**	**MOD**	**CON**	**MOD/CON**	**p**
<whiting	6a	9.58	19.58	48.9%	0.088	0.33	0.66	50.0%	0.16
	6b	18.04	9.31	193.8%	0.139	0.65	0.27	240.7%	0.116
	6c	**13.32**	**4.58**	**290.8%**	**0.001**	**0.29**	**0.12**	**241.7%**	**0.002**
>whiting	6a	**3.13**	**8.79**	**35.6%**	**0.031**	**0.3**	**0.74**	**40.5%**	**0.03**
	6b	**6.67**	**2.66**	**250.8%**	**0.044**	**0.49**	**0.22**	**222.7%**	**0.042**
	6c	0.41	0.61	67.2%	0.525	0.03	0.04	75.0%	0.546
<cod	6a	0.27	0.22	122.7%	0.594	0.09	0.06	150.0%	0.367
	6b	0.09	0.25	36.0%	0.213	0.02	0.04	50.0%	0.313
	6c	0.31	0.36	86.1%	0.854	0.04	0.02	200.0%	0.645
>cod	6a	0.22	0.22	100.0%	1	0.29	0.43	67.4%	0.477
	6b	0.16	0.18	88.9%	0.864	0.1	0.38	26.3%	0.167
	6c	0	0.31	0.0%	0.058	0	1.09	0.0%	0.179

Table 33 ***Discard composition of a 7m electro beam trawl compared to a 7m standard beam trawl. Sum of catches and mean values with standard errors of the ratio: catch electro divided by standard trawl (Mean EL./ST with S.E.)***

Invertebrates in discards			**NUMBERS**			**WEIGHT, KG**		**NUMBERS**					**WEIGHT, KG**				
Electro-net and standard net.		EL	STD	**EL/ST**	EL	STD	**EL/ST**	**EL/ST**					**EL/ST**				
22-23 Nov.99	n	sum N	sum N	sums	sum Kg	sum Kg	sums	Mean	S.E.	mn-SE	mn+SE	t-test	Mean	S.E.	mn-SE	mn+SE	t-test
Total number of hauls :	hls	10	10		10	10		E / S	E / S	E / S	E / S	95%	Kg	Kg	Kg	Kg	95%
Total discard weight	10				363	619	**0.59**						**0.61**	0.11	**0.50**	**0.72**	s
Whelks a.o. *(Buccinum)*	6	42	115	**0.37**	3	8	**0.34**	**0.45**	0.23	**0.23**	**0.68**	s	**0.70**	0.24	**0.46**	**0.94**	s
Queens *(Chlamys)*		8	10	**0.80**	0.3	0.5	**0.74**										
Other epifauna shellfish		4	12	**0.33**	0.2	0.3	**0.63**										
Quahog *(Arctica)*		6	5	**1.20**	1	0.3	**3.07**										
Cockle *(Acanthocardia)*		6	58	**0.10**	0.3	3	**0.11**										
Other infauna shellfish		1	7	**0.14**	0.1	0.2	**0.52**										
All Molluscs	6	67	207	**0.32**	4	12	**0.33**	**0.31**	0.12	**0.18**	**0.43**	s	**0.64**	0.16	**0.47**	**0.80**	s
Edible crab *(Cancer)*	10	15	16	**0.94**	7	10	**0.77**	**0.93**	0.25	0.69	1.18		**0.95**	0.44	0.51	1.39	
Masked crab *(Corystes)*	7	1876	2368	**0.79**	20	25	**0.82**	**0.72**	0.21	**0.52**	**0.93**	s	**0.89**	0.13	0.75	1.02	
Norway lobster *(Nephrops)*	4	34	79	**0.43**	2	6	**0.28**	**0.67**	0.57	0.10	1.24		**0.71**	0.23	**0.47**	**0.94**	s
Swimming crabs *(Liocarcinus)*	10	2550	4256	**0.60**	24	39	**0.60**	**0.58**	0.08	**0.50**	**0.66**	s	**0.71**	0.22	**0.49**	**0.93**	s
Hermits *(Pagurus)*	10	1329	1862	**0.71**	19	27	**0.72**	**0.97**	0.16	0.80	1.13		**0.97**	0.29	0.68	1.25	
Shrimps *(Crangon a.o.)*		25	58	**0.43**	0.1	0.6	**0.10**										
All Crustaceans	10	5829	8639	**0.68**	72	107	**0.67**	**0.71**	0.07	**0.64**	**0.78**	s	**0.78**	0.24	0.54	1.02	
Starfish *(Asterias)*	10	3003	4193	**0.72**	62	73	**0.85**	**0.90**	0.12	0.78	1.02		**1.03**	0.22	0.81	1.25	
Sandstar *(Astropecten)*	4	4955	19557	**0.25**	16	69	**0.24**	**0.20**	0.74	**-0.53**	**0.94**	s	**0.26**	0.43	**-0.17**	**0.69**	s
Brittle stars *(Ophiura)*	10	3147	5083	**0.62**	9	17	**0.50**	**0.61**	0.14	**0.47**	**0.74**	s	**0.76**	0.12	**0.64**	**0.88**	s
Sea potato *(Echinocardium)*		45	133	**0.34**	0.4	2	**0.27**										
Sea urchin *(Psammechinus)*	9	145	204	**0.71**	1	2	**0.54**	**1.80**	0.90	0.90	2.69		**0.92**	0.09	0.83	1.01	
All Echinoderms	10	11295	29170	**0.39**	89	164	**0.54**	**0.54**	0.12	**0.42**	**0.66**	s	**0.68**	0.23	**0.45**	**0.91**	s
Squid *(Loligo)*		5	6	0.83	1	0.5	**2.17**										
Sea mouse *(Aphrodyte)*	9	161	434	**0.37**	5	14	**0.35**	**0.44**	0.12	**0.31**	**0.56**	s	**0.68**	0.18	**0.51**	**0.86**	s
Sponges *(Halichondria)*		2	3	0.67	0.4	0.4	**0.89**										
Soft corals *(Alcyonia)*		0	8		0.0	0.3											
Sea anemonies *(Metridium)*		8	25	**0.32**	0.1	0.3	**0.45**										
All sessile epifauna	9	10	36	**0.28**	0.5	1		**1.63**	1.19	0.44	2.82		**0.97**	0.07	0.89	1.04	
ALL INVERTEBRATES	10	34558	76508	**0.45**	338	580	**0.58**	**0.55**	0.15	**0.39**	**0.70**	s	**0.66**	0.14	**0.52**	**0.80**	s
INFAUNA species	9	7130	22768	**0.31**	48	126	**0.38**	**0.50**	0.15	**0.34**	**0.65**	s	**0.55**	0.18	**0.38**	**0.73**	s
EPIFAUNA species	10	10237	15724	**0.65**	125	172	**0.73**	**0.69**	0.13	**0.56**	**0.82**	s	**0.79**	0.11	**0.68**	**0.91**	s

Table 34 ***Discard composition of a 7m electro beam trawl with one tickler chain compared to a 7m standard. Sum of all catches compared and mean values with standard errors of the ratio: catch electro trawl divided by standard trawl (Mean EL./ST with S.E.)***

Invertebrates in discards		**NUMBERS**			**WEIGHT, KG**				**NUMBERS**				t-test	**WEIGHT, KG**				t-test
ELECTRONET, week 48-1999		EL	STD	**EL/ST**	EL	STD	**EL/ST**		**EL/ST**				95%	**EL/ST**				95%
with one tickler chain	n	Sums	Sums	Sums	Sums	Sums	Sums		Mean	S.E.	mn-se	mn+se		Mean	S.E.	mn-se	mn+se	
Total number of hauls :	hls	8	8		8	8				t/Vn					t/Vn			
Total discard weight	8				357	392	**0.91**							**0.96**	0.18	0.78	1.14	
Whelks a.o. *(Buccinum)*	8	147	219	**0.67**	10	15	**0.69**		**0.70**	0.30	0.40	1.00		**0.85**	0.19	0.66	1.04	
Queens *(Chlamys)*		40	21	**1.90**	2	1	**1.83**											
Other epifauna shellfish		3	13	**0.23**	0.1	0.4												
Quahog *(Arctica)*		21	10	**2.10**	2	1	**1.97**											
Cockle *(Acanthocardia)*	6	99	165	**0.60**	4	9	**0.38**		**0.67**	0.83	-0.16	1.50		**0.63**	0.20	**0.43**	**0.83**	s
Other infauna shellfish			2			0.1												
All Molluscs	8	310	430		18	27			**0.74**	0.31	0.43	1.04		**0.78**	0.18	**0.59**	**0.96**	s
Edible crab *(Cancer)*	7	9	19	**0.47**	4	10	**0.38**		**0.65**	0.29	**0.36**	**0.95**	s	**0.69**	0.22	**0.47**	**0.90**	s
Masked crab *(Corystes)*	8	1114	878	**1.27**	10	9	**1.20**		**1.43**	0.55	0.88	1.98		**1.08**	0.29	0.78	1.37	
Norway lobster *(Nephrops)*		55	197	**0.28**	2	3	**0.48**											
Swimming crabs *(Liocarcinus)*	8	3111	2163	**1.44**	27	22	**1.22**	P > S	**1.44**	0.28	**1.15**	**1.72**	s	**1.15**	0.18	0.96	1.33	
Hermits *(Pagurus)*	8	1764	854	**2.07**	30	22	**1.35**		**2.86**	2.14	0.72	5.00		**1.58**	0.71	0.87	2.29	
Shrimps *(Crangon a.o.)*		5	2															
All Crustaceans	8	6058	4113		73	66		P > S	**1.52**	0.40	**1.12**	**1.91**	s	**1.14**	0.26	0.88	1.41	
Starfish *(Asterias)*	8	5932	5931	**1.00**	152	155	**0.98**		**1.02**	0.28	0.74	1.30		**1.00**	0.25	0.74	1.25	
Sandstar *(Astropecten)*	8	6963	19214	**0.36**	32	114	**0.28**		**0.51**	0.29	**0.22**	**0.80**	s	**0.49**	0.23	**0.26**	**0.73**	s
Brittle stars *(Ophiura)*	8	2465	1684	**1.46**	7	5	**1.40**		**2.18**	1.61	0.57	3.78		**1.18**	0.43	0.75	1.61	
Sea potato *(Echinocardium)*		37	119	**0.31**														
Sea urchin *(Psammechinus)*		3266	1696	**1.93**	18	12	**1.46**											
Luidia e.o.		92	4	**23.0**	0.4	<0.1												
All Echinoderms	8	18755	28648		208	286			**0.80**	0.32	0.48	1.12		**0.80**	0.25	0.54	1.05	
Squid *(Loligo)*		2	1	**2.00**	0.3	1												
Sea mouse *(Aphrodyte)*	8	420	487	**0.86**	10	14	**0.67**		**0.98**	0.27	0.71	1.25		**0.85**	0.17	0.68	1.02	
Sponges *(Halichondria)*		4	5	**0.80**	0.3	2	**0.19**											
Soft corals *(Alcyonia)*		105	127	**0.83**	3	3	**1.11**											
Sea anemonies *(Metridium)*		201	111	**1.81**	9	6	**1.40**											
All sessile epifauna	8	310	243	**1.28**	12	11	**1.14**		**1.46**	0.79	0.67	2.26		**1.08**	0.37	0.72	1.45	
ALL INVERTEBRATES	8	25855	33922	**0.76**	321	405	**0.79**		**0.88**	0.29	0.59	1.16		**0.81**	0.16	**0.65**	**0.97**	s
INFAUNA species	8	8859	21304	**0.42**	69	166	**0.42**		**0.54**	0.26	**0.28**	**0.80**	s	**0.54**	0.18	**0.35**	**0.72**	s
EPIFAUNA species	8	16996	12618	**1.35**	252	239	**1.06**		**1.37**	0.36	**1.01**	**1.72**	s	**1.04**	0.19	0.85	1.24	

Table 35 ***Catch efficiency of standard and alternative gears for benthic invertebrates, expressed as percentage of initial densities estimated from 20 t_0 catches with the Triple-D.***

Taxa	TS4	TE2	TL4	CS	CW2
Molluscs					
Artemis shell (*Dosinia lupina*)	0.0	0.0	0.0	0.0	0.0
Basket shell (*Gorbula gibba*)	0.0	0.0	0.0	0.0	0.0
Prickly cockle (*Acanthocardia echinata*)	1.1	0.6	0.6	1.2	0.4
Quahog (*Arctica islandica*)	8.4	0.1	0.7	0.0	0.0
Tower shell (*Turritella communis*)	0.0	0.0	0.0	0.0	0.0
Crustaceans					
Hermit crab (*Pagurus bernhardus*)	1.0	1.2	1.2	0.7	0.2
Norway lobster (*Nephrops norwegicus*)	1.5	6.3	6.0	5.2	3.0
Helmet crab (*Corystes cassivelaunus*)	1.9*	1.4	0.8	1.0	0.2
Echinoderms					
Sandstar (*Astropecten irregularis*)	7.0	1.5	2.2	2.0	0.7
Sea potato (*Echinocardium cordatum*)	0.0	0.0	0.3	0.3	0.0
Sea cucumber (Cucumaria elongata)	0.0	0.0	0.0	0.0	0.0
Polychaetes					
Seamouse (*Aphrodite aculeata*)	8.6	2.7	3.3	4.8	2.2

Gears: TS= standard beam trawl, TE= electrical beam trawl, TL= longitudinal chain beam trawl, CS= standard chain matrix, CW= window chain matrix

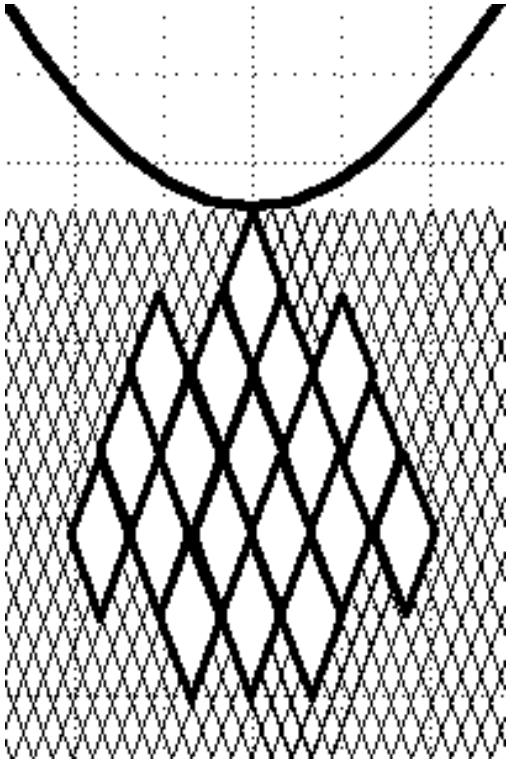

Figure 1 Configuration “Isis” TD1 and “Tridens” TD3.

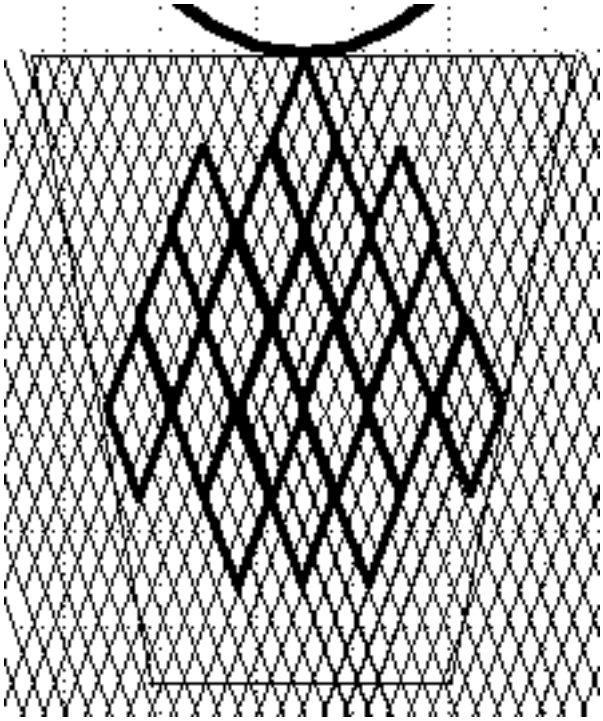

Figure 2 Configuration “Isis” TD2.

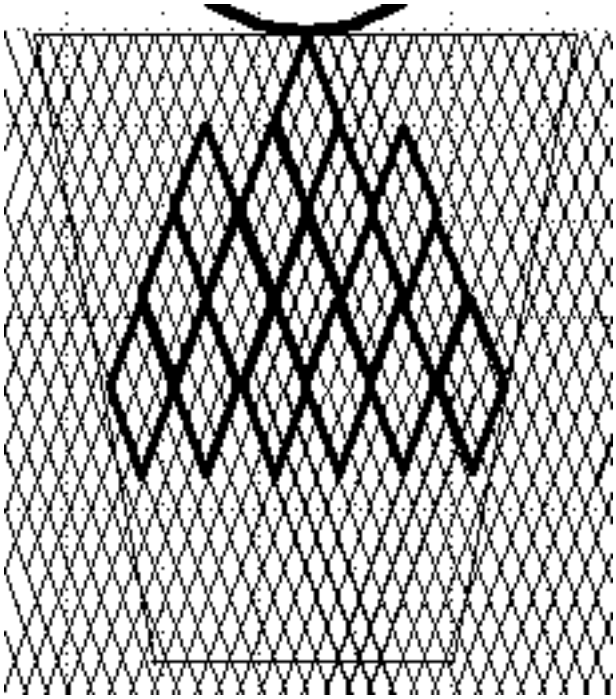

Figure 3 Configuration “Tridens” TD4.

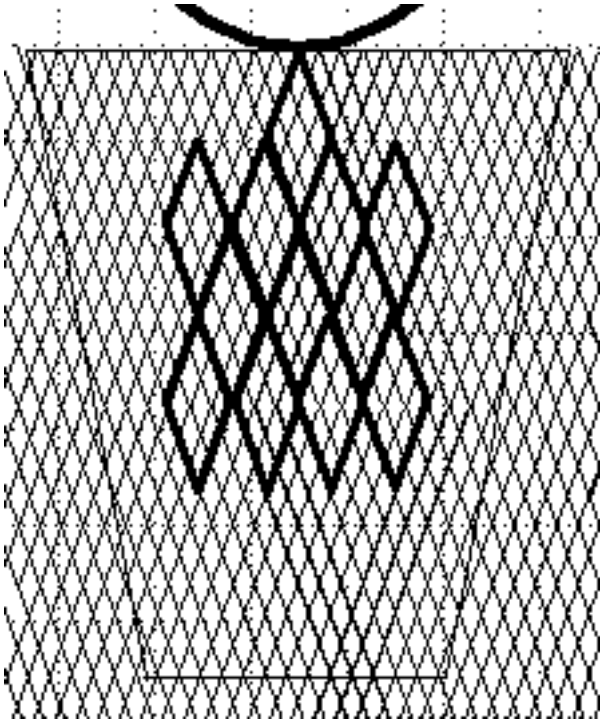

Figure 4 Configuration “Tridens” TD5.

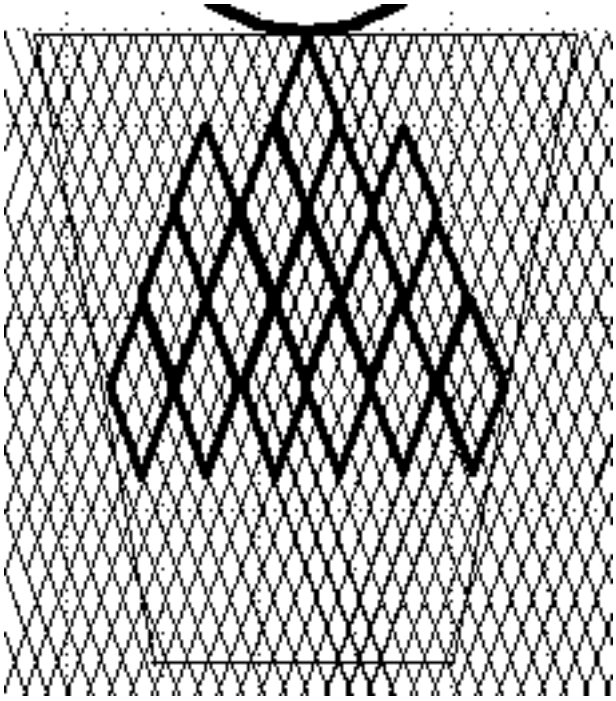

Figure 5 Configuration “Tridens” TD6.

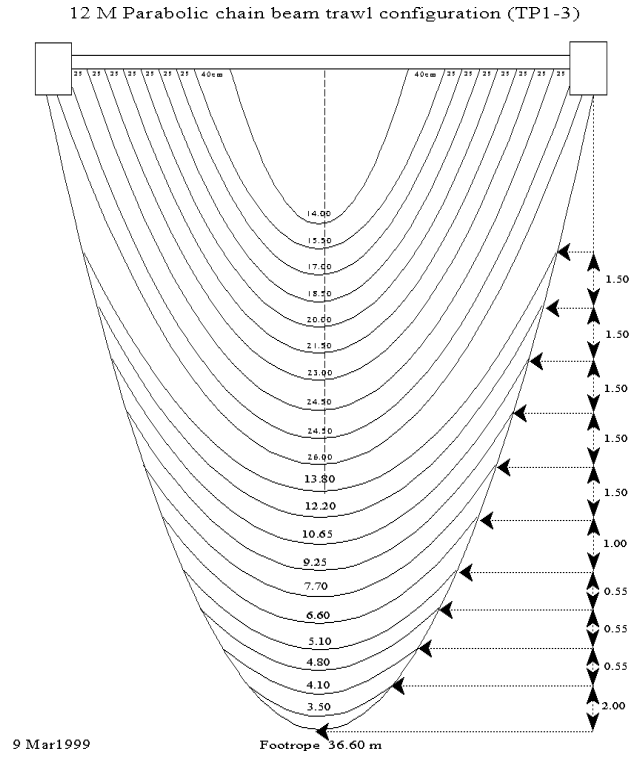

Figure 6 Parabolic chain alternatives (TP1-3) for 12m beam trawl

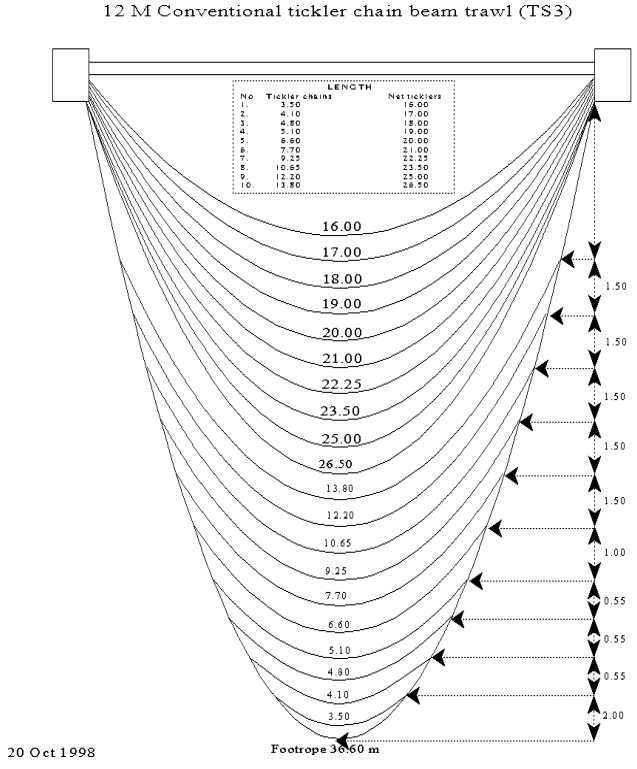

Figure 7 Conventional 12m tickler chain beam trawl (TS3)

Figure 8 Configuration “Tridens” TL1.

Figure 9 Configuration “Tridens” TL2.

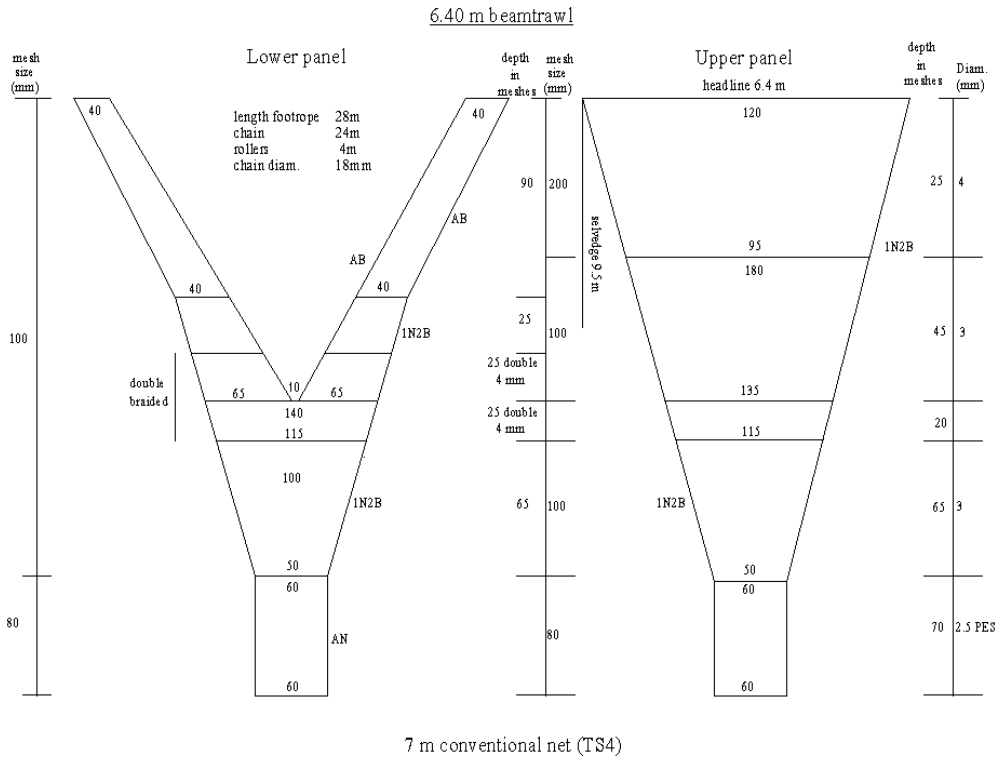

Figure 10 Conventional 7m tickler chain beam trawl (TS4)

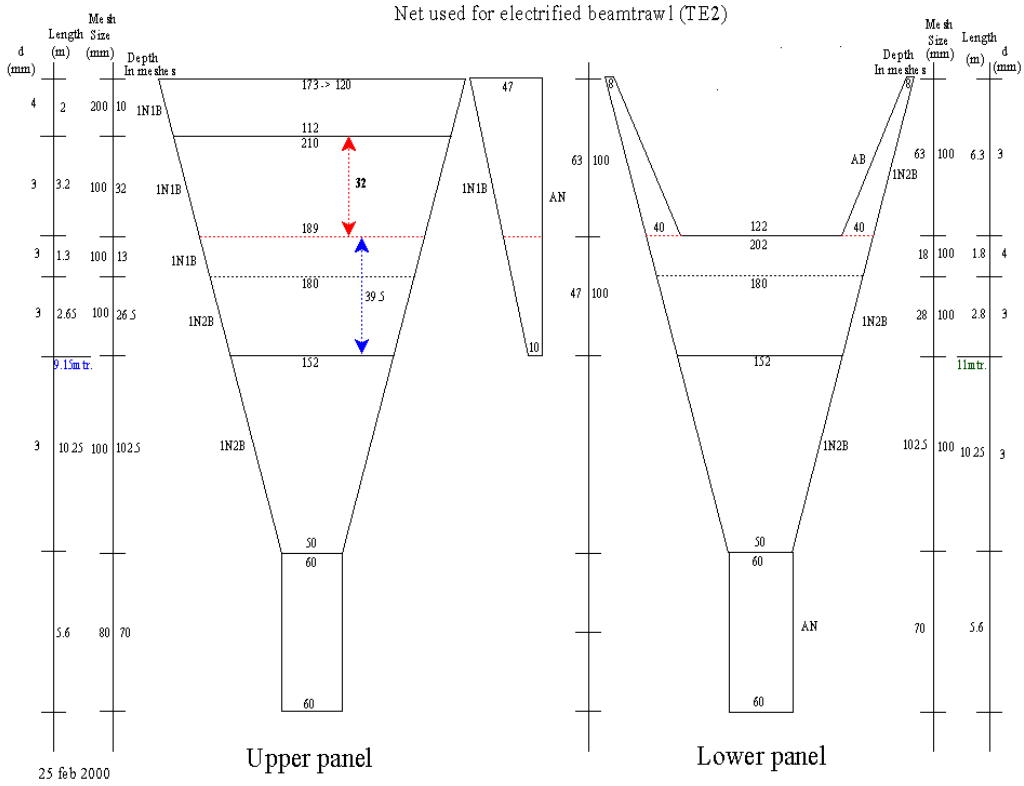

Figure 11 Net from Bakker (TE2) used on electrified beam

Figure 12 Electrotrawl Verburg

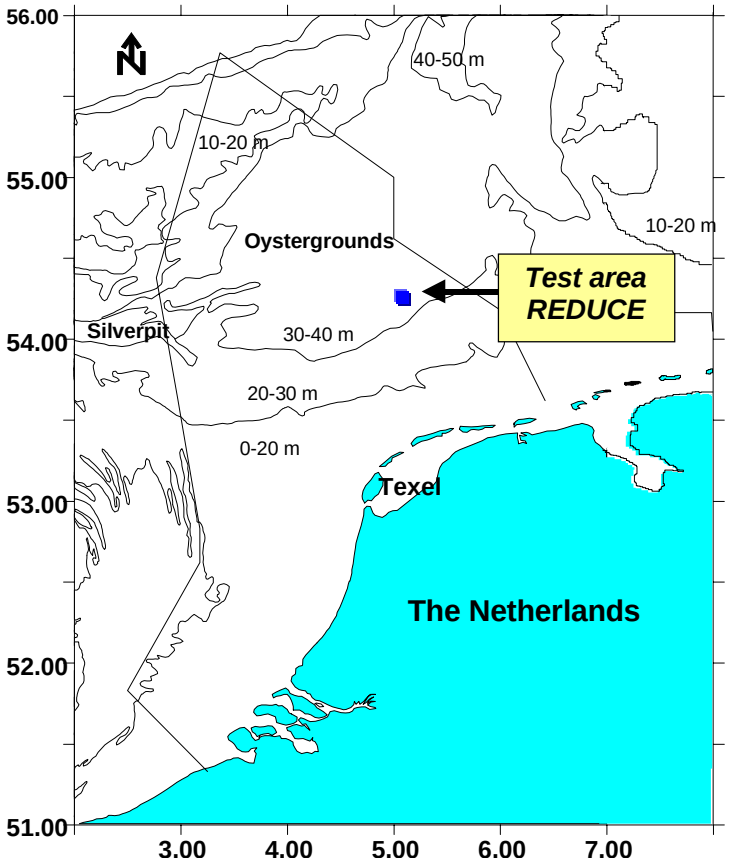

Figure 13 Area of trawl path mortality study

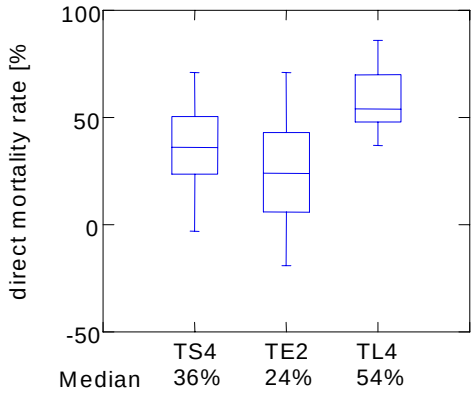

Figure 14 Box-Whisker plots of direct mortality of 15 abundant benthic species (fish and mobile epibenthos excluded).

The median, lower and upper quartiles (boxes) and whiskers are depicted. Gears: TE=electrical beam trawl, TS=standard beam trawl,. TL=longitudinal chain beam trawl

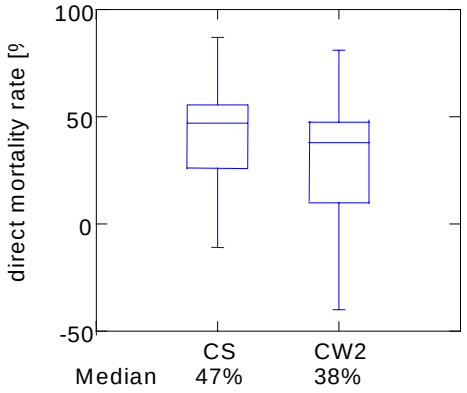

Figure 15 Box-Whisker plots of direct mortality of 15 abundant benthic species (fish and mobile epibenthos excluded).

The median, lower and upper quartiles (boxes) and whiskers are depicted. Gears: CW2=window chain matrix, CS= standard chain matrix.