

# Estimating prey accessibility for waders: a problem still to be solved

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Leyrer, J. & K-M. Exo. 2001. Estimating prey accessibility for waders: a problem still to be solved. *Wader Study Group Bull.* 96: 60–63.

Estimating the accessible prey fraction for short-billed waders, we used a new sampling device – the sediment-plane (Desholm *et al.* 1998) – to record prey density of the uppermost benthos communities in soft-bottom habitats. In contrast to "ordinary" core-samplers, the sediment-plane allows a relatively quick sampling of the uppermost layers of the sediment and, thus, it should allow a more reliable estimate of the accessible benthos community, especially of vertically mobile prey organisms such as polychaetes. To assess its usefulness, we compared samples collected with the sediment-plane that took only the uppermost 3 cm of the sediment with samples taken with a core-sampler. These investigations showed significant differences between the two sampling methods. In comparison with the corresponding layer of the core samples, we found significantly higher numbers and a higher biomass for at least four polychaete species (e.g. Ragworm *Nereis diversicolor*) in the plane samples. Therefore, we recommend the use of the sediment-plane when studying the accessible fraction for foraging waders especially when studying short-billed species.

## INTRODUCTION

Estimation of prey availability in studies on the feeding ecology of waders is often based on 20–30 cm deep core samples (e.g. Mouritsen 1994, Petersen & Exo 1999). Core sampling only allows an estimation of the standing stock. Therefore, these samples may provide a representative estimation of the available benthos fraction for long-billed wader species such as Oystercatcher *Haematopus ostralegus* and Curlew *Numenius arquata*. But prey densities recorded with a core-sampler may deviate significantly from the prey actually available to short-billed sandpipers, Calidridae, e.g. Dunlin *Calidris alpina* feeding on species living in the uppermost part of the sediment (e.g. Zwarts & Esselink 1989, Zwarts & Wanink 1991, Desholm *et al.* 1998).

One may cut the sediment core into slices of depth to obtain an impression of the vertical distribution of the prey organisms and therefore an estimation of prey availability for small wader species (Piersma *et al.* 1994). This, however, gives tube-dwelling polychaetes like Ragworm *Nereis diversicolor* that are the main prey of many waders time to withdraw in their burrows as a reaction to disturbance (Vader 1964, Esselink & Zwarts 1989, Zwarts & Wanink 1991). Desholm *et al.* (1998) introduced an alternative device for estimating prey accessibility to small tactile-feeding waders: a sediment-plane that shaves the uppermost part of the sediment quickly to a fixed depth. Comparing sediment-plane and core samples they found significant differences both in individual numbers and biomass between the two sampling methods. Their results, however, were based only on a comparison of 3-cm samples using the sediment-plane and 20-cm sediment cores using a core-sampler. No direct comparison has yet been made between the 3-cm deep slice from a sediment-plane and the upper 3-cm slice of a core sample (Desholm *et al.* 1998). The main aim of our study was to evaluate the usefulness of the sediment-plane by a direct comparison of the uppermost 3 cm of the sediment taken by

the plane-sampler and the core-sampler, respectively, as suggested by Desholm *et al.* (1998). Additionally, we evaluated the proportion of polychaetes that withdraw themselves in deeper layers of the sediment while probing with a core-sampler.

## STUDY AREA AND METHODS

### Study area

Studies were carried out on the backbarrier intertidal flats south of the island of Minsener Oldeoog (53°43'39"N, 07°59'56"E) in the Wadden Sea of Lower Saxony, Germany, in August–September 1998. Samples were taken at two adjacent sites near the mainland coast. Site A was located between the mainland coast and the island of Minsener Oldeoog about 800 m off the mean high tide level. Time of inundation was approximately 6 h per low-water period. Site B was located in an area sheltered by coastal protection work 10 m off the mean high tide level. This site was exposed for about 8 hours per low-water period. Both sites were relatively flat and the surface was structured uniformly. Sediment composition was similar at both sites ( $p = 0.26$ ,  $n = 6$ , Mann-Whitney-U-test). At site A, mean content of silt (grain size  $< 0.063$  mm) of the upper 3 cm was  $57.4\% \pm 10.9$  (range: 42.9–73.6%). At site B, mean silt content was  $49.1\% \pm 11.6$  (range: 30.0–66.1%) (for details see Leyrer 1999).

### Methods

At site A, 5 "ordinary" core samples and 7 plane samples were taken within an area of  $20 \times 20$  m. At site B, 6 core samples and 8 plane samples were taken within an area of  $10 \times 10$  m. Taking into account tidal variations in surface activity as well as temperature induced differences (e.g. Vader 1964, Pienkowski 1983, Esselink & Zwarts 1989, Zwarts & Wanink 1993), samples were taken on the same day at each



of the two sites (site A: 20 August 1998, site B: 8 September 1998) after low tide.

The core-sampler measured 10 × 10 cm (100 cm<sup>2</sup>) and samples were taken to a depth of 30 cm. The sediment-plane was a replica of the sampling device described by Desholm *et al.* (1998). This is a plane that glides across the sediment surface. Beneath the plane is mounted a box, with both ends open. The sampling box, which is pushed through the substrate during sampling, measured 3 cm (height) × 7 cm (width) × 14.2 cm (length). Hence, the box collected an area of 99.4 cm<sup>2</sup>. Like Desholm *et al.* (1998), we pushed the plane through the sediment at a velocity of 1–2 m/s. To compare both data sets, the samples taken by the core-sampler were divided into three slices (0–3 cm, 3–10 cm, 10–30 cm). The samples taken with the plane were converted to 100 cm<sup>2</sup>.

Samples were sieved through a 1-mm mesh. The identity of all invertebrates was determined, at least to broad taxonomic groups (Campbell 1987, Hayward 1990, Hartmann-Schröder 1996; Table 1). They were then counted and preserved by freezing for further analysis. The number of polychaetes was determined by counting heads. Ash-free dry weight (AFDW) was determined by incineration at 480°C for 4 h, after drying samples at 60°C for 48 h. With the exception of *N. diversicolor*, all worm species were pooled in one group “worm”. Bivalves with the exception of *Macoma balthica* were pooled in the group “bivalve”.

In addition, for site B size-classes of *N. diversicolor* were estimated from a prostomium-breadth/worm-length relationship ( $y = 55.6x - 7.9$ ,  $r^2 = 0.7645$ ;  $n = 138$ , with  $y =$  worm-length,  $x =$  prostomium-breadth; Leyrer 1999).

Statistical analyses were performed using SPSS 3.01.

## RESULTS

In total, 15 macrozoobenthos species or taxonomic groups were found at site A and 11 at site B (Table 1). At both sampling locations, *M. balthica* was by far the most abundant species, reaching densities greater than 4000 and 8000/m<sup>2</sup> at sites A and B respectively. The population of *M. balthica* consisted mainly of small individuals of the same year's cohort (about 85% were <6 mm) (Müller 1999, own obs.). Other potentially important prey species for waders present at densities of at least 1000/m<sup>2</sup> were *Tharyx* spp. at site A and *N. diversicolor* at site B. In biomass, *M. balthica* dominated at both sites, accounting for about 71% of the total biomass at site A and 53% at site B (core-sampler). At site A, the group “bivalve” also reached comparatively high biomass values, mainly from *Cerastoderma edule* and *Mya arenaria*.

At site A, about 55% of all organisms and 54% of the total biomass occurred in the second slice (3–10 cm) of the core samples (Table 1). In the uppermost slice (0–3 cm), mainly small molluscs were found, for example all *Hydrobia ulvae*, 93% of *C. edule* and 91% of *M. balthica*, whereas comparatively mobile polychaetes dominated in the second slice, e.g. *Anaitides mucosa* (100%), *Tharyx* spp. (93%) and *N. diversicolor* (75%). In contrast to site A, at site B higher percentages of individual organisms (81%, Table 1) and of biomass (64%) were found in the uppermost slice of the core-sampler. This was mainly caused by high numbers of small *M. balthica*, *N. diversicolor*, and by high numbers of Oligochaeta.

Comparing the 3-cm plane samples with the uppermost 3-cm slice of the core samples at site A (Table 1), significant differences in individual numbers were found among the following species: *C. edule* ( $p = 0.0060$ ,  $Z = -2.7477$ , Mann-

Whitney-U-test), *H. ulvae* ( $p = 0.0235$ ,  $Z = -2.2657$ ), *A. mucosa* ( $p = 0.0078$ ,  $Z = -2.6592$ ), *N. diversicolor* ( $p = 0.0210$ ,  $Z = -2.3083$ ), and *Tharyx* spp. ( $p = 0.0043$ ,  $Z = -2.8520$ ). *Heteromastus filiformis* occurred in the plane samples, but not in the uppermost slice of the core samples. At site B, significant differences in individual numbers between the two sampling methods were found only in *Polydora ciliata* ( $p = 0.0065$ ,  $Z = -2.7201$ ). At site A, the only significant differences in mean biomass between the two sampling methods were for *H. ulvae* ( $p = 0.0252$ ,  $Z = -2.2382$ ) and the group “worm” ( $p = 0.0183$ ,  $Z = -2.3589$ ). At site B, significant differences were found only in the group “worm” ( $p = 0.0365$ ,  $Z = -2.0910$ ).

Analysis of size-classes of *N. diversicolor* revealed high numbers of small Ragworms at site B where 89% ( $n = 3933$ ) were less than 40 mm. At site A, *N. diversicolor* as well as other polychaete species were much larger (Leyrer 1999).

## DISCUSSION

Species composition, total number of individuals, and total biomass of the macrozoobenthos communities investigated were similar to those found in other studies in East Frisian backbarrier intertidal flats (e.g. Grotjahn 1990, Petersen & Exo 1999, Müller 1999, Wolff 2000). In the autumn of 1998, communities were dominated by a spatfall of *M. balthica* and by *N. diversicolor*. *Nereis* density was much lower at site A than at site B where small individuals from the same year's cohort dominated. This difference can be explained by the different location of the two study sites and the initial settlement patterns of the species. Site B was located near the high tide level. Spats and juveniles of most polychaete species settle mainly on “high mudflats” (de Wilde 1981). Besides larval supply, the initial settlement of a species is mainly determined by species-specific substrate selection and by hydrodynamics (Günther 1999).

Generally, in terms of the numbers and biomass of benthic fauna, feeding opportunities for waders were favourable at both sites in the autumn of 1998. However, overall prey density obtained from core samples may deviate from prey actually accessible on undisturbed mudflats. For example, prey accessibility may be overestimated by core sampling, especially for short-billed waders feeding on tube-dwelling polychaetes or amphipods which can withdraw themselves into deeper layers as a reaction to disturbances such as sampling (Zwarts & Wanink 1991, Desholm *et al.* 1998, Leyrer 1999). Both larger polychaetes and amphipods usually build tubes of a few centimetres depth. The reaction to the sampling procedure explains the higher numbers of most larger polychaete species in the second slice (sometimes the third slice) of the core-sampler than in the top slice, especially at site A (Table 1).

The reaction to the sampling procedure also explains the differences between the two sampling methods. We found significantly higher numbers and biomass of at least four polychaete species in the samples of the sediment-plane than in the uppermost slice of the core samples (Table 1). Using a sediment-plane reduces the opportunity for polychaetes to withdraw themselves into deeper layers. On the other hand, no significant differences were found for most small molluscs as well as for *N. diversicolor* measuring less than 40 mm (site B) as they naturally remain in the uppermost 3 cm of the sediment (Esselink & Zwarts 1989, Mouritsen & Jensen 1992). We regard the significant differences in indi-



**Table 1.** Results of the two different sampling methods – sediment-plane vs. core-sampler: Mean number of individuals per m<sup>2</sup> and mean biomass [g AFDW/m<sup>2</sup>] ± sd at site A and site B in a backbarrier intertidal flat of the Lower Saxonian Wadden Sea, North Germany. For the core samples, data for each slice are given. Site A: n<sub>1</sub> = 7 plane samples, n<sub>2</sub> = 5 core samples; site B: n<sub>3</sub> = 8 plane samples, n<sub>4</sub> = 6 core samples. Significant differences between the two sampling methods are indicated in bold: \* p < 0.05, \*\* p < 0.01 (Mann-Whitney-U-test). The group "worm" includes the sum of all worm species except for *Nereis diversicolor*; "bivalve" includes all bivalve species except for *Macoma balthica*.

species	mean number of individuals per m <sup>2</sup> ± sd			mean biomass per m <sup>2</sup> ± sd		
	plane samples 0–3 cm	core samples 3–10 cm	10–30 cm	plane samples 0–3 cm	core samples 3–10 cm	10–30 cm
<b>Site A</b>						
<i>Cerastoderma edule</i>	144 ± 79	40 ± 89	0			
<i>Ensis</i> spec.	14 ± 38	0	0			
<i>Macoma balthica</i>	5950 ± 3524	400 ± 255	0	46.6 ± 46.8	49.7 ± 85.5	0
<i>Mya arenaria</i>	14 ± 38	0	0			
<i>Hydrobia ulvae</i>	0	0	0	0	0	0
<i>Anatitides mucosa</i>	129 ± 49	180 ± 45	0	0.1 ± 0.1 *	0	0
<i>Heteromastus filiformis</i>	57 ± 79	920 ± 898	1380 ± 697			
<i>Nereis diversicolor</i>	158 ± 98	120 ± 84	20 ± 45	0.9 ± 0.6	4.6 ± 5.7	0.1 ± 0.2
<i>Pygospio elegans</i>	43 ± 79	0	0			
<i>Scoloplos armiger</i>	0	0	0			
<i>Spio</i> spec.	43 ± 79	0	0			
<i>Tharyx</i> spec.	2932 ± 666	6480 ± 3813	60 ± 89			
Oligochaeta	29 ± 76	260 ± 241	0	1.1 ± 1.9	0	0
<i>Carcinus maenas</i>	72 ± 112	0	0	0.004 ± 0.01	0.1 ± 0.2	0
<i>Crangon crangon</i>	0	100 ± 224	0	45.9 ± 52.5	2.7 ± 6	0
"bivalve"				1.7 ± 1	14.5 ± 14.1	9.2 ± 9.5
"worm"						
<b>total</b>	<b>9586</b>	<b>8500</b>	<b>1460</b>	<b>96.2</b>	<b>71.7</b>	<b>9.3</b>
<b>Site B</b>						
<i>Macoma balthica</i>	7973 ± 5086	317 ± 496	17 ± 41	52 ± 35.4	1 ± 1.7	0.01 ± 0.02
<i>Mytilus edulis</i>	0	0	0			
<i>Hydrobia ulvae</i>	50 ± 76	17 ± 41	0	0.1 ± 0.2	0	0
<i>Anatitides mucosa</i>	176 ± 245	0	0			
<i>Heteromastus filiformis</i>	0	17 ± 41	67 ± 163			
<i>Nereis diversicolor</i>	2691 ± 1605	1467 ± 1015	67 ± 52	6.4 ± 4.9	24 ± 36.6	1.9 ± 1.5
<i>Polydora ciliata</i>	13 ± 36	17 ± 41	0			
<i>Pygospio elegans</i>	63 ± 120	0	0			
<i>Tharyx</i> spec.	0	0	0			
Oligochaeta	3810 ± 2193	2467 ± 1754	0	0	0	0
<i>Carcinus maenas</i>	0	0	0	1.4 ± 1.1	0.6 ± 0.3	0.3 ± 0.6
"worm"						
<b>total</b>	<b>14776</b>	<b>4300</b>	<b>150</b>	<b>59.9</b>	<b>25.6</b>	<b>2.2</b>



vidual numbers of *C. edule* and *H. ulvae* – for the latter biomass as well – as an artefact, caused by their patchy distribution and the small sample sizes. This also holds for species occurring in lower numbers, e.g. *Anaitides mucosa*.

Desholm *et al.* (1998) concluded that core samples contain a large quantity of apparently available prey that seems to be beyond the reach of, for example, Dunlins. In our analysis, we demonstrate significant differences between the top slice from a core-sampler and samples of the same depth taken with a sediment-plane. A high proportion of polychaetes, especially large ones, retreated into deeper layers. In conclusion, we think the sediment-plane is a useful device for studying prey availability, especially in relation to short-billed sandpipers feeding on soft-sediments. It will be particularly valuable for measuring accurately the quantity of vertically mobile polychaetes in the upper substrate layers. It should be noted, however, that we only checked the usefulness of the sediment-plane in muddy substrates. Its value in denser, sandy habitats with a higher resistance has yet to be established.

## ACKNOWLEDGEMENTS

We thank Mark Desholm, Christiane Ketzenberg, Stefan Thyen and Leo Zwarts for their valuable comments on an earlier version of the manuscript.

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