Trolliet, B., Fouquet, M., Triplet, P., Girard, O. & Yésou, P. 1995. A propos de lhivernage de la Barge à queue noire *Limosa limosa* dans le delta du Sénégal. *Alauda* 63: 246-247.

Trolliet, B., Fouquet, M., Triplet, P. & Yésou, P. 1993. Oiseaux d'eau dans le delta du Sénégal en janvier 1993. *Bull. mens. ONC* 185: 2-9.

Trolliet, B. & Girard, O. 1991. On the Ruff *Philomachus pugnax* wintering in the Senegal delta. *Wader Study Group Bull.* 62: 10 -12.

Trolliet, B., Girard, O., Fouquet, M., Ibañez, F., Triplet, P. & Léger, F. 1992. L'effectif de Combattants *Philomachus pugnax* hivernant dans le delta du Sénégal. *Alauda* 60: 159-163.

Yésou, P. & Triplet P. 1996. Un site d'importance international pour l'avifaune risque de disparaitre : le lac d'Aleg (République Islamique de Mauritanie). *Alauda* 64: 455-457.

Yésou, P., Triplet, P. & Dubois, P.J. 1995. Winter site fidelity in the Black-winged Stilt *Himantopus himantopus*. *Wader Study Group Bull.* 76: 39.

Yésou.P., Triplet, P. Sylla. I., M., Ndiaye, A., Hamerlynck, O., Diouf, S. & Tréca, B. 1996. Oiseaux d'eau dans le delta du Sénégal en janvier 1996. *Bull. mens.* O.N.C. 217: 2-9

The sediment-plane: an alternative tool for estimating prey accessibility to tactilely feeding waders

Mark Desholm, Anja M. Harder, Kim N. Mouritsen

Desholm, M., Harder, A.M. & Mouritsen, K.N. The sediment-plane: an alternative tool for estimating prey accessibility to tactilely feeding waders. *Wader Study Group Bull.* 85: 73-75.

A sampling method which considers the actual accessibility of infaunal prey to tactilely feeding Dunlins *Calidris alpina* is presented and compared with an ordinary core sample method collecting the sediment to a depth of 20 cm. The alternative method involved a sediment-plane, whose shaving depth was fitted to the maximum probing depth of Dunlins (3 cm). Our preliminary data showed a significant difference between the two sampling methods regarding the biomass of the amphipod *Corophium volutator* and the number of larger polychaetes (mainly Ragworms *Nereis diversicolor*). In comparison with the core samples, only about half of the amphipod dry weight and less than one third of the larger polychaete individuals were actually available to the Dunlins. We propose that a sediment-plane should be applied when studying the influence of bird-prey interactions on the spatial and temporal distribution of foraging waders in soft-bottom habitats.

Mark Desholm, Department of Marine Ecology, Institute of Biological Sciences, University of Aarhus, Finlandsgade 14, 8200 Aarhus N, Denmark, E-mail: Mark.Desholm@Biology.aau.dk; Anja M. Harder, National Environmental Research Institute (NERI), Department of Coastal Zone Ecology, Grenåvej 12, 8410 Rønde, Denmark; Kim N. Mouritsen, Faculty of Science, University of Copenhagen, Øster Voldgade 3, 1350 Copenhagen K, Denmark, E-mail: amharder@stud.aki.ku.dk

INTRODUCTION

In studies of the feeding ecology of waders, prey availability is a frequently applied parameter (Bengtson & Svensson 1968; Wolff 1969; Goss-Custard 1970, Schneider & Harrington 1981, Kelsey & Hassall 1989). In many surveys, prey availability is usually estimated as prey density on the basis of *c.* 20 cm deep core samples (*e.g.* Petersen 1981, Schneider & Harrington 198;, Kelsey & Hassall 1989, Matthews *et al.* 1992, Wilson & Parker 1996). This can be sufficient when studying larger wader species such as Oystercatcher *Haematopus ostralegus*, Bar-tailed Godwit *Limosa lapponica*, and Curlew *Numenius arquata*, that are able to reach deep into the sediment. However, in the case of the smaller sandpipers, *Calidridae*, that only have a limited vertical reach, the overall prey density obtained from 20 cm core samples may deviate significantly from actual prey accessibility.

If prey organisms consist of bivalves whose vertical position is relatively fixed, the sediment core can be cut into slices in order to obtain an exact vertical distribution of prey (Piersma *et al.* 1994). However, tube-dwelling polychaetes and amphipods,which are common prey organisms to an array of wader species (*e.g.* Goss-Custard 1984; Worrall 1984; dit Durell & Kelly 1990), have the ability to withdraw themselves as a reaction to such sampling and slicing methods (see *e.g.* Zwarts & Wanink 1991). Consequently, the recorded vertical distribution of the invertebrate prey will not represent the actual prey accessibility to a tactilely feeding wader on an undisturbed mudflat. One means of overcoming this problem is to sample the sediment very quickly at the depth that corresponds to the bill length of the wader species of interest and thereby give the prey organisms the minimum amount of time to respond to the disturbance. Here, we report on a sampling device which does this for Dunlins *Calidris alpina.*

MATERIALS AND METHODS

The sampling device is basically a plane whose upper flat surface (21 cm wide, 30 cm long) glides on the sediment surface, beneath which is mounted a box (open at both ends) which moves through the substrate during sampling (Figure 1). On the top of the plane there is a pipe stub into which is fitted a 'pushing-stick'. The box measures 3 cm (height) x 7 cm (width) x 14.2 cm and hence collects an area of 100 cm^2 to a depth corresponding to the approximate bill length of Dunlins

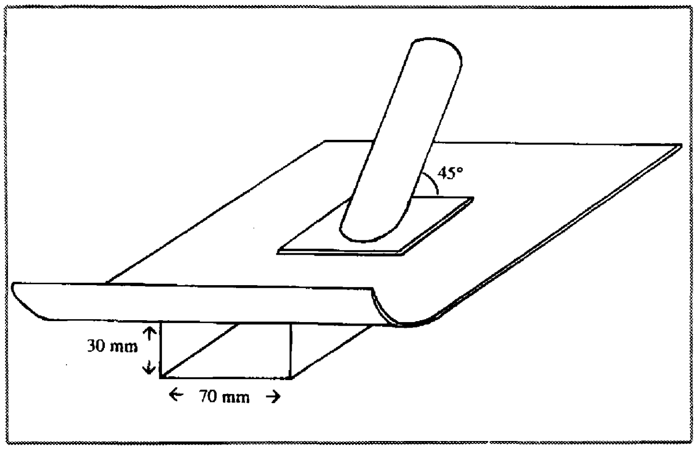

Figure 1. The sediment-plane for sampling the infaunal prey of Dunlin. See text for details.

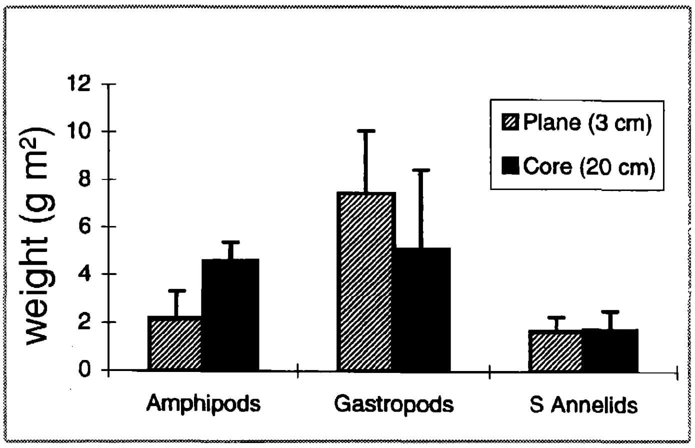

Figure 2. Mean dry weight (g. m^2) + s.d. of the three groups of invertebrates obtained from the two different sampling methods. 'S Annelids' denotes smaller annelids.

(Prater *et al.* 1977). The material of which the plane is made should ensure maximum durability and minimum frictional resistance. In the present study, stainless steel (1 mm sheets) was used.

Depending on the property of the substrate (water content, particle size distribution etc.), the plane can be pushed through the sediment with a velocity of 1-2 m/s, thereby giving the macrofauna very little time to respond to the disturbance. If the sediment is very dense, the plane may initially slide on the surface of the substrate, gliding on the box sampler, before it is directed into the sediment followed by a prompt halt. The plane may then be removed and the collected sediment in the box can be tipped into a sieve for further treatment.

In order to test the usefulness of the sediment-plane, a field study was carried out on 1 October 1996 at the scientific reserve Tipperne (55°53'N, 08°14'E), situated in the non-tidal Ringkøbing Fjord, Denmark. Within an area of 30 x 30 m, we collected at random five ordinary core samples (diameter 10 cm, depth 20 cm) and 15 plane samples. When the substrate was collected it was covered with 1-2 cm water.

The collected sediment was sieved through a 500µm mesh and the invertebrates preserved in 96% ethanol. These were then counted and sorted into four main groups: Amphipods *Corophium volutator*, gastropods *Hydrobia ventrosa* and *Potamopyrgus jenkinsi*, larger polychaetes (mainly *Hediste diversicolor* together with a few *Heteromastus filiformis*), and smaller annelids (mainly oligochaetes: *Tubificidae* spp., and a few polychaetes: *Polydora cornuta* and *Sabellidae* spp.). The collected animals were subsequently dried for 24 hours at 100°C prior to dry weight determination.

Only the number (head count) of larger polychaetes was considered in the present analysis, because any individuals grasped by an avian predator are likely to be consumed even though the majority of their body mass may be out of the bird's immediate reach. Hence, an estimate of accessible biomass from pieces of worms cut off by the sediment-plane in the upper sediment strata, may be severely biased. If desired, regressions describing the relationship between different biometric parameters can be used to estimate the accessible biomass of larger polychaetes in cases where the sampled biomass is likely to be biased (*e.g.* Zwarts & Esselink 1989). For amphipods, this problem was judged to be of little importance.

Statistical analyses were executed in SPSS for Windows (Norusis 1993).

RESULTS

Compared with the 3 cm plane samples, the 20 cm deep cores contained a significantly larger amphipod biomass m^{-2} (Mann-Whitney U-test, p=0.005) (Figure 2). In contrast, the biomass of both gastropods and smaller annelids did not differ between the two sampling methods (Mann-Whitney U-test, p=0.13 and p=0.97, respectively) (Figure 2). The mean number of larger polychaetes was significantly higher in the core samples (5,959 m^{-2}, s.d.=5,368) than in the plane samples (1,675 m^{-2}, s.d.=1,471) (Mann-Whitney U-test, p=0.026).

DISCUSSION

These preliminary results demonstrate a significant difference between potentially available and actual accessible prey to tactilely feeding Dunlins. This does not include gastropods and smaller annelids as they normally remain in the uppermost 3 cm of the substrate (Mouritsen & Jensen 1992; pers. obs.). In contrast, both amphipods and larger polychaetes usually produce tubes deeper than 3 cm (Jensen & Kristensen 1990; pers. obs. of *Hediste*), and a considerable part of these populations (in the present study about one half and two thirds respectively) seems to be beyond the reach of tactilely feeding Dunlins.

Usually, the activity of infaunal organisms is regarded as being positively correlated with the relative water content of the sediment (Vader 1964). Since the present results were obtained during total water cover, this relationship has no influence on the present conclusions.

The present analysis does not assess the extent of withdrawal caused by the inevitable disturbance during plane-sampling. However, results from a similar plane-sampler collecting the upper 1.5 cm of the substrate in an intertidal habitat showed a significant difference between the occurrence of *C. volutator* in the upper 1.5 cm sediment strata during the day and at night (49% and 70% of the population respectively) at exactly the same site (Mouritsen 1994). The fact that the plane-sampler can be used to elucidate such small-scale variations in the vertical distribution of *C. volutator* between night and day, suggests that tube-building infaunal animals are unable to retract themselves sufficiently quickly during plane-sampling.

Based on the present preliminary results, we plan to investigate the usefulness of the plane-sampler in more detail. By (1) increasing sampling size, (2) making a direct comparison between the 3 cm plane samples and the upper 3 cm slice of the core samples, and (3) comparing the two sampling methods in a habitat supporting a higher prey abundance and species diversity, such as the International Wadden Sea. This will strengthen the conclusions as well as expanding it to more prey species.

In conclusion at this early stage, we nevertheless find that the sediment-plane can be useful when studying the interactions between waders and their prey, as well as when the influence of prey accessibility on the spatial and temporal distribution of foraging sandpipers and other waders in soft-bottom habitats has to be assessed.

ACKNOWLEDGEMENTS
We thank the National Environmental Research Institute (NERI) for permission to access the Tipperne reserve and for accommodation at the research station. Furthermore, we thank the staff at the reserve station for their kind assistance. Financial support for this research was provided by the Carlsberg Foundation to Kim N. Mouritsen for development of an earlier application of the device, and by the Beckett-Fonden and Dansk Jagtforenings Jubilæumsfond to Mark Desholm for field equipment.

REFERENCES

Bengtson, S.A. & Svensson, B. 1968. Feeding habits of *Calidris alpina* L. and *C. minuta* Leisl. (Aves) in relation to the distribution of marine shore invertebrates. Oikos 19: 152-157.

dit Durell, S.E.A. Le V. & Kelly, C.P. 1990. Diets of Dunlin *Calidris alpina* and Grey Plover *Pluvialis squatarola* on the Wash as determined by dropping analysis. *Bird Study* 37: 44-47.

Goss-Custard, J.D. 1970. The responses of redshank (*Tringa totanus* (L.)) to spatial variations in the density of their prey. *J. Anim. Ecol.* 39: 91-113.

Goss-Custard, J.D. 1984. Intake rates and food supply in migrating and wintering shorebirds. In: Burger, J. & Olla, B.L. (Eds.). *Shorebirds - migration and foraging behavior. Behavior of marine animals*. Volume 6. Plenum Press, London.

Jensen, K.T. & Kristensen, L.D. 1990. A field experiment on competition between *Corophium volutator* (Pallas) and *Corophium arenarium* Crawford (Crustacea: Amphipoda): effects on survival, reproduction and recruitment. *J. Exp. Mar. Biol. and Ecol.* 137: 1-24.

Kelsey, M.G. & Hassall, M. 1989. Patch selection by Dunlin on a heterogeneous mudflat. *Ornis Scand.* 20: 250-254.

Matthews, S.L., Boates, J.S. & Walde, S.J. 1992. Shorebird predation may cause discrete generations in an amphipod prey. *Ecography* 15: 393-400.

Mouritsen, K.N. & Jensen, K.T. 1992. Choice of microhabitat in tactile foraging dunlins *Calidris alpina*: the importance of sediment penetrability. *Mar. Ecol. Prog. Ser.* 85: 1-8.

Mouritsen, K.N. 1994. Day and night feeding in Dunlins *Calidris alpina*: choice of habitat, foraging technique and prey. *J. Avian Biol.* 25: 55-62.

Norusis, M.J. 1993. *SPSS for Windows*. Base System Users Guide (6.0). SPSS Inc., Chicago.

Petersen, B.D. 1981. Vadefuglenes foruragering og predation på bundfaunaen på Tipperne. *Dansk Ornitologisk Forenings Tidsskrift* 75: 7-22. (English summary)

Piersma, T., Verkuil, Y. & Tulp, I. 1994. Resources for long-distance migration of knots *Calidris canutus islandica* and *C.c. canutus*: how broad is the temporal exploitation window of benthic prey in the western and eastern Wadden Sea? *Oikos* 71: 393-407.

Prater, A.J., Marchant, J.H. & Vuorinen, J. 1977. *Guide to the identification and ageing of Holarctic waders*. Guide 17, British Trust for Ornithology.

Schneider, D.C. & Harrington, B.A. 1981. Timing of shorebird migration in relation to prey depletion. *The Auk* 98: 801-811.

Vader, W.J.M. 1964. A preliminary investigation into the reaction of the infauna of the tidal flats to tidal fluctuations in the water level. *Netherland Journal of Sea Research* 2: 189-222.

Wilson, W.H. & Parker, K. 1996. The life history of the amphipod, *Corophium volutator*: the effects of temperature and shorebird predation. *J. Exp. Mar. Biol. and Ecol.* 196: 239-250.

Wolff, W.J. 1969. Distribution of non-breeding waders in an estuarine area in relation to the distribution of their food organisms. *Ardea* 57: 1-28.

Worrall, D.H. 1984. Diet of the Dunlin *Calidris alpina* in the Severn Estuary. *Bird Study* 31: 203-212.

Zwarts, L. & Esselink, P. 1989. Versatility of male curlews *Numenius arquata* preying upon *Nereis diversicolor*: deploying contrasting capture modes dependent on prey availability. *Mar. Ecol. Prog. Ser.* 56: 255-269.

Zwarts, L. & Wanink, J.H. 1991. The macrobenthos fraction accessible to waders may represent marginal prey. *Oecologia* 87: 581-587.