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The analysis of ringing data: pitfalls and prospects

By A. C. Perdeck

1. Introduction

It is difficult to deny that bird-ringing data have contributed considerably to our ornithological knowledge. As a method it has found applications in many kinds of studies.

A lot of research on orientation and on the population dynamics of breeding populations would have been impossible without the assistance of well organized bird-ringing schemes.

A number of problems can be studied from data obtained by the ringing act itself. The ringing lists in the offices contain a wealth of information that is used only for a small part. Although the catching of birds for ringing purposes has seldom been carried out as a rigorous sampling technique, the annual ringing totals can be used to study changes in the population size. The many pitfalls of this use of the numbers ringed are well described by GINN (1969). A relation between prey density and the numbers ringed was found in the Kestrel *(Falco tinnunculus)* by SNOW (1968). The dramatic decrease of Whitethroats *(Sylvia communis)* in 1970 is well documented by the British ringing totals (WINSTANLEY, SPENCER & WILLIAMSON 1974).

Ringing dates can give information on the breeding time of a species. IMBODEN (1974), in his analysis of all European Lapwing *(V. vanellus)* recoveries, detected a correlation between breeding time and temperature. BEINTEMA (1975) disclosed a shift in the breeding time of this species in Holland from 1911 to 1973 of about half a month.

Ringing dates have also been used to determine migration times and to describe differential migration according to species, subspecies, sex, age. Conclusions are only safe, however, if the catching rate is not influenced by the migration intensity and by the categories mentioned.

A lot of information can be drawn from accurate descriptions of the bird in the hand. Annual cycles of weight and moult are becoming known in a detailed way and can be integrated in the study of migration patterns. For instance, by a comparison of turdine species, SNOW (1969) showed that migrating species have a short moult period as compared with non-migrating ones.

Studies that include both ringing details and finding details of a recovered bird (what is generally called a recovery) can be dvided in two main groups, viz. one that is using recoveries for finding survival rates, while the other concentrates on the movements of birds.

The study of survival rates is still in its infancy. It is, however, indispensible to population dynamics. This topic will be discussed by CAVÉ in this issue.

The present paper concentrates on the study of movements, which is probably the oldest impetus for bird ringing and perhaps also the subject to which it can give its most original contribution.

2. Problems in the analysis of migration patterns

The idea that migration patterns can be described from recoveries of ringed birds is based on a simple hypothesis,viz. that recoveries give a true picture of the distribution of the ringed birds.

It must, however, be realized that from the act of ringing to the arrival of the recovery at the ringing office a complicated process has taken place. Even if we assume that the bird does not loose its ring, that the inscription remains readible and is read off correctly and that otherwise no mistakes have been made, enough difficulties remain.

First of all, the birds ringed have to form a representative sample of the population concerned. One condition for this is that the sample is big enough to cover the heterogenity of the population. A second one is that the sampling itself should be random. This latter condition seems to be fulfilled rather well in ringing of nestlings, but less in that of full growns, where both the catching place (leading lines) and the catching itself (nets) will easily introduce biasses.

Further, the recoveries from the ringed sample must also be representative. The rate of recovery has to be equal from place to place in order to give a true picture of the distribution. If this rate changes in time (e. g. with seasons) this change must be also identical from place to place.

This is evidently not the case. Ringed birds are not sampled in a proper scientific way. For recoveries we depend on the activities of all kinds of people, such as bird catchers, hunters, and just ordinary persons who happen to find a dead, wounded or entangled bird, surprisingly enough bearing a ring. These activities are certainly not distributed randomly. And also the seasonal variation is different from one activity to another (e. g. hunting regulations versus outdoor activities of the general public). There are other differences between the various kind of recoveries. Broadly, we may divide them into two categories. The first comprises the recoveries from birds encountered alive (caught, shot, killed). Here the recovery rate is proportional to the catching, shooting, killing rate. The second includes all recoveries where the bird was already dead when encountered. In this case the recovery rate depends both on the finding rate and the morality rate (in fact in shot birds there is also a finding rate viz. the chance that a shot bird is found by the hunter).

All recoveries are dependent on the chance that a caught, shot or found bird, bearing a ring is indeed reported to the ringing office.

We may now formulate the basic assumption again: recoveries of ringed birds give a true picture of the distribution of the population concerned if

— the ringed sample is not biased

— if catching, shooting, finding, reporting and mortality rates and the change of these rates are evenly distributed in space.

To give some impression about the degree in which these conditions are lacking we might compare the distribution of recoveries according to different manners of recovery.

In Table 1 the mean distance from the ringing place in winter (thus keeping time constant) is given for some species ringed as nestlings in The Netherlands. This is done both for birds „shot" and birds „found dead". In all species there is a clear difference in distance, the shot birds being further away from the ringing place than the found birds. If we rank the species according to distance the ranking will be different in the two cases.

A similar case can be found in the Mallard *(Anas platyrhynchos)* and the Teal *(A. crecca)* ringed from September to Novenber in The Netherlands. If we want to know the breeding area of these populations we may consider the recoveries from the breeding time (May, June). It appears that for both species the breeding area is quite different if we use only shot or birds found dead respectively (Table 2). Shot birds are recovered more to the east than birds found

Table 1. Mean distance in km between place of ringing and recovery of birds ringed in The Netherlands as pulli and recovered Sept.—Febr. Number of recoveries in brackets. Found includes only recoveries of birds found dead or dying (cause of death known or unknown), or unknown to be dead or alive (e. g. „found"), neither shot nor taken otherwise intentionally by man. Shot includes only recoveries of shot birds or recoveries indicated as „killed", „capturé", etc. without further details, not known to be trapped, netted, etc.

	Found	Shot
Vanellus vanellus	694 (141)	1097 (687)
Ardea purpurea	607 (75)	1227 (134)
Larus ridibudus	374 (922)	1109 (390)
Ardea cinerea	143 (519)	726 (181)
Haematopus ostr.	116 (154)	801 (121)
Larus argentatus	48 (1455)	198 (207)

Table 2. East-west distribution of recoveries of Mallard and Teal ringed from Sept. to Febr. in The Netherlands and shot in May and June.

	Mallard		Teal	
	shot	found	shot	found
West of 20° E. L.	8%	75%	10%	33%
20°—40° E. L	59%	22%	51%	67%
East of 40° E. L.	33%	3%	39%	—
Total recovered	24	102	112	70

dead. Further, if only shot birds are considered the breeding areas of the two species are nearly the same, while from the found birds it could be concluded that the Teal breeds more eastward than the Mallard.

CAVÉ (1968) plotted the direction and distance from the ringing place of recoveries of Kestrels ringed as nestlings in The Netherlands and recovered during the subsequent winter. The shot birds showed a pronounced south-western direction tendency, the birds found dead not or not in such a degree. If all recoveries were plotted without considering the way of recovery one would conclude that Dutch Kestrels were for a large part migratory. From the „found“ recoveries alone this is rather doubtful and CAVÉ concluded that the nonrandom distribution of shooting rate simulated a migration.

IMBODEN (1974) plotted the distance from ringing place against time of the year of Lapwings ringed as nestlings in Holland/Belgium and England. He found a distinct difference between these populations, using the combined recoveries of birds shot and found dead. When I plotted the birds ringed in Holland in the same way, but excluded shot birds, the difference with the British birds disappeared (Fig. 1). The difference could be simulated by an unequal shooting/finding ratio of the two populations (higher continental shooting rate).

In most recovery maps no distinction is made between the different manners of recovery, although caught birds are often excluded. Therefore, it is likely that from such maps wrong conclusions have been drawn. It must be remarked, however, that we do not know if a map based only on recoveries of birds which are found dead gives a better picture of the distribution than a map with recoveries of shot birds only.

A rather serious problem gives the bias due to mortality or survival rates. If this rate is not the same from one place to another, one will find different distributions for different age groups. Usually this is interpreted as differential migration. A striking example is found in the Gannet *(Sula bassana)*. Analysing the recoveries of the British ringed specimens, THOMSON (1974) came to the conclusion that the old birds migrated less far to the south than the young ones. If, however, we assume that the birds are faithful to their first wintering place and that there exists a decreasing survival rate from north to south, another explanation is possible. Due to the lower survival, the birds moving farther to the south are more rapidly eliminated, with the result that only the short-distance migrants remain and become older than the long-distance migrants. One could also think of the possibility that by competition the younger birds are driven out of the more favourable areas.

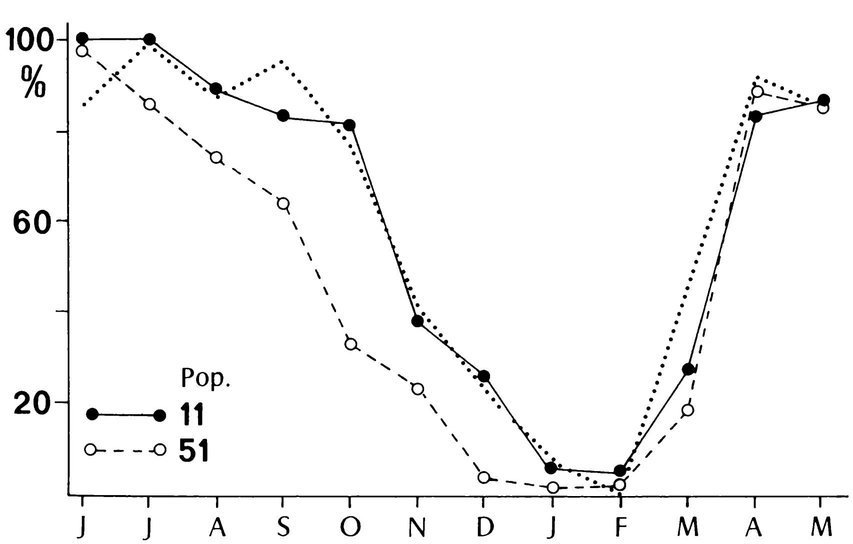

Fig. 1: *Vanellus vanellus.* Monthly percentage of first year birds recovered within 50 km, of English (pop. 11) and Dutch (pop. 51) populations. From IMBODEN (1974, Fig. 6). Added with dotted line: Dutch population with shot birds excluded.

In general, we may conclude that a picture of the true distribution on the basis of ringing data would be possible only if we could make corrections for all the errors enumerated. As long as this is not possible, the best way seems to cut down the number of variables. This can be done by working with material that is as homogeneous as possible, such as with recoveries of birds ringed in a restricted area, all of the same age and studying the spatial and seasonal distribution for each manner of recovery separately. Such homogeneous distributions will not help us, of corse, with finding the true distribution. But they can be used to detect relative differences between groups, such as age groups, sexes, populations, species. For the moment this comparative method seems the most promising.

3. Comparative analysis of distribution patterns

Comparative studies using recoveries of ringed birds are not rare. In fact, the maps of the German atlases of recoveries (Schüz & Weigold 1931; Zink 1973 —) are typically made for, and very useful to comparative analysis. One would like, however, to reduce such maps to a few characteristic parameters. Preferably, the time should be one of them, since we are especially interested in movements.

We deal then, in fact, with three dimensions, time and the two co-ordinates of place. If we work in the geographical co-ordinate system it is tempting to use only one of the co-ordinates. For mainly east-west distributions longitude might be used, for north-south movements latitude (e. g. Langham 1971). Another possibility is to use polar co-ordinates, separately either directions, or distances (both measured from ringing place). The rather frequently used method of giving a map for each period (e. g. month) is time consuming and difficult to quantify. As a replacement to this I have introduced the use of mean positions, which reduces the plotting labour and can be a help for quick comparisons (Perdeck 1967; Imboden 1974; Doude van Troostwijk 1974). Moreover, from the mean positions it is easy to calculate mean directions and distances.

Table 3. Formulas for calculating mean positions.

$$1.\ \bar{B} = \frac{\Sigma\ B}{N}\ ;\ \bar{L} = \frac{\Sigma\ L}{N}$$

$$2.\ \bar{B} = \frac{\Sigma\ B}{N}\ ;\ \bar{L}\ \frac{\Sigma\ (L\ \cos\ B\ )}{N\ \cos\ \bar{B}}$$

$$3.\ \bar{B} = \mathrm{arctg}\frac{\Sigma\ \sin\ B}{\left\{\left[\Sigma\ (\cos\ B\ \cos\ L)\right]^2 + \left[\Sigma\ (\cos\ B\ \sin\ L)\right]^2\right\}^{1/2}}$$

$$\bar{L} = \mathrm{arctg}\ \frac{\Sigma\ (\cos\ B\ \sin\ L)}{\Sigma\ (\cos\ B\ \cos\ L)}$$

B and L: latitude and longitude of individual localities. $\bar{B}$ and $\bar{L}$: mean latitude and mean longitude. Southern latitude and western longitude are entered as negative values. N = number of recoveries. ad 1. correct when one degree of longitude can be considered equal in north and south limit of area. ad 2. correct when surface of area on globe can be considered as flat (e. g. about one quarter of a hemisphere). ad 3. correct for whole globe. When Σ (cos B cos L) is negative, 90° are to be added to $\bar{L}$.

In Table 3 some methods for calculating mean positions are given. With formula 1 just the simple uncorrected means are calculated. This is a good approximation for latitude, since each degree has the same distance of ca. 111 km. For longitude problems arise, since one degree varies from ca. 111 km (equator) to zero (pole). A better method is therefore to correct longitude by multiplying it with the cosine of the latitude (one at equator, zero at pole). To find the mean longitude, the mean value of the corrected individual longitudes has, of course, to be divided by the cosine of the mean latitude (formula 2).

The derivation of the best method, the calculation of the centres of gravity (formula 3), can be given as follows (see Fig. 2): Let l, m, n be perpendiculars from point P with northern latitude B (or southern latitude negative B) and eastern longitude L (or western longitude negative L) to planes through the 90° meridian, the 0° (Greenwich) meridian and the equator, respectively.

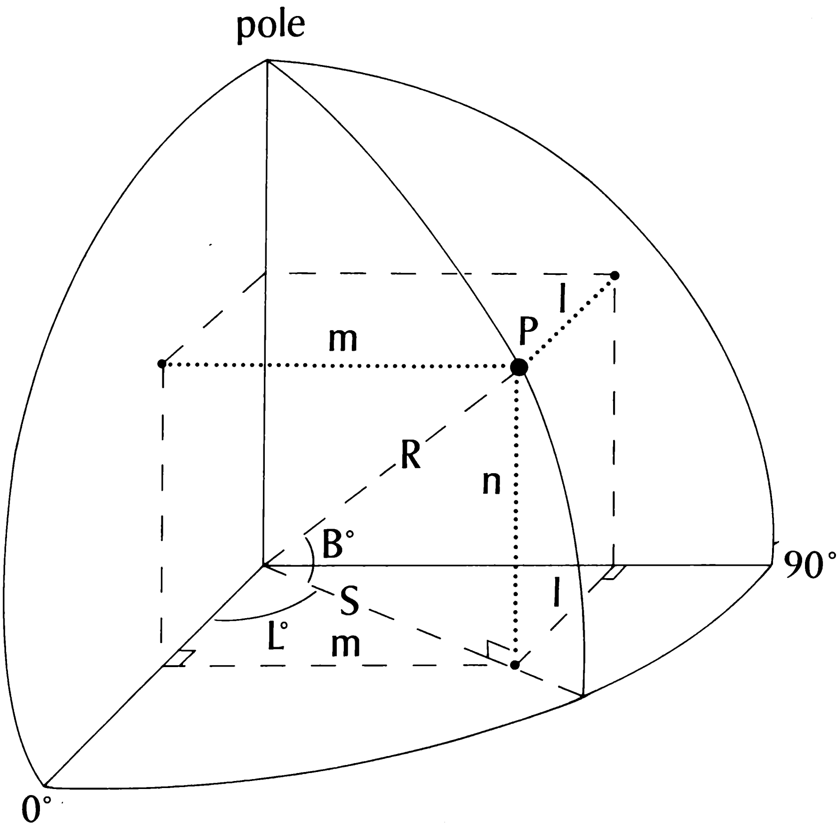

Fig. 2: Diagram of a part of the globe with lines and angles needed for calculation of mean position (see text).

R, the radius of the globe, is set equal to 1
From Fig. 2 it can be seen that:
$n/R = \sin B$; $n = \sin B$
$m/S = \sin L$; $S/R = \cos B$; $S = \cos B$
$m/\cos B = \sin L$; $m = \cos B \sin L$
$l/S = \sin (90\text{-}L) = \cos L$
$l/\cos B = \cos L$; $l = \cos B \cos L$

The geographical co-ordinates ($\bar{B}$, $\bar{L}$) of the mean position are determined by the sum of the individual perpendiculars:

$$l_t = \Sigma (\cos B \cos L) \; ; \; m_t = \Sigma (\cos B \sin L); \; n_t = \Sigma \sin B$$

Then

$$\operatorname{tg} \bar{L} = m_t : l_t \; ; \; \underline{\bar{L} = \operatorname{arctg} (m_t : l_t)}$$

$$\text{If } S_t = \sqrt{l_t^2 + m_t^2}, \text{ then}$$

$$\operatorname{tg} \bar{B} = n_t : S_t \; ; \; \underline{\bar{B} = \operatorname{arctg} (n_t : S_t)}$$

This method was used to analyse migration patterns of four duck species (Wigeon, *Anas penelope;* Pintail, *A. acuta;* Teal, *A. crecca;* Mallard, *A. platyrhynchos*) ringed in big numbers in Dutch duck decoys. Attention was focussed on the position of breeding and winter quarters.

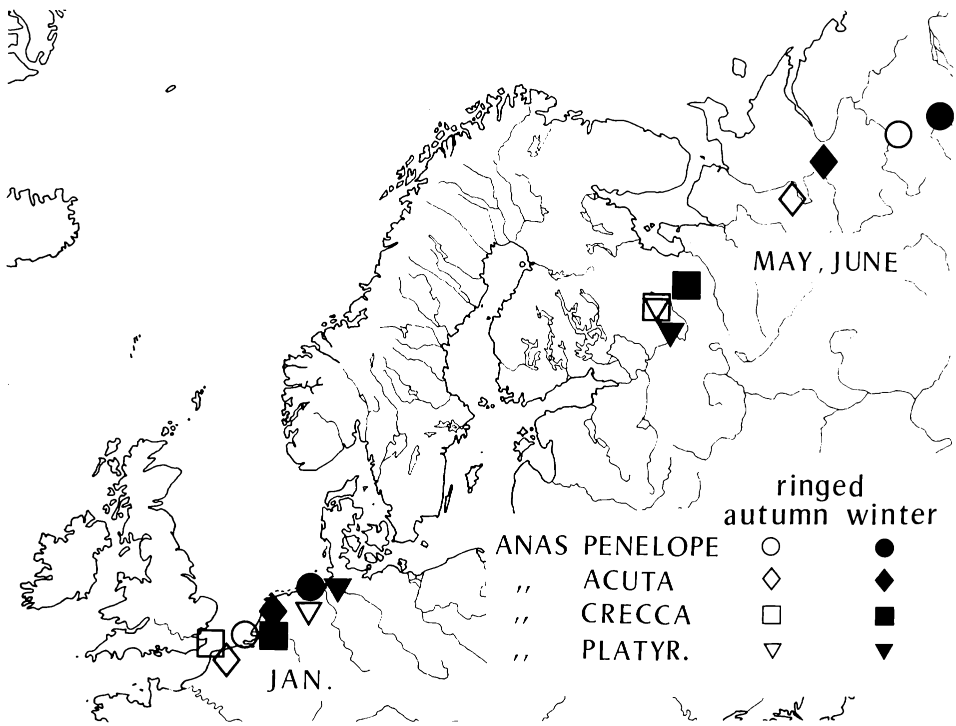

Fig. 3: Mean position in winter and breeding time of ducks ringed in The Netherlands. See also Table 4. Map in conical projection intersecting at 30° and 60° N. L.

Birds shot in May and June were considered to be in the breeding area, those shot in January (first year excluded) in winter quarters.

In Fig. 3 the centres of gravity are shown both for the birds ringed during autumn (Sept.—Nov.) and winter (Dec.—Febr.). Differences and similarities should, of course, be tested. A bivariate T-test (Hotelling T-test; RAO 1952) is not to be recommended since the distributions are often far from normal. Therefore, a non-parametric two-sample test has been used, the Mardia-Watson-Wheeler Test (BATCHELET 1972). Further information about this attractive test can be found in MARDIA (1972) under the Uniformscores Test.

It appeared that all interspecific differences in position of breedign areas were significant at the 5% level, except between Teal and Mallard. None of the intraspecific differences in breeding area were significant. As regards to the winter positions, both inter- and intraspecific differences were significant, except for the intraspecific difference in Pintail.

From these mean positions the direction and distance between breeding and wintering area were calculated, using loxodromes (IMBODEN & IMBODEN 1972). The result is given in Table 4, and the specific character in distance and direction appear to be rather constant. They can be used as a simple set of parameters to make comparisons between the species.

Since the time of the year was restricted and only one manner of recovery was used, the differences between the species are free from error due to relations between season and distribution, and also between recovery method and distribution. The differences may therefore be considered as real. The similarities are however not so trustworthy. For instance, no difference was found between the breeding areas of Teal and Mallard.

If, however, only recoveries of birds found dead are used such a difference becomes evident (Table 2). The distribution of the shot birds represents also the distribution of the hunters, and when the latter is non-random, the distribution of the birds is less likely to appear. This holds especially when interspecific differences are small. Mutatis mutandis, the same can be argued for the birds found dead.

Table 4. Loxodromic distance and direction from centre of gravity of breeding area (shot May, June) to centre of gravity of wintering area (shot January, after first year). The birds are ringed in The Netherlands.

species	ringing period	distance (km)	direction (degrees)	number recovered May-June	number recovered Jan.
Anas penelope	Dec.-Febr.	3965	248	131	83
	Sep.-Nov.	3589	246	54	26
Anas acuta	Dec.-Febr.	3315	239	78	83
	Sep.-Nov.	3303	239	69	47
Anas crecca	Dec.-Febr.	2702	236	30	144
	Sep.-Nov.	2580	237	52	277
Anas plath.	Dec.-Febr.	2146	239	20	139
	Sep.-Nov.	2246	237	4	67

Finally, one remarkable point may be noted. Within all species the mean position in January is farther to the south west in the winter-ringed birds than in the autumn-ringed birds. The same holds for the mean position in May and June, except for the Mallard, with only 4 recoveries of autumn-ringed birds. So the „autumn" birds come from less far breeding areas and go to farther winter quarters as compared with the „winter" birds, but the distance remains nearly the same. A similar effect was found in Starling *(Sturnus vulgaris)* populations migrating through Holland (PERDECK 1967).

4. The use of Fourier analysis in describing migration patterns

Migration can be considered as a periodic phenomenon with a constant fundamental period of one year. An effective statistical method for such a periodic regression is to be found in Fourier analysis (BLISS 1958, 1970).

If, for instance, we plot the distance of recoveries of ringed nestlings from the ringing place against the time of the year, we will find a distribution with high distance values in winter and low distance values in summer. Through the points a sine curve can be fitted by an equation:

$$y = a_0 + a_1 \cos t + b_1 \sin t$$

y is the distance belonging to a certain value of the time t

t is the time expressed in a cycle of 360° degrees for a year, with an angular value of $t = d \times 360°/365$, d being the number of the day numbered from 1 (Jan. 1st) to 365 (Dec. 31st).

a_0 is the mean of all observed distances

a_1 and b_1 are regression coefficients.

In most cases such a simple sine curve (the first harmonic) will not give a good fit. It is then possible the extend the equation with a second cosine — sine term, a third term, etc., each representing a sine curve with 180°, 120°, etc. cycle (the second, third, etc. harmonic), by multiplying t with 2, 3, etc.

A three-term equation is then as follows:

$$y = a_0 + a_1 \cos t + b_1 \sin t + a_2 \cos 2t + b_2 \sin 2t + a_3 \cos 3t + b_3 \sin 3t.$$

This equation is just a special case of the general multiple linear regression equation:

$$y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 + a_5 x_5 + a_6 x_6$$

Most treatises on Fourier analysis deal with observations equally spaced in time and with frequencies that are identical for all intervals. This is not the case in recoveries of ringed birds. One method would be to calculate means for each month. But then information is lost. We have therefore used programmes for the general multiple linear regression and replaced the term $a_1 x_1$ by $a_1 \cos t$, the term $a_2 x_2$ by $b_1 \sin t$, etc. The linear regression equation can be used to represent a curve, since the parameters cos t, etc. are linear.

If we add sufficient terms the computed curve will fit any observed distribution exactly, but this refinement makes handling unneccessary difficult and would include insignificant terms. We have therefore added no more terms than are needed to reduce the variance from the scatter about the fitted curve to the same magnitude as the residual error. This was done by F-tests according to the backward elimination procedure (DRAPER & SMITH 1966). Up till now we needed 3 harmonics at most, and the periodic regression was significant for the cases mentioned below (overall F-test, P less than 1%).

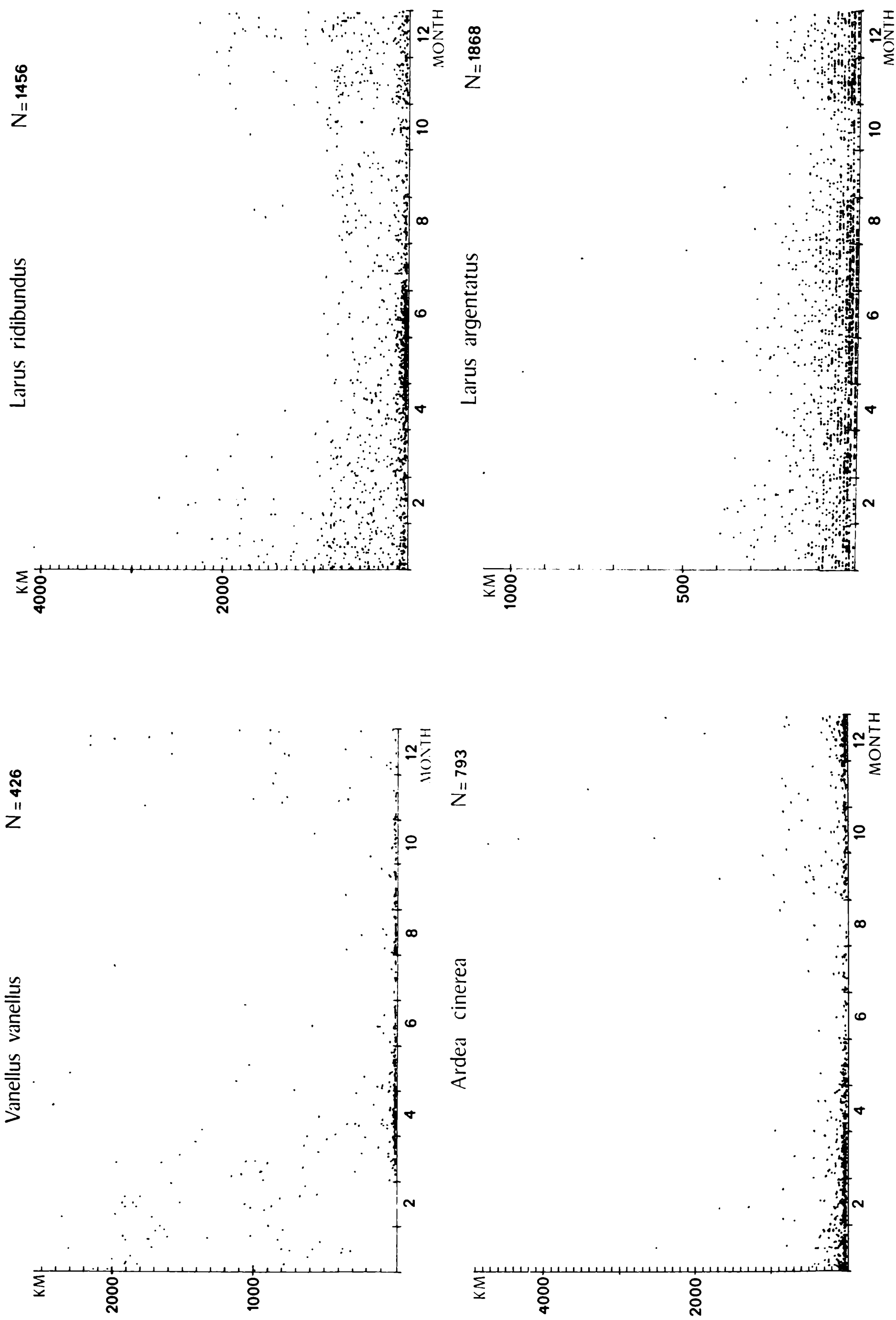

Fig 4: Distance from ringing to recovery place plotted against time of the year. Birds ringed as nestlings in The Netherlands and found dead subsequently.

As a start the distance-time distribution is shown in Fig. 4 for Lapwing *(Vanellus vanellus)*, Black-headed Gull *(Larus ridibundus)*, Common Heron *(Ardea cinerea)* and Herring Gull *(Larus argentatus)*. The material consists of recoveries of birds ringed as nestlings in the Netherlands. Only recoveries of birds in the category „found dead" were used (for selection see Table 1). Further the recoveries in the first year after ringing were only used from August (Lapwing, Heron) or November (Gulls) onward.

It can be seen that the distribution is rather skew and that the variance increases with the mean distance. Therefore the data were transformed to a more normal distribution by entering the distances (km) as square roots, after adding half the unit of the measurement ($^1/_2 \times 10$ km) to be able to deal with distance zero.

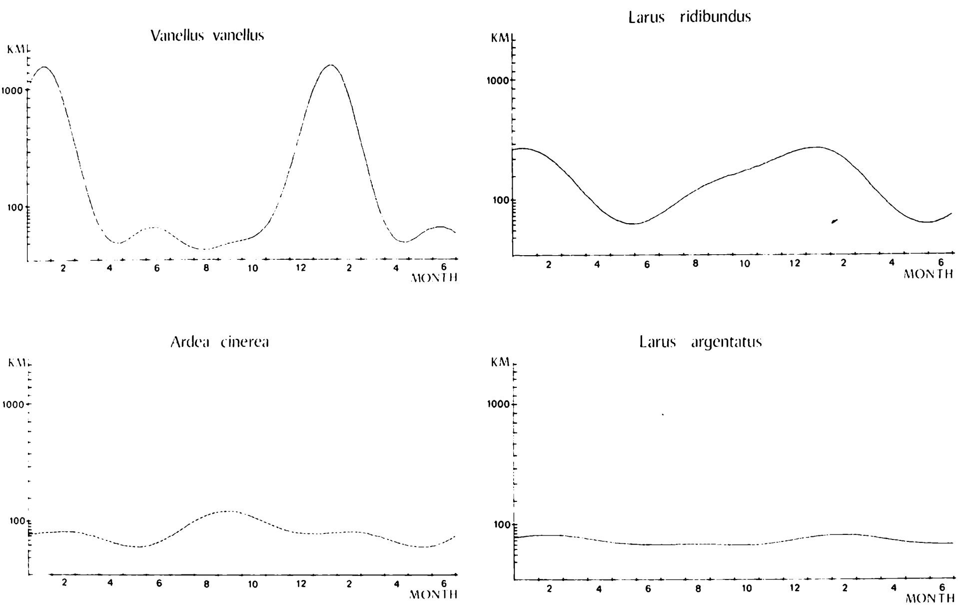

Fig. 5: Fitted Fourier curves for the (distance)-(day of the year) relation.

In Fig. 5 the obtained best fitting Fourier curves are given. Differences in the migration patterns are now clearly visible. The small peak during breeding time in the Lapwing represents the degree of abmigration. The method permits a further analysis of variance and the calculation of the position of peaks and other turning points.

Although this procedure is an improvement over plotting mean distances for each month, it is still not a representation of the position-season relation. This can also be done by Fourier analysis. In stead of one equation, two are used. one to fit latitude, another to fit longitude with time. From the combination of the two equations the mean position for every day of the year can be calculated and the mean route plotted on the map. In the next case just the latitude and the longitude corrected for latitude were taken (Formula 2 of Table 3).

The results are given in Fig. 6. Here too it is possible to calculate the turning points and to carry out analysis of variance. Since this has not yet been done it is dangerous to make detailed comments on the particular form of the migration routes. They are shown here just as an example to demonstrate the method. Further developments are planned. The method seems to be a good instrument to handle large masses of recoveries and to reduce the migration patterns to a set of easely comparable data.

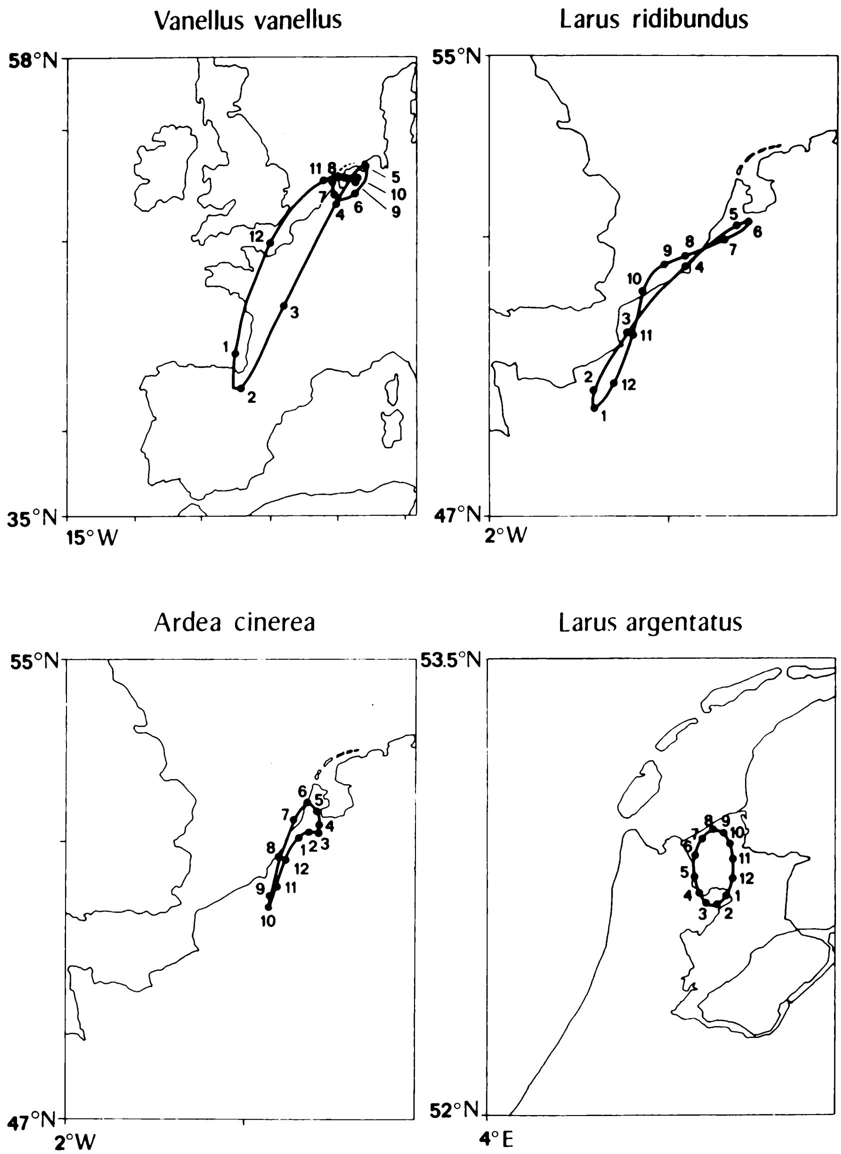

Fig. 6: Combined fitted Fourier curves for the (latitude or longitude)-(day of the year) relation. For reference the first day of each month is indicated by the number of that month. Maps in Mercator projection.

5. Concluding remarks

In a sketchy way, it was demonstrated what kind of information could be extracted from bird-ringing data, and by what methods this could be done. I have left out a lot of practical problems, such as data collection, conversion methods for computer analysis and computer methods. Some of these points give great difficulties and all of them are rather important.

Further I have not been able to formulate here clear biological problems and to give hints for their solution. This is mainly due to the fact that with bird ringing only a limited insight is obtained in the life histories. To comprehend for instance migration patterns, it is not enough to describe them from the recoveries. Even if we are able to avoid the many pitfalls and can add data on survival and details from the bird in the hand, information from other sources is needed. All these data should be placed into a theoretical framework helping us to understand the mechanism and survival value of the movements of birds. This will be a major task for future research.

I must stress, however, that if we fail to open the treasure box of the files in the ringing offices, bird ringing will be considered as a hobby, also by the subsidizing authorities, with all consequences.

6. Zusammenfassung

Die Auswertung von Ringfund-Material: Fehlermöglichkeiten und Vorzüge der Methode.

Die Vogelberingung ist eine der vielen Möglichkeiten, Datenmaterial über die Biologie der Vögel zu sammeln. Ihr Beitrag zur Ornithologie ist vielschichtig und eindrucksvoll. Ein großer Teil dieses Materials ruht allerdings noch in den Archiven der Beringungszentralen. Seine Nutzbarmachung verlangt neue technische Hilfsmittel und enge internationale Zusammenarbeit.

Nach einer kurzen Übersicht über die verschiedenen Möglichkeiten, die Kennzeichnung von Vögeln in der Forschung zu verwenden, wird ein Gebiet eingehender behandelt, nämlich die Zugbewegungen der Vögel.

Es wird gezeigt, daß die Wiederfunde beringter Vögel in der Regel kein naturgetreues Bild ihrer Verbreitung in Raum und Zeit geben. Wiederfunde werden in sehr verschiedener Weise erzielt: durch Fang, Erlegung, Totfunde usw. Jeder dieser Fundumstände vermittelt ein anderes Bild von der Verbreitung der untersuchten Art. Unterschiedlich ist dabei auch die Wiederfundrate. Diese Unterschiede kommen dadurch zustande, daß die menschlichen Tätigkeiten nicht zufällig nach Raum und Zeit verteilt sind. Wenn Wiederfunde gefangener, erlegter und gefundener Vögel zusammengeworfen werden, können daher erhebliche Irrtümer bei der Interpretation entstehen. Ein naturgetreues Bild kann deshalb nur dann gegeben werden, wenn die in der Methode liegenden Fehler korrigiert werden können. Das ist heute noch nicht möglich.

Relative Unterschiede zwischen einzelnen Gruppen können aber durch vergleichende Untersuchungen gefunden werden. Besonders verlockend ist dabei der Vergleich verschiedener Arten. Als Beispiel wird eine Auswertung der Brut- und Winterverbreitung von Enten vorgelegt, die in den Niederlanden beringt wurden. Dabei werden Mittel-Positionen errechnet und die Art der Berechnung diskutiert. Um die Auswertung einer großen Zahl von Wiederfunden zu erleichtern, wird eine Methode vorgestellt, bei der die Beziehung zwischen Wiederfundort und Wiederfunddatum als periodisches Phänomen behandelt wird (Fourier-Analyse).

7. Literature

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Richtungsänderungen auf dem Zuge bei europäischen Singvögeln

Von Gerhardt Zink

Jeder, der Wiederfunde beringter Vögel auf Karten darstellen will, steht vor der Frage, wie der einzelne Fund wiedergegeben und welche Kartenprojektion verwendet werden soll. Die Anforderungen, die an solche Karten gestellt werden, sind recht verschieden (Klein 1976). Man will z. B. den Winkel zwischen der Nord-Süd-Linie und der Zugrichtung messen oder die Entfernung zwischen Beringungsort und Wiederfundort feststellen können. In beiden Fällen müssen die beiden Orte unmißverständlich einander zuzuordnen sein, in der Regel durch eine Linie, die Beringungsort und Fundort miteinander verbindet. Zugwinkel und Entfernung lassen sich aber nicht auf derselben Karte messen. Karten in Mercator-Projektion sind zwar winkeltreu, verzerren aber die Entfernungen beträchtlich. Flächentreue Projektionen geben die Zugwinkel nicht richtig wieder. In meinem Atlas des Singvogelzugs (Zink 1973, 1975) habe ich mich gegen die Mercator-Projektion entschieden, u. a. deshalb, weil auf diesen Karten Skandinavien unverhältnismäßig groß dargestellt ist und die Mittelmeerländer, wo die Mehrzahl der Ringfunde erzielt wird, erheblich kleiner erscheinen. Dabei spielte auch die Überlegung eine Rolle, daß es gar kein Nachteil sein muß, wenn der Zugwinkel nicht exakt gemessen werden kann, da der tatsächliche Zugweg eines Zugvogels von der Strichverbindung zwischen Beringungsort und Fundort mehr oder weniger stark abweichen kann. Es soll hier deshalb untersucht werden, wie häufig es vorkommt, daß die Zugrichtung während des Zuges erheblich geändert wird, und wie groß der Fehler werden kann, der dadurch zwischen der tatsächlichen Anfangsrichtung des Vogels und der durch die Strichverbindung vorgetäuschten Richtung entsteht. Dabei bleiben Abweichungen von der direkten Linie, die durch Leitlinienwirkung über kürzere Entfernungen oder durch Witterungseinflüsse verursacht sein können, unberücksichtigt. Selbstverständlich dürfen für die Beantwortung dieser Fragen nur Funde in der ersten Wegzugperiode nach der Beringung verwendet werden, da der tatsächliche Zugweg eines Vogels von der Strichverbindung zwischen Beringungsort und Fundort extrem weit abweichen kann, wenn zwischen Beringung und Wiederfund ein Aufenthalt im Winterquartier oder in einem fernen Brutgebiet stattgefunden haben kann (vgl. Abb. 2 der Einleitung zu Zink 1973). Die Unterlagen für die folgende Darstellung finden sich bei Zink 1973 und 1975. Bei den Abbildungen sind hier teilweise neue Funde in geringer Zahl hinzugefügt. Schüz (1950) diskutiert die Frage der angeborenen Zugwege und gibt Beispiele für Richtungsänderungen auf dem Zuge.