

# Stomach-pumping of waders does not necessarily provide more information on diet than faecal analysis

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Martin & Hockey (1993) recently suggested a 'new' method to study the diet of waders: stomach-flushing. In this note the reliability of data collected by stomach content analysis is compared with dropping analysis. For several reasons, dropping analysis has fewer disadvantages than stomach analysis in the collection of sound data on diets. Firstly, since waders can process their food very rapidly and since they generally are caught on high tide roosts, *e.g.* some time after feeding, most food may have passed through the stomach before the birds are stomach-pumped. Different food types are processed at different rates, so small prey and soft prey will be underestimated in stomach content samples. Further, only data on nocturnal diets are collected when birds are mist-netted during the night. Moreover, as the 'unlimited' availability of faeces and regurgitates makes more extensive analyses possible, dropping analysis can yield extra information on the ecology of waders, such as quantitative data on energy intake, prey size selection and prey choice.

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## INTRODUCTION

A general starting point when studying the feeding ecology of waders is an assessment of the diet of the species concerned. This information can be obtained in various ways. Until quite recently students generally shot birds to analyze their stomach contents (Rundle 1982). Today this is considered an unacceptable way of collecting data in many parts of the world, and other methods that avoid killing or seriously harming the birds have been introduced. The most direct and least disturbing method is that of observing prey being swallowed by foraging waders. However, when birds eat very small prey items (as smaller wader species usually do), it can be extremely difficult and often impossible to determine the prey species being swallowed. For waders relying on a diet containing a variety of prey items, and eating both visible and invisible prey species, remote observations on birds may not be an adequate method to estimate the contribution of the different prey species in the diet. Alternative methods to describe the diet in these cases are the analysis of faeces and of regurgitates, and/or the analysis of stomach contents of incidental catching casualties.

Martin & Hockey (1993) recently described a method to obtain stomach contents of captured waders: stomach-flushing, *e.g.* filling the stomach with water by a plastic tube to let the birds regurgitate. The authors considered this method as a non-destructive way of collecting sound data on waders diet. Although the method may be 'non-destructive' at first sight, it will impose considerable stress on the birds. Stress in captured and handled waders can lead to leg cramp (Purchase & Minton 1982; see also Henschel & Louw 1978; Piersma *et al.* 1991). This 'new' method may therefore lead to higher numbers of cramp casualties and finally to a higher overall number of

casualties, as it will take the birds longer to strengthen after their release, during which period they are easy victims to predators. Critically, I don't believe that stomach pumping will provide us with more information about diets than by the alternative method of dropping analysis. In this note, I discuss the constraints to diet assessments by stomach flushing and indicate the advantages of the alternative method.

## FOOD PROCESSING IN BIRDS

Factors that may limit the use of stomach content data are the generally high food processing rate, the unequal processing rates for different food types, and the time of feeding relative to the time of catching.

Martin & Hockey (1993) noted the problem of different processing rates of traces of different prey species (*e.g.* Lifjeld 1983; Jenni *et al.* 1989; Levey & Duke 1992). Soft and small prey can be processed much more rapidly than larger prey and prey with solid skeletal parts. Stomach content analyses have the disadvantage of over-estimating the contribution of prey with a long residence time in the stomach (Goss-Custard 1973; Rundle 1982), and thus soft-bodied prey can be under-estimated, as their (possible) remains pass quickly to the intestines. In addition, in stomach contents collected by stomach flushing, lumped prey items may be under-estimated since these are difficult to regurgitate (Jenni *et al.* 1989).

In many experiments on digestion and assimilation efficiency of prey, the processing rate of food in birds is found to be very high. For example, van Koersveld (1950) found that in Jackdaws *Corvus monedula spermologus* the digestion of soft prey, earthworm and leatherjackets in the

stomach was already far advanced even 20 min. after feeding. In Blue-winged Teal *Anas discors* 100% of amphipods, 82% of snails and 24% of diptera larvae passed through the gizzard (the muscular stomach) in only 10 min., hard prey items took some time longer (Swanson & Bartonek 1970). And, in the Cedar Waxwing *Bombycilla cedrorum*, a fruit-eating bird, pulp remained in the gizzard for only 7.7 min., whilst the residence time for seeds was 27 min. (Levey & Duke 1992).

For waders, residence times in the stomach can be even shorter. In Knots *Calidris canutus*, molluscs can pass the digestive trajectory in 24.8 ( $\pm 11.6$ ) min. (J. van Gils pers. comm.). The total length of the gut can be taken at 60 cm, of which only the first 8 cm (oesophagus + stomach) will be flushed (T. Piersma pers. comm.). This means that in a species like Knot, where all components are discarded through the intestines (Dekinga & Piersma 1993), the average residence time in oesophagus + stomach is  $8/60 \times 24.8 = 3.3$  min.. Captive Broad-billed Sandpipers *Limicola falcinellus* fed with *Nereis diversicolor* or Gammaridea had a throughput time of 17-25 min (pers. obs.), and residence time in the stomach will also be a few minutes only.

Pienkowski *et al.* (1984) mentioned that problems can occur also with the examination of the gut contents of freshly shot waders, since digestion of prey is generally very rapid (see also Greenwood & Goss-Custard 1970). Swanson & Bartonek (1970) warned that in shot birds the (soft-bodied) prey may already be digested immediately after ingestion: in Blue-winged Teal collected while feeding, the food items identified from the oesophagus and gizzard were not identical. Rundle (1982) showed that, because of the long retention time of hard food items, the analysis of gizzard alone yielded an inaccurate picture of diet composition in four shorebird species. He advocated to use only the oesophageal content of birds shot while feeding.

The third problem is that in order to apply stomach flushing to waders these will generally be caught on the high tide roosts. That means that the majority of these waders will be trapped *after* they have stopped foraging. Waders on the Banc d'Arguin lost most weight during the first four hours of the roosting period, probably because they defecated more frequently in this first period after feeding (Zwarts *et al.* 1990). This may imply that a large part of the stomach content may have been digested before the waders on the roosts are caught. Furthermore, birds trapped in mist nets are usually not taken out immediately, and from 10 minutes to up one hour can ensue before processing. At the time they are brought to the place where measurements will be taken, most of the soft material has probably disappeared from the stomach.

Accordingly, finding fresh soft prey species in the stomachs of waders not shot while actively foraging can be very difficult.

## DIURNAL CHANGES IN DIET

A second constraint of stomach-pumping, not mentioned by Martin & Hockey (1993), is that waders are mist-netted mostly during the night. Collecting stomach contents of these birds will only yield data on the prey species eaten during night. Shorebirds may eat different prey species during night and day because they may use different foraging techniques. For example, Oystercatchers *Haematopus ostralegus*, making pecking movements during daytime to search for buried prey, changed to sewing movements during the night and ate less Baltic Tellin *Macoma balthica* and more crab *Carcinus maenas* during nighttime (Hulscher 1976). Pellets of Dunlins *Calidris alpina* collected during the night contained less remains of the ragworm *Nereis diversicolor*, and more of *Macoma balthica* and *Hydrobia ulvae* (mudsnail) than during daytime (Dugan 1981). Visually foraging Grey Plovers *Pluvialis squatarola* at night were less successful in catching crabs *Cleistostoma* spp., while numbers of *Upogebia* prawn captured were similar, but of larger size than during daytime (Turpie & Hockey 1993). Moreover, in the stomachs of waders that are not nocturnal foragers, only prey with long stomach residence times will be found.

## FAECAL ANALYSIS

I think that in many studies the best estimate of the contribution of different prey items to the diet can be achieved by the analysis of faecal droppings and regurgitates (in Table 1 the (dis)advantages of both methods are summarised). Important is that droppings should be collected from birds known to have been feeding for a specified minimum time, to avoid over-estimating the smaller prey items (Dekinga & Piersma 1993) or collecting faeces from other feeding areas. Moreover, when waders feed in mixed flocks it must be possible to discriminate between droppings of different species.

Stomach analysis does not yield more information than analysis of faeces and regurgitates. As Martin & Hockey (1993) showed in their Table 2, a similar proportion of prey types (based on percentage volume) was found in the stomach samples as in the remaining content of the stomachs and intestines of birds killed after stomach-pumping. On this result they based the conclusion that their technique yielded sound data on the prey types and their relative proportion present in the guts of waders. However, this means that (as prey reconstruction usually relies on recognisable, indigestible parts) no extra information has been obtained by this technique than when the birds could have emptied their guts naturally, since in the intestines the (solid) parts of the prey species that can not be assimilated, pass through the intestines rather undamaged (Levey & Duke 1992; Stevens 1988). Collecting faeces may thus be a much easier method to collect the same information on wader diets.

Table 1. The advantages and disadvantages of two methods used for assessing the diet of waders: stomach flushing, and faecal and regurgitates analysis. Note that the latter yields most reliable information on diet composition and can more easily result in a comprehensive study on feeding ecology of the studied species. See text for further explanation.

	STOMACH FLUSHING	FAECES AND PELLETS
disadvantages	<ul style="list-style-type: none"> <li>- underestimating small prey</li> <li>- rapid processing soft prey</li> <li>- few remains soft prey lacking solid parts</li> <li>- lumped prey are missed</li> <li>- only data on nocturnal diet<sup>2</sup></li> </ul>	<ul style="list-style-type: none"> <li>- overestimating small prey<sup>1</sup></li> <li>(-)</li> <li>- no remains soft prey lacking solid parts</li> <li>- regurgitates may be missed</li> <li>(-)</li> </ul>
advantages	<ul style="list-style-type: none"> <li>- no additional field work necessary</li> <li>(-)</li> <li>(-)</li> <li>- more relaxing for researcher</li> </ul>	<ul style="list-style-type: none"> <li>- extra data<sup>3</sup> can be collected in the field</li> <li>- 'unlimited' availability of material</li> <li>- dropping content yields estimate on energy intake</li> <li>- more relaxing for the birds</li> </ul>

<sup>1</sup> this problem can be avoided by collecting droppings from birds feeding for more than 30-60 minutes.

<sup>2</sup> if birds are mist-netted during the night.

<sup>3</sup> data on habitat use, food availability, prey size selection, time budgets and food intake rates.

Moreover, collecting faeces has many other advantages over stomach flushing (Table 1). Samples can be collected from captured individuals, just as with stomach pumping, but procedures are easier (keeping wader species separately in keeping cages, with plastic sheets placed underneath). Most importantly, a good deal of extra information can be obtained simultaneously while droppings are collected in the field. Information on habitat use and food intake rates can be gathered. In the same area as where the droppings are found, benthic food or pelagic food availability can be sampled, giving information on prey species selection and prey size selection. Later in the laboratory, specimen of collected prey species can be helpful in sorting out the fragments found in the faeces. To find out whether prey size selection has occurred, specimens have to be collected to quantify the relationships between parts of prey in faeces and intact-prey sizes. Examples of such recognisable and measurable parts are the hinges of bivalves (*Macoma balthica*, Dekinga & Piersma 1993), a white line near the hinge of mussels (*Brachidontes rodriguez*, Gonzalez *et al.* MS), the width of the last whorl in snails (*Hydrobia ulvae*, Zwarts & Blomert 1992), parts of the exoskeleton (carapace width of crabs, Zwarts & Dirksen 1990) or other structures, like jaws (*e.g. Nereis diversicolor*, Zwarts & Esselink 1989). Beintema *et al.* (1991) even reconstructed the diet from faeces of charadriiform chicks with recognisable parts from small grassland insects, larvae and worms. Green & Tyler (1989) did the same with tibia and mandibles of carabid beetles and length of chaetae of earthworms eaten by Stone Curlews *Burhinus oedicnemus*.

Another advantage is that on feeding sites faeces are usually left behind in large quantities, so that per sampling site more material is available than that contents of a few stomachs provide, since per stomach normally little recognisable material is found. Faecal analysis may thus yield more reliable information on the relative contribution of different prey species and prey sizes to the diet.

Finally, the results of faecal analysis may be used to reconstruct energy consumption. When faeces samples have generated data on prey size selection (see above), prey size can be related to energy content or prey biomass so that the energy content per dropping can be calculated (see for comprehensive description see Dekinga & Piersma 1993). When time intervals between droppings are known, energy intake rate can be estimated. Data on these intervals can be collected by counting droppings in an defined area where an known number of waders in a single-species flock has been feeding for a known time period (Gonzalez *et al.* MS), or just by observing the ejection of faeces in individual birds. For small waders eating prey too small to be seen ingested, observations on dropping intervals may form a good alternative for observing food intake rates.

Analysis of ejected food remains has two disadvantages. Firstly, regurgitates (pellets) may contain the larger parts of the indigestible material (Ziswiller & Farner 1972; Dekinga & Piersma 1993: Figure 7) and may be missed easily. However, not all waders make regurgitates and, if they do so, these remains can be found between the droppings or at the high tide roosts and have to be collected separately. Furthermore, soft-bodied prey lacking hard body parts such as jaws (*e.g.* earthworms), leave few remains in the droppings. There is better chance to find these in stomach samples, but as said before the high processing rate of these soft-bodied prey implies also an unknown chance of finding them in disproportional low numbers. For wader species expected to rely partly on such prey, additional visual observations on prey choice must be made. To avoid all possible bias caused by missing regurgitates or by missing soft prey leaving no remains, studies on diet should include control experiments with captive waders, to study the relative amount of prey items that can be traced in faeces (see *e.g.* Dekinga & Piersma 1993).

## CONCLUSION

For most studies on wader diets, I think that there is no need to kill birds or to stress mist-netted birds with a painful and stressful method as stomach-pumping. Both stomach and faecal analyses necessitate correction factors for all soft prey. In most cases, rough to very detailed data on diets can be obtained by collecting faeces and regurgitated pellets of birds temporarily kept in cages during catching activities, or of birds in the feeding areas. Combined with observations on dropping intervals in the field, faecal analysis not only results in information on the diet, but also on food intake rates and prey choice under different circumstances.

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