ICES Journal of Marine Science, 57: 1389–1394. 2000
doi:10.1006/jmsc.2000.0930, available online at http://www.idealibrary.com on IDEAL®

The impact of trawl fishery on the epifauna of the southern North Sea

Heye Rumohr, and Thomas Kujawski

Rumohr, H., and Kujawski, T. 2000. The impact of trawl fishery on the epifauna of the southern North Sea. – ICES Journal of Marine Science, 57: 1389–1394.

Qualitative historical benthos data (1902–1912) were compared with recent data (1986) to find long-term trends in epifauna species composition in the southern North Sea that may be attributed to fishery-induced changes. In general, the frequency of occurrence of bivalve species declined, whereas scavenger and predator species (crustaceans, gastropods, and sea stars) were observed more frequently in 1986. We suggest that these shifts can be attributed not only to the physical fishery impact, but also to the additional potential food for scavenging and predator species provided by the large amounts of discards and moribund benthos. Our findings are put into the perspective of the general development of the demersal fishery in the southern North Sea. Despite the problems with the historical data set, the comparison presented may be the best illustration achievable of the changes in the benthos from a near-pristine situation to the present conditions after long-term disturbance.

Key words: benthic epifauna, historical data, impact trawl fishery, North Sea.

H. Rumohr and T. Kujawski: Institut für Meereskunde, Düsternbrooker Weg 20, D-24105 Kiel, Germany. [tel. +49 431 597 3957; e-mail: hrumohr@ifm.uni-kiel.de]

Introduction

The effects of bottom fisheries on benthic marine ecosystems are still a point of discussion. Investigations by means of experimental trawling showed that trawl fisheries increase the mortality of target and by-catch species, and also of benthic species not caught in the nets but which are damaged by the passing gear (Bergman and van Santbrink, 1994). In general, large (long-living) species with low fecundity will be affected more than small (short-living) species with high fecundity. On the other hand, fisheries may be beneficial for scavenging species if their increased mortality is balanced by an increasing food supply from discarded offal, by-catch, and moribund animals left in trawl tracks (Lindeboom and de Groot, 1998).

The effect of fisheries on demersal fish and benthic invertebrates will also depend on the type of fishing gear in relation to the vertical distribution of the species. In an otter trawl, the groundrope slides over the seabed, whereas the doors plough through the bottom. Beam trawlers use heavy tickler chains or chain mats to chase the target flatfish species out of the sediment. Consequently, otter trawls and beam trawls both catch demersal fish and epifaunal invertebrates, but beam trawls also also affect animals that live buried in the top layer (approximately 1–5 cm depending on the type of sediment) and belong to the infauna. Two main problems in evaluating long-term effects of bottom fisheries on benthic ecosystems are that: (i) experimental work refers to short-term effects; and (ii) consistent long-term series on the abundance of non-commercial species are scarce. Systematic surveys that aim to collect information on by-catch fish and invertebrates did not start before the 1970s, i.e., after a long period of intensive commercial fishing (van Leeuwen *et al.*, 1994). Nevertheless, ICES initiated some early routine surveys (1902–1912) during which samples of invertebrates were collected and stored. From these data, more or less realistic catch protocols have been reconstructed (Stein *et al.*, 1990). We compare these data with information collected during the ICES Benthos Survey 1986 (Künitzer *et al.*, 1992).

Material and methods

Qualitative historical data from 1902–1912 (about 7000 records) have been made available from museum jars (Stein *et al.*, 1990). In 1901, the Deutsche wissenschaftliche Kommission für die internationale Meeresforschung was founded in Germany to allow participation in the international marine research that developed with the foundation of ICES. A small marine laboratory with

Addendum

Captions for figs.3. and 4. are wrong. They shoud read instead:

Fig.3. Frequency of occurrence of different faunal groups

Fig.4. Corrected yields per trip of a Unit trawler as a relative measure for the population density of commercial fish in the North sea under the impact of fishing (after Hempel, 1978).

Acknowledgments: We gratefully acknowledge the permission to use epifauna data from the NIOZ (G. Duineveld) and the Senckenberg Institution (I. Kroencke and M. Tuerkay) from our common ICES North Sea Survey 1986. This study was funded by EU project IMPACT II (AIR 2-CT94-1664):

Table 1. Data set, type of gear, cruise data, and number of stations.

Data set	Gear	Cruise	No. stations
1902–1912	Dredge+different trawls	"Poseidon" and others	403
1986 A	Standard dredge	ICES NS survey May (Rumohr)	5
1986 B	Standard dredge	ICES NS survey April (Turkay)	12
1986 C	Beam trawl	ICES NS survey May (Duineveld)	58

a biological and an oceanographic section was set up in Kiel, and from 1902 to 1908 four research trips ("Terminfahrten") were completed annually in the Baltic and the North Sea with the RFF (Reichsforschungsdampfer) "Poseidon". Further expeditions were carried out from 1909 to 1912 in the North Sea as part of an international agreement. The cruises took place in February, May, August, and November, and with few exceptions the same stations were visited. In addition to the Terminfahrten, material was collected during cruises carried out from 1903 to 1906 by the Biologische Anstalt Helgoland to various locations in the North Sea.

Animals collected have been preserved in jars in the Zoological Museum of Kiel with labels giving details about location (station number), date, and, occasionally, gear used. Sampling positions and information on depth and sediment could be assigned to station numbers with the available literature. Stein *et al.* (1990) used these historical data in combination with references in Wissenschaftliche Meeresuntersuchungen, Neue Folge Vols. VIII–XV in their reconstruction of the catches. No direct quantitative conclusions can be drawn from the material presented, because it is uncertain whether all animals caught have been kept in the museum material, and as there is only a little evidence of individual numbers in the available literature. The data can be used only to indicate that species were present, because there may be different reasons why a species has not been listed. In addition, an attempt to investigate temporal changes in the ten consecutive years of sampling had to be abandoned because the number of data records drastically declined from more than 100 in the first years to less than 50 in the last few years. Therefore, the whole 10-year dataset was lumped together, and we assume that the species list represents an almost complete record of those that occurred in the samples. This seems justified because at the time the taxonomic experts were keen on getting an complete overview of the species spectrum.

The other data set was derived from the ICES Benthos Survey 1986. Sample information is listed in Table 1. From 1902 to 1912, the entire North Sea was sampled with various kinds of towed gears, such as dredges, trawls, Helgoländer Knüppelnetz and shrimp trawls. For 1986, the only data available for the southern North Sea are based on material collected with standard (1 m) dredges and beam trawls (2–4 m). For the comparison, the data had to be restricted to stations in the area between 0°30′ to 7°00′E and 52°30′ to 56°30′N (Fig. 1). Stations with doubtful positions or uncertain depth-sediment information and species that were observed at one or two stations only were omitted. A total of 56 stations from 1902 to 1912 were compared with 40 stations from 1986.

A further reduction of the species list to only epifaunal species or taxa (except for bivalves and some echinoderms) makes a comparison with recent data more realistic because the data collected in 1986 include many small infaunal species (especially polychaetes). These could not have been caught with the gears used early in the century when quantitative sampling of benthos was impossible. Therefore, only information on Decapoda, Echinoidea, Ophiuridea, Asteroidea, Gastropoda, and Bivalvia has been included in the comparison (98 species).

Various multivariate techniques (cluster analysis, MDS-plots using the Bray-Curtis index, analysis of similarities (ANOSIM), similarity percentages, (SIMPER) were applied using PRIMER (Warwick, 1993; Clarke and Warwick, 1994). Stations were grouped according to sediment/depth-strata (<30 m,

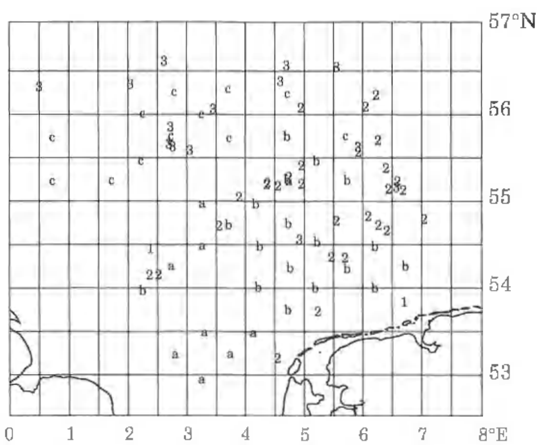

Figure 1. Map of the stations selected (1, 2, 3: stations 1902–1912; (a), (b), (c): stations 1986; 1, (a): depth 0–30 m; 2, (b): depth 30–50 m; 3, (c): depth >50 m).

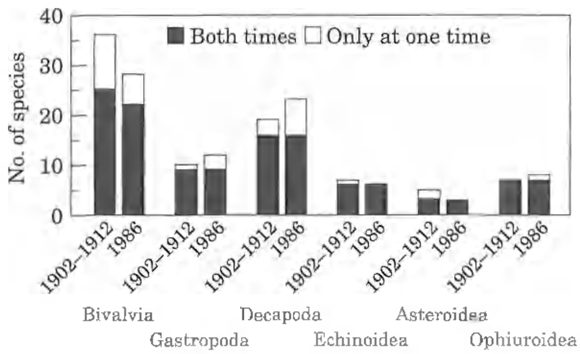

Figure 2. Number of species in the selected area for the six major taxa.

30–50 m, and >50 m) in accordance with the findings of Künitzer *et al.* (1992).

Results

The comparison of historical species numbers from different faunal groups with recent ones (Fig. 2) reveals some distinct changes. Among the bivalves, 11 species were not reported in 1986, and three species seem to be new. Among the Decapoda, four were not reported in 1986 and eight new species had appeared.

In general, species observed only in one data set occurred on fewer than 15% of the stations (mostly <10%). Exceptions (all in 1986) are *Lunatia pulchella* (47%), *Spirontocaris liljeborgii* (23%), and *Macropipus depurator* (20%). ANOSIM revealed that the stations in the two data sets differ significantly with respect to species composition. The differences became weaker when taxonomic level was increased (genus, family, order) but stayed significant. The differences between the two data sets were also significant for individual depth strata. Changes within the six main taxa are described in the following.

Asteroidea (Fig. 3a)

The starfish *Astropecten irregularis* and *Asterias rubens* were found in 1986 at almost all stations <50 m. From 1902 to 1912, *A. irregularis* occurred only on stations >30 m, while *A. rubens* was only found on one-third of the stations <30 m. Overall, there have been marked increases. While *Lepasterias muelleri* and *Henricia sanguinolenta* were found frequently on stations >50 m in 1902–1912, they were not found in the 1986 survey.

Ophiuroidea (Fig. 3a)

The brittle star (*Amphiura filiformis*) occurred in 1986 on only 5% of the stations while it was present in the majority of the stations in 1902–1912. In contrast, *Ophiura albida* showed a marked increase. *Ophiura sarsi* appeared in 1986 as a new species on stations >50 m (35%). *Ophiura ophiura*, found in the early days on 55% of the stations >50 m, was absent in that stratum in 1986.

Echinoidea (Fig. 3b)

In 1986, the small sea urchin (*Echinocyamus pusillus*) had virtually disappeared compared with the the situation at the beginning of the century. In contrast, the frequency of occurrence of the green sea urchin (*Psammechinus miliaris*) increased markedly. There was also an increase in *Brissopsis lyrifera* on stations >50 m. The greatest increase, however, occurred in *Echinocardium cordatum*, especially in shallower waters (<50 m): from 33% to 100%.

Gastropoda (Fig. 3c)

The frequency of occurrence of the common whelk (*Buccinum undatum*) has more than doubled. Also, the less common *Colus gracile* has increased (9% to 25%) in frequency, and its depth range has also changed. The largest increases were observed within the genus *Lunatia*. In 1902–1912, only one species (*L. pallida*) was found on 11% of the stations. This species was not recorded in 1986 but was replaced by three smaller species: *L. montagui* (50% of the stations >50 m), *L. catena* (22% of the stations in the 30–50 m range) and *L. pulchella* (47% of all stations but most frequent on stations <30 m).

Bivalvia (Fig. 3d)

Virtually all species originally present had decreased drastically by 1986. *Spisula solida* and *Nucula tenuis* were the most frequently observed species early in the century and were now seen on fewer than 5% of the stations. The following species were found recently only on 20–30% of all stations: *Phaxas pellucidus* (earlier 70%), *Nucula nitidosa* (earlier 53%), *Arctica islandica* (earlier 45%). Only very few and less common species have more or less maintained their original frequency: *Ensis arcuatus*, *Mysia undata*, *Hiatella rugosa* (the now apparently extinct *H. arctica* may have been confused with *H. rugosa* in the earlier data set), *Thracia phaseolina*, *Venus ovata*, *Tellina pusilla*, *Ensis siliqua*, and *Mactra corallina*. However, in many cases there have also been changes in depth range.

Decapoda (Fig. 3e)

Most species were found in 1986 on more stations than in 1902–1912. The generally abundant hermit crab (*Pagurus bernhardus*) showed only a slight increase. *Crangon allmani* and *C. crangon* were found on more

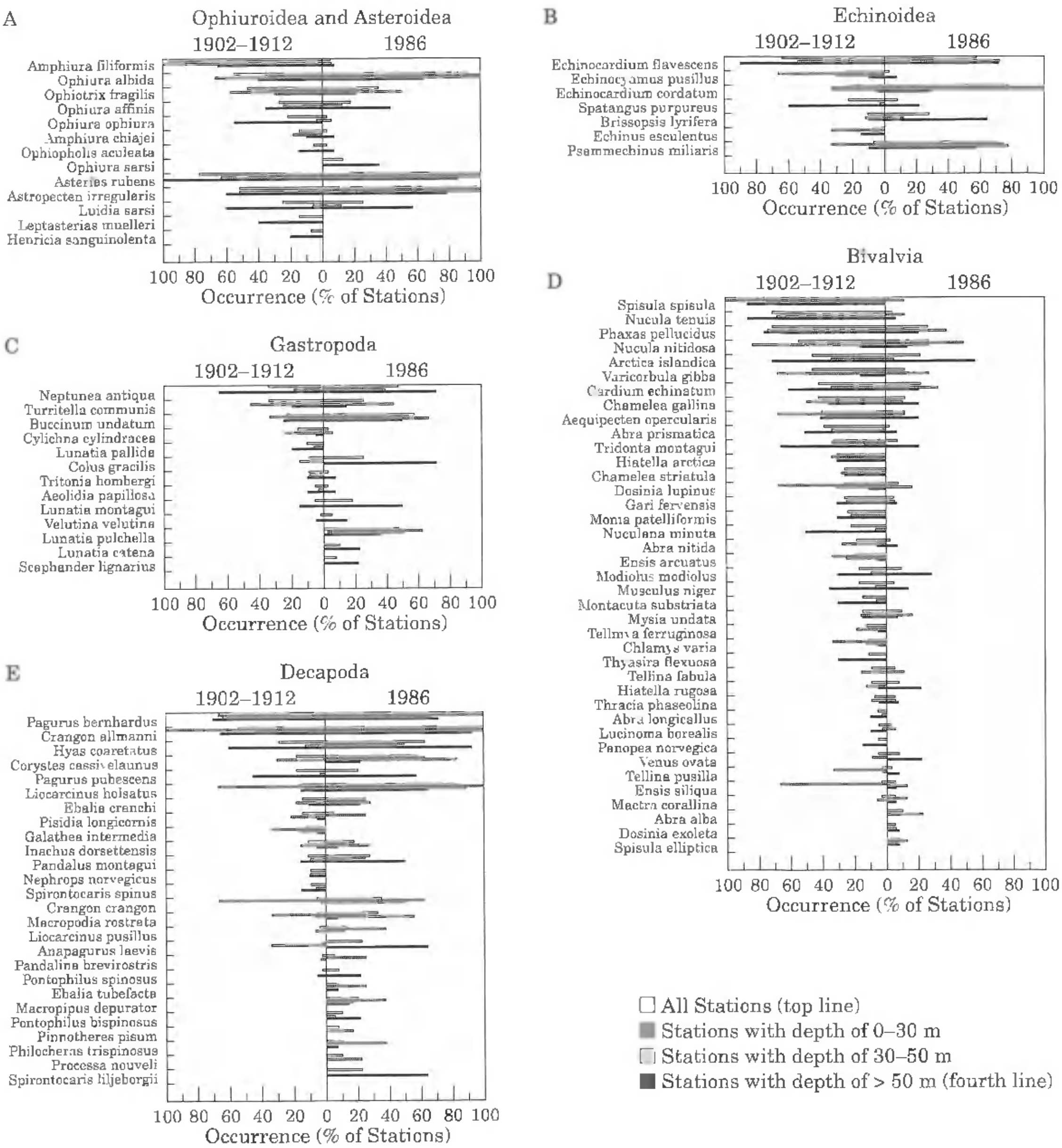

Figure 3. Frequency of occurrence of Asteroidea and Ophiuroidea.

stations overall, but especially in the depth stratum of 30–50 m. The swimming crab (*Liocarcinus holsatus*) increased markedly, particularly in the depth zone >30 m. Further drastic changes occurred in *Hyas coarctus* and in the masked crab (*Corystes cassivelaunus*).

Discussion

In such a comparative study, the question of comparability of the different data sets automatically arises. The historical data used have been reconstructed from museum specimens (Stein *et al.*, 1990), whereas the 1986 data set has been collected using standardized procedures. In both cases, the presence of a species on a particular station is a more reliable piece of information than its absence.

The question, as to how comparable the results of different sampling gears are, is one that cannot be satisfactorily answered. In both cases, towed gears were used (Table 1) that penetrate to some extent into the upper sediment layers, resulting in a certain amount of infauna in the samples. There is no information about

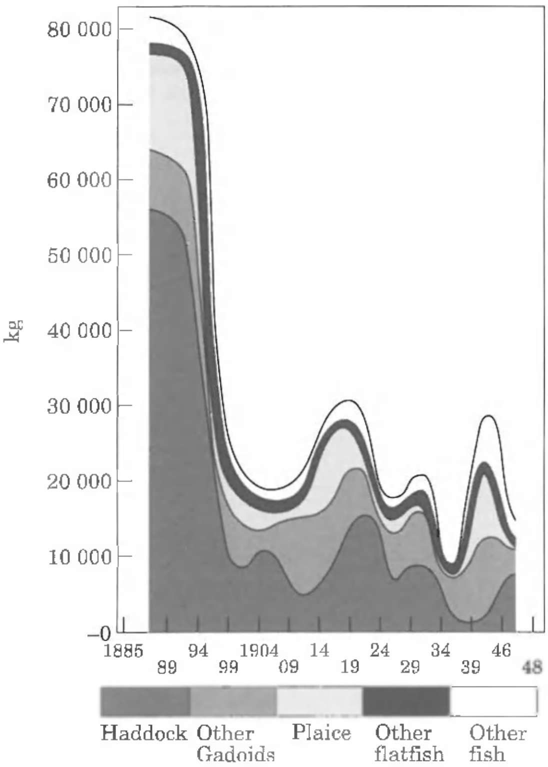

Figure 4. Frequency of occurrence of Echinoidea.

the size of the meshes used in the earlier surveys, which may affect the presence of smaller species. Of the different depth strata sampled, the area <30 m has been sampled least (1902–1912: three stations; 1986: eight), which may influence the comparisons. Nevertheless, the overall changes appear to be fairly robust over the entire depth range and also detectable on higher taxonomic (and thus coarser) levels. Aggregation of species removes bias caused by taxonomic problems such as exist in the genera *Hiatella* and *Lunatia*. Also among the Echinodermata, misidentification may play a role. Nevertheless, the general increase in this group can be illustrated by combining echinoid species into families. For Spatangoidae, the frequencies of occurrence obtained were 68% in 1902–1912 and 98% in 1996, whereas for the Echinoidea they were 13% and 65%, respectively. Assuming that *Amphiura filiformis* may have been confused with other *Amphiura* species, but not with *Ophiura* species, frequencies of occurrence were also calculated for *Amphiura* sp. (63% in 1902–1912 and 8% in 1986) and *Ophiura* sp. (82% in 1902–1912 and 93% in 1986). Clearly, the results are insensitive to possible misidentification.

The distribution by sediment stratum could not be directly investigated because too few sediment data were available in both data sets. However, we may assume this to be of minor importance, since the sediment distribution in general follows the depth zonation.

The general conclusion must be that there has been a decline in the occurrence of bivalves, whereas scavengers and predators, such as crustaceans, gastropoda, and sea stars were found more frequently in 1986. The most likely explanation for these large shifts seems to be that they must be attributed to fishery impact; discards, in combination with moribund benthos on the sea floor, provide a large amount of potential food for scavenging and predator species. If so, the extra mortality of these species caused by fishing is apparently more than compensated by better conditions for growth and reproduction.

Putting our findings in the perspective of the general development of the demersal fishery in the southern North Sea (Fig. 4), we cover the time span just after the onset of a widespread trawl fishery that skimmed off the surplus of the unexploited (virgin) stocks in the 19th century. ICES routine investigations were started because of the general concern about declining fish stocks. Nonetheless, steam engines were less powerful than modern ones, and discards were probably fewer in those years, and therefore, benthos may still have been close to their pristine conditions. In 1986, almost 100 years of trawling impact have passed. Despite the problematic historical data set, this comparison may be the best illustration possible of the changes from a near-pristine situation to the present conditions after long-term disturbance.

References

Bergman, M., and Van Santbrink, J. W. 1994. Direct effects of beam trawling on macrofauna in a soft bottom area in the Southern North Sea. *In* Environmental Effects of Bottom Gears on Benthic Fauna in Relation to Natural Resources Management and Protection of the North Sea, pp. 179–208. Ed. by S. J. de Groot, and H. J. Lindeboom. NIOZ-Rapport 1994-11.

Clarke, K. R., and Warwick, R. M. 1994. Similarity based testing for community pattern: the two-way layout with no replication. Marine Biology, 118: 167–176.

Hempel, G. (ed.) 1978. North Sea fisheries and fish stocks – a review of recent changes. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 173: 145–167.

Künitzer, A., Basford, D., Craeymersch, J. A., Dewarumez, J. M., Dörjes, J., Duineveld, G. C. A., Eleftheriou, A., Heip, C., Herman, P., Kingston, P., Niermann, U., Rachor, E., Rumohr, H., Wilde, P. A. J. de. 1992. The benthic infauna of the North Sea: species distribution and assemblages. ICES Journal of Marine Science, 49: 127–143.

Lindeboom, H. J., and de Groot, S. J. (eds) 1998. IMPACT II – The Effects of Different Types of Fisheries on the North Sea and Irish Sea Ecosystems. NIOZ-Rapport 1998-1, 404 pp.

Stein, U., Hukriede, W., and Rumohr, H. 1990. Historische Benthosdaten aus Nord- und Ostsee in den Jahren 1902–1912. Mitteilungen Zoologisches Museum, Universität Kiel, Suppl. 3, 189 pp.

Van Leeuwen, P. I., Rijnsdorp, A. D., and Vingerhoed, B. 1994. Variations in abundance and distribution of demersal fish species in the coastal zone of the south-eastern North Sea between 1980 and 1993. ICES CM 1994/G: 10.

Warwick, R. M. 1993. Environmental impact studies on marine communities: pragmatical considerations. Australian Journal for Ecology, 18: 63–80.