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POINT COUNTS WITH UNLIMITED DISTANCE

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ABSTRACT.—Point counts with unlimited distance give the number of species and quantitative informations either in the form of an index of abundance (IPA) or in frequencies (EFP). The number of points to count in any biotope should be increased according to the total number of species progressively recorded. It depends also on the number of individuals per species and of the sensitiveness of the tests we can apply to compare them. The mean richness (i.e., the average number of species per point) is an important parameter: coupled with the variance of the sample, it allows comparisons between biotopes; it is highly correlated with other parameters of the community: total richness, total density and H' diversity. An adequate dispersion of the points in both time and space in the biotope is a prerequisite for a reliable treatment of the data. The standardized recording of a definite set of environmental factors at each counting point allows one to analyze the correlations between the birds and the habitats.

Mapping method is the appropriate one to census breeding birds in one limited environment; the densities which it gives remain for us the standard of abundance. IPA is a good way of censusing and comparing bird communities in different homogeneous biotopes. EFP is the appropriate method to obtain at the least cost data on the structure of communities of extensive and patchy habitats.

A censusing technique should be chosen after (1) the aim of the study, (2) the scale of the habitats, (3) the manpower of the censusing team, and (4) the properties of the different methods have been determined.

Directly descended from an original transect censusing technique (Ferry and Frochot 1958), the point count methods presented here, IPA (Blondel et al. 1970, Ferry 1974, IBCC 1977) and EFP (Blondel 1975, 1977), are derived from a trivial observation: when a birdwatcher stands quietly for a moment in the field, on a spring morning, he notices a certain number of birds, mainly singing males. This gives him initial information on the bird community of the habitat. Standardization of the collection and the treatment of this information has led us to the point count methods for censusing birds. We stress that our technique is to record all available information, i.e., all the birds detectable, whatever their location. These are point counts with unlimited distance.

These methods were developed in consideration of three complementary censusing requirements: (1) To obtain quantitative results in a short time to permit counting birds simultaneously in several different habitats. (2) To obtain these data from samples, with a measure of the dispersion around the mean, so results can be objectively compared by statistical tests. (3) To be able to census birds in patchy habitats, where line transects are impossible to perform.

In this respect, it is important to stress that bird censusing is only a tool, which must be adapted to the aim of the research. We have found these point count methods to be suitable in a wide variety of situations in our research.

METHODS

IPA ("INDICE PONCTUEL D'ABONDANCE") METHOD

Data collection

The IPA method was first described by Blondel et al. (1970); the standardized procedure was published in English by the IBCC (1977). Data are collected at a fixed censusing spot, or station, which is well marked for relocation. Each station is counted twice in the breeding season, once within six weeks before and once within six weeks after the main time of settlement of the migrant species. This time varies with latitude and altitude. Counts are done early in the morning, only with little or no wind, only if not too cold, and only if not raining too hard. Each count lasts exactly 20 minutes, with the data separable into consecutive 5-minute periods. All birds seen and heard are recorded. Experience suggests that an observer's attentiveness and the conspicuousness of the birds limit the number of stations that can be counted in a morning to four or five.

For each species, counts are translated into a number of pairs, according to the following conventions: A singing male, a pair of birds, an occupied nest, or a family party are all counted as a pair of birds; a single bird seen or heard calling is one-half a pair. The higher of the two values, either from the first or the second count, is used as the IPA of that species for that spot and that breeding season. Taken together, the values for all species detected at a station comprise the "list of IPA" for that station and year.

Managing the data

The "list of IPA" of a point has little meaning by itself. It is just one sample, which must be combined with lists from other stations; together they comprise an IPA sample of a particular biotope. Such a sample of IPA will yield information about species abundances and species richness for the studied biotope.

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For each species a mean IPA, with standard deviation, can be calculated as an index of abundance. These two parameters permit statistical comparison with the abundance of the same species in other habitats, censused in the same way, and assuming that the detectability of the species is the same in the different habitats (an assumption we have not tested). It must be stressed that the IPA is a strictly specific index; it is not possible to compare, or to add, IPAs of different species.

The sample of IPA lists allows us to assess the number of species (species richness) in the habitat. Two parameters of richness are measured. The average number of species per point is the *mean richness* ($\bar{s}$) for which we can compute the standard deviation; $\bar{s}$ can be compared statistically between different habitats. *Total richness* (S) is a cumulative parameter; the greater the number of censused spots, the nearer it will be to the actual richness of the bird community.

From IPA to density

As such, point counts in IPA do not yield densities; this is a drawback when we wish to know such parameters of the community as biomass or diversity. It is possible, however, to determine for each species a coefficient of conversion by which its IPA can be converted to a density estimate. We must simultaneously census the biotope by mapping and by IPA. (We use the word "biotope" as defined by Kendeigh (1961:6) "a topographic unit characterized by both uniform physical conditions, and uniform plant and animal life.") The coefficients of conversion thus obtained are specific to the species and the observer. Their use introduces nonmeasurable uncertainty, which precludes statistical comparisons between the densities.

EFP ("ECHANTILLONNAGE FREQUENTIEL PROGRESSIF") METHOD

The EFP, a frequency sampling method, was proposed and used later than the IPA (Blondel 1975, 1977). It differs from IPA on the following points: (1) The Point Count lasts 20 minutes, but instead of recording the number of birds of each species, one just records the species as present; (2) Each station is counted only once in the breeding season, instead of twice; and (3) This apparent simplification is an adaptation to both extensive and patchy environments, allowing the observer to census many points in a season (several hundred), but the dispersion of the points in the habitat and in the season must have been previously prepared to ensure a representative sample in space and time.

Since one records only the presence of each species, not all the singing males of each given species, it is possible to continue sampling points later in the day. Seven to nine points a day are feasible, instead of four or five as in IPA.

As for IPA, at the end of the field work season, one has for each biotope in the studied area a list of species, the EFP list, yielding parameters of richness, $\bar{s}$. One also has an index of abundance for each species, in this case frequency computed as the percent of the sampled points at which the species was recorded. The frequencies in different biotopes may be compared by appropriate tests.

It is not possible to infer densities from the frequencies. Although it has been shown that at lower densities the frequency of a given species is correlated with its density (Blondel 1975), this correlation breaks down with increasing density. At some high level of density of a species in the biotope, its frequency reaches 100%. Of course it can never increase thereafter, even with great increases in density. This drawback is not too important, however, because in our extensive studies we find that the mean richness ($\bar{s}$) derived from EFP data is, in all cases, highly correlated with the total density of the birds.

DESCRIBING THE HABITAT

Bird counts by the IPA or EFP method are useless unless correlated with environmental conditions. Up to now our experience is mainly limited to the study of "biotopes," i.e., areas homogeneous at least with respect to the main features of the habitat. The definition and localization of such biotopes are achieved according to preexisting maps (e.g., forestry, phytosociology). We must check in the field the exact structure of the biotopes, however, because the basic criteria are not always the same for an ornithologist as they are for a forester or a botanist. In practice the exact localization of biotopes to census remains to be done by the bird observer. In order to describe as accurately as possible the selected census area, we devised a simple optical apparatus, the "stratiscope" (Blondel and Cuvillier 1977), which permits a quantification of some relevant parameters of the biotope: number of layers, percent cover, and both horizontal and vertical structural diversities. These parameters often correlate well with such bird community variables as richness, overall density and the Shannon index of diversity (see also Blondel et al. 1973).

This method was devised for IPA censuses because it is very precise. It is so time-consuming that it must be done independently of the census work, at random locations in the biotope. This is a reasonable approach since it is assumed that the censused area is homogeneous. Time constraints preclude similar sampling of EFP sites. Instead, at EFP sites we record a set of habitat variables, immediately after completing the bird count. This is easily done by filling a precoded sheet, on which several sets of data are to be recorded: geography, topography, exposure, vegetation structure, vegetation form (with the dominant plant species) and particular ecological features. Details of this habitat description may be found in Blondel (1975, 1978).

SAMPLING DESIGN

SPACING AND TIMING OF POINT COUNTS

The representative sampling depends on an appropriate timing and spacing of counts in the study area.

In time, the frequency of singing by territorial males differs from one species to another. A poster in this symposium shows how reassessing our IPA data in two forests, month-by-month, has confirmed that birds with protracted breeding seasons have the same detectability over the season. On the other hand, residents with one

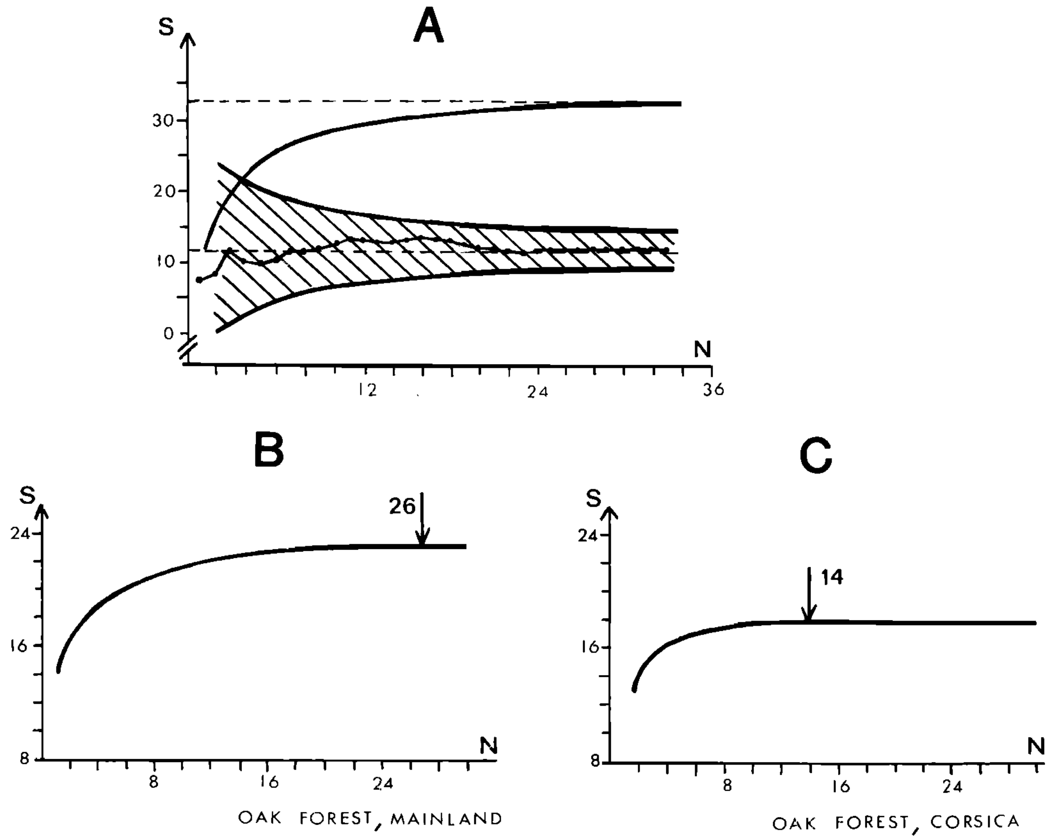

FIGURE 1. The upper figure (A) shows the two richnesses as a function of the number of IPA points, in a cedar forest in southern France. The total richness (S) is a cumulative parameter (upper curve); the mean richness ($\bar{s}$) is shown within its 95% confidence limits (lower curve). The two lower figures (B and C) show how the total richness is acquired in two similar old *Quercus ilex* forests. The arrows show the number of IPA points where the curve slope becomes zero.

early brood are better recorded at the beginning, and late migrants can be heard only during the second half of the counts. Considering only the higher value of the two counts in IPA sampling yields for the two last categories of birds a higher mean and a narrower variance.

In EFP sampling it is imperative that each area compared be counted by points equally spaced week after week, throughout the season. This helps to assure that measured differences in frequency for a given species reflect differences in abundance and not in detectability.

The counting stations can conveniently be regularly spaced by superimposing a metric grid upon the chosen biotope. It seems probable that the points thus located are not far from random spacing, because the grid will probably be independent of the inescapable, small differences within the biotope (e.g., old decaying trees and small glades). Points should be at least 200 m apart in IPA. This distance is evidently less than the detectability radius of some birds, but experience has shown that the differences between indices of abundance are equivalently estimated with or without overlapping of count station limits. In EFP sampling, our points are generally further apart, up to 1 km.

The order in which stations are counted may be drawn by lot, since station locations are determined before the field season.

THE NUMBER OF POINTS NEEDED IN A GIVEN BIOTOPE

The number of points will be chosen to yield sufficient information on the number of species and individuals present in a given biotope.

On the number of species.

Thirty-four IPAs were collected in a cedar (*Cedrus atlanticus*) forest in southern France.

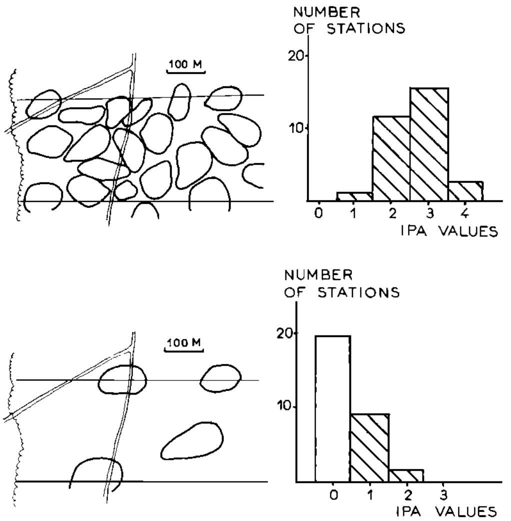

FIGURE 2. Territories and histograms of IPAs of Blue Tit (above), and Crested Tit (below), simultaneously censused in beech forest habitat by IPA and by a mapping plot of 15 ha.

Figure 1A shows the two components of richness assessed as a function of the number of points. Total richness (S) is 33 species, as shown by the upper curve. This curve was computed from a great number of permutations of the individual lists of IPAs; its slope is level from the 30th point on, suggesting that 33 species is near the actual total richness of the community. The forms of such curves differ markedly from one biotope to another, as shown by Figure 1B and 1C, so that the values of S are not comparable so long as the cumulative curves have not reached the same slope (Ferry 1976). Fifteen to 30 points in IPA sampling are necessary to obtain this result.

The mean richness ($\bar{s}$) of the cedar forest is 12.0 species (SD = 2.2). The lower curve of Figure 1A shows how the knowledge of this parameter is better assessed between narrowing limits of confidence as the sample size increases. This parameter is statistically comparable from one biotope to another, and this comparison is justified because it has been experimentally shown that $\bar{s}$ is correlated with S: for 23 bird communities (Blondel 1975) we find $\bar{s} = 0.43S + 0.56$ ($r = 0.94$, $P < 0.001$). In practice a dozen points in each biotope allows easy comparisons between $\bar{s}$ values.

We wish to stress here that mean richness ($\bar{s}$), besides its usefulness as a statistical parameter of the bird community, might have some biological significance, if we refer to the censusing procedure and assume that the hearing ability of the observer is of the same order of magnitude as that of the birds. Mean richness, being the number of species (mainly represented by singing males) found at any spot of the biotope, may give a rough estimate of the potential interspecific competition which would face a bird trying to settle in that habitat. This is because point counts with unlimited distance are based mainly on the recording of singing males and thus reflect the main natural mechanism of dispersal of territorial species in the environment.

To test this hypothesis we used the data from a beech forest censused by IPA method (Ferry 1974) at 30 stations. For each station, we calculated the number of species (point richness) and a point index of diversity ($H'\alpha$) from the IPAs converted to densities. The two parameters are highly correlated ($r = 0.60$ $P < 0.001$) by the equation: $\bar{s} = 9.57\ H'\alpha - 17.70$. This

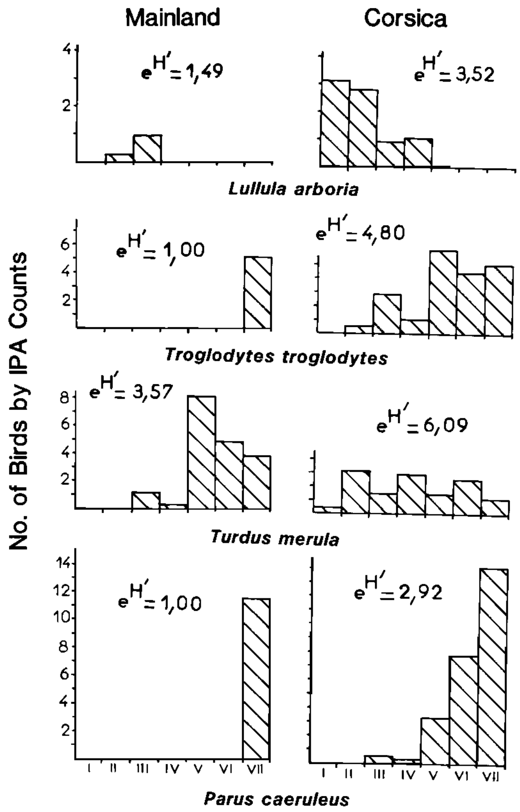

FIGURE 3. IPAs of four species in the seven stages of two gradients, from grassland to old forest. One of the mainland (left histogram) and Corsica (right histogram). The index of habitat breadth ($e^{H'}$) is the natural exponential of the Shannon Index calculated in nits from the IPA values (Ferry et al. 1976). The other species of the two gradients demonstrate the same trend.

TABLE 1
GUIDELINES SUGGESTED FOR SELECTING SAMPLING METHODS ACCORDING TO STUDY SCALE AND GOALS

Scale	Type of required information	Appropriate method
One habitat (homogeneous or not)	Species' densities Partitioning of territories in the habitat	Mapping plot
Two or more biotopes (or one biotope over several years)	Comparable parameters of the species (abundance) and the communities (richness, abundances, diversities)	IPA or EFP (anywhere) Line transects (in extensive, homogeneous biotopes)
Many habitats in a patchy area	Comparable parameters as above	EFP

confirms that $\bar{s}$ may be a simple first approximation of local diversity, of which Lloyd et al. (1968) write: "the average local diversity is the expected uncertainty of encounter that would confront an immigrant individual landing in a random plot in the community."

The preceding paragraphs concern the mean richness assessed by IPA methods. In EFP sampling, $\bar{s}$ is lower but highly correlated with the value yielded by IPA in the same place. Thus for 23 biotopes (Blondel 1975) the correlation between the two values is $r = 0.99$, with $\bar{s}$ EFP $= 0.76$ $\bar{s}$ IPA. Moreover, in EFP the mean richness ($\bar{s}$) is a reliable index of the total abundance in the community. For the same 23 biotopes, $\bar{s}$ was highly correlated with the total densities yielded by converted IPAs ($r = 0.91$, $P < 0.001$). And in fact in EFP, $\bar{s}$ takes the same value as the sum of the specific frequencies.

Finally the ratio $\bar{s}/S$ is probably of interest. For a sample of n EFP points it could theoretically vary from $1/n$ to 1. In practice, for 23 biotopes (Blondel 1975) it varied from 0.29 to 0.75. Moreover it is not correlated with total richness, nor with the total density of the bird community. If assessed from a random sample of points, the ratio $\bar{s}/S$ is low and might give an idea of the heterogeneity of the censused area. On the other hand, when calculated for biotopes assumed to be homogeneous, as the 23 cited communities, it might give an idea of the balance between inter- and intraspecific competition within the community, being lower when interspecific competition predominates, and higher when intraspecific competition is more important, as in isolated or insular communities. This hypothesis is enforced by the fact that in EFP the ratio $\bar{s}/S$ takes the same value as the mean specific frequency of all species ($\bar{F}$).

On the number of individuals

One of the main uses of IPA data is to compare, species-by-species, the abundance of birds between two or more biotopes (Ferry 1974). The feasibility and the sensibility of the comparison will depend on the number of points censused in each biotope.

A beech (*Fagus sylvatica*) forest was sampled simultaneously by mapping and by IPA methods. Figure 2 shows the dispersion of the territories of two species (based on the mapping plot) and the distribution of their samples of 30 IPAs. The Blue Tit (*Parus caeruleus*), a common species, had adjoining territories throughout the plot, and the values of its IPAs were distributed roughly normally. On the other hand, the Crested Tit (*Parus cristatus*), a rare species, had only three territories on the 15-ha plot. It was recorded in only one-third of the 30 counting spots; and the distribution graph of its IPAs was skewed. Such a relationship between the field dispersion pattern of territorial birds and the statistical distribution of their IPAs seems to hold well for the other species of the same biotope and also in other cases.

These experimental findings can help us to decide upon the number of points to count in a given biotope in order to compare species' abundances. Common birds, as the Blue Tit, are correctly tested by Student's t test, even for small samples, because their IPAs are normally distributed around the mean. Rare birds, with the distribution of their IPAs far from normal, must be tested either by nonparametric tests when the sample is small, or rather censused by a large sample (at least 30 stations) for one to be allowed to use tests on the mean and standard deviation.

With the EFP technique, we rely on frequencies to compare the numbers of individuals in different biotopes. Comparison of frequencies by χ^2 test necessitates that the absolute number of detections be high enough for the calculated value to be at least five. Thus for rare species large samples will be mandatory. Moreover, even if the test is applicable, its sensitivity will improve when the sample increases (graphical illustration in these proceedings by Dawson 1981b, figure 5). In practice, several dozen points per sample will be necessary to detect with confidence small differences between samples.

In summary, we suggest that a sample of a dozen stations in IPA, or twice as many points in EFP, will give a first idea of the bird community in a biotope, allowing abundance comparisons of the common species, and yielding such collective parameters as mean species richness and (in IPA) overall density (after conversion), and an index of species diversity. On the other hand, larger samples (30 stations in IPA, 40 or 50 points in EFP) are necessary for a good assessment of total richness, and fine abundance comparisons of most species.

How to Correlate the Data on Birds and Habitats

Simple correlations may be calculated by hand in most situations, from one biotope to another, if the sampling conditions are fulfilled. Figure 3 exemplifies the use of IPA values to assess the habitat breadth of individual species in two comparable gradients of habitats, one on the mainland and the other on the island of Corsica. Blondel and Frochot censused these gradients with 12 to 26 IPAs in each stage. This permitted us to calculate and compare indices of habitat breadth, because the stages had been chosen to ensure a good match between environmental variables in the two situations, as confirmed by "stratiscoping" the habitats. The broadening of habitat selection is a general characteristic of populations in insular situations (Ferry et al. 1976, Blondel 1979).

Complex relationships between the breeding birds and the environment may be studied by multivariate analyses. An example of such data processing will be found in Blondel (1976). A set of 340 EFP counts, collected in Mont Ventoux (southern France), gave data on 80 species of birds in 10 biotopes; the environmental parameters had been recorded at each point, as previously described. This permitted computation of a correspondence analysis between the presence of the breeding birds and the class value of twelve environmental variables. The location of the censusing stations had been stratified to ensure an equivalent sampling of the recognized biotopes, but during computer analysis the data for each point were interpreted independently to eliminate (or lessen) the bias of preadmitted partitioning of the ecological situations.

As yet we have not carried out counts with strictly random dispersion of points over an extensive area. Such a study is in progress in Provence, but results are not yet available. A short preliminary trial with two sets of 40 and 38 EFP points has been made in Burgundy (Grimoldi 1976). It confirmed that the various habitats had been sampled in proportion to their importance in the studied area, but the consequence was that the more restricted biotopes had been censused by only a few stations, with no interpretable results.

SELECTING A SAMPLING METHOD

No single method is most appropriate to all bird censusing studies. When we plan a study we must design the censusing work in accordance with the aim of the research, the characteristics of the area to be studied, and the manpower of the team. In most cases our aim will be to compare two or more systems or situations; in these cases great precision may not be necessary, and satisfactory results will be attained if data permit objective and reliable comparisons between or among systems and situations.

Table 1 proposes how to choose a censusing method after the scale of the study. For one given habitat, whether homogeneous or not, the mapping plot is the standard technique. It yields directly the number of breeding species, and for each of them a density estimate. Moreover, it is possible to correlate the location of the breeding territories with the ecological peculiarities which appear on the map. Certainly, in spite of the effort at international standardization made by the IBCC, an uncertainty remains in the number of "territories" identified on the maps (Svensson 1974b). But we may keep in mind that the notion of density does not refer to a fixed reality; the actual number of breeding pairs and other birds fluctuates during the course of a reproductive season. Mapping remains the reference technique, but we are aware of its main drawback, which is the fact that it yields values that are not objectively comparable from one plot to another.

When we need to census two or more biotopes, or the same biotope during several years, the advantages of the IPA method are obvious. It allows objective comparisons based on statistical parameters. Of course one could sample many mapping plots in an extensive biotope and compute the means and standard deviations of results. Besides the cost in field work, the many observers required for such a study would introduce the bias of their different field abilities; whereas several samples of IPAs may be covered in one season by one person or a small, homogeneous team.

At this scale (several biotopes), Point Counts should be compared with line transects. We have much experience with one kind of line transect (Ferry and Frochot 1958). The technique is suitable in extensive, homogeneous habitats, but it has a theoretical disadvantage compared to Point Counts. The relative index of abundance it yields is a function both of the time spent and the length of the route, whereas the figures derived from IPAs depend only on the time spent, which simplifies the interpretation.

Finally, EFP is an ideal method of censusing breeding birds in extensive and patchy areas, so long as sampling requirements are fulfilled. One cannot deal with densities, but at the species level the comparisons of the frequencies are objectively possible with large samples. EFP yields both richness values ($\bar{s}$ and S); and for the total abundance recall that mean richness is highly correlated with the total number of individuals. H' may be computed from the species' frequencies, as easily as from densities, even if its meaning is not so obvious as when it is derived from densities, but we note that Shannon's index is a robust one.

Another point of importance is the cost in time and manpower of the various techniques. One sample of a dozen IPAs requires less time than one mapping plot of 14 ha; about 12 "good" hours of spring mornings vs. 40. However, if we wish to compute densities, a mapping plot must be coupled with the IPA counting; thus for a single biotope Point Counts are not cheaper. However, one field worker can easily complete three or four samples of IPAs with one reference mapping plot in the time (one season) required for two plots that permit no comparison.

EFP is not much cheaper than IPA, even though more points are counted in a day, because a very large sample is necessary to apply tests with confidence to the frequency values obtained.

Finally, we have determined by a trial at censusing that the method of capture–recapture is much more time consuming than the other technique (400 h for 59 ha; Frochot et al. 1977).

CONCLUSION

Point Counts with unlimited distance have their own "niche" in the realm of bird censusing techniques. They give reliable and comparable parameters of abundance at the species level. They also yield collective parameters of the bird community, among them the mean richness, which has biological meaning as a measure of species packing in the habitat. Together with data on the biotope, they allow analysis of bird-habitat relationships. They must be considered as an appropriate tool for censusing breeding birds in many situations.