base to tip, pressing firmly against the rule all the while. It must be emphasised that no attempt must be made to pull the wing straight from the tip; a firm stroking action is required. Small differences in measurement may result from variation in the degree of straightness achieved, but the method reduces errors due to alteration of the lateral curvature during trapping and handling, or occasioned by dampness. It is, however, essential to keep the wing closed, and parallel to the long axis of the bird's body.

The measurement method is illustrated in Figure 1. In particular I would emphasize the need to keep the wing close against the body to minimize inter-observer differences in measurement of the same bird. Holding the wing away from the body, or partly opened, will greatly reduce the accuracy of the method.

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Biometrics in waders

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In most ringing programmes it is now standard to measure waders that are trapped for ringing. This paper summarises an evaluation of which measurements are useful in distinguishing between different sexes and/or different population of a species. We conclude that as yet we are far from making precise statements for many species, and that the number and identity of the appropriate measures differ between species. For now we recommend measurements of at least bill-length and wing-length for all species, and where appropriate the extra measurements listed here for each species. A co-operative world-wide approach to the collation of measurement data collected from live breeding birds is proposed.

For many years wader measurements have been collected, to trace the breeding origins of birds and to differentiate between sexes. In most cases, maximum wing-length, bill-length and tarsus-length are measured, and much effort has been given to standardise measuring techniques (Evans 1964, 1986). When we started to analyse our results from large-scale trapping in the Dutch part of the Wadden Sea we faced the problem that it was not clear which populations and which groups could be distinguished from each other from external measurements.

In general, the problem was that although the measurements of two populations might be statistically discernible from each other, this does not mean that both populations can necessarily be identified outside their breeding areas. This is a particular difficulty when there may be more than just two populations or groups; and at times there could be up to ten more populations in the area. Unfortunately, along the East Atlantic flyway, and especially at a crossroads like the Wadden Sea, this is reality.

A second problem is that nearly all differences in measurements between populations or sexes (in dimorphic species, sexual and geographical differences can even out each other) are statistical differences, which can often involve a rather broad overlap. In such a case, many individual birds have a measurement which cannot help to distinguish its breeding origin. Therefore, if such overlap could be reduced by incorporating more measurements, we would then be able to collect more information from the same amount of data. So we looked for a multivariate approach, using wing-, culmen-, and tarsus-lengths, instead of a univariate approach (wing or culmen or tarsus). This approach would give us the tool we needed to predict the chance that an individual bird belongs to a certain group/population. This paper summarises our progress so far, and suggests some future directions.

We agreed rather quickly that a reference collection was required. As a bird present in the Wadden Sea could originate from a wide area from Arctic Canada in the west to Central Siberia in the east, measurements of many breeding populations need to be sampled. It was not possible to collect this information in the short term from live birds trapped on their nests, because few birds are trapped on the nests, and the data comes from scattered observations over enormous areas and collected by a few widely dispersed research-workers over a long time span. Therefore, there was no other choice than to use museum data of birds collected in several breeding areas. Many of these specimens were already measured by CSR, but this data file is still growing, thanks to the help of the Zoological Museums in Moscow, Tring, Bonn, Copenhagen, Leningrad, Reykjavik, Toronto, Leiden and Amsterdam.

The ideal situation is that we can distinguish all different populations and both sexes of a species with as little effort as possible. This means that the number of groups distinguished needs to be as large as possible and that the number of measures that need to be taken must be as small as possible. Using multivariate discriminate-analysis we tried to find this ideal situation. However, the more we have analysed, the more we realise that we are as yet far from this idea.

For several species we have been able to add other measurements to wing-, bill- or tarsus-lengths. These include:

- ▶ Bill-depth: the largest height possible to measure along the bill.
- ▶ Middle-toe length: the distance from the middle point of the joint between tarsus and middle toe at the front of the leg to the tip of the middle claw.
- ▶ Tail-length: the distance from the point where the central tail feathers emerge from the skin, to the tip of the longest feather.

The results of all these analyses are summarised in Table 1. For each species Table 1 shows which measurements should be taken, and which groups may be distinguished using these measurements.

Examination of Table 1 leads to several conclusions.

Measurements

In most species bill-lengths are more important than wing-lengths. If both bill-length and wing-length are included, the inclusion of tarsus-length is not always necessary. In the Greenshank and the Spotted Redshank none of the available measurements are much use in distinguishing between groups. It seems probable that there are no geographical differences in both species.

For the estimation of structural body size or the lean weights of birds, wing-length appears to be an appropriate measurement (e.g. Davidson 1983), although too little material is available to see whether other measurements would given even better results. Whilst such information is lacking or scarce, it is always best to stay and always measure wing- and bill-lengths.

Group-divisions in species

Regarding the distinctions which are possible in the different species, we are still far away from an ideal situation. We would like to differentiate between, for example, Dunlins *Calidris alpina* breeding in Iceland and those breeding in Britain, or between the sexes in the Grey Plover *Pluvialis squatarola*. We cannot distinguish Neararctic Turnstones *Arenaria interpres* of the subspecies *interpres* from those breeding in northern Europe. Therefore we need to collect much more data on the distinction between populations. We need also to be more creative in finding new measurements which will increase the discriminative power. If it were possible to determine the sex of a bird accurately during trapping, for instance by using laparotomy (Maron & Myers 1984), we would be much further forward. However, use of this technique is much restricted by law in some countries e.g. Britain.

Measurements to be taken during future ringing. For each species there is an ideal set of measurements which should be collected in a standard way. Unfortunately the measurements needed differ between species. This makes measurement during ringing more difficult, as it is much easier to collect the same measurements from each bird, especially when the next hundred are waiting to be handled and it is still freezing cold!

Table 1 indicates the implications of not measuring all useful measurements for the subsequent data analysis. For example if 100 Curlew Sandpipers *Calidris ferruginea* are trapped and only bill-length and wing-length were measured, only about 65 birds can be sexed. However, if the length of the middle toe were also obtained, about 85 birds could be sexed, i.e. an improvement of about 20 percent. As we trap only few Curlew Sandpipers in the Wadden Sea area, this could be a difference of 1–2 years work in data collection.

There are measuring errors inherent in taking the length of wing and bill. These are about 8 percent (Engelmoer *et al.* in prep.). To reduce this error it can be better to measure the best discriminating measurements twice, instead of taking another measurement that adds little to the discrimination.

The use of total-head-length and tarsus-&-toe length

These two measures have recently become increasingly taken during trapping and ringing operations. In some instances we were able to measure both bill-lengths and total head lengths. We also have some data on both tarsus-length and tarsus & toe lengths of the same birds. For both measures it appeared that the discriminative power of the discriminate-equations did not improve. However, Clark (pers. comm.) found an increased discriminatory power using total-head-length rather than bill-length for some samples. Total-head-length and tarsus-and-toe length have the advantage that they are easy to take in the field. It is possible also that both total-head-length and tarsus-and-toe-length are measured more accurately than bill-length and tarsus-length in the field. However, these measurement cannot be taken from museum-specimens. Therefore, if these measurements are taken in the field, without measuring bill-length and tarsus-length, we need to have correction-formulae to combine these with museum data.

The use of weight data

In some instances weights are used to separate populations or sexes (e.g. Brennan *et al.* 1984). Although these authors insert weight data in a discriminate analysis for wintering birds, one needs to be very careful, because weights may vary considerably, especially during migration periods and during winter in some areas. When weight changes are relatively predictable, systematic deviations from the grand mean can be included in the discriminate analysis.

Museum-specimen or live-trapped birds?

Museum birds yield different measurements to birds measured in the field. For instance, as mentioned above, total-head-lengths, and tarsus-and-toe lengths cannot be obtained from museum specimens. Secondly, measurements from museum specimens may differ from the ones obtained in the field because of post-mortem shrinkage (e.g. Greenwood 1979, Fjeldsa 1980, Engelmoer *et al.* 1983). On the other hand, many birds from different breeding populations are available in the museum collections, whilst measurements of live birds trapped on their nests are scarce and scattered in the data of many researchers. This problem is particularly

Table 1. The results of discriminate-analysis made on the measurements of wader species to identify differences between populations, subspecies and/or sexes (from Engelmoer *et al.* in prep.). For each species the groups listed can be separated using the measurements indicated. For each species the relative importance of the different measures is indicated by the number of + symbols. A – symbol indicates a measure of little importance. Values in the "percentage discrimination" are the percentage of trapped birds that can be identified to group from the discriminate-analysis. The first value is that derived by using only wing-length and bill-length. Values in parentheses are for the best combination of measurements, where these are not just wing-length and bill-length.

	Bill	Wing	Tarsus	Other(s)	Percent useful
Ringed Plover *Charadrius hiaticula*	++	+	–		50%
1. (*hiaticula* Greenland & Iceland)					
2. *tundrae* N. Europe					
3. *hiaticula* W. Europe					
Grey Plover *Pluvialis squatarola*	++	+	++++	+++[a]	48% (90%)
1. Canada low Arctic					
2. W. Palearctic < 130°E					
3. Palearctic > 130°E & Alaska					
Knot *Calidris canutus*	+++	++	+		82% (96%)
1. females *canutus* & *rufa*					
2. males *canutus* & *rufa*					
3. females *islandica* & *rogersi*					
4. males *islandica* & *rogersi*					
Sanderling *Calidris alba*	+++	++	+		65% (83%)
1. males Greenland & Siberia					
2. females Greenland & Siberia males Canadian low Arctic					
3. females Canadian low Arctic					
Curlew Sandpiper *Caldris ferruginea*	+++	+	–	++[b]	64% (86%)
1. males					
2. females					
Dunlin *Caldris alpina*	++	+	–		70%
1. males *arctica* & *schinzii*					
2. females *arctica* & *schinzii* & males *alpina*					
3. females alpina & males large-sized subspecies					
4. females large-sized subspecies					
Bar-tailed Godwit *Limosa lapponica*	++	+	–		69%
1. males N. Europe & W. Siberia					
2. males Central Siberia & E. Siberia					
3. males Alaska					
4. females N. Europe & W. Siberia					
5. females Central Siberia & E. Siberia					
6. females Alaska					
Curlew *Numenius arquata*	++	+	–		74%
1. males *arquata*					
2. males *orientalis*					
3. females *arquata*					
4. females *orientalis*					
Spotted Redshank *Tringa erythropus*	+++	+	–	++[c]	17% (63%)
1. males					
2. females					
Redshank *Tringa totanus*	+++	+	–	++[c]	17% (63%)
1. females Iceland					
2. males Iceland					
3a. males Scandinavia & Denmark & Great Britain and females Scandinavia					
3b. males Netherlands and females Denmark & Great Britain & Netherlands (no easterly races included)					
Greenshank *Tringa nebularia*	–	–	–	+[c]	– (6%)
1. males					
2. females					
Turnstone *Arenaria interpres*	+	++++	+++++	+++++[d]	13% (63%)
1. *interpres*					
2. *morinella*					

[a] bill-depth; [b] middle-toe-length; [c] tail-length; [d] middle-toe-length, and tail-length

acute for the high-Arctic breeding birds. One approach to solving this problem that may prove very worthwhile would be to start a WSG-data file which contains exclusively measurements of breeding birds, which have been trapped on their nests. Such a data-file should be of great benefit to all those people and groups, who are trapping birds outside the breeding season. Therefore, both museum- and field-work are needed.

The final goal

The Wader Study Group gives the opportunity to co-operate extensively world-wide. We are now looking at the prospects of organising a Wader Study Group project, which would aim to collect the measurements of live birds, of known sex and known breeding area (trapped on the nest). The value of such data will increase enormously when put together. Such data collected from live birds will avoid the problems that arise from "museum-shrinkage". This collection of data will be useful not only for Arctic-breeding species, but also for birds breeding in Temperate and Southern areas. We hope to give more details in a further *Bulletin*. The success of such a project will depend totally on the help and enthusiasm of individual researchers or ringing groups throughout the world. The more comprehensive the collection of data, the more useful will be the results.

What measurements to take

For now, we summarise below the measurements which should be collected for each species. This is based on our own studies, and any other sources of which we are aware. It is rather preliminary, and any comments on this are very welcome.

***Haematopus ostralegus*:** bill-length, bill-depth, weight, thickness of the bill-tip, wing-length (Hulscher *et al.* pers. comm.; 85% can be sexed).

***Recurvirostra avosetta*:** length of the first secondary, bill-length, curvation-height of bill, the number of the first black-tipped primary (Engelmoer & Blomert, in prep.; 95% can be sexed).

***Charadrius hiaticula*:** bill-length, wing-length.

Pluvialis squatarola: tarsus-length, bill-depth, bill-length, wing-length.

***Calidris canutus*:** bill-length, wing-length, tarsus-length.

***Calidris alba*:** bill-length, wing-length, (tarsus-length) (Maron & Myers 1984 and this study).

***Calidris ferruginea*:** bill-length, length of middle toe, wing-length.

***Calidris alpina*:** bill-length, wing-length, (white vane, Greenwood 1986), (weight, Brennan *et al.* 1984).

***Limosa lapponica*:** bill-length, wing-length, tarsus-length, (axillaries, Roselaar pers. comm.).

***Numenius phaeopus*:** bill-length, tail-length, wing-length (Skeel 1982).

***Numenius arquata*:** bill-length, wing-length, weight (Zegers & Zwarts pers. comm.; 100% can be sexed).

***Tringa erythropus*:** bill-length, tail-length, wing-length.

***Tringa totanus*:** bill-length, wing-length, tarsus-length.

***Tringa nebularia*:** tail-length, wing-length.

***Arenaria interpres*:** tarsus-length, wing-length, middle-toe-length, tail-length, bill-length.

Sometimes, reality is rather cruel . . .

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