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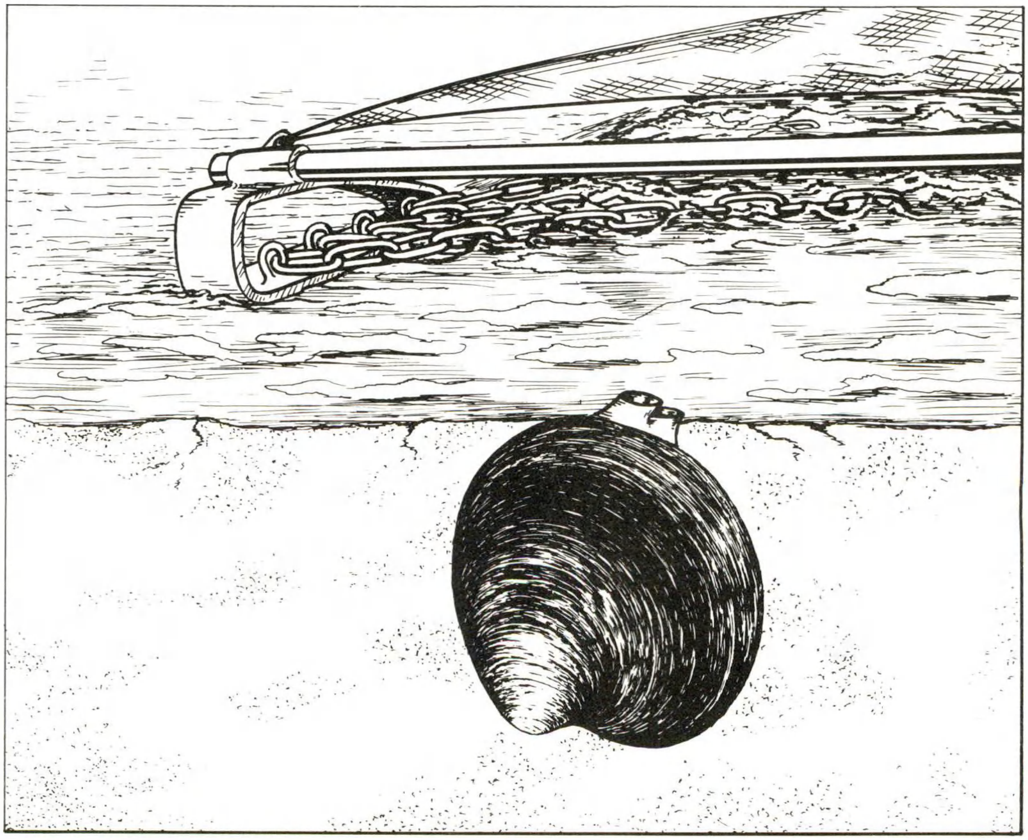
THE APPEARANCE OF SCARS ON THE SHELL OF *ARCTICA ISLANDICA* L. (MOLLUSCA, BIVALVIA) AND THEIR RELATION TO BOTTOM TRAWL FISHERY

R. Klein & R. Witbaard



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R. Klein, R. Witbaard

De inhoud berust gedeeltelijk op gegevens verkregen in het kader van een project dat met financiën van het Ministerie van Onderwijs en Wetenschappen en van Rijkswaterstaat in opdracht door het Rijk in BEON kader is verricht

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Department of Applied Scientific Research NIOZ (BEWON)
Department of Benthic Systems

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SAMENVATTING EN AANBEVELINGEN

INLEIDING

In 1992 is een pilot study uitgevoerd waarin onderzocht werd of het optreden van littekens op de schelp van de noordkromp (*Arctica islandica*) gerelateerd is aan visserij activiteiten.

De Noordkromp is een groot tweekleppig weekdier dat groeit door middel van jaarlijkse schelp-afzettingen (incrementen) en een hoge leeftijd kan bereiken. Dit en het feit dat deze dieren bij bodemvisserij beschadigd kunnen worden, gaf de aanzet te onderzoeken of het mogelijk is om de noordkromp te gebruiken als indicator voor visserij activiteit. Deze studie heeft voornamelijk betrekking op de nederlandse boomkorvisserij omdat die het belangrijkste aandeel heeft in de bodemvisserij op het bestudeerde gebied. Door voor een groot aantal noordkrompen de aanwezige beschadigingen te typeren en te kwantificeren, is getracht meer inzicht te krijgen in de relatie tussen bodemvisserij en schade aan noordkrompen. Bij deze analyse werden noordkrompen vergeleken afkomstig van de noordelijke, de centrale en de zuidelijke Noordzee.

Van een uit één vangst afkomstge selectie aan noordkrompen zijn de aan de buitenzijde zichtbare littekens gedateerd door het tellen van interne groeilijnen.

RESULTATEN

- Littekens en beschadigingen werden vooral aan de posterior ventrale zijde van de schelp aangetroffen. Hier bevinden zich de siphonen welke boven het sediment uitsteken wanneer het dier zich (net onder het bodemoppervlak) ingegraven heeft.
- In vangsten van de zuidelijke Noordzee werden hogere percentages beschadigde schelpen gevonden dan op de meer noordelijke stations.
- Het monster waarvan de littekens gedateerd zijn, bevatte geen onbeschadigde exemplaren. Door voor het hele monster het aantal littekens op te tellen en uit te zetten tegen de tijd werd van 1959 tot 1991 een stijgende trend gevonden, met pieken in 1978 en 1986. Voor de periode 1974 tot 1991 werden in totale monster voor elk jaar één of meer littekens aangetroffen.
- Een relatie tussen de beschadiging-frekwentie en de leeftijd van de noordkromp kon niet worden aangetoond.
- Uit schelpsterkte metingen blijkt dat grote noordkrompen relatief sterker zijn dan kleine.

DISCUSSIE

Uit de literatuur en eigen observaties blijkt dat noordkrompen door boomkorvisserij beschadigd kunnen worden. Littekens die veroorzaakt zijn door mechanische invloeden zoals visserij laten zich door hun lokale karakter goed onderscheiden van groeistoringen die veroorzaakt zijn door abrubte verandering van bijvoorbeeld salintiteit en temperatuur. Daarnaast lijkt het onwaarschijnlijk dat de hoge percentages beschadigde noordkrompen zoals gevonden in de zuidelijke Noordzee, veroorzaakt zijn door predatoren.

De trends in het aantal littekens per jaar kunnen dus een weerspiegeling zijn van veranderingen in de Nederlandse boomkorvloot die in het verleden zijn opgetreden. Er kan echter aan de hand van de bovengenoemde trends geen onderscheid gemaakt worden tussen kwantitatieve (grootte van de vloot en motervermogen) of kwalitatieve (vangst efficiëntie en keuze van visgronden) veranderingen van de visserijvloot.

Het feit dat gegevens over de visserij-intensiteit slechts beschikbaar zijn op basis van ICES kwadranten en dat het door ons gebruikte monster afkomstig is van een veel beperkter gebied belemmert de extrapolatie van de gegevens.

AANBEVELINGEN

De resultaten en conclusies die betrekking hebben op het dateren van littekens op schelpen van *Arctica* zijn gebaseerd op 48 exemplaren afkomstig van 1 lokatie in de Noordzee. Om de mogelijke relatie tussen de beschadiging-frekwentie en bodemvisserij intensiteit beter te kunnen funderen zijn er noordkrompen van andere lokaties nodig.

Er is zowel materiaal nodig uit de frekwent beviste zuidelijke Noorzee als uit het minder beviste noordelijke deel van de Noordzee. De op deze wijze verkregen gegevens kunnen vergeleken worden met gegevens over visserij intensiteit op deze gebieden. Daarvoor is meer gedetailleerde informatie over intensiteit en verspreiding van de visserij noodzakelijk dan op dit moment beschikbaar is.

Uit dit rapport komen aanwijzingen naar voren dat het mogelijk is om littekens op de schelp van de noordkromp als indikatie voor visserij-activiteit te gebruiken. De verschillen in het totaal aantal littekens per gebied zou gebruikt kunnen worden als controle op het effect van maatregelen die met betrekking tot bodemvisserij genomen zijn.

VERANTWOORDING/APPENDICES

Dit rapport is gebaseerd het artikel "Long term trends in the effects of beamtrawl fishery on the bivalve mollusc *Arctica islandica* L." (ICES Journal of Marine Science, geaccepteerd; Witbaard & Klein, 1993).

Achter in dit rapport zijn de figuren opgenomen die ten grondslag lagen aan de hier gepresenteerde studie.

SUMMARY AND RECOMMENDATIONS

INTRODUCTION

In 1992 a pilot study was conducted to investigate if the occurrence of scars on de shell of *Arctica islandica* was related to fishery activities. *Arctica islandica* is a large bivalve mollusc that has a high longevity and grows by means of annual shell-deposition (increments). This and the fact that *Arctica* can be damaged by bottom fisheries led to the idea of using *Arctica* as an indicator for bottom fishery activities. The results of this study mainly refer to beam trawl fishing as this is the most important type of fishing in the area studied. By analysing a large number of shells for the presence and nature of damage it was attempted to gain more insight into the relation between bottom fishery and damage on *Arctica*. Within this analysis shells from the northern, central and southern North Sea were compared.

From a sample of shells collected in one single catch the scars found on external shell surface were dated by counting internal growth lines.

RESULTS

- Damage and scars were mainly found on the posterior ventral side of the shell. This is the side where the siphons are located and which faces the sediment surface when the animal has buried itself.
- In samples from the southern North Sea higher percentages damaged shells were found than in samples from the more northerly sites.
- In the sample of which the scars were dated no specimens without scars were found. By adding the total amount of scars per year and plotting this against time an increasing trend was found with peaks in 1978 and 1986. For the period between 1974 and 1991 for every year one or more scars were found.
- A relation between damage frequency and age could no be determined.
- Shell strength measurements show that large *Arctica* are relatively stronger than small ones.

DISCUSSION

Field observations and literature data showed *Arctica* can be damaged by beam trawl fishery. By the local character of mechanical influences the effects of bottom fisheries can be distinguished from abrupt changes in for example temperature and salinity. It furthermore seems unlikely that the high percentages of damaged *Arctica* found in the southern North Sea are caused by predators.

Therefore, the trends found in the number of scars per year might be a reflection of changes that took place in the Dutch fishing fleet. However in respect to the above mentioned no distinction can be made between quantitative (size of the fleet and capacity) and qualitative (catch efficiency and choice of fishing grounds) changes of the fishing fleet.

The fact that known estimates of fishing intensities are based on ICES quadrants and the fact that the sample used for this study originated from a much more confined area, impairs extrapolation of the results.

RECOMMENDATIONS

The results and conclusions that concern the dating of scars are based on 48 shells from one location in the North Sea. Additional samples from other locations are needed to found the possible relation between the occurrence of scars on shells of *Arctica* and bottom trawling intensity. Samples from the frequently fished southern North sea as well as samples from the less fished northern North Sea are necessary to get more insight in the differences in scar occurrence per area.

The obtained results can be compared to known fishing intensities for these areas. For this comparison more detailed information about fishing intensities then available on this moment is needed. This report indicates that *Arctica islandica* can be used as an indicator for fishery activities. The differences in scar occurrence per area can be a possible tool to monitor the effects of measures that were taken concerning bottom fisheries.

ACKNOWLEDGEMENTS/APPENDICES

This report is based on the article Long term trends in the effects of beam trawl fishery on the bivalve mollusc *Arctica islandica* l. (ICES Journal of Marine Science, accepted; Witbaard & Klein, 1993). In the appendices additional figures are enclosed on which the study presented here was based.

1 INTRODUCTION

In the southern North Sea the most important fishing gear used is the beam trawl (DE GROOT, 1973; WELLEMAN, 1989; ANONYMOUS, 1992 D)(see appendix 4; figure 3). This gear consists of two sledges held apart by a beam to which the net is attached. In front of the net a variable number of tickler chains is present in order to increase the catch (DE GROOT, 1984; CREUTZBERG *et al.*, 1987; FONDS, 1991). A detailed description of the gear is given by BLOM (1990).

WELLEMAN (1989) gives a brief review of research carried out in the 1970's, to describe the effects of trawling on the seabed qualitatively. However, since then the Dutch fishing fleet has changed considerably. For example engine power, action radius, beam width, gear weight, fishing speed and the number of vessels (>300 HP) have increased (WELLEMAN, 1989; ANONYMOUS, 1992 A)(see appendix 4; figure 1,2). These changes initiated a renewed interest in research on the effects of fishing gear on the seabed and benthos of the North Sea. Most of this present-day research focuses on short-term or direct effects, such as penetration depth of the tickler chains (BERGMAN AND HUP, 1992), survival of by-catch (BERGMAN *et al.*, 1990; BERGMAN, 1992; FONDS *et al.*, 1992) or the change in sediment characteristics (LABAN AND LINDEBOOM, 1991).

Recent attempts to study long-term effects by comparing the fauna of "unfished" and fished areas are frustrated by the fact that even in these "unfished" areas trawl marks were found (BERGMAN, 1992).

In the present paper preliminary results obtained from using *Arctica islandica* as an indicator organism of the long term effects in fishing are presented.

Arctica islandica is a large bivalve mollusc which is widely distributed over the North Sea and northern Atlantic (NICOL, 1953). The animal lives buried in the sediment with its short siphons protruding from the sediment surface. It produces annual internal growth marks (TUREKIAN *et al.*, 1982) which can be made visible and used for age determinations (ROPES, 1985). Some specimens grow very old. ROPES (1985) reported that 100 year old specimens are frequently found in the population he studied. Growth is rapid for the first 15 to 20 years, then it slows down dramatically (WITBAARD AND DUINEVELD, 1990; ROPES, 1985).

WITBAARD AND DUINEVELD (1990) discussed the possible use of the annual growth marks of *Arctica* to evaluate the status of the benthic environment. The present study deals with such an application. Because repeated damage was regularly found, the question was raised if *Arctica islandica* could be used as an indicator species to study the effects of beam trawling on the benthic environment.

The following aspects were considered:

1. Description of damage and damage patterns in *Arctica* shells, to see if there is any systematic pattern possibly caused by fisheries.
2. Dating of externally visible scars by using growth lines with the aim to estimate the frequency of the bottom disturbance and try to relate this to any trend in fishing intensity.

2 MATERIAL AND METHODS

2.1 DAMAGE PATTERNS

Between March and December 1991 about 1700 empty shells were collected from 146 stations in the North Sea. These shells were analysed on the presence, degree and position of damage.

To study the position of the injuries the shell was divided into 4 parts of equal size; anterior dorsal, anterior ventral, posterior ventral and posterior dorsal. The post. ventral side is where the siphons are located (see figure 1). Damage was assigned to one of the four categories according to the position of the major area of damage. Shells of which more than 50% was missing were treated as a separate group because the location of the damage could not be determined.

The relative size of damage of each shell (in percentage) was estimated to classify it into categories ranging from shells of which more than 50% was missing to undamaged. Scars originating from previous encounters were recorded separately. Main categories distinguished here were: recuperated cracks and a bulbous greyish thickening of the internal shell layers caused by the enclosure of sediment within the calcium carbonate.

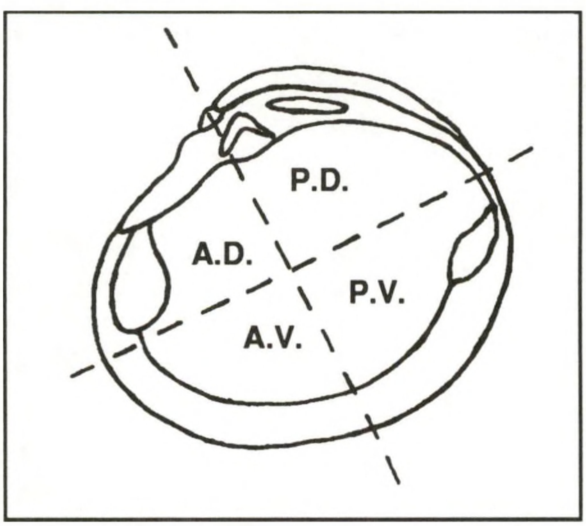

Figure 1: A right hand valve of *Arctica islandica* subdivided in four equal sized areas. The siphons are located at the post ventral margin. This side is oriented upwards at the sediment water interface. P.D. Posterior dorsal, P.V. Posterior ventral, A.D. Anterior dorsal, A.V. Anterior ventral.

2.2 GROWTH LINES

On 4 October 1991 a sample of 52 living *Arctica* was collected from the catch of a commercial beam trawler at location: 54.03 N., 06.18 E. After freezing the animals to death, they were carefully cleaned.

A drawing was made of each shell in which the position and size of scars were recorded. Observed scars were arranged into categories according to their position mentioned above. Then the left-hand valves were embedded in epoxy resin (polypox, THV 500, harder 125) to facilitate further processing, i.e. sawing along mapped scars. The obtained sections were ground, polished and etched in order to make acetate peels (KENNISH *et al., 1980*). These peels were photographed by means of light microscopy. Recognition and dating of the scars were done by comparing the drawings, photographs and original shell sections.

2.3 SHELL STRENGTH

The idea that shell strength is size dependent was tested. The sample used was collected from the SE North Sea at 53.52 N., 4.59 E. From the sample four groups were formed according to shell height. The shell heights within these groups were approximately 20, 40, 60 and 80 mm. After removal of the soft tissue, the shells were dried at room temperature for one week.

To estimate the shell strength the maximum force needed to crush a shell was recorded with an automated material testing system (INSTRON corp. series IX 1.04). The force was applied on a maximum of 0.8 mm^2 shell surface at the point of maximum valve convexity. The shell was kept in place by a piece of plasticine.

3 RESULTS

3.1 DAMAGE PATTERNS

The ratio of undamaged to damaged doublets is given in figure 2. Only 10% of the empty doublets from the SE North Sea were undamaged. The percentage of damaged doublets was about 1.5 times higher than found for the more northern areas.

A similar trend was found when the size of the damage was expressed as a percentage of the missing shell material. The samples from the central and northern North Sea showed a lower percentage of damage in the categories 5-25%, 25-50% and >50% missing. The category <5% did not differ between areas studied. (see appendix 1; figure 2, 3)

In all geographical areas most damages were situated on the post. ventral side of the shell. In the northern and central North Sea this accounted for about 50% while in the SE North Sea 80% of the damages were found on the post. ventral side.

Other shell parts were less frequently damaged. Within the SE North Sea only 15% of the damages were found at the ante ventral side.

In both groups (shells caught empty and alive) about 90% of the scars were found on the posterior shell side (see appendix 1; figure 4).

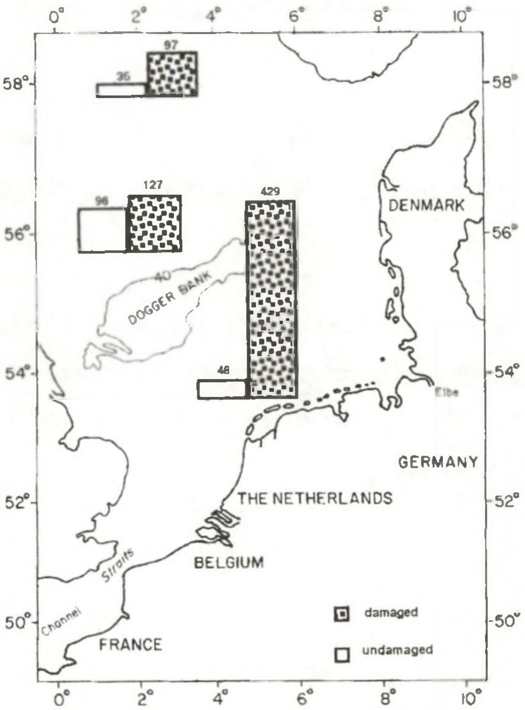

Figure 2. For three areas in the North Sea, the empty caught doublets are subdivided into damaged and undamaged. Above each bar the number of doublets is given.

3.2 GROWTH LINES

Of the 52 shells collected, 4 showed chaotic growth line patterns so they were excluded from further analyses.

The sample consisted of at least three age groups: 11, 12 and 18 years old. Within the sample the number of shells older than 18 years was too small to define any age group (see appendix 2).

The oldest animal found was 33 years old, hence offering the possibility to back-dating to 1959. There was not a single specimen without scars. One 19-year-old animal had no less than eight scars.

Figures 3 and 4 illustrate the appearance of scars in shell sections. Two types were distinguished:

Type I. The former shell margin does not show any sign of breakage. Only soft tissue has been damaged which causes a depression in the shell surface that delineates pre- and post damaged growth (figure 3 C).

Type II. The former shell margin is demolished. Sometimes shell fragments clinging onto the shell are still present. Because the shell margin which supported the mantle was removed, post damage growth is resumed at a lower level causing a dip in de shell. This dip may be visible over a prolonged growth interval (figure 3 D).

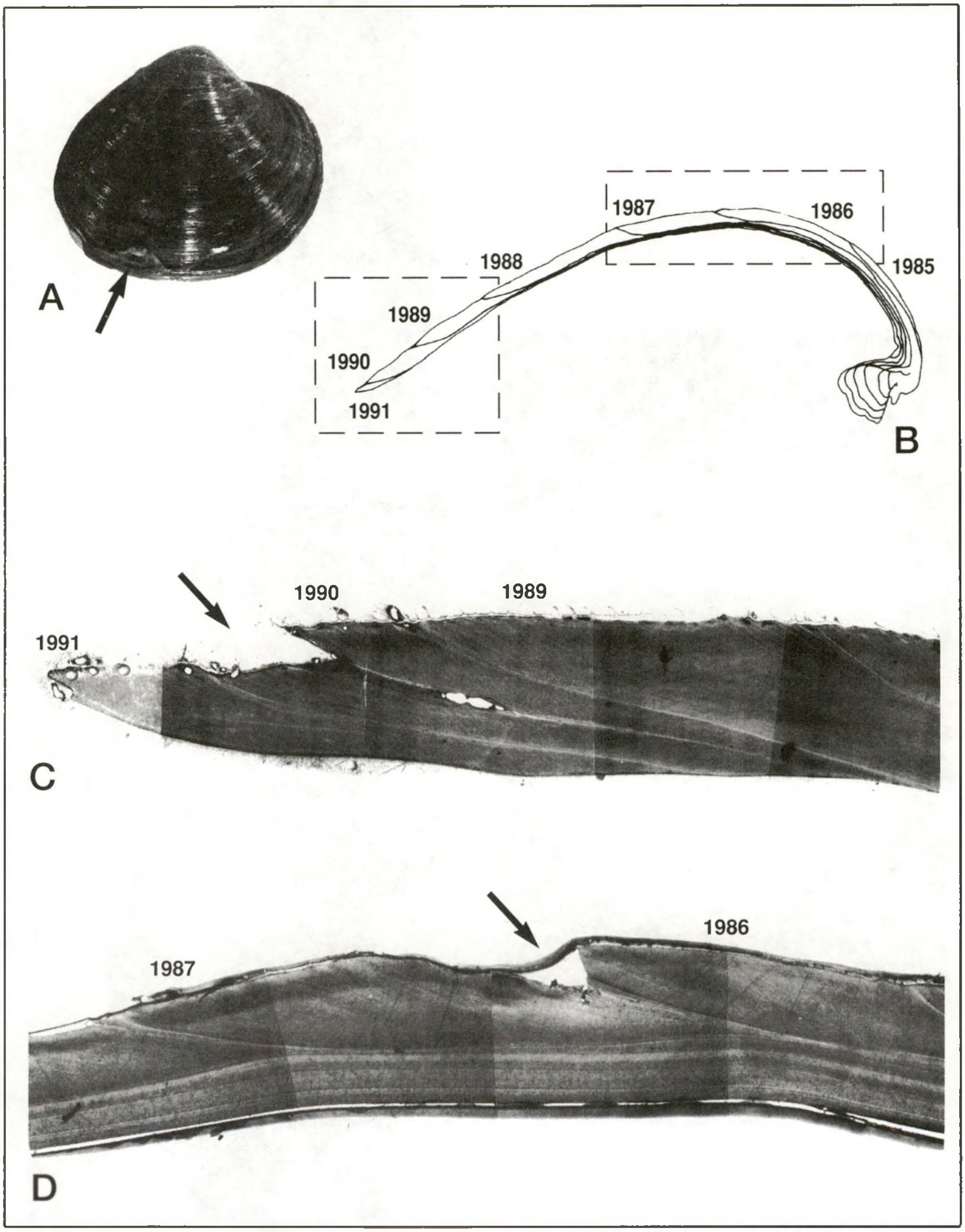

Figure 3: A: The appearance of a scar on the external post ventral shell side, together with two samples of the appearance in a cross section (acetate peel) ; B: Schematic drawing of a cross section showing the outline of photos C and D. C: The former shell margin has been broken (arrow). D: A clear dip in the shell is found, but no definite signs of a broken shell margin is visible.

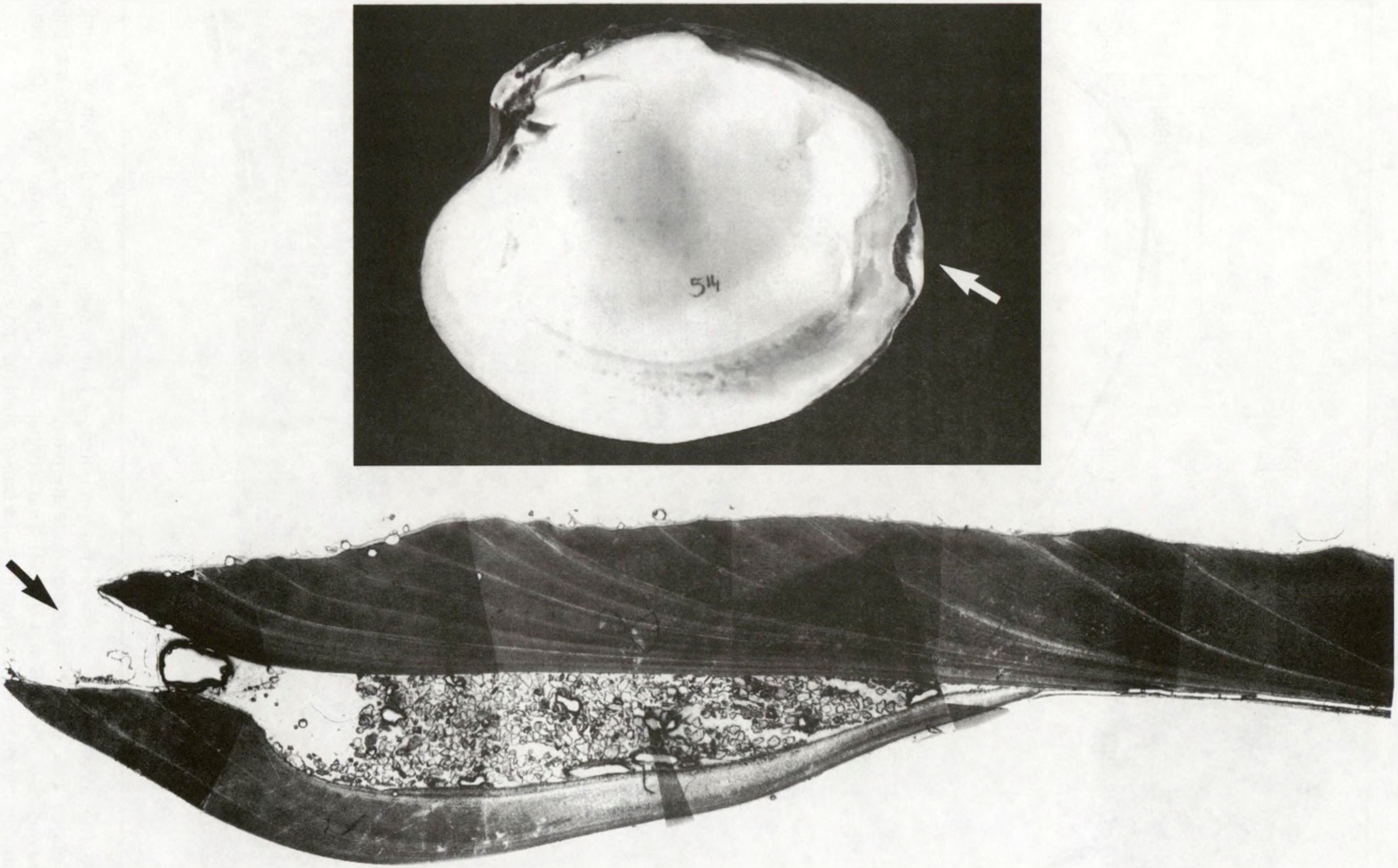

Figure 4: Between the internal shell layers the greyish thickened ventral shell margin can be seen. Sand is enclosed in the shell. B: The appearance in a cross section.

Both types of injury often occur in combination with the enclosure of sand grains within the shell material (figure 4). Sometimes complete aggregations of sand are present. The periostracum may or may not be present over the injury.

Figure 5 illustrates the frequency of scars (damaged increments) present in each year relative to the total number of shells studied for that year. Scars were found for all years between 1974 and 1991. For the period 1959-1973 damage was only found in 1967 and 1971.

There is an upward tendency discernible in the occurrence of scars per year over the total time interval.

Abrupt increases can be recognised for the years 1976 and 1986. Mean values were calculated for the periods delimited by those years. For the period 1959-1975, 1976-1985 and 1986-1991, the means were 2.0% (± 4.1), 17.3% (± 5.1) and 38.2% (± 8.9) respectively. All differences observed were significant (H-test, P≤ 0.001).

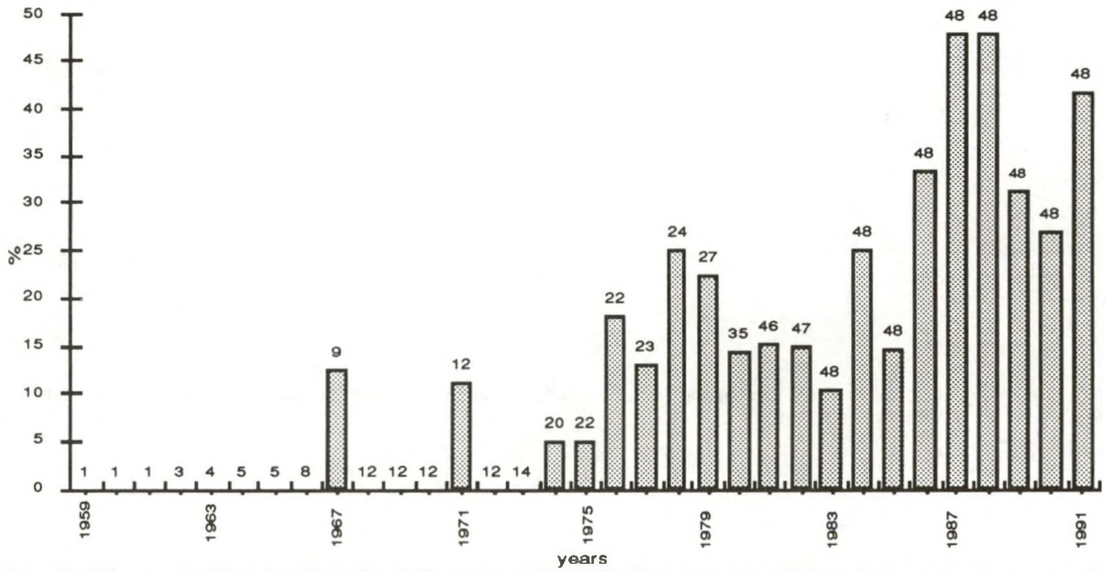

Figure 5: Occurrence of damage in *Arctica* shells for the period 1959-1991. Each bar represents the relative occurrence of scars (damaged increments) per year. The number of shells with a scar in a certain year is given as a percentage of all shells studied for that year. The total number of shells is given above each bar.

3.3 SHELL STRENGTH

Figure 6 shows that shell strength increases with size (see appendix 3). Mean forces to crush shells from the smallest and largest categories were 0.3 (± 0.06)kN and 0.8 (± 0.3)kN. Only the category with the smallest shells (20 mm) differed significantly from the other categories. The other categories did not differ from each other (H-test, P≤ 0.05).

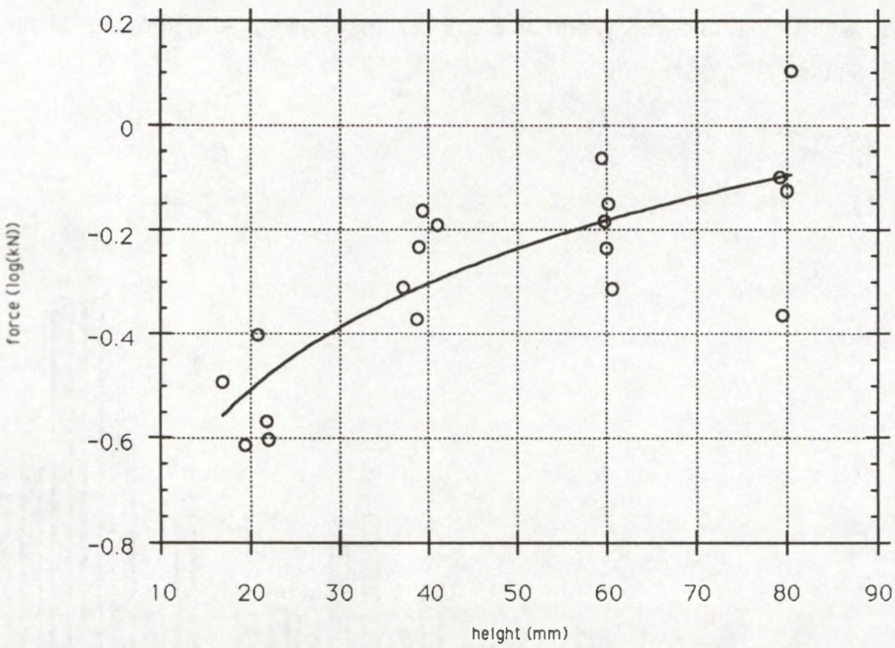

Figure 6: The relation between shell height and the force needed to crush it. Through the points a logarithmic regression is fitted; y= -1.4+ 0.7 log(X) r= 0.8 (p<0.05)

4 DISCUSSION

Direct evidence that *Arctica islandica* is influenced by fisheries came from FONDS (1991), FONDS *et al.* (1992) and own observations. FONDS (1991) reported that up to 90% of *Arctica* caught by a commercial trawler were severely damaged. His estimate for mortality of these shells ranged from 74 to 90%. He demonstrated that shells are damaged aboard as well as during the process of fishing.

Both the number of damaged shells and the total number of shells caught increases when tickler chains are used. The mean number of damaged shells was 74% with ticklers versus 27% without (FONDS, 1991).

The destructive effect of bottom trawling is also illustrated by the low numbers of undamaged shells found in the heavily fished SE North Sea (see appendix 4; figure 3). In more northern areas about four times as many undamaged shells were found (figure 2).

Estimates for the penetration depth of the tickler chains vary depending on bottom type WELLEMAN (1989). These estimates are based on direct experimental evidence (MARGETTS AND BRIDGER, 1971; BRIDGER, 1972) as well as on the occurrence of certain infaunal species in the catch. BERGMAN AND HUP (1992) estimated in this way a penetration depth of 6 cm in hard sand.

Stones can be dug out by tickler chains (BRIDGER, 1970; MARGETTS AND BRIDGER, 1971). *Arctica* may be dug out in the similar way.

These observations illustrate the vulnerability of *Arctica* to bottom trawling. Even ticklers only moving over the sediment surface can explain the damage pattern observed. This is illustrated by the high percentage of post. ventral damage (siphon side) found (see appendix 1; figure 1, 3, 4).

CADDY (1968) observed that sand was pushed into the shell of *Placopecten magelanicus* by the passage of a dredge. The greyish thickening (sand enclosures in the calcium carbonate) found in *Arctica* shells may be explained by a similar process, in this case possibly caused by the passage of a trawl.

Abrupt physical changes, for instance temperature, may cause growth disturbances (ROPES *et al.*, 1984) comparable to the scars caused by fisheries. In this case the whole shell metabolism is influenced causing a growth disturbance which is visible as a dip along the whole increment (KENNISH, 1980). This is in contrast to growth interruptions caused in a mechanical way for example by bottom trawling, which can be distinguished by their local character and mainly posterior position. There is, however, very little current research on the effects of physical disturbances on benthos (ANONYMOUS, 1992 B), and it is therefore difficult to estimate its significance.

Predators may also damage *Arctica* shells but it is unrealistic to assume that damage by for instance lobsters can explain the mass occurrence of damaged shells in the SE North Sea. Despite its near absence in this area it was tested whether a lobster (*Homarus americanus)* was able to open living *Arctica* . After series of repeated trials it succeeded in opening a 7 cm high shell. However the fractures observed on the shell were irregular while fractures on shells from the SE North Sea are mainly straight and sharp. The damage caused by the lobster were furthermore not limited to the post. ventral side of the shell. ARNTZ AND WEBER (1970) also demonstrated that cod (from the Baltic) was not able to crush *Arctica* shells larger then 4 cm. Because *Arctica* from the North Sea have thicker shells than those from the Baltic a great impact by cod in the North Sea is not expected.

Bottom trawl activities may be reflected in the age-frequency distribution of the *Arctica* population. In the SE North Sea juvenile shells (1-4 cm high) are rarely found, while spat (1-2 mm high) and full grown shells (6-7 cm high) are more regularly found (own observations). This odd size distribution can be explained by the difference in shell strength as presented in figure 6. The results found by RUMOHR and KROST (1992), however, suggest a contradictory effect of an otter trawl. They found higher percentages of damaged shells with increasing shell size. It is unknown whether this has to do with any specific action of the otter trawl.

The observed increase in the occurrence of scars since 1972 may be explained by developments in the fishing fleet initiated by the European policy on fisheries in 1957 (see appendix 4; figure 1, 2). This policy aimed at the improvement of the economic position of the fisheries. Despite measures that have been taken since the early eighties to limit the overall fishing capacity, the result has been a net increase of this capacity (ANONYMOUS, 1992 C).

This was caused by both structural changes within the fishing fleet and the gear used (see appendix 4). In the period 1972-1990 total engine power increased from approximately 250.10^3 to 600.10^3 HP (ANONYMOUS, 1992 A), which was mainly caused by the increase of the number of vessels larger then 1500 HP. These structural changes have led to higher fishing speeds, a wider range of action and qualitative changes of the fishing gear (larger beam width and gear weights). The pattern observed in figure 5 may be a reflection of these general changes (see appendix 4). Whether the increase in occurrence of scars per year is caused by the overall increase of fishing capacity or a redistribution of the fishing fleet in space and time cannot be said. Known estimates for the above mentioned redistribution concern areas of approximately 3400 km^2 (ICES quadrants). The results presented in figure 5 have been based on a sample area from which the surface is approximately 1/1000 of such an ICES quadrant, so a comparison is hard to be made.

RIJNSDORP *et al.* (1991) described that within an ICES quadrant the fishing intensity may be heterogeneously distributed. However time series of the distribution of fishing effort on these scales are lacking.

Dating scars in *Arctica* may be a possible way to reconstruct such time series. Figure 5 shows for instance that the study site has been trawled each year since 1974.

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APPENDICES

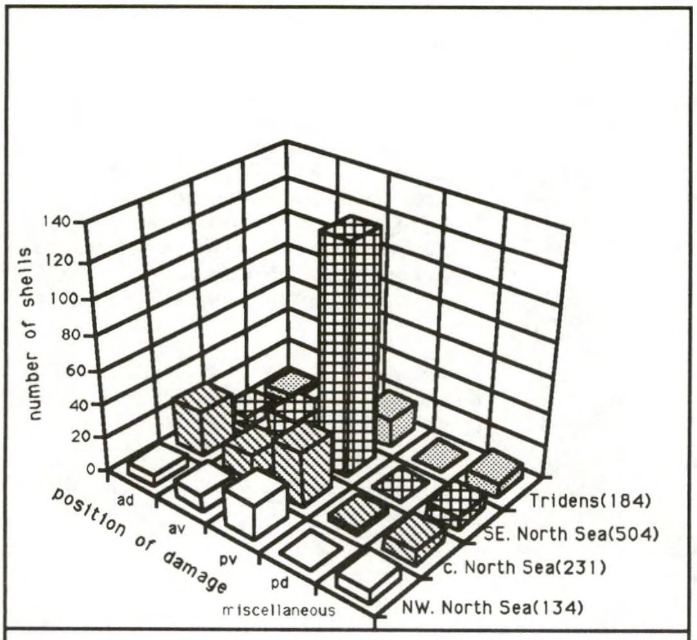


Figure 1: Position of damage on *Arctica* shells. All sampled stations are grouped into three separate areas. A sample collected by means of commercial gear with RV. Tridens is treated separately. The total number of shells within one group is denoted between brackets. The position of the scars is abbreviated as mentioned in the text.

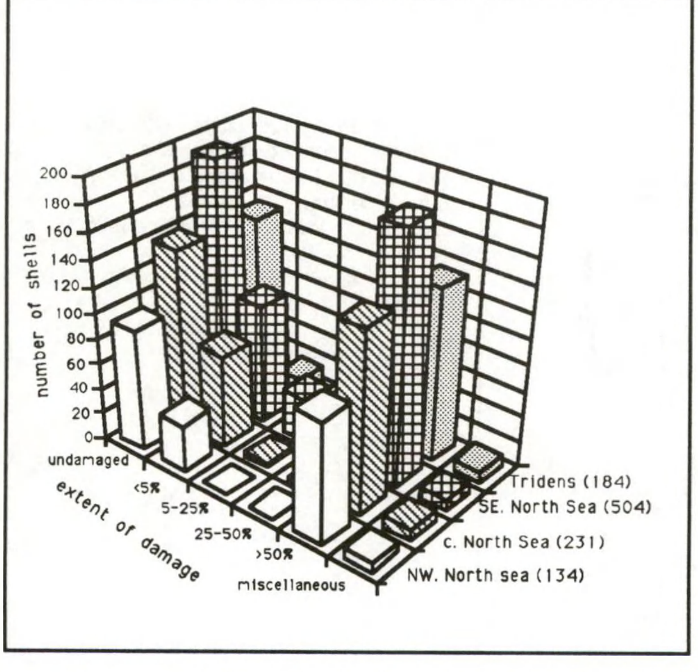


Figure 2: Extent of damage on *Arctica* shells. All sampled stations are grouped into three separate areas. A sample collected by means of commercial gear with RV. Tridens is treated separately. The total number of shells within one group is denoted between brackets.

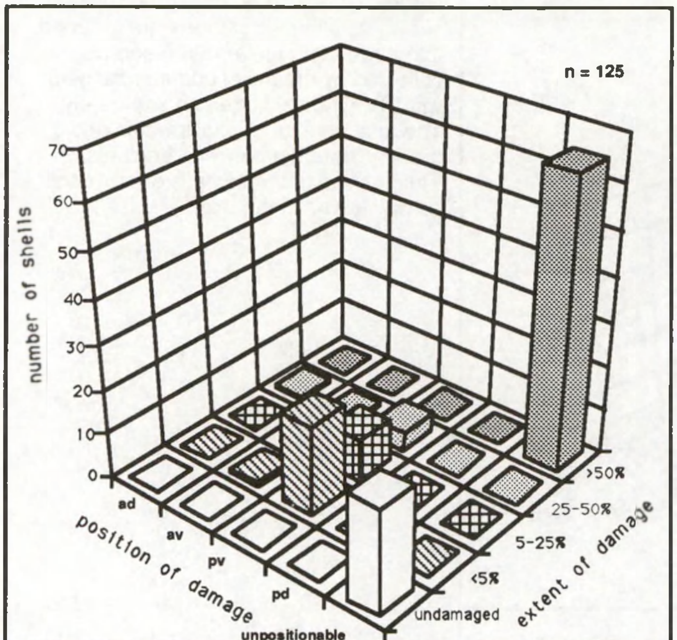


Figure 3: Direction and extent of damage. From the group of shells from the SE North Sea a random sub-sample was taken to see if the pattern observed in the overall picture (appendix 1; figure 1, 2) was based on a homogeneous distribution. The damages found on these shells were categorised the same way as before. The position of the scars is abbreviated as mentioned in the text.

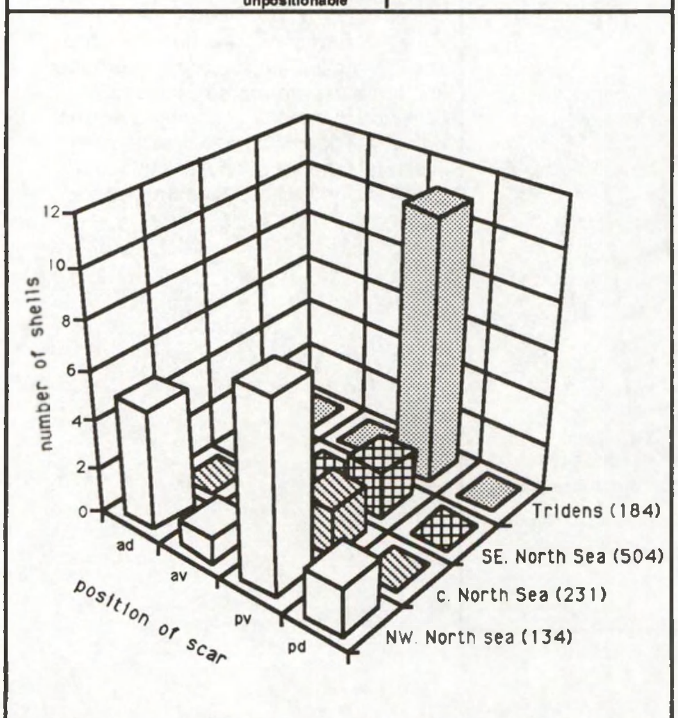
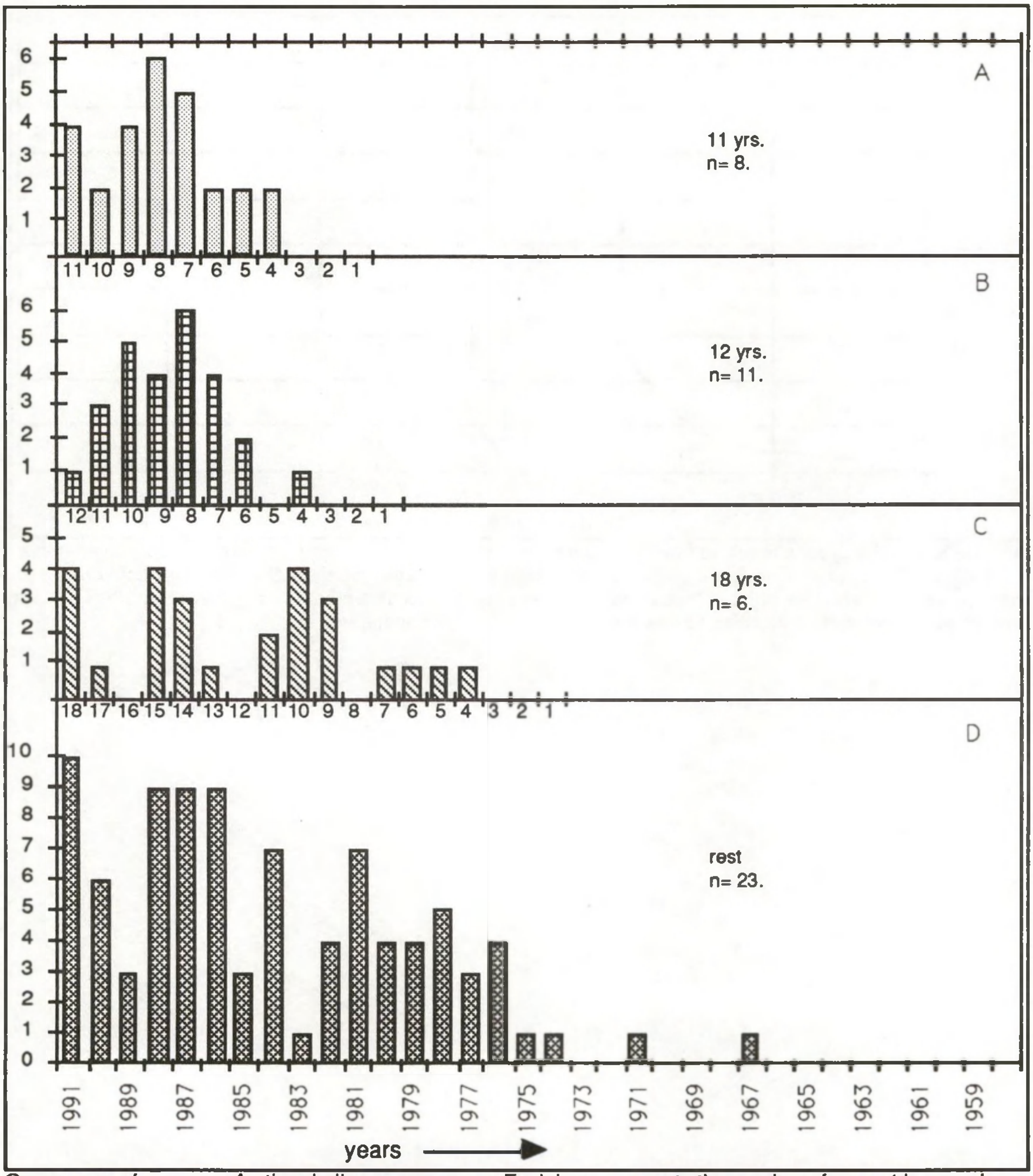
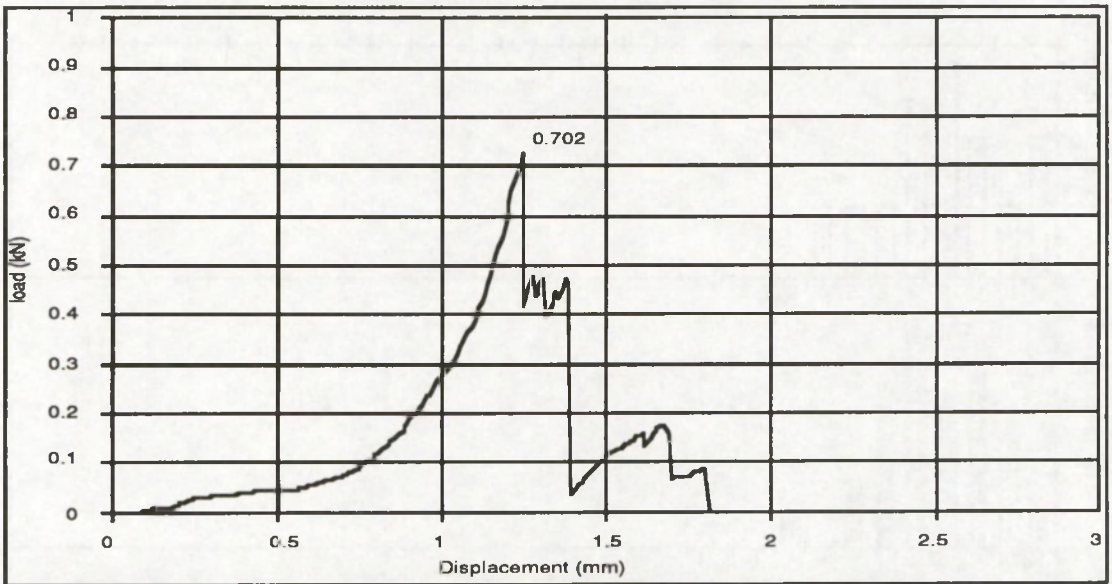


Figure 4: Position of scars on *Arctica* shells. All sampled stations are grouped into three separate areas. A sample collected by means of commercial gear with RV. Tridens is treated separately. The total number of shells within one group is denoted between brackets.



Occurrence of scars on *Arctica* shells per age group. Each bar represents the number of scars (damaged increments) per year. Along the x-axis of each figure the ontogenetic years are denoted. From the shells with other ages then represented by graph A, B and C the number was too small to define age groups, so they were combined and represented by graph D.



An example of the graphs resulting from the shell strength tests. An increasing load was applied on a, in this case 63 mm large, shell. The figure shows an abrupt dip after the shell crushed, thus the shell could resist a force up to 0.702 kN. This point of "maximum resistance" was used as a measure for shell strength. The same was done for shells of other sizes, to see if shell strength is size dependent.

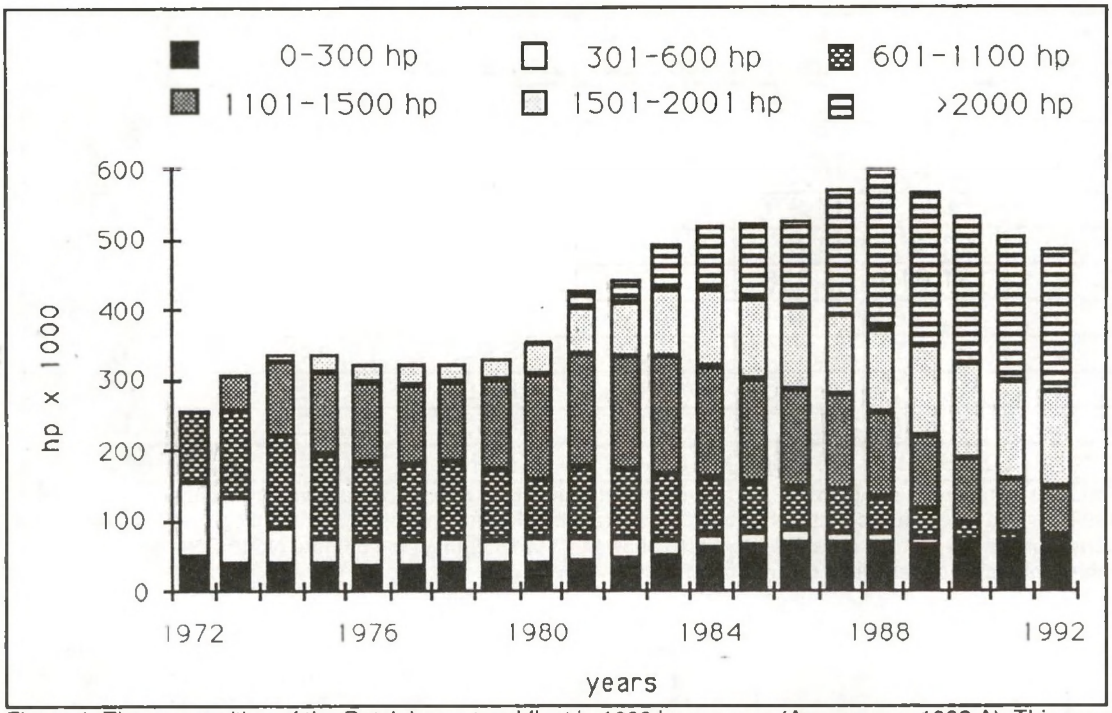


Figure 1: The composition of the Dutch beam trawl fleet in 1000 hp per year (ANONYMOUS, 1992 A). This graph shows that in the period 1972-1988 the total fleet capacity increases. This is mainly due to a tendency towards ships with higher engine power. After 1988 all categories decrease.

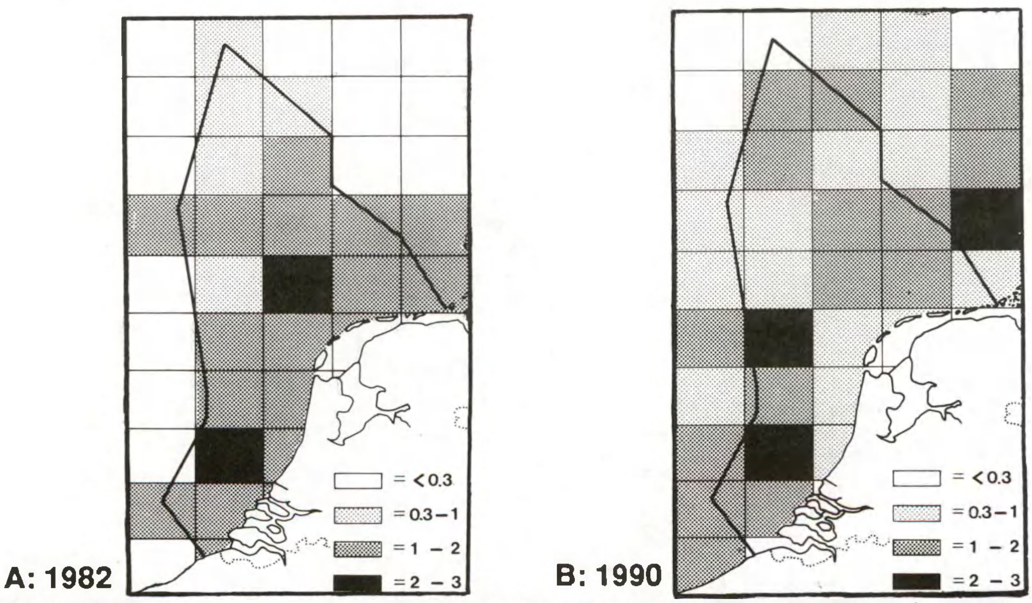


Figure 2: Registrated mean yearly trawling frequency by Dutch beam trawlers (>300 hp). A: 1982 (pers. com. Lindeboom, 1993: data adapted from WELLEMAN, 1989). B: 1990 (data RIVO). The figures illustrate that the intensity of trawling is not homogeneously distributed over the years.

NSTF area	beam trawl	otter trawl	industrial pair trawl	industrial single trawl	pair trawl	seine	Total
1		15,797	195	6,077	7,940	90	30,099
2a		15,731		514	12,684	9	28,938
2b	3,461	10,216	224	10,481	9,133	32	33,547
3a	176	14,870	7	62	9,989	21	25,125
3b	23,735	11,571		1,909	5,300	4	42,519
4	131,619	6,896		1,095	23,498	0	163,108
5	47,520	6,491	587	14,331	4,189	10	73,128
6	3,040	6,252	8,803	35,943	16,302	17	70,357
7a	33,311	5,745	616	28,199	13,718	45	81,634
7b	80,147	5,387	216	28,554	4,796	17	119,117
total	323,009	98,956	10,648	127,165	107.549	245	667,572

Figure 3: Total areas swept in 1989 (km²/year) by towed fishing gear in contact with the seabed (ANONYMOUS, 1992 D). The table shows that in the North Sea, beam trawl fishery has the greatest impact on the seabottom, particularly in the sample area (4&7b). It also shows that in 1989 that the southern North Sea had the highest fishing intensity (coastal fisheries excluded).

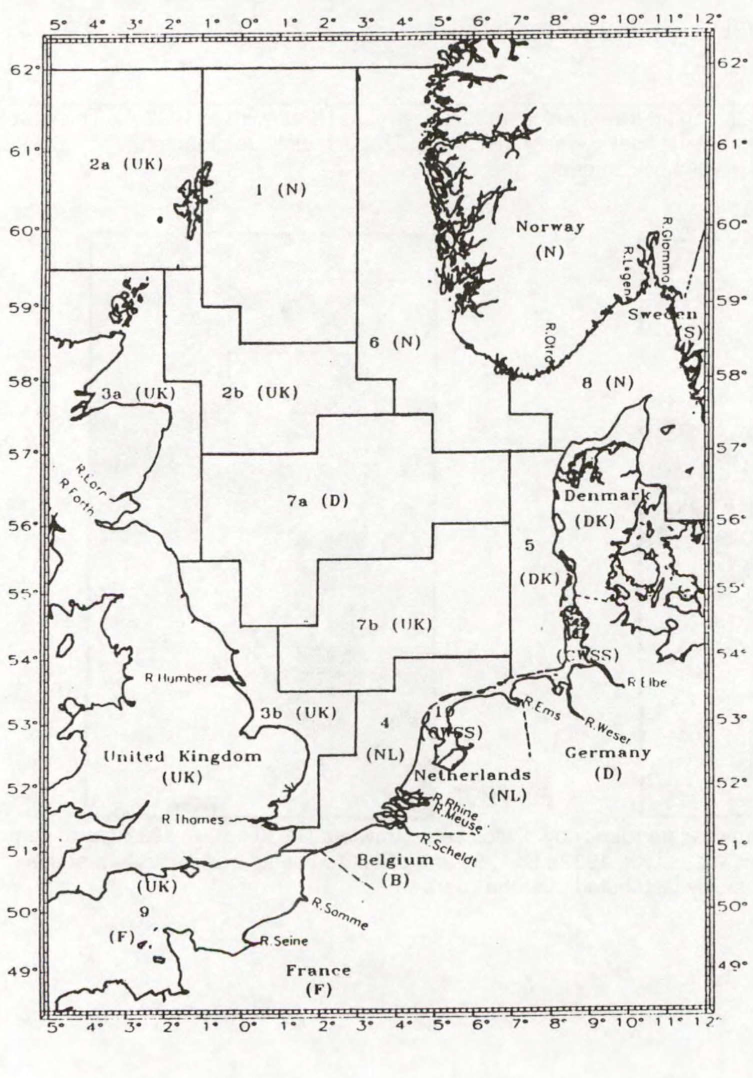


Figure 4: Subregions of the North Sea adopted by the North Sea Task Force.

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