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KURZMITTEILUNG – SHORT COMMUNICATION

Experimental evidence of damage to benthos by bottom trawling with special reference to *Arctica islandica*

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Abstract

In Kiel Bay (Western Baltic), benthos samples were taken at 20 m water depth using rectangular botanical dredges fixed to the otter boards of an 80 ft Sønderborg standard trawl to document possible effects of trawl fishery on the benthic fauna. Thin-shelled bivalves like *Syndosmya (Abra) alba, Mya* spp. and *Macoma calcarea*, as well as the starfish *Asterias rubens* were damaged by otter boards to a high extent. Thick-shelled bivalves such as *Astarte borealis* and *Corbula gibba*, however, seem to be more resistant to mechanical stress of bottom-trawl fishery. *Musculus niger*, an epibenthic species, is probably only resuspended and dislocated. The rate of damage to *Arctica islandica, Macoma baltica* and *Macoma calcarea* is related to their body size. Large specimens are more affected than smaller specimens due to the unfavourable relationship between shell surface and shell thickness. The size distribution of *Arctica islandica* in heavily trawled areas of Kiel Bay shows reductions in the upper size class in these areas.

Kurzfassung

Experimentelle Untersuchungen zu Schädigungen des Benthos durch Grundschleppnetzfischerei unter besonderer Berücksichtigung von Arctica islandica

In einem Experiment wurde der zerstörerische Einfluß der Grundschleppnetzfischerei auf Benthosorganismen in der Kieler Bucht (Westliche Ostsee) untersucht. Hierzu wurden botanische Rechteckdredgen direkt an den Scherbrettern eines 80-Fuß-Sønderborg-Standardtrawls befestigt. Dünnschalige Muschelarten wie *Syndosmya (Abra) alba, Mya* spp. und *Macoma baltica* wie auch der Seestern *Asterias rubens* wiesen eine höhere Anzahl beschädigter Exemplare auf als dickschaligere Muscheln gleicher Größe wie z. B. *Astarte borealis* und *Corbula gibba*. Die epibenthische Art *Musculus niger* wird wahrscheinlich nur resuspendiert und umgelagert. Innerhalb einzelner Arten *(M. baltica, M. calcarea, Arctica islandica)* waren die größeren Exemplare wegen ihres unvorteilhaften Verhältnisses zwischen Schalenoberfläche und -dicke stärker betroffen. Dies spiegelt sich in den reduzierten oberen Größenklassen von *A. islandica* in den intensiv befischten Gebieten der Kieler Bucht wider.

Introduction

The main bioturbator of coastal benthic environments is man due to his trawling and dredging activities. Although the fishing effort in shelf areas has increased considerably since World War II (FAO Statistical Yearbooks and Annual Reports on German Fisheries), the environmental impact of bottom trawl fishery on the seabed and its living inhabitants has not well been documented. References can be found in GRAHAM (1955), ARNTZ and WEBER (1970) and DE GROOT (1984). Recent reviews on the topic were given by FOWLER (1989) and KROST (1990). A literature list was provided by REDANT (1987).

Dependence of bottom fishery on the spatial distribution of *Arctica islandica* in Kiel Bay has been discussed by ARNTZ and WEBER (1970), WEIGELT (1987) and BREY et al. (1990). The latter publication anticipates correlation between body size and probability of damage by otter boards, which will be discussed in detail in the present paper.

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Study area, material and methods

The trawling experiment was performed in July 1989 in Kiel Bay (Western Baltic), west of Stollergrund in approx. 20 m water depth. This is a relatively undisturbed area with respect to commercial fishery. Two botanical dredges ("Kieler Kinderwagen") with a 1 m opening were fitted to the rectangular wooden otter doors (1.2 m × 0.8 m, approx. 100 kg) of an 80 ft Sønderborg standard trawl. They were attached directly onto the heels of the boards so that the tracks of the otter boards were sampled by the dredges (Fig. 1). The dredges were equipped with net bags of 2 m length and 1 cm meshes (in the cod end 0.5 cm). Ten-minute hauls were performed. Two reference dredges were taken on a parallel but undisturbed course. The towing speed was approx. three knots in all cases.

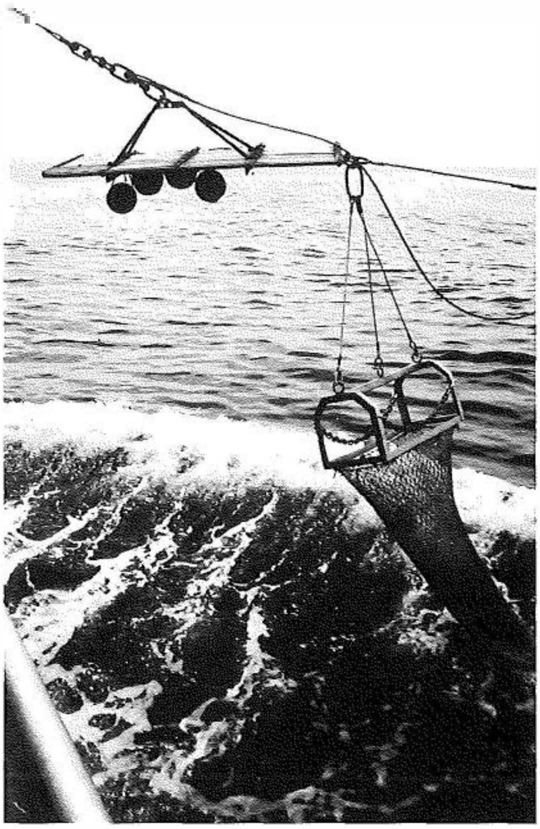

Fig. 1. Botanical dredge attached to otter board

Due to failure of a dredge, only one reference dredge was available for comparative purposes. The large amount of sample material was nevertheless enough to fulfill the aims of this study. The individuals and species were counted and the extent of damage examined. The ratio of damaged bivalves was correlated with their shell size and thickness.

Results

A total of 4081 individuals were caught in the dredges: three species of Crustacea, seven species of Polychaeta, one species of Echinodermata, and twelve species of Bivalvia. The most abundant species were larger bivalves and starfish. Polychaetes were also caught in large quantities but were not taken into account because all species were theoretically able to pass through the meshes of the dredge bag – either actively or passively. The Table shows the abundance and percent of damaged individuals for the reference and the "otter board" samples.

Shell thickness versus damage

Thin-shelled bivalves such as *Syndosmya alba, Mya* spp. and *Macoma calcarea* show higher numbers of damaged individuals in the otter-board samples than in the reference sample. The same is true for the starfish *Asterias rubens.* Little or no damage occurs to the solid-shelled bivalves such as *Astarte borealis, Corbula gibba* and *Musculus niger*, and, surprisingly enough, to the more fragile *Macoma baltica. Macoma calcarea,* however, is damaged

Number and rate of damage to benthic organisms in dredge samples

	Reference sample (1 dredge)		Otter board samples (2 dredges)	
	Number of individuals caught	% damaged	Number of individuals caught	% damaged
Syndosmya alba	16	18.8	307	32.8
Arctica islandica	62	1.6	390	10.4
Astarte borealis	6	0	92	0
Cardium fasciatum	49	12.2	21	3.0
Corbula gibba	17	0	13	0
Macoma baltica	53	3.8	1651	2.4
Macoma calcarea	2	0	436	13.4
Musculus niger	49	0	62	0.9
Mya spp.	9	66.7	39	26.3
Asterias rubens	134	2.2	229	12.9

to a much higher extent. Fig. 2 shows decreasing damage of bivalve species with increasing shell thickness in the otter board sample (calculated as ratio of dry shell weight to total dry weight, after Rumohr et al. 1987).

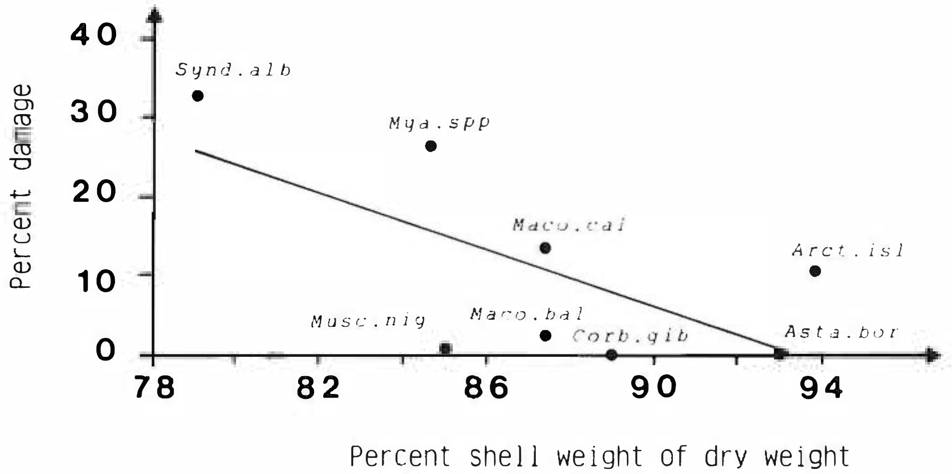

Fig. 2. Linear regression of damage to shell thickness (percent dry shell weight to total dry weight [data after Rumohr et al. 1987]; the value for *Macoma calcarea* was considered to be equal *Macoma baltica*; r = 0.67; a = 167.32; b = –1.79. *Arct. isl = Arctica islandica; Asta. bor = Astarte borealis; Corb. gib = Corbula gibba; Maco. bal = Macoma baltica; Maco. cal = Macoma calcarea; Musc. nig = Musculus niger; Synd. alb = Syndosmya alba*)

Shell size versus damage

Shell surface area, and thus the exposure to mechanical stress, increases with the square of shell thickness. The effect of body size on degree of damage is shown in Fig. 3 for bivalves caught in large quantities in the otter board samples. The proportion of damaged *Arctica islandica* reaches 50 % for individuals longer than 35 mm. An increase in the proportion of damage with body size is also found for *Macoma baltica, Macoma calcarea* and *Musculus niger* (one damaged individual in the biggest size class, the latter not shown in Fig. 3).

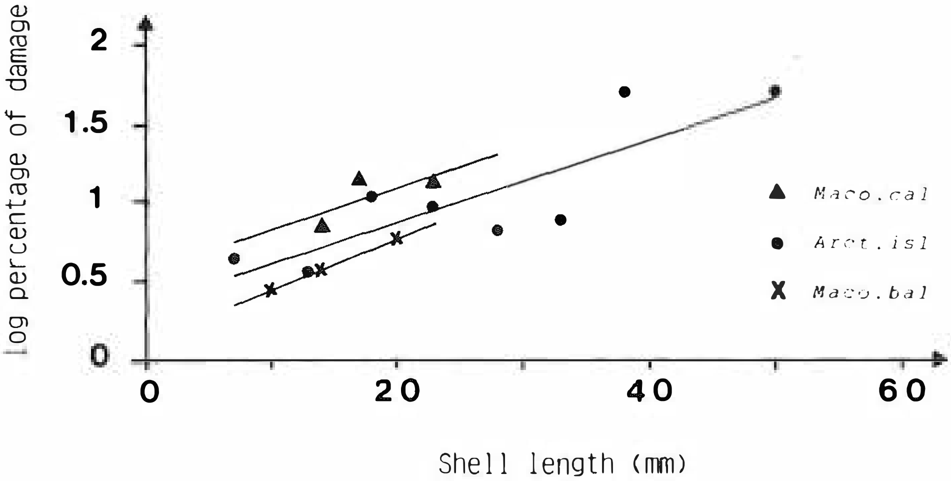

Fig. 3. Linear regression of log percentage of shell damage to shell length. (*Arctica islandica*: r = 0.85; a = 0.34; b = 0.026; *Macoma baltica*: r = 0.99; a = 0.12; b = 0.032; *Macoma calcarea*: r = 0.74; a = 0.55; b = 0.026). Size classes (in mm): *Arctica islandica*: 4–10, 11–15, 16–20, 21–25, 26–30, 31–35, 36–40, 41–60. *Macoma baltica*: 9–11, 12–16, 17–23. *Macoma calcarea*: ca. 14, 15–19, 20–26

Syndosmya alba, however, showed a decreasing proportion of damage with an increase in size. Shell size shows a higher correlation with the total per cent of damage, than does shell thickness.

Discussion

Remarkable is the large amount of individuals caught in the otter-board samples compared to the reference sample. A considerable number of organisms caught in the otter-board sample (for example the deep dwelling *Mya* spp.) is probably dug out by the otter boards.

The total proportion of all damaged species caught in high quantities was ≤ 33 %. An otter board passage does not necessarily lead to a complete destruction of the benthos community as anticipated by Rauck (1988), but rather to a resuspension of sediments and dislocation of the organisms living there. As has been pointed out by Krost (1990), this is especially true for epibenthic organisms (mostly vagile species of crustaceans and errant polychaetes) which were found to be considerably reduced in numbers in recent otter-board tracks. However, they regained their original density after approx. 24 h. The epibenthic *Musculus niger*, which was damaged in only one case (see Table), gives proof of this assumption. An exception seems to be the starfish *Asterias rubens* which, due to its large body size, suffers considerable damage by otter boards (De Groot 1984, Krost 1990). For this species, the damaged proportion was 12.9 % in the otter board dredges, compared to 2.2 % in the reference samples. In general, the most endangered animals are the infaunal species which live in the upper 5 cm of the sediment and thus well within the depth range of otter-board tracks.

Effects of trawling on *Arctica islandica* in Kiel Bay

There is a controversy about the impact of otter-trawl fishery on the distribution of *Arctica islandica* in Kiel Bay. Arntz and Weber (1970) found large quantities of broken and empty shells of *A. islandica* at the margins of the trawl tracks and concluded that the irregular distribution of this species is a consequence of otter-board impact. WEIGELT (1987), however, denied a major impact of fishing activity on *A. islandica* distribution.

ARNTZ and WEBER (1970) found soft parts of *Arctica islandica* in the stomachs of cod *(Gadus morhua)*, and as cod themselves are not able to break shells of *A. islandica*, they concluded that cod feed on clams when their shells are broken by otter boards. BREY et al. (1990) used the ARNTZ and WEBER (1970) approach. After calculating the annual production of *A. islandica* in Kiel Bay (~ 10 700 t) they concluded that 40 % of the cod production in Kiel Bay can be supported by utilisation of the total *A. islandica* production. The analysis of food of adult cod showed a share of approx. 50 % *A. islandica* in the stomach contents. We assume that approx. 50 % of the *A. islandica* bigger than 35 mm are damaged and become available for cod after an otter-trawl passage (see Table). This number corresponds well with the calculated average length of 46 mm for *Arctica* in cod stomachs, in contrast to the average of 25 mm in natural populations (BREY et al. 1990).

According to BREY et al. (1990), approx. 64 % of *A. islandica* biomass, 11.776 g AFDW/m^2, or 20 019 t AFDW in Kiel Bay is provided by animals > 38 mm. KROST (1990) assessed the annual disturbance of the fishing area by otter boards to be 20 % of the total fishing area, which coincides closely with the *Syndosmya alba* community. The resulting mass of destroyed *A. islandica* would amount to 4000 t AFDW and would have therefore been enough to support 7.7 % of the cod production in the years between 1970 and 1985 (BREY et al. 1990). (It should be noted that the cod population has undergone a severe decline in recent years.)

It was found that mainly specimens with a shell diameter > 35 mm were damaged. Furthermore, KROST et al. (1990) observed frequent disturbance by fishing activity in the deeper channel system of Kiel Bay. Both factors should result in an effect on the size distribution of *A. islandica* in the channels of Kiel Bay. In fact, WEIGELT (1987) pointed out that in 1984 and 1985 only specimens ≤ 55 mm could be found in Vejsnaes channel, and a similar observation was also reported by ARNTZ and HEMPEL (1972) for the years 1968 to 1969. We consider the trawl fishery to be the most probable cause for this phenomenon.

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