ACTA ORNITHOLOGICA

Ryszard Zając

Different autumn migration rates of sexes in the Dunlin *Calidris a. alpina* as determined by means of normal probability paper

Zając, R. 1980. Different autumn migration rates of sexes in the Dunlin *Calidris a. alpina*, as determined by means of normal probability paper. Acta orn. 17: 107—118.

A graphical method is presented for determining the parameters (proportion, mean, standard deviation) in samples of measurements deriving from two normal populations, using the normal probability paper. The method has been used to determine the quantitative ratio of males to females for *Calidris alpina*, caught at the mouth of the Vistula River during the autumn migration in the years 1964—1972, using bill-length measurements. By analysing the measurements, separately for individuals caught during the first and those caught during the second parts of the season, it has been found that the females were more numerous at the beginning of the migratory season than during the later period, whereas a converse situation has been found for the males.

R. Zając, Institute of Pomology, 96—100 Skierniewice, Poland

Дифференциация осеннего перелета чернозобика *Calidris a. alpina* в зависимости от пола, определяемая при помощи сетки вероятности для нормального распределения.

Представили метод графического определения параметров (численность, средние, стандартные отклонения) двух групп, измерения которых были смешаны, при использовании сетки вероятности для нормального распределения (normal probability paper). Этот метод применили для определения количественного соотношения самцов и самок чернозобика, отловленных в период осеннего перелета в устье Вислы в 1964—1972 г.г., используя промеры длины клюва. Анализируя отдельно промеры для птиц, отловленных в первой половине миграционного периода и во второй, констатировали, что самки были более многочисленны в начале миграционного периода чем во второй его половине, а самцы — наоборот.

The paper is based on the Dunlin bill-length measurements, collected at the mouth of the Vistula River during the early autumn migration period between 1964 and 1972 (except 1968), by the staff of the Ornithological Station in

Gdańsk and the Operation Baltic team. Adult birds constituted the vast majority of individuals caught and they only are considered in this paper.

We do not know of an effective method for determining with certainty the sex of a living Dunlin by morphological features. To some extent, the size of the bill may be useful in this matter. According to SOIKKELI (1966) there exists a distinct, positive difference between the bill-length of females and that of males in *C. alpina schinzii* pairs breeding in Southern Finland. However, the range of the difference is from 0.5 to 8 mm. This is also true for other subspecies of Dunlin from breeding areas of North America and East Asia, as has been shown by MacLEAN and HOLMES (1971).

In a typical sample of birds, containing both sexes, e.g. caught during migration, the bill-length always creates a bimodal distribution, the first peak of which is attributed to males and the second — to females. Some attempts have been undertaken to differentiate between the sexes in such samples using bill-length (GRIFFITHS 1970, OAG Münster 1976) by means of probability paper. GRIFFITHS emphasizes the importance of the sample size for producing acceptable results when a graphical method is to be used.

The size of seasonal samples of birds caught at the mouth of the Vistula between the middle of July and the end of August (sometimes until mid-September as in 1971 and 1972) varied from 425 to 1 441 individuals (Table 1). Such numerous data were useful in an attempt to investigate the proportion of sexes in smaller, sequential subgroups of birds. All seasonal samples were, therefore, arbitrarily subdivided into at least two approximately equal subsamples, the first containing birds caught earlier, the second — those caught later.

If we first examine the frequency curves of the bill-length in the two sequential subsamples we see in the Figs. 1 and 2 as well as in 3 and 4 (bottom) a remarkable difference between the number of males in each. The first group of migrants always contained fewer individuals with shorter bills (i.e. males) than the latter group. The converse is true for females (i.e. individuals with longer bills) which are more numerous in the first half than in the second. Because of the regular repetition of this observations for all seasons regarded, we can assume a difference in the migration rate of the sexes, at least in the migration period investigated here.

For particularly numerous samples, such as were collected in 1967 and 1971, a similar relation was obtained even if the entire data were divided into 3 or 4 sequential subsamples of approximately the same size. The number of males is constantly increasing from earlier subgroups to the later ones as we see at the top of Figs. 3 and 4.

It would be worth while to confirm this impression of different migration rates of the sexes in Dunlin, trying to assess the proportion of males and females in sequential subgroups of birds arranged chronologically from the time of their capture. For this purpose, normal probability paper have been applied. The theory and many instances of application of this graphical estimation method,
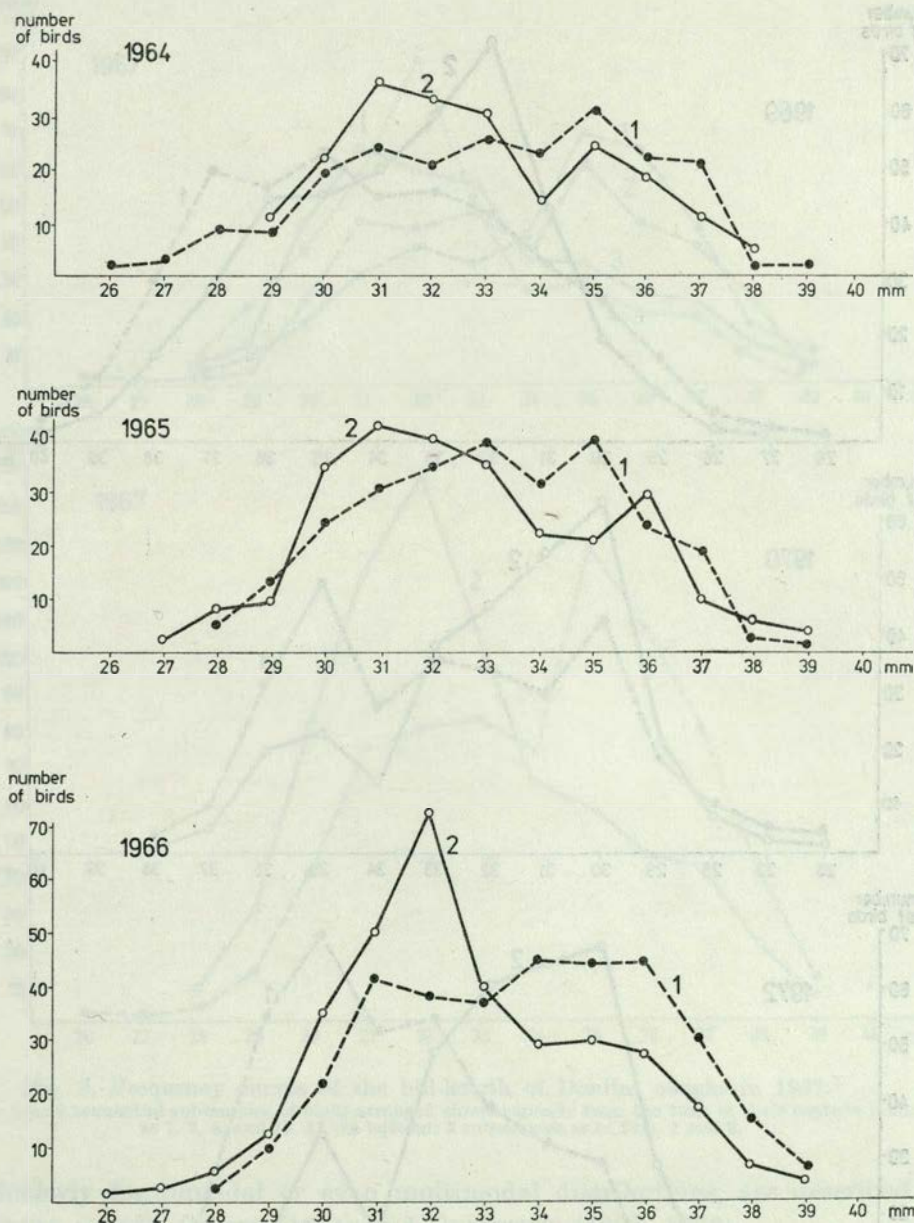
Fig. 1. Frequency curves of the bill-length of Dunlins caught at the mouth of the Vistula during the early autumn migration period in 1964, 1965 and 1966.

Each seasonal sample of adult birds has been divided into 2 sequential halves (indicated as 1 and 2) according to time of sampling.
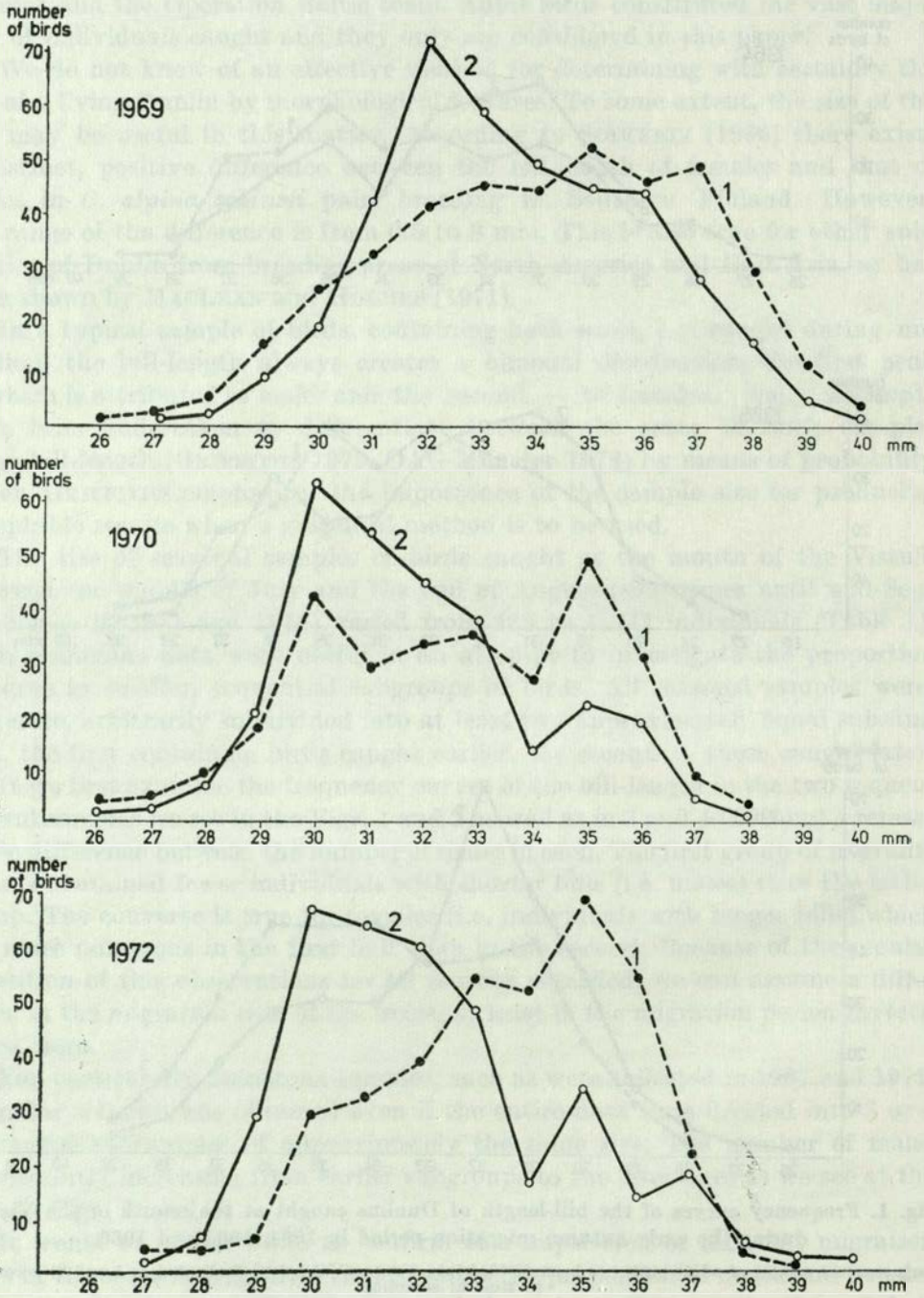
Fig. 2. Frequency curves of the bill-length of Dunlins caught in 1969, 1970 and 1972.
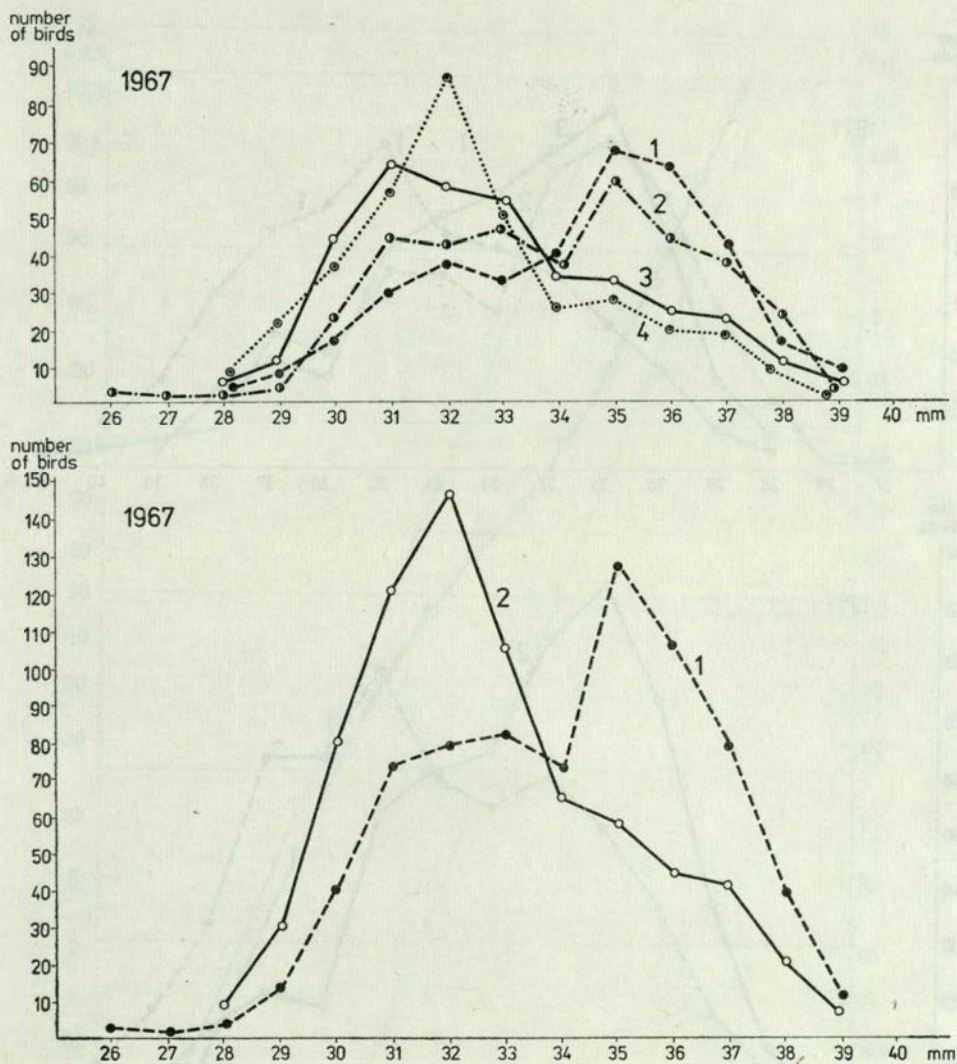For further explanations see Fig. 1.

Fig. 3. Frequency curves of the bill-length of Dunlins caught in 1967.
At the top: 4 sequential subsamples of birds arranged chronologically from the time of their capture (indicated as 1, 2, 3, and 4). At the bottom: 2 subsamples as in Figs. 1 and 2.

particularly for bimodal or even multimodal distributions, are described by HARDING (1949), CASSIE (1954) and GRIFFITHS (1968, 1970).

We plot on probability paper the cumulated frequencies (as percentages or fractions) for a set of values of the random variable being realized as empirical sample values. When the population that the sample is coming from, is normal, the line bounding the points should be approximately a straight line. In the case of bimodality, as in this instance, we can assume that the empirical distribution is a mixture derived in certain proportions from two different normal
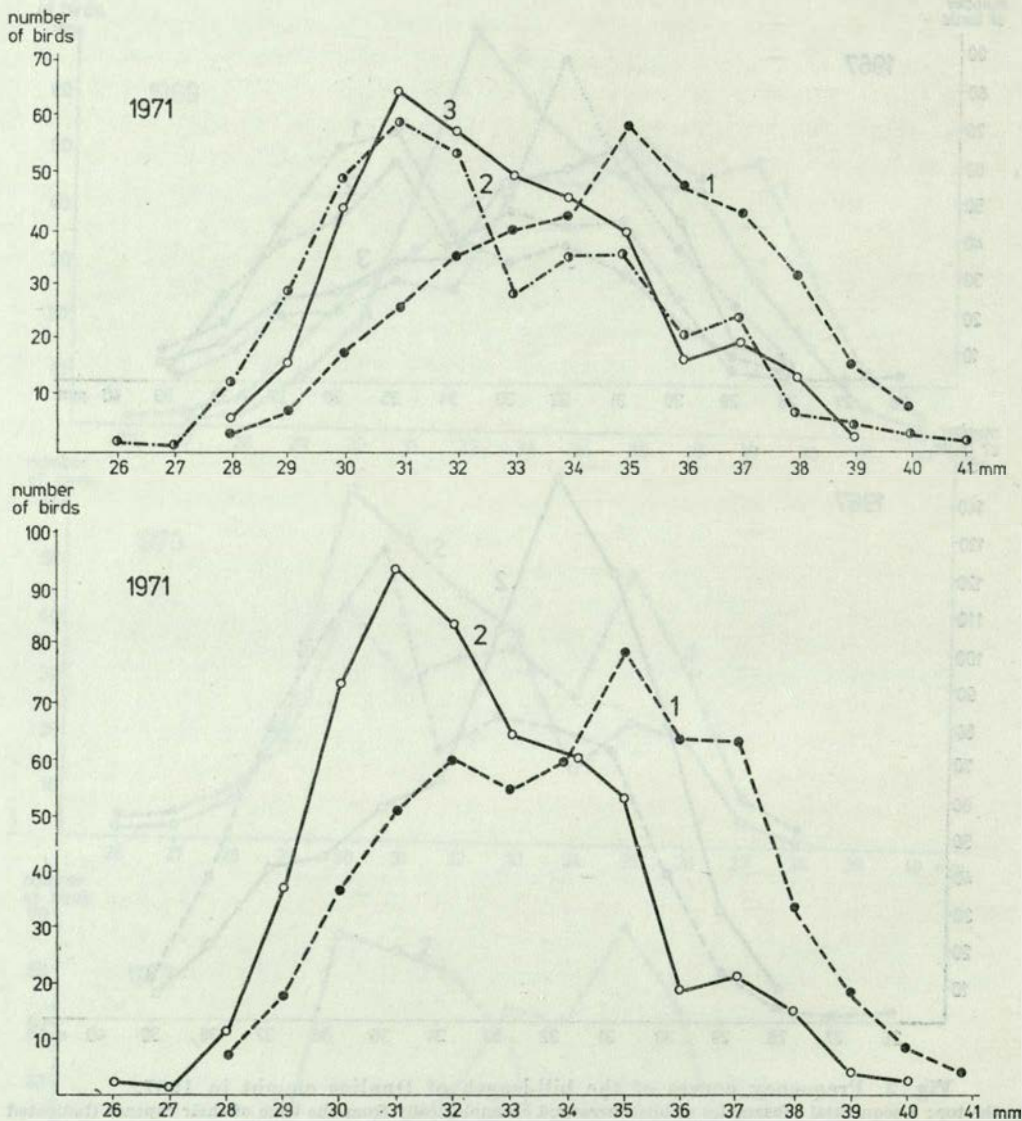
Fig. 4. Frequency curves of the bill-length of Dunlins caught in 1971.
At the top: 3 sequential subsamples (indicated as 1, 2 and 3) as in Fig. 3 (top). At the bottom: 2 sequential sub-
samples — as in Figs. 1 and 2.

populations. The PCF (percentage cumulative frequency) points are now lying
along a curve of sigmoid shape (Figs. 5 and 6).

The most important parameter to estimate now is the proportion of the
component populations in the sample. We determine this by means of the ordi-
nate of the inflexion point, that is, the point at which the curve passes from con-
versity to concavity. In order to assess further parameters of the component
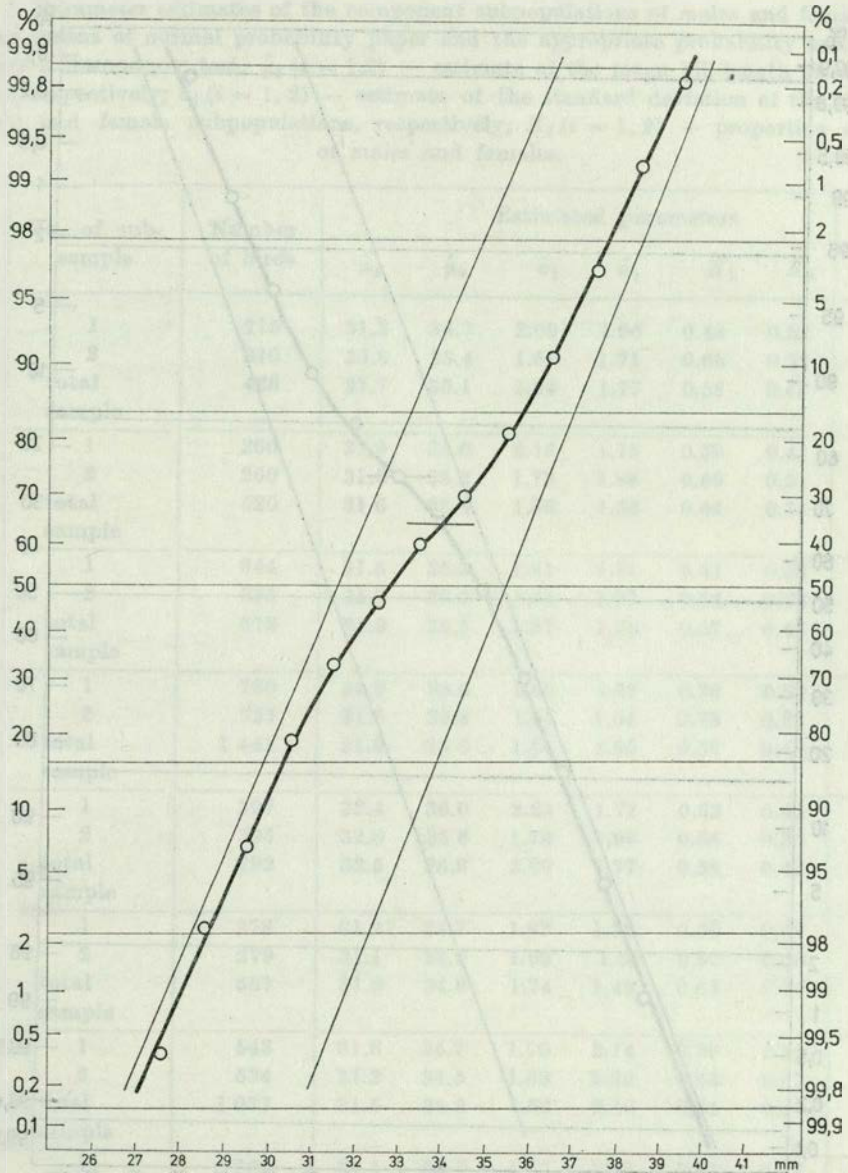
Fig. 5. Percentage cumulative frequency distribution of the bill-length of 520 adult Dunlins (sigmoid curve) caught in 1965.
The straight lines indicate the theoretical distribution functions of the two component subpopulations of males and females, respectively.

populations — the means and standard deviations — we have to estimate the population lines. The ordinates of the sigmoid curve should then be multiplied by the reciprocal of the proportions and new points plotted on the paper. Only a set of the first few points near the beginning and the end of the curve should

http://rcin.org.pl
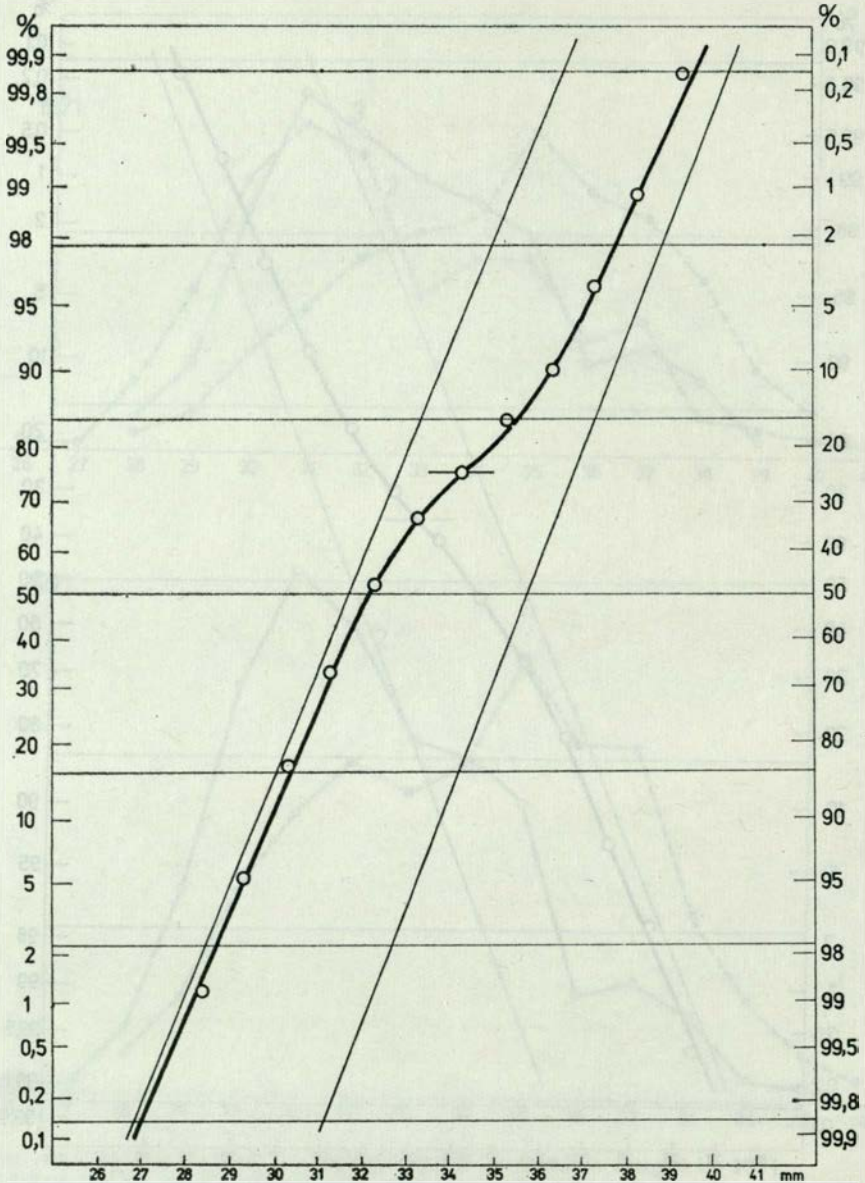
Fig. 6. Percentage cumulative frequency distribution of the bill-length of 721 adult Dunlins constituting the second (later) subgroup of migrants in 1967. For further explanations see Fig. 5.

be fitted by eye to a straight line. A point lying on the population line at an ordinate equal to 50 % has an abscissa equal to the mean of the theoretical population. Two other points of the population line having ordinates equal to about 16 and 84 % have abscissa located at an interval of 2 standard deviations. One-half of that distance is an estimate of the true standard deviation.

Table 1. Parameter estimates of the component subpopulations of males and females obtained by means of normal probability paper and the appropriate probability according to SMIRNOV-KOLMOGOROV test. $\hat{\mu}_i$ $(i = 1,2)$ — estimate of the mean bill-length of males and females, respectively; $\hat{\sigma}_i$ $(i = 1, 2)$ — estimate of the standard deviation of the bill-length in male and female subpopulations, respectively; K_i $(i = 1, 2)$ — proportion estimates of males and females.

Year	No. of sub-sample	Number of birds	Estimated parameters						Probability p
			$\hat{\mu}_1$	$\hat{\mu}_2$	$\hat{\sigma}_1$	$\hat{\sigma}_2$	K_1	K_2	
1964	1	215	31.3	34.7	2.09	1.96	0.48	0.52	0.44
	2	210	31.8	35.4	1.56	1.71	0.68	0.32	0.64
	total sample	425	31.7	35.1	1.94	1.77	0.58	0.42	0.61
1965	1	260	31.9	35.0	2.13	1.75	0.59	0.41	0.99
	2	260	31.6	35.2	1.78	1.88	0.69	0.31	0.58
	total sample	520	31.6	35.4	1.68	1.56	0.64	0.36	0.93
1966	1	344	31.8	35.3	1.81	1.81	0.41	0.59	0.45
	2	335	31.9	35.3	1.97	1.97	0.74	0.26	0.18
	total sample	679	31.9	35.1	1.87	1.98	0.57	0.43	0.27
1967	1	720	31.9	35.6	1.60	1.52	0.38	0.62	0.41
	2	721	31.9	35.8	1.63	1.54	0.78	0.22	0.82
	total sample	1 441	31.9	35.6	1.54	1.55	0.58	0.42	0.56
1969	1	397	32.4	36.0	2.23	1.72	0.52	0.48	0.78
	2	395	32.6	35.6	1.78	1.96	0.64	0.36	0.85
	total sample	792	32.5	35.8	2.09	1.77	0.58	0.42	0.44
1970	1	278	31.2	34.7	1.83	1.36	0.50	0.50	0.81
	2	279	31.1	34.9	1.69	1.59	0.80	0.20	0.68
	total sample	557	31.0	34.6	1.74	1.49	0.65	0.35	0.23
1971	1	543	31.8	35.7	1.76	2.14	0.39	0.61	0.85
	2	534	31.2	34.5	1.52	2.30	0.63	0.37	0.71
	total sample	1 077	31.5	35.3	1.52	2.16	0.51	0.49	0.43
1972	1	368	31.4	34.7	1.82	1.59	0.32	0.68	0.85
	2	368	31.1	33.6	1.45	3.13	0.58	0.42	0.58
	total sample	736	31.3	34.4	1.59	2.15	0.45	0.55	0.34

The graphical procedures have at first been applied to whole seasonal samples (Fig. 5). All parameters estimated in that way are in Table 1. The proportion of males (K_1) was always higher than 56% for years in which birds were caught only during first six weeks of their autumn migration (the middle of July to the

Table 2. The SMIRNOV-KOLMOGOROV test verifying the parameter hypothesis about two normal component subpopulations. Parameter estimates have been obtained from the whole 1965 sample graphically, by means of probability paper (Fig. 5). x — empirical values of the random variable (bill-length); z_i $(i = 1, 2)$ — standardized normal variable, $z_i = (x - \hat{\mu}_i)/\hat{\sigma}_i)$; $\Phi(z_i)$ — values of the theoretical distribution function; K_i $(i = 1, 2)$ — proportion estimates; $G_n(x_k)$ — values of the empirical distribution function or PCF (if in per cents), $G_n(x_k) = k/(n+1)$ for all measurements of the bill-length arranged in a series: $x_1 < x_2 < ... < x_n$; $|D_n|$ — the difference between both theoretical and empirical distribution values; n — number of observations. Probability: $p\{|D_n|\sqrt{n} > 0.0237\} = 0.93$

x	26.5	27.5	28.5	29.5	30.5	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5	41.5
z_1	−3.0357	−2.4405	−1.8452	−1.2500	−0.6548	−0.0595	0.5357	1.1310	1.7262	2.3214	2.9167	3.5119	4.1071	4.7024		
z_2			−4.3974	−3.7564	−3.1154	−2.4744	−1.8333	−1.1923	−0.5513	0.0897	0.7308	1.3718	2.0128	2.6538	3.2949	3.9359
$\Phi(z_1)$	.00120	.00733	.03251	.10565	.25630	.47628	.70391	.87097	.95784	.98987	.99823	.99978	.99998	1.0000	1.0000	1.0000
$\Phi(z_2)$			.00001	.00009	.00092	.00667	.03338	.11657	.29072	.53574	.76755	.91494	.97740	.99602	.99951	.99996
$K_1\Phi(z_1)$	.00077	.00469	.02080	.06762	.16403	.30482	.45051	.55742	.61302	.63355	.63887	.63986	.63999	.64000	.64000	.64000
$K_2\Phi(z_2)$			.00000	.00003	.00033	.00240	.01202	.04197	.10466	.19287	.27632	.32938	.35186	.35857	.35982	.35999
$\Sigma K_i\Phi(z_i)$			.02080	.06765	.16436	.30722	.46253	.59939	.71768	.82642	.91519	.96924	.99185	.99857	.99982	.99999
$G_n(x_k)$		.00384	.02495	.06910	.18810	.32438	.46257	.59693	.69866	.80998	.91363	.96545	.99232	.99808	1.0000	1.0000
$|D_n^{\pm}|$				.00145	.02374	.01716	.00004	.00246	.01902	.01644	.00156	.00379	.00047	.00049	.00018	.00001

end of August, 1964—1970). Prolonging the capture to mid-September has produced more equalized proportion of sexes such as 51% in 1971 and 45% in 1972. The estimated mean of male subpopulations did vary from 31.0 to 32.5 mm with an interval from the estimated females mean of 3.1 to 3.8 mm.

All parameter hypotheses were analytically verified by means of the SMIRNOV-KOLMOGOROV test, the appropriate probabilities being put at the end of Table 1. The agreement of both empirical and theoretical distributions is quite good. The contents of Table 2 present in particular the procedure used in an application of the SMIRNOV-KOLMOGOROV test.

Now the entire seasonal samples were artificially divided into two sequential subsamples approximately equal in size, the first containing birds caught earlier, the second with those caught later. To the PCF values of every subsample, plotted as points on probability paper, a sigmoid curve has been fitted by eye and, after localizing the inflection point, estimates of the proportion were read (Fig. 6).

All estimated proportion parameters, shown in Table 1, do confirm in full the supposition of different migration rates of the sexes in Dunlin as was illustrated in Figs. 1 to 4. In every year investigated, the first subsample contained fewer males than the next one, and conversely, there were more females in the earlier subsample than in the later one.

One thing, however, should be emphasized. We can by no means state, that the earlier subsample contains more females than males. But it is entirely true that the later subsamples always contain more males than females.

Some remarks concerning the sample size should be made. All seasonal samples, among which the smallest contained 425 individuals, gave clear pictures when their PCF values were plotted on probability paper. After the chronological arrangement of individuals sampled, the whole sample should not be partitioned into approximately equal subgroups with less than 200 individuals. This is far more than has been suggested by GRIFFITHS (1970). In smaller subsamples troubles do arise with accurate fixing of the inflexion point of the sigmoid curve. A possible reason for this difficulty may be the heterogeneity of the set of measurements, being collected by different persons, replacing one another during every season although the measurement method remained unchanged. In the presented data only some seasonal samples could be therefore divided into more than two sequential groups. This has been done for the seasons 1967 (4 subsamples) and 1971 (3 subsamples), the frequency curves being shown in Figs. 3 and 4.

In conclusion it was ascertained that a more detailed analysis of the presented data by means of normal probability paper showed a distinct differentiation in the autumn migration rate of the sexes in Dunlin. The females, even if a minority in almost all of the seasons observed, were regularly more numerous in the first half of migrants than in the second half, and oppositely, the males were more numerous in the later part than in the earlier one.

REFERENCES

CASSIE, R.M. 1954. Some use of probability paper in the analysis of size frequency distributions. Aust. J. mar. Freshw. Res. 5: 513—522.

GRIFFITHS, J. 1968. Multi-modal frequency distributions in bird populations. Bird Study 15: 29—32.

GRIFFITHS, J. 1970. The bill-lengths of Dunlins. Bird Study 17: 42—44.

HARDING, J.P. 1949. The use of probability paper for the graphical analysis of polymodal frequency distributions. J. mar. biol. Ass. U.K. 28: 141—153.

MACLEAN, S.F., HOLMES, R.T. 1971. Bill lengths, wintering areas and taxonomy of North American Dunlins, *Calidris alpina*. Auk 88: 893—901.

OAG Münster. 1976. Zur Biometrie des Alpenstrandläufers (*Calidris alpina*) in den Rieselfeldern Münster. Vogelwarte 28: 278—293.

SOIKKELI, M. 1966. On the variation in bill- and wing-lengths of the Dunlin (*Calidris alpina*) in Europe. Bird Study 13: 256—269.

STRESZCZENIE

[Zróżnicowanie stosunków ilościowych biegusów zmiennych różnej płci w czasie wędrówki jesiennej, określone przy pomocy siatki prawdopodobieństwa]

Zanalizowano długość dzioba biegusów zmiennych, zatrzymujących się w ujściu Wisły w czasie wędrówki wczesnojesiennej, celem określenia stosunku liczbowego samców do samic w kolejnych okresach sezonu jesiennego. Pod uwagę wzięto ptaki stare, tj. będące w 2. lub późniejszym kalendarzowym roku życia, chwytane w okresach od połowy lipca do końca sierpnia (niekiedy — do połowy września) lat 1964—1968 i 1970—1972.

Krzywe częstości długości dzioba są dwuszczytowe, gdyż samce mają średnio dzioby znacznie krótsze, niż samice. Dla określenia stosunkowego udziału, tj. wielkości frakcji obu grup płciowych, zastosowano metodę graficznej analizy kumulanty częstości długości dzioba, naniesioną na siatkę prawdopodobieństwa dla rozkładu normalnego (rys. 5—6). Rzędna punktu przegięcia krzywej określa wielkości obu frakcji. Mnożąc rzędne punktów o kilku najniższych i najwyższych odciętych (tj. liczby ptaków o najkrótszych i najdłuższych dziobach) przez odwrotność wielkości danej frakcji, uzyskuje się na siatce punkty, wyznaczające dwie proste, z których można odczytać średnie i odchylenia standartowe długości dzioba samców i samic*.

Średnia długość dzioba samców, określona oddzielnie dla różnych części okresu chwytania różnych lat, wynosi 31.0—32.6 mm., samic — 33.6—36.0 mm (tab. 1). Stwierdzono że samice są liczniejsze w pierwszej części okresu chwytania, niż w drugiej, samce zaś — odwrotnie (rys. 1—4, tab. 1).

* Dokładny opis stosowania tej metody podaje ZAJĄC w pracy *Zastosowanie siatek prawdopodobieństwa w badaniach biologicznych*, wydanej w 1976 r. nakładem Instytutu Sadownictwa w Skierniewicach (red.).

Redaktor pracy — dr Wojciech Kania