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Improving quantitative surveys of epibenthic communities using a modified 2 m beam trawl

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ABSTRACT: The addition of heavy, spiked, linked tickler chains (chain mat) to a 2 m beam trawl without chain mat increased the catch rates of some epibenthic species, but not others. Catch rates of the invertebrates *Asterias rubens, Ophiura ophiura, Liocarcinus holsatus* and all combined flatfish species increased. In contrast, the catch rates of the epibenthic teleosts *Callionymus* spp. decreased, but those of *Echiichthys vipera* were not affected. Comparisons with data in other studies suggested that this modification increased the catch rates of epifauna to give an improved estimate of population density. Although total biomass of the catch increased with tow durations between 2.5 and 7.5 min, there was no significant effect on estimates of either standardised species abundance or biomass ha^{-1} Although short tows reduce catch sorting time, the variation between samples was greater than for longer tows (7.5 min). Hence, it is suggested that the latter are preferable for estimating population density and community structure, although this may depend on the spatial dimensions and objectives of the study. The results are discussed in the context of the use of the gear as a sampling tool in ecological surveys of epibenthic communities in sublittoral and coastal shelf areas.

KEY WORDS: Epibenthic communities · Quantitative surveys · 2 m beam trawl

INTRODUCTION

Studies of trophic interactions within subtidal communities require an array of sampling techniques such as grabbing, coring, underwater video, diver observation, dredging and trawling, the choice of which depends on the type of substrate present, the aims of the study and financial constraints (Holme & McIntyre 1984). While it is desirable to use a range of sampling techniques for different components of a subtidal community, it is not always practical (due to financial or time constraints), leading to the use of more generalistic devices, such as beam trawls. Small demersal fish and epibenthic species are caught effectively in shallow coastal waters with small beam trawls (2 to 4 m width), but, as yet, the efficiency of this gear as a sampling device for the whole epibenthic community has not been assessed. The term 'efficiency', as used here, is defined as the number of individuals of the target species caught, expressed as a proportion of the total population in the sampled area. When the efficiency of the gear is increased, the catch rate of some species can eventually reach an asymptote (Creutzberg et al. 1987). This suggests that, for some species, the gear may be close to obtaining the best possible sample of that particular species (Creutzberg et al. 1987, Rogers & Lockwood 1989). Although this is a reasonable assumption for relatively immobile animals such as starfish and sea urchins, it may not be relevant to faster animals, such as fish and crabs, which are able to avoid trawls (Main & Sangster 1981).

The specific aims of this study were (1) to determine how effectively a modified 2 m beam trawl samples the different species that constitute the epibenthic component of an inshore subtidal community, and (2) whether this varies with tow duration.

The 2 m beam trawl is frequently used as a sampling tool during ecological surveys of juvenile flatfish populations and the associated epifauna (Riley & Corlett 1965, Edwards & Steele 1968, Lockwood 1974, Kuipers 1975, Poxton et al. 1982, Riley et al. 1986). The efficiency of the trawl varies around 35% depending on the target species, trawl size and substrate over which the gear is used (Edwards & Steele 1968, Kuipers 1975, Rogers & Lockwood 1989), and hence several attempts have been made to improve the efficiency of the gear (Christensen 1969, Rogers & Lockwood 1989). These improvements have generally been aimed at maximising the catch rates of fish (de Groot & Boonstra 1970, Rogers & Lockwood 1989) rather than epibenthic invertebrates (but see Creutzberg et al. 1987).

Similar modifications have been made in commercial beam trawls in response to falling fish stocks and the concomitant need to increase effort. These developments, such as longer beams, flip-up ropes, more tickler chains and chain mats, combine to make the gear heavier (de Groot 1984, Messieh et al. 1991, Jones 1992). They allowed rougher ground to be fished, and, as with smaller survey gears, have increased the catch rates of flatfish (e.g. Creutzberg et al. 1987) and the by-catch of noncommercial fish species and benthic animals (Bergman et al. 1990, Bergman & Hup 1992, Fonds et al. 1992).

MATERIALS AND METHODS

Study site. The study site (Fig. 1) is a flatfish nursery ground off the coast of North Wales, UK, where both commercial and survey fishing gears operate throughout the year. The site has been surveyed regularly by the Fisheries Laboratory, Conwy (Ministry of Agriculture, Fisheries and Food, UK) since 1989 as part of an ecological study of juvenile sole *Solea solea* (L.). A detailed description of the site and the environmental characteristics was given by Rogers (1992).

Sampling method. The 3 tickler chains of the standard 2 m beam trawl (Riley & Corlett 1965) were replaced with heavier, spiked chain, joined perpendicularly by shorter lengths of plain chain (see diagram in Rogers & Lockwood 1989). This modification is referred to hereafter as chain mat. In all cases the trawls were fitted with a net with a mesh size of 20 mm, a cod-end liner of 4 mm mesh and a foot rope weighted with a plain linked chain. In July 1992 the epifaunal community was sampled as part of a larger ecological study (Rogers in press) using a pair of these modified 2 m beam trawls towed simultaneously behind a 10 m commercial fishing vessel during daylight at a speed of approximately 1 knot (i.e. 0.53 m s^{-1}; Riley & Corlett 1965). A single tow of 10 min duration, using both beams, was made at the study site. Two weeks later the exercise was repeated but the chain mat of one of the pair of trawls was removed, leaving only the light, plain chain on the foot rope of the net. Nine separate tows were made in a Latin square design (Fig. 1). Each tow, the duration of which was 2.5, 5.0 or 7.5 min, was made in the direction of the prevailing tide, which reduced the chances of fishing a previously sampled area (Fig. 1). Thus, there were 3 replicates of each tow duration to reduce bias caused by patchiness of animals' distribution and differences in substrate type. In an attempt to further reduce the effect of patchiness, all tows were made in an area which had maximum dimensions of 180 × 1000 m. The tow distance was estimated from the shoot and haul

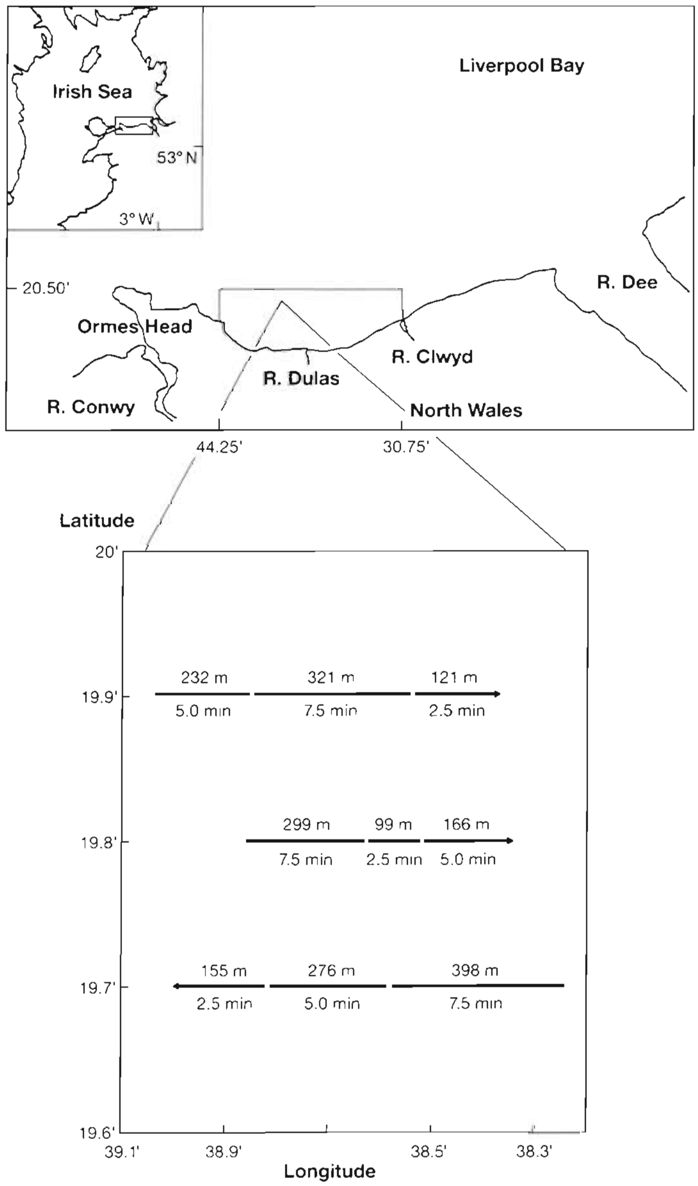

Fig. 1. Study site on the North Wales coast, showing experimental design, direction of towing, and distance towed (m)

positions recorded from the Decca navigator and provided a record accurate to within ±10% (Rogers 1992). The entire catch from each cod end was placed immediately into separate polythene bags and on return to the laboratory was frozen and stored.

Each catch was weighed (±1 g) and then sorted by either species or taxa. To simplify the analysis, only dominant species which normally accounted for >90% of the biomass were recorded (Table 1). All species of flatfish were pooled as it was too time consuming to identify them all to species level, especially as their physical condition had degenerated on return to the laboratory. The number of individuals of each species or taxon and their total wet weight (±1 g), after blotting dry on absorbent cloth, were recorded.

Statistical analysis. Catch data were standardised by raising the number of individuals of each species per haul to number per hectare (no. ha^{-1}). Similarly, the total catch weight per haul was raised to kg ha^{-1}. Statistical comparisons of the effect of the 2 treatments (addition of chain mat and tow duration) on estimates of the number of animals per hectare were made using Kruskal-Wallis ANOVA which is a nonparametric 1-way analysis of variance (Sokal & Rohlf 1981). The effect of chain mat on the total catch weights for different tow durations was compared using ANCOVA, after $\log_e$ transformation of the raw and standardised data. A Wilcoxon signed rank test (nonparametric test similar to a *t*-test) was used to compare whether the proportion of each species in the catch differed with the addition of chain mat. Modifications to the sampling gear could lead to different interpretations of community structure. To test whether this was the case, each catch was treated as a distinct sample and the similarity between samples determined by cluster analysis on standardised $\log(x + 1)$ species density using the Bray-Curtis similarity method, and multidimensional scaling (MDS), a multivariate ordination technique. Further details of these methods can be found in Warwick et al. (1990).

Table 1. Epibenthos caught in the 2 m beam trawl survey at the beginning of July 1992. Biomass (kg ha^{-1}) and nos. ha^{-1} are expressed as % of total catch. *Species used to compare the different catch rates of a 2 m beam trawl fitted with and without chain mat. Unsorted material: general debris and other species of animals collected

Species	% numbers	% biomass
*Asterias rubens**	12.1	52.3
*Liocarcinus depurator**	18.6	17.0
Unsorted material*	–	10.4
Crangon crangon	36.6	9.5
*Pleuronectes platessa**	0.2	2.1
*Buglossium luteum**	2.2	1.9
*Limanda limanda**	3.8	1.6
*Solea solea**	1.2	1.5
Callionymus spp.*	0.4	1.0
*Echiichthys vipera**	0.4	1.6
Carcinus maenas	0.1	0.5
*Ophiura ophiura**	20.8	0.3
Pomatoschistus spp.	3.0	0.3
Eupagurus bernhardus	0.2	0.2
Macropodia tenuirostris	0.1	<0.1
Corystes cassivelaunus	<0.1	<0.1
Eutrigla gurnardus	<0.1	<0.1
Syngnathidae	<0.1	<0.1
Merlangius merlangus	<0.1	<0.1
Ammoditidae	<0.1	<0.1
Argentidae	0.1	<0.1
Agonus cataphractus	<0.1	<0.1

RESULTS

Community composition

Annual and seasonal samples of the community at the experimental site have shown that it is highly consistent (Rogers in press) which is the basis for the comparison of the field data with our experimental data. Almost 90% of the community (expressed as nos. ha^{-1}) consisted of the invertebrates starfish *Asterias rubens*, shrimp *Crangon crangon*, swimming crabs *Liocarcinus holsatus*, and brittlestars *Ophiura ophiura* (Table 1). Flatfish accounted for <8% of the community, and other teleosts were mainly represented by gobies *Pomatoschistus* spp. (3%). In terms of biomass (g wet wt ha^{-1}), *A. rubens* and *L. holsatus* were dominant (70%), but the smaller species, *C. crangon* (9.6%) and *O. ophiura* (0.3%), represented a smaller proportion of the community by weight. The structure of the epibenthic community, sampled using the modified 2 m beam trawl, did not vary significantly between the experimental investigation and the field survey (Wilcoxon test: $p = 0.90$, $n = 14$), except that the density of *O. ophiura* had increased substantially (Fig. 2). In contrast, the same community surveyed with the gear without chain mat described a different, fish dominated, community (Wilcoxon test: $p < 0.001$, $n = 12$, Fig. 3).

Cluster analysis and MDS revealed differences between species/taxon abundance both within and between samples collected with both gear types. These differences are attributable to species/taxon abundance, rather than diversity, as the same species and taxa occurred in all samples. It is apparent that the first major dichotomy of the dendrogram splits the samples into 2 distinct groups based on the gear used (Fig. 4a). However, within these 2 clusters, no clear differences were linked to tow duration (Fig. 4a). The MDS plot presents the similarity between all the samples in

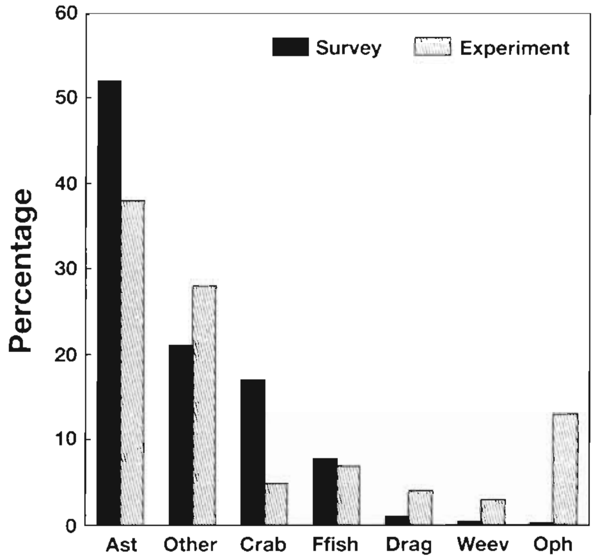

Fig. 2. Percentage composition of the study site (see Fig. 1) community in August 1991 and during the experiment in August 1992. Ast: *Asterias rubens*; Other: all other species in the community; Crab: *Liocarcinus holsatus*; Ffish: all flatfish species pooled; Drag: *Callionymus* spp.; Weev: *Echiichthys vipera*; Oph: *Ophiura ophiura*

2-dimensional relationship to each other (Fig. 4b). The degree of similarity is represented by the distance between points. It is clear that the samples again fall into 2 distinct groups based on the gear used to collect them (Fig. 4b). Furthermore the samples collected with the modified gear are more tightly clustered that those collected with the unmodified gear, which suggests that the variation between samples collected with the modified gear is lower. Also, within clusters, the greatest similarity occurs between samples of the longest (7.5 min) tow duration and the least similarity occurs between samples of short duration (2.5 min). Hence, it would appear that longer tows give greater similarity between samples.

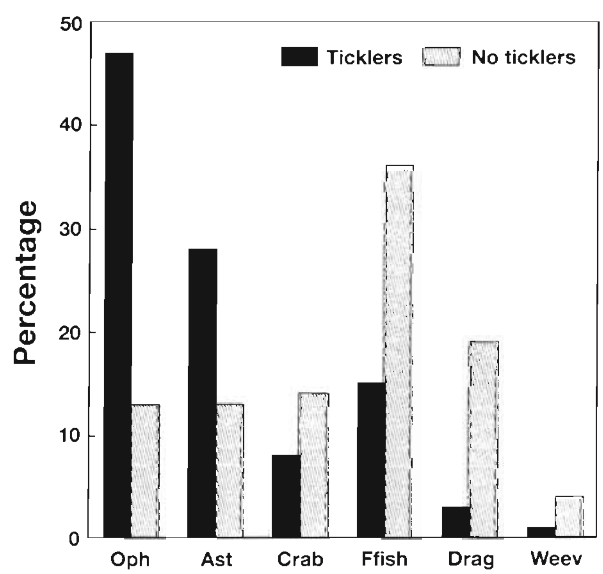

Fig. 3. Percentage of total catch accounted for by each group of animals for beam trawls fitted with and without chain mat. Oph: *Ophiura ophiura*; Ast: *Asterias rubens*; Crab: *Liocarcinus depurator*; Ffish: all flatfish species pooled; Drag: *Callionymus* spp.; Weev: *Echiichthys vipera*

Effect of chain mat and tow duration

The geometric mean wet weight of total catch was significantly (2 to 3 times) higher when the beam trawl was fitted with chain mat (Table 2: ANCOVA, $F_{1,15}$ = 52.2, p < 0.001). As expected the wet weight of catch also increased significantly with tow duration (Table 2: ANCOVA, $F_{1,15}$ = 10.2, p < 0.01). When the catch was standardised to wet wt ha^{-1} the addition of chain mat once again gave a significantly greater calculated biomass ha^{-1} (Table 2: ANCOVA, $F_{1,15}$ = 37.2, p < 0.001), but tow duration had no significant effect on the calculated biomass ha^{-1} (Table 2: ANCOVA, $F_{1,15}$ = 1.5, p = 0.24).

The calculated mean catch rates (no. ha^{-1}) for certain animals were significantly greater when the beam trawl was fitted with chain mat (Table 3). The catch rates of *Asterias rubens*, *Ophiura ophiura*, *Liocarcinus*

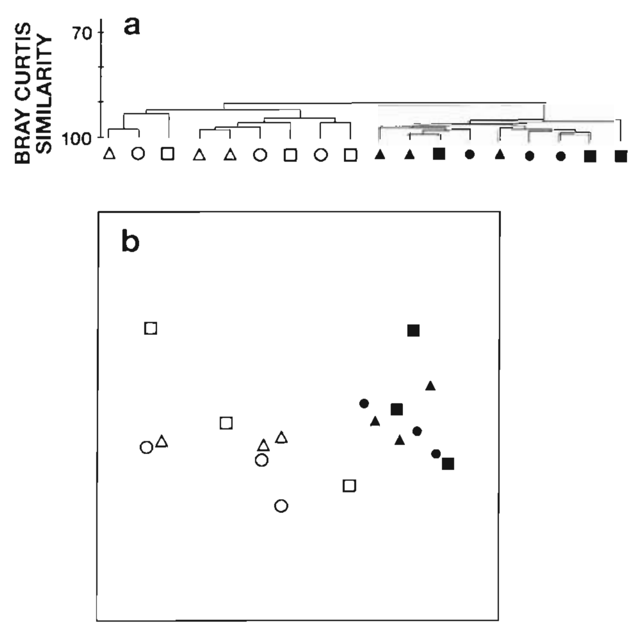

Fig. 4. (a) Cluster analysis and (b) the first 2 axes of multidimensional scaling (MDS) of the samples (standardised data) taken with the unmodified beam trawl (open symbols) and the beam trawl fitted with chain mat (solid symbols) using 3 tow durations: 2.5 min (squares), 5.0 min (circles) and 7.5 min (triangles)

Table 2. Geometric mean ± SE wet weight (kg) of total catches and standardised wet weight (kg ha^{-1}) when the beam trawl was fitted with or without chain mat, towed for different periods, with an ANCOVA for differences associated with the addition of chain mat, with tow duration (min) set as the covariate

	Catch weight (kg)				**Standardised wet weight (kg ha^{-1})**			
Tow duration (min):	2.5		5.0	7.5	2.5		5.0	7.5
No chain mat	1.6 ± 5.6		2.6 ± 0.6	3.4 ± 0.9	31.0 ± 10.5		18.9 ± 4.6	16.8 ± 4.6
Chain mat	5.7 ± 0.2		9.2 ± 2.3	10.9 ± 1.6	108.0 ± 3.2		68.0 ± 17.6	53.7 ± 8.1
ANCOVA								
Source	df	SS	*F*	p	df	SS	*F*	p
Covariate	1	1.43	10.06	0.006	1	0.30	1.49	0.241
Presence of chain mat	1	7.46	52.17	0.001	1	7.46	37.18	0.001
Error	15	2.14			15	3.01		
Covariate	Coefficient	SD	*t*-value	p	Coefficient	SD	*t*-value	p
	0.139	0.044	3.172	0.006	−0.063	0.052	−1.12	0.241

Table 3. Mean ± SE and median (Med.) catch rate (no. ha^{-1}) of selected species from a 2 m beam trawl fitted with and without chain mat. Values are calculated from the pooled data from tows of 2.5 to 7.5 min duration (replicated 3 times, n = 18). Significant differences were tested using Kruskal-Wallis ANOVA (*H*): *$p < 0.05$; **$p < 0.001$; ns: $p > 0.05$

Species	No. ha^{-1}				*H*	p
	Chain mat		No chain mat			
	Mean ± SE	Med.	Mean ± SE	Med.		
Asterias rubens	6185 ± 937	7025	608 ± 211	625	12.8	**
Ophiura ophiura	10137 ± 2053	11520	612 ± 317	619	12.2	**
Liocarcinus holsatus	1790 ± 478	1683	665 ± 271	747	5.1	*
Flatfish	4534 ± 682	4050	2369 ± 441	1706	5.1	*
Callionymus spp.	441 ± 106	413	804 ± 153	769	3.9	*
Echiichthys vipera	293 ± 39	358	252 ± 48	276	1.42	ns

holsatus and flatfish were significantly increased by the addition of chain mat (Table 3). In contrast, there was a significant decrease in the catch rate estimates of *Callionymus* spp. when chain mat was fitted to the beam trawl (Table 3). It should be noted, however, that, of the principal catch components listed, it was the only species to show lower catch rates with the chain mat than with the unmodified gear. The catch rates of the weevers *Echiichthys vipera* tended to be higher when the modified gear was used, but the difference was not significant (Table 3).

Table 4. Comparison of the estimate of the mean ± SD biomass (g wet wt) of selected species sampled with 2 m beam trawl fitted with or without chain mat, tested using 1-way ANOVA ($F_{1,16}$, ns: $p > 0.05$)

Species	Individual biomass			
	Chain mat	No chain mat	*F*	p
Asterias rubens	11.7 ± 2.4	13.8 ± 4.6	1.5	ns
Ophiura ophiura	1.9 ± 0.4	1.8 ± 0.7	0.2	ns
Liocarcinus holsatus	5.6 ± 2.6	5.7 ± 1.7	0.1	ns
Flatfish	5.2 ± 3.5	5.7 ± 10.2	0.1	ns
Callionymus lyra	16.9 ± 6.0	14.9 ± 2.6	0.8	ns
Echiichthys vipera	19.3 ± 14.0	13.3 ± 3.5	1.5	ns

To test the possibility that the addition of chain mat to the 2 m beam trawl led to selection of different sized animals, the mean weight of individual animals was compared from the 2 gears, however no significant change in estimated biomass for any species was detected (Table 4).

DISCUSSION

In studies that assess community dynamics, it is important to assess the trophic status of each animal group by using sampling devices which maximise the catch rate for as many species as possible, reduce variation between replicate samples and give a representative sample of the population structure. We have shown that the addition of chain mat to a 2 m beam trawl increases the calculated density of certain species in an epibenthic community (Table 3) and reduces variation between replicate samples, as demonstrated by the tighter grouping of samples in the MDS plot (Fig. 4). Samples taken with the unmodified beam trawl indicated that the epibenthic community in the study area was dominated by fish species, whereas those from the modified beam trawl sampled a greater proportion of the invertebrate fauna and indicated that these were the dominant organisms (Figs. 2 & 3). While the addition of chain mat alters the percentage composition and estimated abundance of each species and weight of catch, increasing the tow duration had no effect (Tables 2 & 3, Fig. 3). On the basis of these results it might be assumed that using the shortest tow duration provides adequate data. In practice, however, tow duration is a compromise between the need for a short tow which minimises the time required to sort the catch, and a long tow to reduce the error and variation between samples. This point is underlined by the MDS analysis which shows a much closer similarity (i.e. less variation) between the samples from longest tows (triangles, Fig. 4b) than the shortest tows (squares, Fig. 4b), irrespective of whether or not chain mat is fitted. It is possible that errors associated with estimating distance towed, and hence total area sampled, are proportionally greatest for the shortest tow duration, and may account for the greater variation between samples. Although this problem could partly be overcome by using a meter wheel to record distance travelled over the bottom, this, in our experience, has not always been a reliable technique. Alternatively, as tow duration increases the effects of epifaunal patchiness on sample variation will be reduced, which may or may not be a desirable effect, depending on the aims of the study. Furthermore, it may be argued that when seeking a measure of small-scale heterogeneity, other techniques, such as underwater video surveys, should be used.

When sampling populations of animals within a community, it is important to minimise bias towards specific year classes. The 2 m beam trawl was specifically designed to catch juvenile flatfish (Riley & Corlett 1965), and also has been used extensively in surveys of sublittoral communities (e.g. Lockwood 1974, Ansell & Gibson 1990, Rogers 1992, in press). It is important when studying trophic interactions in a community to take a representative sample of the population. Hence, developments which seek to improve estimates of density and biomass should also avoid biased samples of population structure. In the case of beam trawls size-selection is affected by the size of mesh used, the towing speed or modifications such as the addition of tickler chains. In our study, however, the mean weight for individuals of each species sampled was not affected by the addition of chain mat. Thus, while the addition of chain mat improved the estimates of epibenthic animal density and biomass, the mean size of individuals was not affected.

In studies of benthic communities dredges and beam trawls are used to catch the rarer and more mobile animals which are not sampled using corers and grabs (Holme & McIntyre 1984). In general, trawls and dredges can have efficiencies as low as 30% (Edwards & Steele 1968) or 5 to 12% (Dickie 1955) respectively, reducing their utility in quantitative estimation of epifaunal communities. Rogers & Lockwood (1989) found that a modified 2 m beam trawl fitted with chain mat increased sampling efficiency for juvenile flatfish possibly to a notional maximum of 100% for some species. Similarly, Creutzberg et al. (1987) demonstrated that by continually adding more tickler chains to a 5.5 m beam trawl, the catches of some fish and epibenthic species eventually reached an asymptote which suggested a maximum catch rate for *Limanda limanda, Asterias rubens, Liocarcinus holsatus* and *Ophiura* spp. at a particular trawling speed and in the prevailing environmental conditions (Fig. 5). In the present study, chain mat increased the catch rate of *A. rubens* and *O. ophiura* by a factor of 10 and 16 respectively, similar to the asymptotic levels observed by Creutzberg et al.

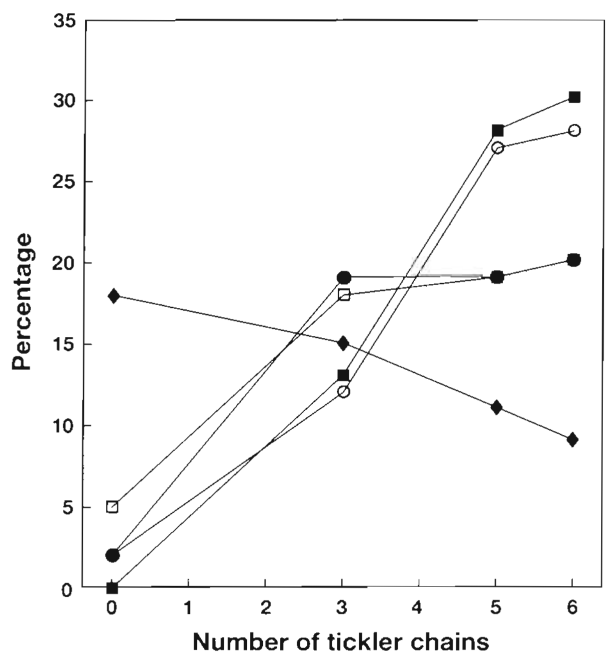

Fig. 5. Change in the proportion of the catch of different species with increasing numbers of tickler chains fitted to a 5.5 m beam trawl fished over 2 substrates. Sandy substrate: (□) *Limanda limanda*, (○) *Ophiura ophiura*, (●) *Asterias rubens*, (■) *Liocarcinus depurator*. Mud: (♦) *Limanda limanda*. Redrawn from Creutzberg et al. (1987)

Table 5. Factor increase in the catch of some invertebrates due to the addition of a chain mat to an unmodified 2 m beam trawl in this study, and the use of 6 tickler chains on a 5.5 m beam trawl (from Creutzberg et al. 1987)

Species	Increase in catch	
	2 m beam trawl	5.5 m beam trawl
Asterias rubens	×10	×10
Ophiura spp.	×16	×14
Liocarcinus holsatus	×3	×30

(1987) (Fig. 5, Table 5). Hence, we suggest that the modified 2 m beam trawl maximises the catch of these species. This conclusion is valid only if both 2 m and 5.5 m unmodified gears catch the same proportion of the population, i.e. they have the same efficiency under certain conditions. While this may not apply to actively swimming animals, it is a reasonable assumption for more sedentary species, e.g. *O. ophiura*. Thus the addition of chain mat to the 2 m beam trawl seems to have achieved maximum sampling efficiency for some relatively inactive epibenthic species (Fig. 5). However, although chain mat increased the catch rate of *L. holsatus* this increase did not approach the levels achieved by the 5.5 m beam trawl (Creutzberg et al. 1987). *L. holsatus* is an active swimmer and may have escaped more effectively from the smaller survey gear which was towed at a quarter of the speed (1 knot) of the commercial gear (4 knots; Creutzberg et al. 1987). Ground type is another factor which can affect the efficiency of beam trawls, for example, the number of dabs caught decreased as more tickler chains were added to a 5.5 m beam trawl fished over mud, probably because the chains dig so deeply into the mud that the efficiency of the trawl is impeded (Fig. 5) (Creutzberg et al. 1987). Hence, while adding chain mat to a 2 m beam trawl improves samples obtained from sandy grounds, the same may not occur in muddy areas.

Although the modified beam trawl increased catch rates of invertebrates, results varied for different species of fish. For example, catches of flatfish increased using the modified gear, fewer dragonets were caught, but the catch rate of weevers remained constant. Gear design influences the reactions of fish in response to trawls (Main & Sangster 1981), and the addition of chain mat probably increases the noise generated and alerts the fish in its path. The normal reaction of (juvenile) flatfish to fright stimuli is to dig into the substrate and hide. This reaction does not protect them, however, from the increased efficiency of spiked tickler chains which 'dig' the fish out. In contrast, it appears that the less cryptic dragonets actively avoid the noisier trawl but weevers may either dig in and be caught, or swim away. Similarly, saithe *Pollachius virens* have been observed actively avoiding trawls fitted with bobbins which generate noise (Main & Sangster 1981).

In quantitative studies of fish and benthic communities it is necessary to optimise the catching efficiency of any sampling device used. When catch efficiency is low, other factors such as temperature and visibility, which affect the activity and reactions of animals, and bottom structure and towing speed could mask variation in the abundances of animals. Our results indicate that when used as an ecological sampling tool, a 2 m beam trawl fitted with chain mat provides better quantitative data for repeatable estimates of community structure, density and biomass by reducing inter-sample variation, compared with unmodified trawls. Increasing tow duration does not affect calculated density, but longer tows reduce variation between samples. To sample the more mobile epibenthic animals effectively, the use of additional fishing methods is recommended.

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