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A PRELIMINARY ASSESSMENT OF THE IMMEDIATE EFFECTS OF BEAM TRAWLING ON A BENTHIC COMMUNITY IN THE IRISH SEA

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ABSTRACT

After an experimental box had been fished 10 times with a 4-m commercial beam trawl, the density of sessile animals such as *Alcyonium digitatum* and hydroids decreased by ca. 50%. The density of more mobile animals, such as fishes, crabs and *Palaemon* spp. remained constant or increased. Assessment of the survival of animals caught in the codend indicated large variation between species. Echinoderms with flexible tests, eg *Asterias rubens*, showed low mortality, whereas those with brittle tests, eg *Psammechinus miliaris*, were readily damaged leading to high mortality. The extent of fish mortality, as a result of being caught and landed, was related to the presence or absence of phenotypic features such as scales, spines, boney plates and slime. After 120 h in tanks of running seawater, between 68 to 97% of *Callionymus* spp. and 34 and 38% of *Pleuronectes platessa* and *Raja naevus* died. Those animals which have predatory or scavenging feeding behaviour, and are able to survive the trauma of being caught in the codend and handled on deck (eg. *A. rubens*), may increase in abundance as a result of fishing activities.

INTRODUCTION

Beam trawls are used extensively in the North and Irish Sea and are extremely effective for catching flatfish (eg. Cruetzberg et al., 1987). As commercial stocks have declined the need to increase fishing effort has led to gear modifications which increase its weight, eg longer beams and the addition of more chain mat or more tickler chains. Typically, a Dutch 12-m beam trawl weighs 7 to 8 t of which 1 t is made up of 19 tickler chains (BEON, 1991). These chains are designed to penetrate the sediment and disturb sole, *Solea solea*, that remain buried by day. The total depth to which these chains penetrate depends on both the vessel towing speed and substrate hardness, estimates vary from 3 cm on hard sand to 8 cm in soft mud (Bridger, 1972; BEON, 1991). However, while tickler chains increase catches of commercial flatfish they also increase the by-catch of non-commercial fish, epi- and infaunal invertebrates. Fragile animals such as sea urchins and some bivalve molluscs tend to be damaged and killed by trawling activity (Bergman & Hup, 1992; Rumohr &

Krost, 1992). Conversely, other animals, such as starfish, survive in high numbers (BEON, 1991; present study) and may even benefit by scavenging the dead animals produced after the passage of the trawl. These effects, coupled with the intensity of the beam trawling effort in the North Sea, have led to suggestions that the latter is a possible cause of the long-term changes observed in the North Sea benthic community (Pearson et al., 1985; Lindeboom, 1990).

To date, most research has concentrated on large (6 to 12-m) beam trawls; no information exists on the effect on the benthic community of lighter 4-m beam trawls. When fished over rough ground, as in the Irish Sea, 4-m beam trawls tend to be fitted with chain mat, ie tickler chains linked longitudinally. This mat is designed to prevent rocks entering the net as well as to catch more flatfish, but concomitantly has a potentially destructive effect on benthic communities. To identify the ecological consequences of beam trawling the Directorate of Fisheries Research, Conwy is investigating the short and long-term effects of this gear on a benthic community in the Irish Sea.

In March 1992 a preliminary investigation of an area between Point Lynas, Anglesey, and Great Ormes' Head, North Wales, was carried out to locate a suitable site for a short-term and long-term study of the effects of beam trawling on a benthic community. A suitable site with a conspicuous filter-feeding community, was found at approximately 4° 00' W, 53° 27' N. The presence of this community, which comprised long-lived species such as *Alcyonium digitatum* and abundant fragile animals such as hydroids, indicated that trawling in the area is relatively infrequent.

In August 1992 we returned to this site to carry out experimental fishing with a commercial 4-m beam trawl fitted with chain mat to examine the following effects:

1. The immediate effects on the benthic community.
2. The survival capabilities of animals caught in the cod-end.

Objective 1 will be discussed in terms of the epibenthic data as the infaunal samples are currently being processed.

Effects on epibenthos

METHODS

An experimental box 40 m x 200 m, was marked on the ship's navigation plotter which was linked to a Sercel NR53 DGPS positioning system (accurate to ±2.5 m). All samples were taken from an area with a water depth of between 32 and 34 m. Prior to fishing with the commercial beam trawl, preliminary sampling was carried out by three 10 min tows (ship speed 0.4-0.9 kt) through the box with a 2-m young flatfish beam trawl (Rogers & Lockwood, 1989). The position at the start and end of each tow was recorded from the DGPS positioning system. The number of individuals and wet weight (±1 g) of each species was recorded from each catch. Catch data was standardised by expressing values as density (numbers per 1000 m^2) or biomass (g per 1000 m^2). Following this preliminary sampling, the box was fished 10 times with the 4-m commercial beam trawl rigged with chain mat and a sole net (8 cm mesh codend). This was followed by another three tows with the 2-m beam trawl and the catch was quantified as before. Effects on the structure of the epibenthic community were assessed using Wilcoxon matched-pairs signed-ranks, cluster analysis and multidimensional scaling on log x+1 transformed data (MDS). Details of the latter two methods can be found in Field et al., 1982.

RESULTS

The dominant macrofauna (expressed as numbers and biomass per 1000m^2) in the community were the anthozoan, *Alcyonium digitatum*, bryozoans, echinoderms (*Psammechinus miliaris, Ophiura texturata, Asterias rubens, Ophiothrix fragilis*) and crustaceans (*Macropodia tenuirostris, Eupagurus bernhardus, Pisa armata*) (Fig. 1). In general, the numbers and biomass per 1000m^2 of animals in the community altered significantly after fishing with the commercial trawl (Wilcoxon matched-pairs signed-ranks test, numbers per 1000m^2 $n=8$, $P<0.03$, biomass per 1000m^2 $n=10$, $P<0.006$). The density and biomass of many of the sessile or slow moving animals (molluscs, echinoderms, anthozoans) was much lower after experimental trawling (Table I). However, the density of mobile invertebrates such as *Eupagurus bernhardus, Liocarcinus holsatus, Palaemon* spp. and fish increased after trawling (Table I). After fishing with the commercial trawl the community structure had changed sufficiently to be differentiated by both cluster analysis and MDS (Fig. 2). Moreover, MDS revealed that the variation between samples taken after fishing was much lower than samples obtained before fishing, which suggests that beam trawling reduces spatial variation within the community in the trawled area.

Assessment of Survival

METHODS

In March and August 1992 and April 1993, three 30 min tows with a 4-m commercial beam trawl (rigged as before) were made on each occasion. After each haul, a sub-sample of the catch from the cod-end was placed immediately into a 50 l bin filled with sea water and then transferred to a survival system. The survival system consisted of six 4.0 x 0.5 x 0.3 m tanks, attached to a steel frame which was locked to the deck of the ship using twist locks. Each tank was fitted with three evenly spaced, removable partitions drilled with twenty 1 cm diameter holes which allowed free circulation of water. The entire system was enclosed with a tarpaulin cover to eliminate light which may have increased stress effects. The species selected for examination were maintained in separate compartments with sea water flowing to waste. An assessment was made of the initial mortality of each species collected in the subsample. Only live animals were placed in the survival system. Their mortality was recorded at intervals of 24 h for up to 120 h, although the procedure varied from year to year depending on circumstances.

RESULTS

Echinoderms were, generally, highly resilient. The initial and delayed mortality (0 to 1%) of *Asterias rubens* and *Astropecten irregularis* was lower than that for other animals (Table II). *Ophiura ophiura* suffered low initial mortality, which increased to 14-19% after 120 h. Delayed mortality occurred in those animals which had badly damaged or crushed oral discs, which disintegrated with time. Amongst echinoderms, *Psammechinus miliaris* had both the highest initial mortality (20%) and the highest final mortality (51%). *Eupagurus bernhardus* showed low overall mortality (6%), and the animals that died tended to be those which had abandoned their shells and had been crushed in the codend. However, *Eupagurus prideauxi* suffered slightly higher mortality (<14%). Despite their fragile appearance, *Macropodia tenuirostris* suffered relatively low total mortality (32%) after 72 h. In March 1992, swimming crabs suffered 45% initial mortality, which only increased to 58% after 72 h. In April 1993 however, overall mortality was much lower (<15%). Although *Callionymus* spp. had an initial mortality of only 6-12%, final mortality increased to between 68 and 97%. *Pleuronectes platessa* and *Raja naevus* showed delayed mortality increasing from an initial 6 and 0% to 38 and 34% final mortality respectively. Although mortality of *Alcyonium digitatum*, was impossible to determine by casual inspection, it was apparent that polyps emerged with their tentacles extended within 24 h and retracted when exposed to light.

DISCUSSION

These results show that fishing with the 4-m beam trawl lowered both the number and the biomass of sessile animals in the experimental box. In particular, the biomass of *A. digitatum* and hydroids was reduced by approximately 50% after trawling (Table I). How quickly these animals are likely to recolonize the area is unknown but the period could span months to years. Furthermore, cluster analysis and MDS demonstrate that, in the short term, beam trawling significantly alters the overall structure and diversity of the benthic community. The density of some mobile species increased after trawling (Table I). Most of these species are scavengers or predators (eg *E. bernhardus, Callionymus* spp. and *Palaemon* spp.) and move rapidly (1-3 h) in response to chemical stimuli (Nickell & Moore, 1992) exuding from damaged or dead animals which occur as a result of beam trawling activity. Other scavengers, such as *B. undatum* and *A. rubens*, may respond more slowly, arriving after 12 h (Sainte-Marie & Hargrave, 1987; Nickell & Moore, 1992). Other results also showed that dogfish, whiting and gurnards take advantage of this extra food source (Kaiser & Spencer, 1993), as do dabs, *Limanda limanda,* in the North Sea (M. Fonds, personal communication).

Animals that form the by-catch of a beam trawl can suffer injuries from a variety of sources. The beam shoes, chain mat and abrasion from the net can inflict wounds and injuries of different degrees of severity. On hauling the net, pressure from the weight of catch can inflict bruises and internal injuries which may lead to delayed mortality. Some animals survive this experience better than others (Table II). As in other studies (BEON, 1990, 1991) echinoderms, in particular asteroids, showed a high percentage survival which is not surprising considering their ability to regenerate limbs (Barnes, 1980). The susceptibility to damage seems to be related to the flexibility of the test. Sea urchins have brittle tests, which are easily smashed and expose them to predation. Ophiuroids have flexible plates, which are also more susceptible to damage than the more flexible test of asteroids. Although swimming crabs, *L. holsatus*, are able to regenerate limbs, they are killed when their carapaces are crushed. In another study (Kaiser & Rogers, unpublished data) tickler chains were identified as the part of the beam trawl that was mainly responsible for crushed carapaces. *Callionymus* spp. suffered high delayed mortality, which was surprising as superficially they appeared undamaged. It is probable that a combination of stress and internal injuries contributed to their high mortality. More than 60% of *Pleuronectes platessa* and *Raja naevus*, were still alive after 120 h. This is probably attributable to their thick, armoured slimy skin. Those specimens which died showed signs of either severe (>30%) scale loss (*P. platessa*) and/or bruising (*R.. naevus*).

Scavenging animals which are also able to survive the fishing process (eg. starfish), may eventually increase in abundance as a result of fishing activity. Thus beam trawling, as well as other forms of fishing that generate discards, could favour populations of predators and scavengers, which may become abnormally elevated as has been suggested for seabirds (eg. Furness, 1982).

REFERENCES

BARNES, R.D., 1980. Invertebrate Zoology, 4th edition. Saunder College, Philadelphia, 1089pp.

BEON, 1991, Effects of beamtrawl fishery on the bottom fauna in the North Sea. BEON, Report 13. 85pp.

BERGMAN, M.J.N. & HUP, M., 1992. Direct effects of beam trawling on macrofauna in a sandy sediment in the southern North Sea. J. du Conseil, 49, 5-13.

BRIDGER, J.P., 1972. Some observations on the penetration into the sea bed of tickler chains on a beam trawl. ICES, CM. 1972/B: 7.

CRUETZBERG, F., DUINEVELD, G.C.A. & VAN NOORT, G.J., 1987. The effect of different numbers of tickler chains on beam-trawl catches. J. du Conseil, 43, 159-168.

FIELD, J.G., CLARKE, K.R. & WARWICK, R.M. 1982. A practical strategy for analysing multispecies distribution patterns. Mar. Ecol. prog. ser., 8, 37-52.

FURNESS, R.W. 1982. Competition between fisheries and seabird communities. Adv. Mar. Biol., 20, 225-309.

KAISER, M.J. & ROGERS, S.I. in prep. Improving quantitative surveys of epibenthic communities using a modified 2-m beam trawl.

KAISER, M.J. & SPENCER, B.E., 1993. Opportunistic feeding on benthos by fishes after the passage of a 4-m beam trawl. ICES CM 1993/G:

LINDEBOOM, H., 1990. How trawlers are raking the North Sea to death. Daily Telegraph, 16/03/1990.

PEARSON, T.H., JOSEFSON, A.B. & ROSENBERG, R., 1985. Peterson's benthic stations revisited. I. Is the Kattegatt becoming eutrophic? J. Exp. Mar. Biol. Ecol., 92, 157-206.

RILEY, J.D., SYMONDS, D.J. & WOOLNER, L., 1981. On the factors influencing the distribution of 0-group demersal fish in coastal waters. Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer, 178, 223-228.

ROGERS, S.I., 1992. Environmental factors affecting the distribution of sole (*Solea solea*) within a nursery area. Neth. J. Sea Res., 29, 153-161.

ROGERS, S.I. & LOCKWOOD, S.J., 1989. Observations on the capture efficiency of a two-metre beam trawl for juvenile flatfish. Neth. J. Sea Res., 23, 347-352.

RUMOHR, H. & KROST, P., 1992. Experimental evidence of damage to benthos by bottom trawling with special reference to *Arctica islandica*. Meeresforsch., 33, 340-345.

Table I. The change in density (numbers/1000 m²) and biomass (g/1000 m²) (mean of 3 samples) of selected dominant species sampled with a 2-m juvenile flatfish beam trawl before and after experimental fishing with a 4-m beam trawl. Mobility of animals is indicated by (S) sessile/slow moving or (M) highly mobile.

Species	Density		Biomass		Mobility
	Before	After	Before	After	
Alcyonium digitatum	—	—	9570	4620	S
Bryozoan/hydroids	—	—	1055	670	S
Psammechinus miliaris	115	27	927	89	S
Asterias rubens	43	20	859	247	S
Ophiura ophiura	64	25	402	46	S
Macropodia tenuirostris	128	47	67	12	S
Palaemon spp.	17	27	2	3	M
Eupagurus bernhardus	34	47	313	513	M
Callionymus spp.	7	16	161	181	M
Pomatoschistus spp.	23	23	10	6	M

Table II Results of survival experiments carried out between March 1992 and April 1993. The cumulative % mortality for each species in 24 hourly intervals.

Species	Date	Nos.	CUMULATIVE % MORTALITY 0	24	48	72	96	120	Notes
Aphrodite aculeata	Mar. 92	46	0	5	7				No apparent reason for initial mortality.
	Apr. 93	65	0		3.1	3.1	3.1	6.2	Some intraspecific predation later.
Ophiura ophiura	Mar. 92	26	0	0	19				Mortality occurred in those individuals
	Apr. 93	34	5.9		5.9	11.7	11.7	14.7	with >50% damage to oral disc.
Astropecten irregularis	Mar. 92	17	0	0	0				No mortality, strong test, damage confined to arms.
Asterias rubens	Mar. 92	126	1	1	1				Mortality only occurred when whole animal crushed.
Psammechinus miliaris	Mar. 92	91	20	37	51				Delayed mortality indicated by loss of spines.
Eupagurus bernhardus	Mar. 92	39	6	6	6				Crabs well protected in shell.
	Apr. 93	15	0		0	0	0	0	
Eupagurus prideauxi	Apr. 93	29	13.7		13.7	13.7	13.7	13.7	Crabs not so well protected , only carrying piece of shell with attached anemone. Dead crabs severed at abdomen.
Macropodia tenuirostris	Aug. 92	22	8	22	25	25			Crabs fold delicate legs under body and avoid damage.
Liocarcinus depurator	Mar. 92	45	29	29	40				Mortality tends to occur as a result of
	Apr. 93	34	8.8		12.9	12.9	12.9	14.7	intraspecific predation when individuals moult.
Eledone cirrhosa	Apr. 93	15	0		0	0	0	13.3	Nine animals escaped from the tanks. Two dead animals at the end of the experiment.
Plueronectes platessa	Apr. 93	50	4		18	24	30	38	Dead animals tended to have >30% scale loss and bruising.
Agonus cataphractus	Apr. 93	13	7.6		25	25	25	25	No obvious reason for death.
Callionymus spp.	Aug. 92	65	12	71	89	97			Some fish showed signs of bruising. Mostly reason not obvious.
	Apr. 93	50	6		24	46	68		
Raja naevus	Apr. 93	32	0		0	12.5	34		Dead fish showed signs of bruising.
Alcyonium digitatum	Apr. 93	50	0		0	0	0	0	After 24 h the colonies appeared to have taken up water. All colonies had feeding polyps throughout the experiment.

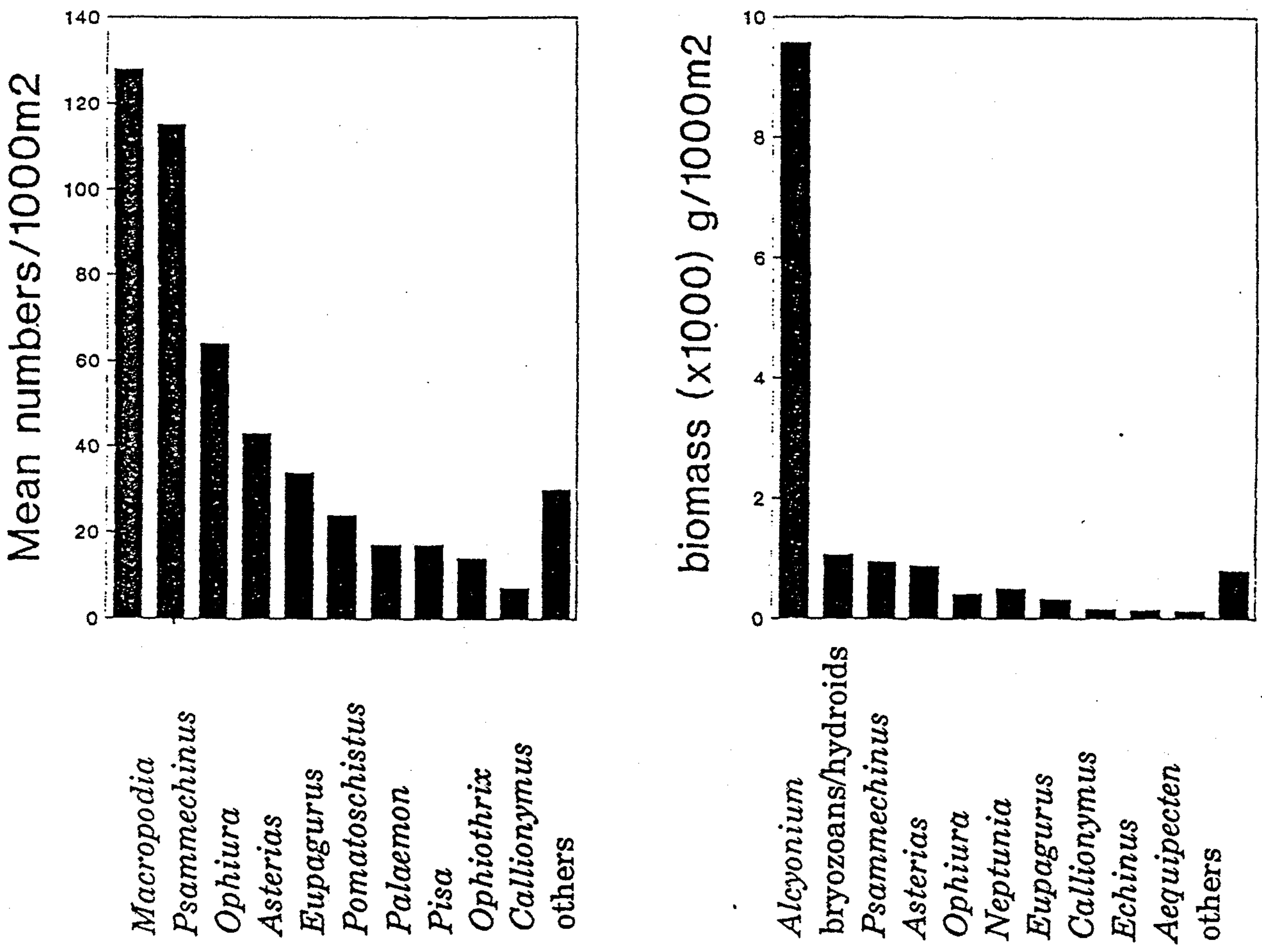

Figure 1. The ten dominant species in the benthic community at the experimental site, based on density and biomass. NB. *A. digitatum* and bryozoans/hydroids have been omitted from the density analysis because of the difficulty of quantifying individuals or colonies.