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Estimating the catching efficiency of a 2-m beam trawl for sampling epifauna by removal experiments

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The catching efficiency of a standard 2-m beam trawl for sampling epifauna was estimated by removal experiments at two sites in the southern North Sea. In order to allow repeated sampling of the same area, a rig of three beam trawls one behind the other was constructed, the three being tied together by steel ropes. Catching efficiency was estimated on the basis of the sum of the catches of all three trawls relative to the numbers caught in the first trawl. The catching efficiency of the beam trawl for epifauna ranged from 36% to 44% of total abundance between sites. Efficiency was least for partly buried species (*Liocarcinus holsatus*, 9% and 18%; *Buglossidum luteum*, 27%; *Arnoglossus laterna*, 35%), and slightly better for species living on the surface of the sediment (*Asterias rubens*, 42% and 46%; *Pomatoschistus minutus*, 58% and 46%; *Pagurus bernhardus*, 51%). The abundance of epifauna will be underestimated by a factor of 1.4–11 relative to the abundance in the three trawls. Also, sediment type seems to influence the catching efficiency of the beam trawl, efficiency being less at the sandy study site than at the muddy site for most species.

Keywords: catchability, epifauna, fish fauna, fishing gear, North Sea.

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Introduction

The benthic infauna of the North Sea has been studied intensively since the work of Petersen in the 1910s (Petersen, 1914, 1918; Salzwedel *et al.*, 1985; Künitzer *et al.*, 1992; Craeymeersch *et al.*, 1997), but few studies have investigated epifaunal communities. As larger macrofauna form a significant proportion of the bycatch of trawl fisheries, initial studies of the epifauna of the North Sea relied on examination of the invertebrates caught as bycatch during fishery surveys (Dyer *et al.*, 1982, 1983). Semi-quantitative investigations with smaller gear (a 2-m beam trawl) were first carried out by Frauenheim *et al.* (1989), and this work was subsequently followed by that of Jennings *et al.* (1999), Zühlke *et al.* (2001), and Callaway *et al.* (2002) for the whole North Sea.

Generally, epifaunal sampling gears, such as a 2-m beam trawl, are considered to be semi-quantitative. Several attempts have been made to improve the sampling procedure in order to generate more quantitative results, and these include modifications to the trawl (Rogers and Lockwood, 1989; Kaiser *et al.*, 1994; Jennings *et al.*, 1999), estimation of the towing distance using a metered wheel or a net probe (Carney and Carey, 1980; Eleftheriou and Moore, 2005), and standardization of trawling duration and speed (Zühlke *et al.*, 2001). However, the catching efficiency of a 2-m beam trawl is still unknown. The term catching efficiency is generally defined as the number of individuals or the biomass of one or several species expressed as a proportion of the total population in a study area (Allen *et al.*, 1992; Kaiser *et al.*, 1994). Realistic estimates of catching efficiency and therefore the abundance or biomass of fish and invertebrate epifauna in an ecosystem are particularly important in determining secondary production or consumption rates, as well as for ecosystem modelling (Harley *et al.*, 2001). Therefore, any limitations of sampling gear have to be considered in assessing how well an assemblage is described.

Studies of catching efficiency have focused primarily on gears targeting commercial fish or shrimp species, where the main objectives were to increase the relative catchability of a target species rather than to estimate the catching efficiency related to the quantitative species composition in the assemblage (Harley *et al.*, 2001). The relative efficiency of small trawls has been studied by comparing different gears or gear modifications (Kuipers, 1975; Creutzberg *et al.*, 1987; Rogers and Lockwood, 1989; Kaiser *et al.*, 1994). However, this approach cannot give reliable information about the real catching efficiency of a gear because each gear has different but unknown catching efficiencies.

Combined underwater image (video or photographic analysis) and trawl catches (Yeh and Ohta, 2002, Sonntag, pers. comm.), or experimental approaches such as repeated sampling (Fonds, 1994; Loneragan *et al.*, 1995), can provide realistic estimates of catching efficiency. However, such approaches have serious drawbacks. On the one hand, image analyses can only give information about the catching efficiency for easily visible larger epibenthos and fish species, whereas small and buried species cannot be considered. On the other hand, repeated sampling of the same area is virtually impossible in offshore areas because of inaccurate positioning if using ship-deployed gears, and immigration of mobile species into the trawled area will affect abundance estimates (Fonds, 1994). Therefore, repeated sampling with small trawls has only been used in shallow waters, such as estuaries and intertidal channels, where the study site can be spatially restricted (Edwards and Steele, 1968; Kuipers, 1975; Allen *et al.*, 1992; Loneragan *et al.*, 1995). Fonds (1994), however, did try repeated sampling in an offshore area in the southern North Sea with commercial beam trawls.

In order to allow repeated sampling with a 2-m beam trawl, which is commonly used for epifauna sampling in offshore waters, we developed a sampling design in which three beam trawls were tied one behind the other to guarantee repeated sampling of the same area. The objectives of this study were (i) to estimate the catching efficiency of a standard 2-m beam trawl for sampling epifaunal species (small fish and invertebrates), and (ii) to investigate whether this efficiency varies between species or sediment types.

Material and methods

Study sites and sampling

The study sites are located in two boxes (10 × 10 nautical miles) situated in different areas of the southern North Sea (Figure 1). These boxes are part of the German Small-scale Bottom Trawl Survey (GSBTS), which was started in 1986 by SE to investigate mesoscale variability in the fish fauna (Ehrich and Stransky, 2001). The sediment structure of the two boxes is different, with muddy sand in box A and coarse sand in box N (Table 1).

Samples of the epifauna were obtained with FRV "Walther Herwig III" in January 2004. Sampling was carried out with a standard 2-m beam trawl with a chain mat attached. It was fitted with a 20-mm stretched mesh and a codend liner of 4-mm knotless mesh. Details about the equipment are given in Jennings *et al.* (1999). To estimate the towing distance and hence the area sampled, a net probe (SCANMAR©) was fixed to the headline of the trawl

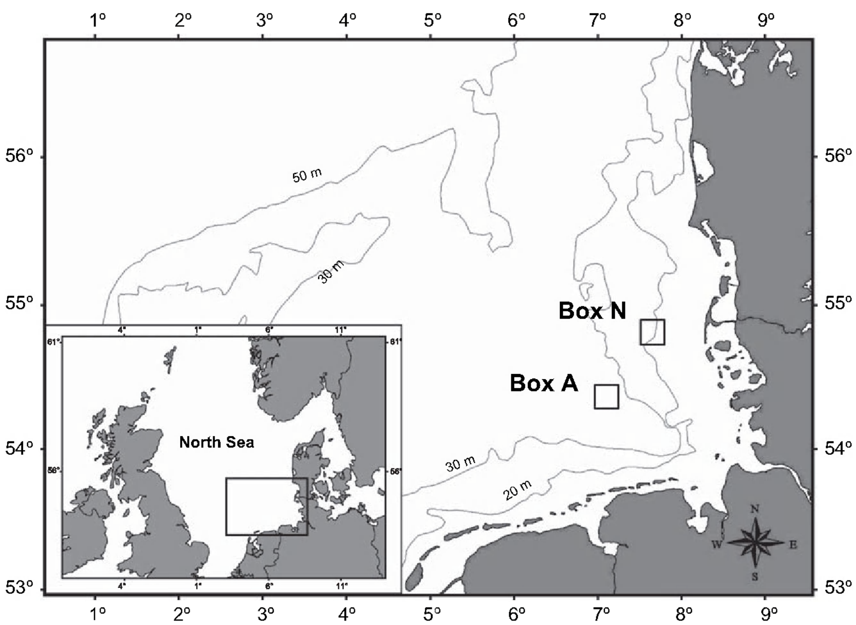

Figure 1. Study areas in the North Sea.

Table 1. Geographical positions (centre of the boxes) and main characteristics of the study sites. For the mean towing distance, the standard deviation is given.

Parameter	Box A	Box N
Latitude	54°22.02′N	54°48.00′N
Longitude	007°06.48′E	007°40.02′E
Date of sampling	7 January 2004	10 January 2004
Mean depth (m)	39	25
Sediment type	Muddy sand	Coarse sand
Mean towing distance (m)	218 ± 15	306 ± 63

to determine the exact times when the gear touched and left the bottom. In order to guarantee repeated sampling of the same trawl track, three identical beam trawls were rigged one behind the other, attached by steel ropes 6 m long (Figure 2a). The net probe was fixed to the headline of the first trawl. Figure 2b shows the hypothetical pattern of abundance or biomass in the consecutive trawls, assuming a sequential catching efficiency of 50%. In each box, the experiment was repeated three times.

Because of differences in the diurnal activity of some epibenthic species, sampling took place only during daylight. The samples were sieved through a 5 mm mesh and the organisms collected. Most species were identified on board, counted, and weighed (wet weight) with

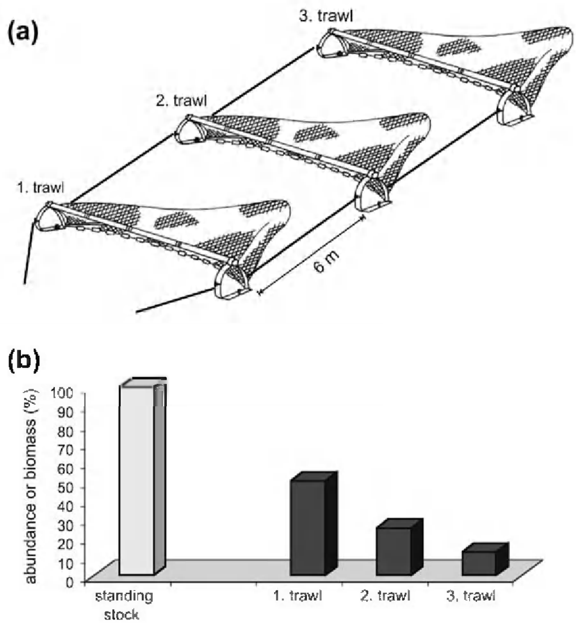

Figure 2. (a) Schematic drawing of the gear used in the three-beam-trawl experiment, and (b) the hypothetical pattern of epifaunal abundance or biomass within each trawl assuming a catching efficiency of 50%.

a motion-compensated marine scale. If onboard identification of species was not possible, specimens were fixed in 4% buffered formalin for identification in the laboratory. In addition, three hauls with a single trawl were carried out in the vicinity of the positions of the three-beam-trawl hauls (maximum distance away, 2 nautical miles), to compare the catches of both deployments. The single-trawl and three-beam-trawl samples were treated in the same way.

Analysis

The abundance and biomass data were standardized to a tow length of 250 m (area sampled = 500 m^2). Prior to analysis, large demersal and pelagic fish caught with the trawls were excluded. To calculate catching efficiency, regression methods such as those of Leslie or DeLury (see Loneragan *et al.*, 1995) could not be applied to our data, because only two repeats were possible. Therefore, to estimate catching efficiency, the sum of the catches of all three trawls was assumed to represent the total abundance and biomass of the epifauna. Total numbers, the sum of all three trawl catches, were compared with the numbers caught in the first trawl, and from those data the percentage efficiency was calculated. Therefore, the estimated catching efficiency will only provide a value of maximum efficiency, because the results indicate that the total abundance (biomass) was probably higher than the numbers (biomass) caught by the three trawls. For species with a total abundance of <10 individuals, no catching efficiency was calculated. A Mann–Whitney U test was used to assess significant differences in the catching efficiency between the different sampling sites and between catches of the different deployments.

Results

Total abundance and biomass

In box A, fewer individuals were caught with the second and third trawl than in the first trawl, as expected from the experimental design (Figure 3). However, the decrease in abundance was not consistent from one net to the next. In box N, a similar pattern was found for one replicate only, whereas in the two other replicates, most individuals were caught in the second trawl. The catching efficiency of total epifaunal abundance and biomass was 44% and 32% in box A, and 36% and 45% in box N, respectively (Table 2).

The surprising catch pattern of the three trawls compared with our initial expectations seemed to be caused mainly by differences in the vulnerability of different species. Extrusion of small specimens through the net does not explain the high abundances sometimes found in the second and third trawl. The effect of mesh selectivity could not be analysed in detail, because no size measurements of the epifauna were made during the study. However, the biomass pattern in the three trawls, which was similar to that for

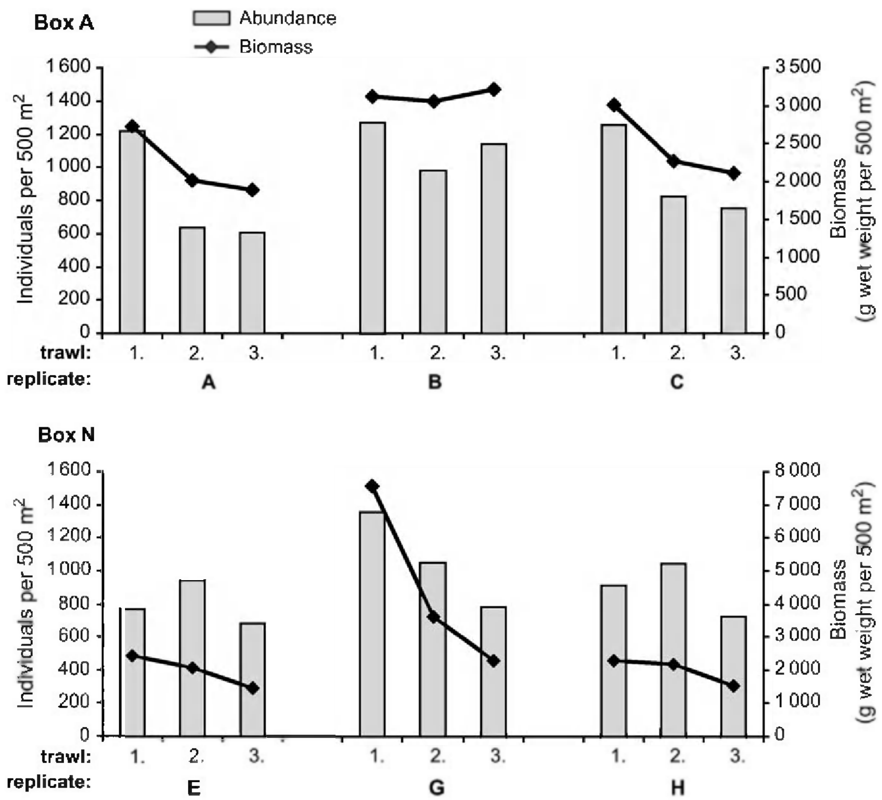

Figure 3. Pattern of total abundance (bars) and biomass (lines) for the first, second, and third trawl for each replicate (A–C and E, G and H) in boxes A and N.

abundance, as well as visual observations, revealed no substantial differences in the size of the specimens in the catches of the consecutive trawls.

The comparison of the data of the first trawl with the data of single-trawl deployments of the standard programme shows no significant differences in total abundance or biomass (U test$_{(3/3)}$, $p > 0.05$). Therefore, we conclude that towing two trawls behind the first did not affect the catching characteristics of the first trawl, compared with a single-trawl haul.

Species numbers

The first trawl caught between 70% and 76% of the total species taken in all three trawls in box A and between 54% and 84% of all species taken in all three trawls in box N (Figure 4). In both study areas, most species caught by the first trawl were species with an epifaunal life mode, living most of their life at the surface of the sediment or only occasionally burrowing in its upper layers (Figure 4). In contrast, the additional species caught by the second and/or the third trawl contained a higher proportion of infaunal species, such as bivalves and polychaetes. This is taken as an indication that the first trawl disturbed the surface sediments and dug out specimens, resulting in their greater vulnerability to the second and third trawl. Because this pattern was consistent among sites, differences in sediment type appear to have a minor effect on the relative composition of catches, although the chain mat was expected to penetrate deeper into the sediment of the muddy sand of box A than into the sandy substratum of box N.

Abundance and biomass at a species level

For the highly mobile sand goby (*Pomatoschistus minutus*), there was a clear decrease in abundance from the first to the second trawl in each study area (Figure 5a), the catching efficiency reaching 58% and 46% in boxes A and N, respectively (Table 2). In box A, abundance in the third trawl was slightly greater than in the second, perhaps through buried individuals being disturbed by the first and second trawl and caught by the third. The disturbance effect of the trawls is clearly reflected by the abundance pattern of the swimming crab *Liocarcinus holsatus* in the three trawls (Figure 5b). Greatest abundance was in the third trawl and lowest in the first trawl for all replicates, contrary to our initial expectations. This was probably caused by the disturbance of this night-active species, which buries in the sediment during daylight. Therefore, the estimated catching efficiency for *L. holsatus* was just 18% in box A and 9% in box N (Table 2). In contrast, the catching efficiency of the shrimps *Crangon crangon* and *C. allmanni*,

Table 2. Mean catching efficiency (±s.d.) of the 2-m beam trawl at the two study sites in boxes A and N.

Taxon	Catching efficiency in box A		Catching efficiency in box N	
	Abundance (%)	Biomass (%)	Abundance (%)	Biomass (%)
Fish				
Arnoglossus laterna	35 ± 2	41 ± 5	—	—
Buglossidium luteum	27 ± 15	28 ± 5	—	—
Limanda limanda	44 ± 17	37 ± 8	29 ± 24	35 ± 25
Callionymus lyra	45 ± 14	46 ± 16	29†	4 ± 0
Callionymus reticulatus	—	—	36 ± 19	25 ± 10
Syngnathidae	—	—	43 ± 11	45 ± 9
*Pomatoschistus minutus**	58 ± 6	58 ± 6	46 ± 3	53 ± 6
Decapoda				
Corystes cassivelaunus	64†	55 ± 5	—	—
*Liocarcinus holsatus**	18 ± 5	20 ± 10	9 ± 2	9 ± 3
Pagurus bernhardus	—	—	51‡ ± 1	64 ± 8
*Crangon allmanni**	56 ± 4	58 ± 4	26 ± 8	27 ± 7
Crangon crangon	43 ± 6	40 ± 6	31 ± 7	28 ± 5
Processa spp.	72‡ ± 8	83 ± 24	—	—
Asteroidea				
Asterias rubens	42 ± 7	46 ± 8	46 ± 6	53 ± 7
Astropecten irregularis	34 ± 9	34 ± 9	35 ± 10	37 ± 12
Other taxa				
Nucula nitidosa	19‡ ± 19	11 ± 16	—	—
Branchiostoma lanceolata	—	—	0‡ ± 0	0 ± 0
All taxa	44 ± 5	32 ± 8	36 ± 4	45 ± 9

*Indicates significant differences (U test$_{(3/3)}$, $p < 0.05$) in catching efficiency between sites.
†Based on one replicate only.
‡Based on two replicates only.

which also live partly buried in the sediment, was comparatively high in box A at 43% and 56%, respectively. However, in box N the efficiency was lower, at 31% for *C. crangon* and 26% for *C. allmanni* (Figure 6, Table 2). Even the catching efficiency of slow-moving epifaunal species living most of the time on the sediment surface, such as the sea stars *Asterias rubens* and *Astropecten irregularis*, was <50% (Figure 7, Table 2).

There was considerable variability in the catching efficiencies among species and sites (Table 2). Sediment type seemed to have an influence on catching efficiency for some species. Significant differences between the sites were found for *P. minutus*, *L. holsatus*, and *C. allmanni* (U test$_{(3/3)}$, $p < 0.05$), indicating lower catch efficiencies in box N than in box A.

Discussion

Until now, studies of the catching efficiency of the small beam trawls and dredges used for sampling epifauna were mainly restricted to analysis of findings for a limited group of commercially fished species, such as juvenile flatfish, prawns, or scallops. Dickie (1955) documented a scallop dredge efficiency of 5–12% for the target species, depending on the type of sea bottom. For juvenile flatfish, estimates of catching efficiency for a 2-m beam trawl varied between 23% and 57% (Creutzberg *et al.*, 1987), between 23% and 37% for plaice (Edwards and Steele, 1968), and were 100% for juvenile plaice (Kuipers, 1975). These rather low estimates of catching efficiency indicate that epifauna sampling with a beam trawl provides a fragmentary rather than a complete inventory of the epifaunal community.

The standardized 2-m beam trawl described by Jennings *et al.* (1999) was used recently in studies of epifauna communities of the North Sea (Zühlke *et al.*, 2001; Callaway *et al.*, 2002; Hinz *et al.*, 2004; Reiss and Kröncke, 2004), and the analyses included standardization of trawl duration and speed, as well as recording of the start and end position of the trawl. However, because the catching efficiency of the gear was still unknown, abundance estimates from those studies were still not calibrated. The results from our study provide initial estimates of the catching efficiency of a 2-m

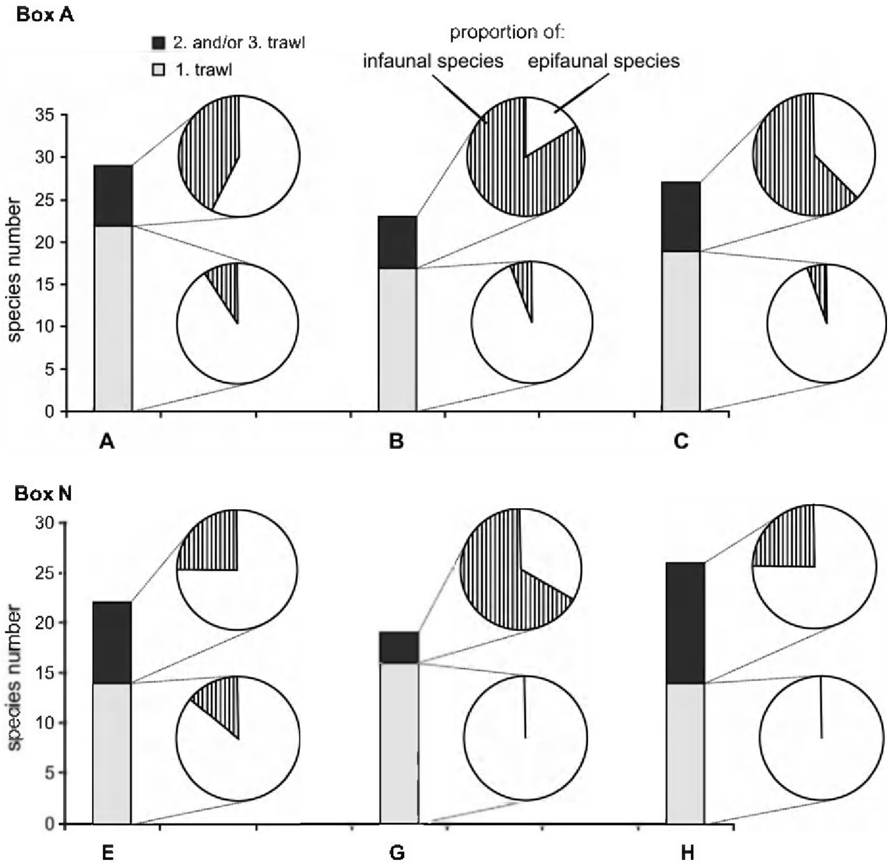

Figure 4. Total species numbers by the first trawl (grey bars), and additional species caught by the second and/or third trawl (dark grey bars). The pie charts show the proportion of infaunal (shaded) and epifaunal (white) species numbers in each category.

beam trawl for several species in two different habitats. Catching efficiency for most species was <50%, although there were marked differences between species. However, accurate estimates of gear catching efficiency and, therefore, of abundance or biomass of epifauna in an ecosystem are particularly important in determining secondary production and, hence, for modelling the ecosystem (Harley *et al.*, 2001).

Estimating catching efficiency – the three-beam-trawl approach

Some of the main difficulties in repeated sampling in offshore areas arise from inaccuracy in positioning the trawl tracks and migration of scavenging specimens into the trawled area. To guarantee repeated sampling of the same area, we used three beam trawls one behind the other, which made immigration of specimens into the trawl track nearly impossible because the distance between each trawl was only some 6 m from beam to beam. However, specimens could still escape from an approaching trawl by moving to the side. Kuipers (1975) showed that the lateral escape of fish from the trawl track of a 2-m beam trawl was significant in the case of large specimens (>15 cm). However, because large fish, which are not sampled quantitatively by a 2-m beam trawl, were omitted from our analyses, lateral escape of fish specimens is considered to be of minor importance here. However, highly mobile invertebrate specimens such as *L. holsatus* or shrimp species might have escaped from all three trawls, which would have led to an underestimation of the catching efficiency.

Comparing epifaunal abundance in the first of the three trawls with that in single-trawl hauls revealed that towing additional trawls closely behind the first had no significant influence on the performance of the front trawl. Therefore, the catching efficiency for the three beam trawls towed one behind each other can be applied to the results for single beam trawl hauls. However, we do acknowledge that bottom contact of the three-beam-trawl arrangement was recorded by a net-probe fixed only on the first beam trawl. Consequently, there may have been a time-lag in bottom contact between the first and the third trawl, the latter perhaps making bottom contact before the first, and vice versa during hauling. This might conceivably have biased our results towards greater abundance in the third trawl. However, we believe that such a time-lag would have been very

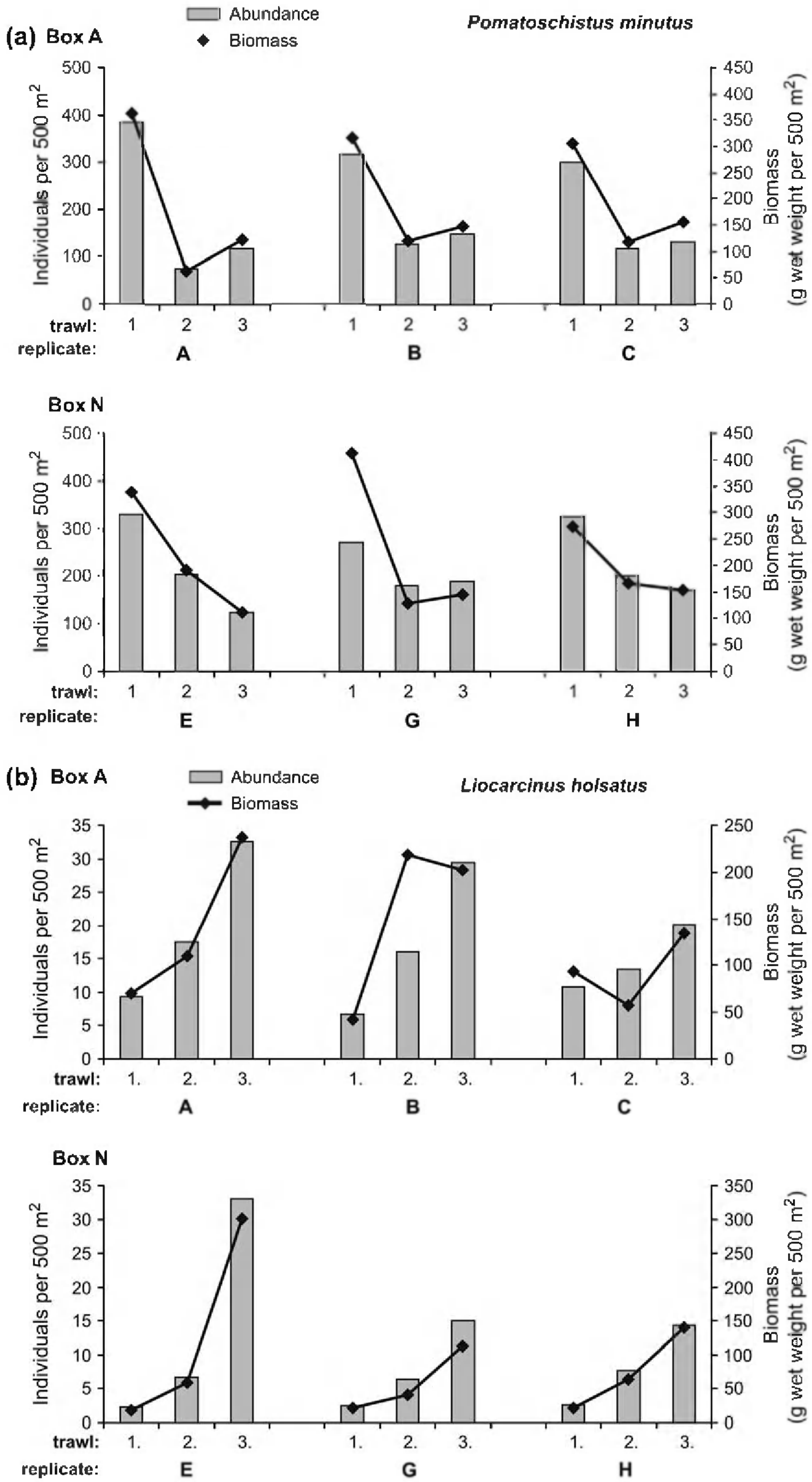

Figure 5. Pattern of abundance (bars) and biomass (lines) for (a) sand goby (*Pomatoschistus minutus*) and (b) swimming crab (*Liocarcinus holsatus*) for the first, second, and third trawl for each replicate (A–C and E, G and H) in boxes A and N.

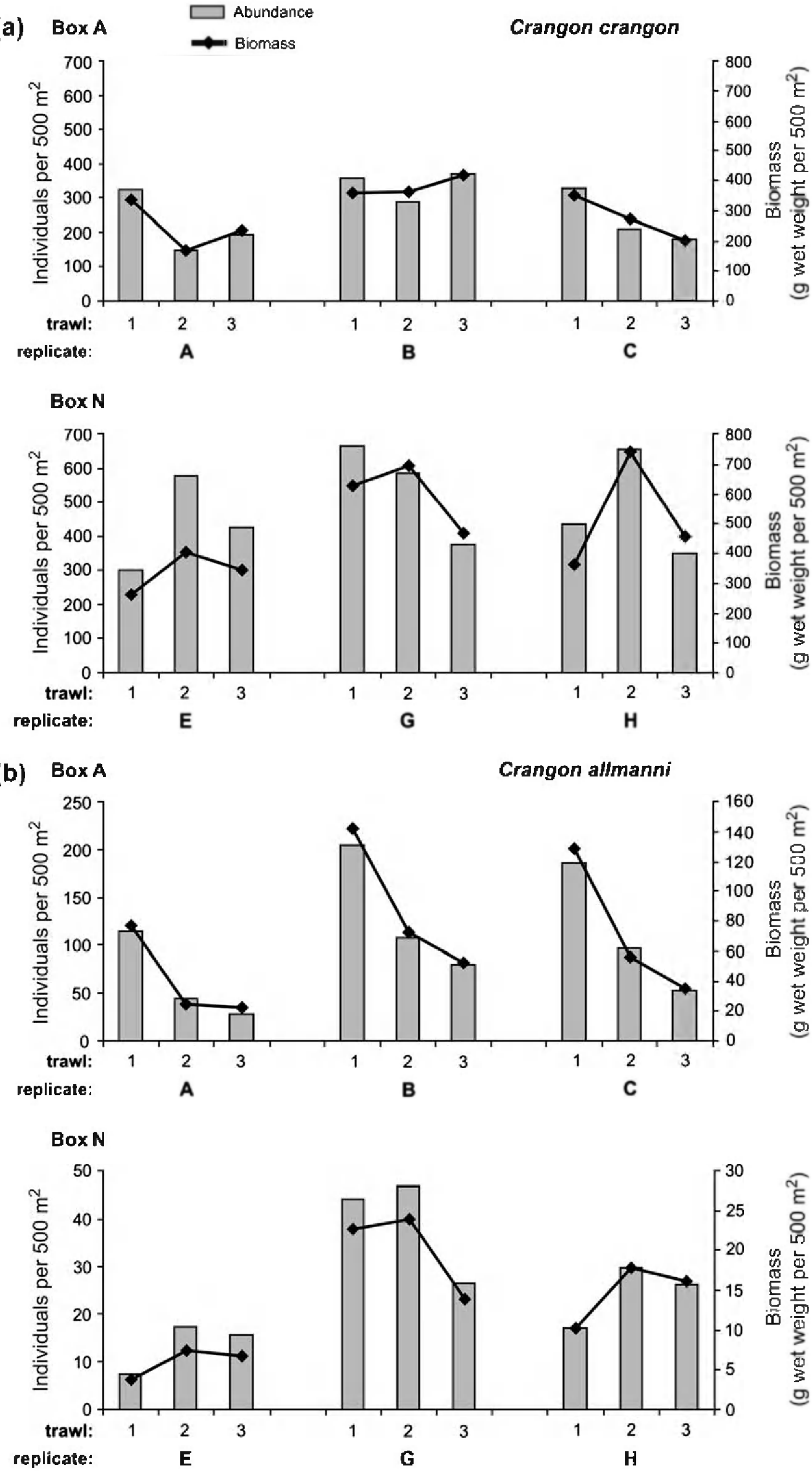

Figure 6. Pattern of abundance (bars) and biomass (lines) for (a) common shrimp (*Crangon crangon*) and (b) brown shrimp (*Crangon allmanni*) for the first, second, and third trawl for each replicate (A–C and E, G and H) in boxes A and N.

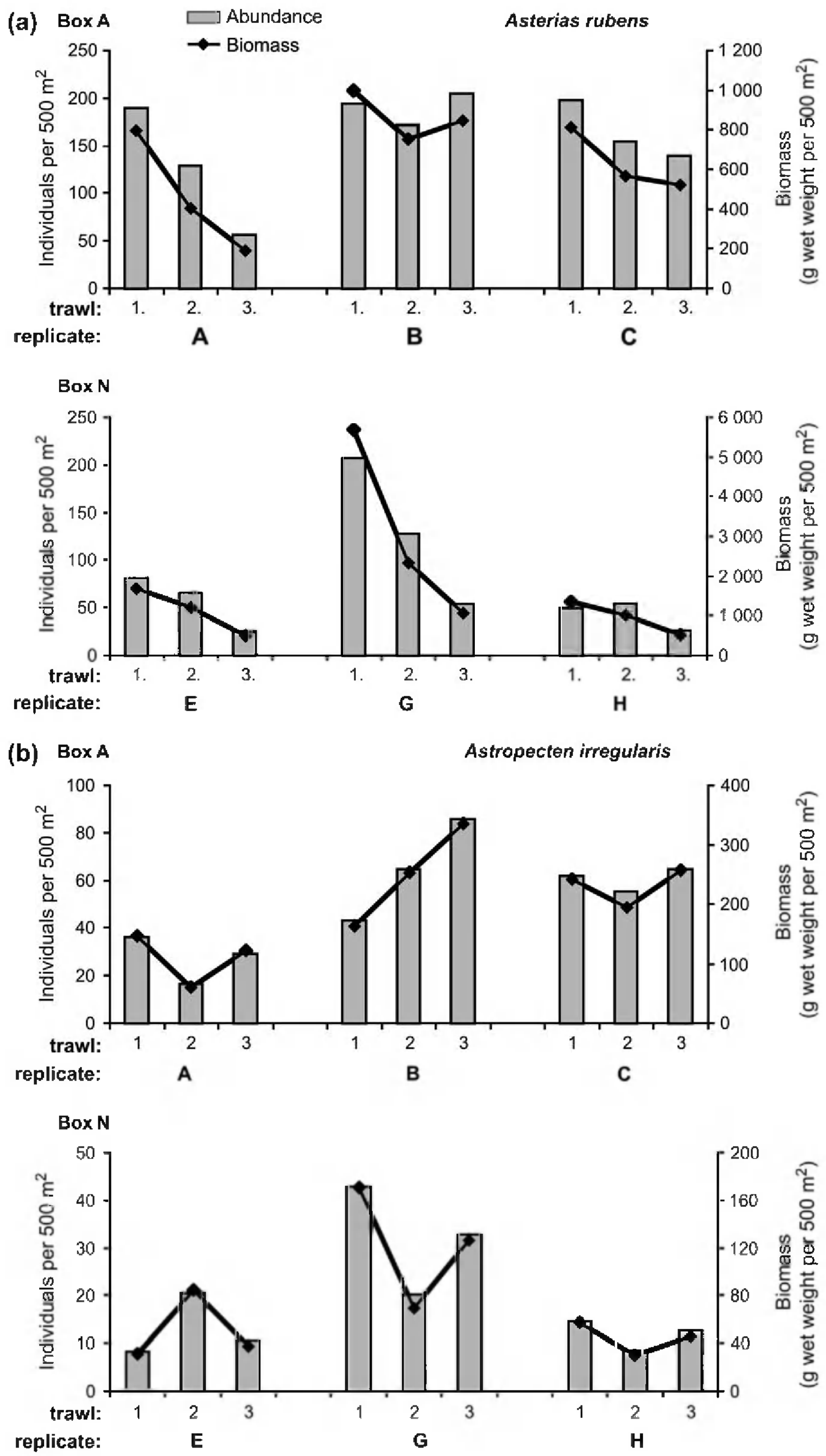

Figure 7. Pattern of abundance (bars) and biomass (lines) for (a) common sea star (*Asterias rubens*) and (b) sand star (*Astropecten irregularis*) for the first, second, and third trawl for each replicate (A–C and E, G and H) in boxes A and N.

short and of minor importance relative to the total distance sampled.

The sum of the catch of all three trawls was assumed to represent the total populations in the sampled area. The abundance of several species in the three trawls indicates that this assumption is rather simplistic, because the abundance was often higher in the rear trawls than in the first (e.g. *L. holsatus*). Therefore, the catching efficiency could have been overestimated, so the estimated catching efficiency calculated here is likely to be a maximum value; real catching efficiency might be less.

Catching efficiency for different epibenthic species

The results of our study have shown that the estimates of catching efficiency for the 2-m beam trawl were 44% and 36% of total abundance in boxes A and N, respectively. These results are in a range similar to those of previous studies on single species, mentioned above. However, there were differences in catching efficiency between epifaunal species. The catching efficiency for different species is determined by the behaviour of the individual animals, which influences their likelihood of being caught by a trawl. Slow-moving species are expected to be caught more efficiently than highly mobile ones, which may escape from the trawl. Also, species living on the sediment surface would be expected to be caught more effectively than species partly buried in the sediment. Our lowest estimates of catching efficiency were for species living partly buried in the sediment, e.g. solenette (*Buglossidium luteum*), 27%, and scaldfish (*Arnoglossus laterna*), 35%, in box A (Table 2). In contrast, the catching efficiency in box A for more mobile fish species such as the sand goby and the dragonet (*Callionymus lyra*) was somewhat higher, 58% and 45%, respectively. The lowest catching efficiency within the invertebrate epifauna was for the swimming crab *Liocarcinus holsatus*, which lives buried in the sediment, with 18% in box A and 9% in box N (Table 2).

The high abundances in the second and the third trawl, and the resulting low catching efficiency for some species, might have been caused by disturbance of the sediment by the first trawl, which could have made buried specimens more accessible to the trawls following immediately behind. Weinstein and Davis (1980) considered the loss of fish through their burial in soft mud to be an important consideration in estimating true population size using a seine net. On the other hand, the downward force of the rear trawls might be greater than that of the first one, which could have resulted in deeper penetration of the second and third trawl into the sediments. However, the low catching efficiency calculated here shows that the abundance and biomass, especially for species buried partly in the sediment, will be significantly underestimated if a single 2-m beam trawl is used.

The 2-m beam trawl with a chain mat, as used in this study, maximized the catch of *A. rubens* and *Ophiura albida* by factors of 10 and 16, respectively, when compared with the results of an unmodified beam trawl (Kaiser *et al.*, 1994). From the latter findings, we would expect the 2-m beam trawl to be the most appropriate gear for sampling less mobile epifaunal species. However, our results show that the catching efficiency for species such as *Asterias rubens*, *Astropecten irregularis*, and *Pagurus bernhardus* was well below 50% (Table 2).

Differences in the catching efficiency depending on non-gear-specific parameters

Aside from the general design and construction of a beam trawl, its catching efficiency may depend on sediment type (Bergman and van Santbrink, 1994; Ball *et al.*, 2000), light intensity (Glass and Wardle, 1989), and the seasonal or diurnal activity patterns of the epifauna (Gibson *et al.*, 1996; Casey and Myers, 1998; Korsbrekke and Nakken, 1999). Penetration depth of a beam trawl is an important factor determining the catching efficiency, particularly for buried species, and this will depend on sediment type (Creutzberg *et al.*, 1987; Rogers and Lockwood, 1989; Bergman and van Santbrink, 1994). In this study, catching efficiency of almost all species at the sandy site (box N) was lower than at the muddy sand site (box A), but differences were significant only for *C. allmanni*, *L. holsatus*, and *P. minutus*. These differences in catching efficiency between the sites were probably caused by differences in the sediment type and the resulting variation in penetration ability of the beam trawl. Penetration depth of commercial beam trawls is up to 8 cm in muddy sediment and up to 3 cm in sandy sediment (Kaiser and Spencer, 1994; Van Santbrink and Bergman, 1994).

Our results show that the likelihood of species being caught by a beam trawl depends *inter alia* on the life mode or behaviour of the species. Therefore, environmental factors causing changes in behaviour will probably have an effect on the catching efficiency of the gear. Diurnal variations in activity of a species may lead to differences in catching efficiency between day and night (Korsbrekke and Nakken, 1999), which is most likely the case for night-active decapods such as the swimming crabs *L. holsatus* and *L. depurator* (Abelló *et al.*, 1991). Loneragan *et al.* (1995) found that catch rates of tiger prawns by day, when the prawns are buried in the sediment, were about half of those by night. Also, seasonal differences in behaviour were found for several epifaunal species, as a result of their reproductive cycle (Hartnoll, 1972; Reiss and Kröncke, 2004), reduced locomotory activity attributable to low temperature (Allen *et al.*, 1992; Freeman *et al.*, 2001), or changes in food availability (Abelló *et al.*, 1991; Maes *et al.*, 1998). For example, the masked crab *Corystes cassivelaunus* remains buried in the sediment throughout the whole year, but mature crabs leave the sediment during the breeding season in spring and early summer (Hartnoll, 1972; Reiss and Kröncke, 2004). Although differences in catching efficiency attributable to seasonal or diurnal differences in the vulnerability of species could not be tested during this study, they are likely to occur. Such potential differences should be taken into account when comparing beam-trawl samples from different seasons or at different times of day.

Implications of catching efficiency for epifauna studies

The 2-m beam trawl was initially designed to catch juvenile flatfish (Riley and Corlett, 1966), but since then, several studies have focused on modifications designed to improve the catch of invertebrate epifauna. When sampling benthic communities, each gear (grab, core, or trawl) will sample only a component of the benthic assemblage (Eleftheriou and Moore, 2005). However, if the catching efficiency of a gear is too low, other biotic and abiotic factors that influence estimates of abundance could mask possible spatial or temporal variations in the communities (Kaiser *et al.*, 1994). Our results show that the catching efficiency of a 2-m beam trawl was below 50% for most epifaunal species, varying between 9% for the swimming crab *L. hosatus* in box N and 72% for the shrimp *Processa* spp. in box A (Table 2). Therefore, the abundance and biomass of epifauna will be significantly underestimated by the use of beam-trawl samples. When studying spatial differences between epifaunal communities, differences in the catching efficiency between species may result in biased estimation of functional properties. For example, partly buried species such as swimming crabs or flatfish will be underestimated compared with species that live on the sediment surface. This bias might be even more important if comparing different habitats, because of differences in the catching efficiency by sediment types for some species. Therefore, infauna species should be omitted from such analyses, although these species are regularly retrieved in the trawl samples.

Realistic data on the population abundance and biomass of benthic species are particularly important in determining secondary production in an ecosystem. Our results show that estimations of secondary production based on beam-trawl samples will be underestimated by factors of 1.4–11, depending on the species under consideration, showing that improvement of the catching efficiency of the 2-m beam trawl is needed. However, the three-beam-trawl approach may be used in epifaunal studies to determine conversion factors based on the catching efficiency for each species in specific habitats.

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