Estimation of the sampling effort per 10x10 km UTM square for the *Catalan Winter Bird Atlas 2006-2009*

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During the design phase of the *Catalan Winter Bird Atlas 2006-2009*, a pilot study was carried out to compare the number of species detected during a certain time interval with the real number of species present in a 10x10 km UTM square. In all, 24 squares representing the main climatic and geographical gradients in Catalonia were surveyed and from the species lists obtained in eight independent one-hour surveys, species accumulation curves were plotted. The total richness was estimated using the estimators Chao2 and Jack2 and these estimates were compared with the observed richness. In this way, it was inferred that eight hours of effort permitted the detection of an average of 71-81% of the total number of species estimated for a 10x10 km square. This percentage suffices for performing robust comparisons between squares and also for both intra-annual and inter-annual comparisons in a given square.

Key words: bird winter atlas, sampling effort, species richness, Catalonia.

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Bird atlas methodology involves searching for species in a territory that has previously been subdivided into a certain number of sampling units. These units usually consist of squares of equal surface area with sides of 50, 10, 5 or 1 km (e.g. Hagemeijer & Blair 1997, ADN 2002, Martí & del Moral 2003). Beyond the obvious interest in knowing which species are present in a particular area, the use of similar sampling units allows comparisons to be made between squares to ascertain, for example, which units have greatest species richness. Moreover, very interesting quantitative comparisons can also be made in areas that have previously been surveyed using the same methodology (Gibbons *et al.* 1993, Schmid *et al.* 1998, Estrada *et al.* 2004). Determining changes in species distribution is not only an exercise of scientific interest, but also an excellent way of determining the conservation status of species.

Comparative exercises of this nature have recently been carried out in Catalonia (Estrada *et al.* 2004) and Europe (BirdLife International 2004). Nevertheless, such comparisons are often hampered by the need to employ both the same sampling unit and a standardised sampling effort, since the number of species found in an area obviously depends on both the real number of species present and also on the time invested in searching. Therefore, it is vital to be able to quantify the sampling effort in order to adequately compare, both spatially and temporally, results from different squares. The key question is how much effort should be applied, that is, how many hours per square should be invested in searching. Obviously, the more hours spent in a square,

the more species will be found; however, available resources are limited and so it is necessary to fix a reasonable cut-off point in the amount of effort that will still ensure a good approximation of the species-richness present in the square in question. This equilibrium point should be carefully calculated when dealing with large projects such as bird atlases that are based on work by an enthusiastic group of volunteer ornithologists.

The relation between sampling effort and the real species-richness of a study area is a recurrent topic in the study of population biology and still provokes considerable debate (e.g. Colwell & Coddington 1994, Brose *et al.* 2003).

At the beginning of the design work on the methodology for the *Catalan Winter Bird Atlas 2006-2009*, we conceived a pilot study aimed at determining the relationship between the percentage of species detected within a 10x10 km square and sampling effort. In this article we present the results of this pilot study, which, by using quantitative data to establish the sampling effort needed per square to achieve adequate results, has enabled us to adapt the atlas methodology to the available human resources.

Methods

The collaborators interested in participating in this pilot study were asked to choose one of the 386 10x10 km UTM squares in Catalonia and to survey it during the period November 15th-February 15th 2006 with the aim of detecting as many species as possible. The survey effort was not systematically distributed across all the environments present in each square; instead, greater effort was allocated to the supposedly richest environments (as chosen by the observers). In order to draw the graphs of the cumulative effort, data had to be collected in one-hour time-fractions and in each of these fractions all the detected species had to be annotated, regardless of whether they had been detected in the previous fractions or not. Ideally, each square had to be surveyed for a minimum of eight effective hours. In order to minimise both the effect of bird movements in and out the square and the variation in weather conditions during the winter, collaborators were asked to carry out their surveys on just one day or on two consecutive days. Surveys were

Table 1. Results from the squares in which 8 or more hours surveying were conducted. As well as the location and the code of each 10x10 km UTM square, the effort for each square (in number of hours), the richness observed for 8 hours surveying, and its percentage relative to the square's total richness obtained by means of the estimators Chao 2 and Jack 2 is shown.
Resultats dels quadrats on es van dur a terme 8 o més hores de mostratge. A més de la localització i del codi de cada quadrat UTM 10x10 km, es mostra la riquesa observada en 8 hores de cens i el percentatge que representa aquest valor respecte el total de riquesa del quadrat segons els estimadors Chao 2 i Jack 2.

Location	10x10 UTM	No. of hours	Observed richness	% according to model (Chao2)	% according to model (Jack2)
Alfacada-illa de Buda	CF10	8	83	75%	69%
Santa Maria de Miralles-La Llacuna	CF79	8	28	74%	65%
Banyeres del Penedès-La Múnia	CF87	8	63	76%	68%
St. Sadurní d'Anoia-La Granada	CF98	8	62	90%	79%
El Poal-Vilasana- Mollerussa	CG21	8	64	81%	70%
Serradell-Sant Gervàs	CG28	8	29	88%	74%
Guissona-Hostafrancs	CG52	8	41	89%	78%
Calaf-Calonge de Segarra	CG72	8	43	85%	71%
Rialp-Llessuí	CH40	8	63	82%	72%
Puigpedrós-Pic de la Muga	CH90	10	29	49%	53%
Collbató-Montserrat	DF08	8	58	74%	64%
Esparregura-St. Esteve ses Rovires	DF09	9	57	86%	76%
Barcelona-La Floresta	DF28	8	49	73%	69%
Barcelona-Badalona	DF38	8	51	86%	75%
Montcada-Mollet del Vallès	DF39	8	57	76%	66%
El Masnou-Premià de Mar	DF49	8	43	82%	68%
Guardiola de Berguedà-Bagà	DG07	8	35	79%	65%
La Garriga-Cardedeu	DG41	9	45	92%	83%
Bescanó-Anglès	DG74	8	64	95%	88%
Banyoles-Fontcoberta	DG86	8	44	82%	71%
Verges-Parlavà-Bellcaire d'Empordà	EG05	9	56	82%	73%

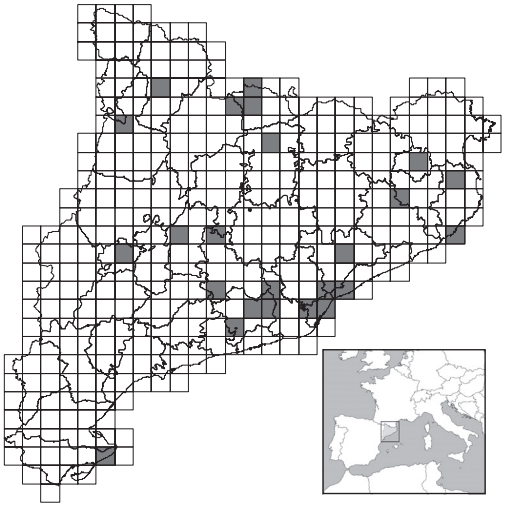

Figure 1. Location of the study area and of the squares (grey) included in this pilot study.
Localització de l'àrea d'estudi i dels quadrats inclosos en aquest estudi pilot (en gris).

mostly conducted on foot, although time-fractions done from a car were also accepted for open areas where driving allowed better square coverage, provided that driving was slow and always with the windows rolled down to aid bird detection.

The results were summarised in a table of species presence-absence per one-hour fraction and per square. Species accumulation graphs were used in order to estimate the effort needed per square. These graphs extrapolate species-richness data from samples of a certain size (Colwell & Coddington 1994).

Non-parametric estimators are theoretical methods for extrapolating species richness that depend only on the number of samples in which a species is present and ignore parametric information about abundance. These methods were originally developed to estimate population size in closed populations for capture-recapture techniques (Burnham & Overton 1979). This procedure was then adapted to estimate species richness simply by replacing individual recaptures with the resighting of species in different surveys. Many non-parametric estimators of species richness have been developed from this conceptual basis.

Walther & Moore (2005) ranked the results from 14 studies conducted with different taxa and concluded that, of the 10 most commonly used richness estimators, Chao 2 and Jackknife 2 (Jack 2) were the least biased and most precise estimators of species richness, a pattern that can be also applicable to bird communities (Walther & Martin 2001). One of the advantages of these two estimators for our study is that they perform better for a reduced number of samples and for moderate species richness (Colwell & Coddington 1994). Therefore, Chao 2 and Jack 2 were selected to estimate the theoretical species richness from all the available samples (n one-hour fractions) in each square. Finally, the percentage of species detected in a certain number of hours was calculated by dividing the number of species detected in the field by the estimated total of species in the same square (with the Chao 2 and the Jack 2 estimators). All the species-richness estimates were performed with EstimateS (Colwell 2005).

Results

In all, 24 10x10 UTM squares were surveyed during this pilot study. These squares constituted a representative sample of the main types of environments in Catalonia and also of its main climatic and geographical gradients, from sea level up to over 2,000 m (Fig. 1). Two of the 24 squares were only surveyed for five one-hour fractions, one was surveyed for seven, 17 were surveyed for eight, three were surveyed for nine, and one was surveyed for ten.

Estimated values of richness ranged between 33 and 111 species/square (mean = 63, SD = 18) for the Chao-2 estimator, whereas the range for the Jack2 estimator was between 39 and 120 species per square (mean = 71, SD = 19). On the basis of these figures, the species accumulation graph in relation to the duration of the surveying was drawn: in eight one-hour censuses between 71% (according to Chao2) and 81% (according to Jack2) of the total number of species occurring in the square were detected (Table 1, Fig. 2). Despite the fact that four squares provided data for more than eight hours, such a small sample size was manifestly insufficient for estimating the corresponding percentages for censuses of more than eight hours.

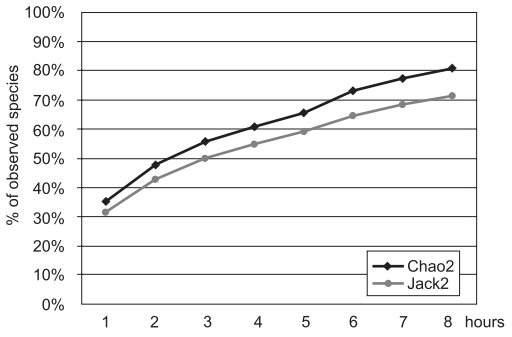

Figure 2. Mean percentage of the species detected in a 10x10 UTM square according to the sampling effort invested (1-8 hours). For each square (n=24) this percentage was obtained by dividing the number of accumulated species detected in the field by the estimated number of species. The richness estimated for each square was obtained by means of the Chao2 and Jack2 estimators, using the entire available sample in each case (between 8-10 hours, depending on the square).
Percentatge mitjà de les espècies detectades per quadrat en funció de l'esforç de mostratge invertit (1-8 hores). Per a cada quadrat (n=24) aquest percentatge es va obtenir dividint el nombre d'espècies detectades al camp per a l'acumulat d'hores pel total d'espècies estimat per a aquell quadrat. Aquesta estimació de la riquesa del quadrat es va realitzar mitjançant els estimadors Chao2 i Jack2 per a tota la mostra disponible en cada cas (entre 8-10 hores, segons el quadrat).

Discussion

These results show how difficult it is to detect all the species present in a particular area. Eight hours of effort enables an observer to detect an average of 71-81% of the total number of species estimated to be present in a 100 km^2 square. This percentage may be considered acceptable as regards efficiency (Brose *et al.* 2003). A number of studies have been carried out that attempt to determine the effort needed to attain an acceptable percentage of the total species richness; however, their results all depend heavily on the size of the unit sample. An example of a large sample unit approach is that of Özesmi *et al.* (2002), who carried out a pilot study to determine the time effort needed for the Breeding Bird Atlas of Turkey (sample unit is a 50x50 km square). They found that with 24-27 hours surveying (depending on the location), 80% of the total observed species was obtained. In the case of a much smaller sample unit (1x1 km square), Kéry & Schmid (2006) reported that 89% of species were detected after 6-12 hours surveying. Apart from the relevance of the size of the sample unit, differences in field methodology and the total number of species and their spatio-temporal distribution make it difficult to compare directly the results of these type of studies.

Nevertheless, these studies do show how imperfect the usual field surveys for an atlas are. It is worth noting that the shape of our species accumulation graph (Fig. 2) is somewhat asymptotic. In spite of the relatively high percentage of species attained after just one or two hours surveying, as the number of hours is increased, there is a parallel and relatively steady increase in the number of species detected: only towards the seventh or eighth hour does this increase slow down slightly. Rather surprisingly, it is found to be an almost straight line instead of an asymptotic function. Despite the lack of results for beyond the eighth hour, the shape of the species accumulation graph indicates that a great effort is needed to detect 90-95% of the species occurring in a square. The rectilinear portion of the species accumulation graph may be partly explained by the sampling design. Observers conducted surveys in different habitats in each new one-hour census; the increase in the number of detected species reflects a continuous incorporation of species dwelling in minor habitats. If we had conducted the surveys in a single habitat the asymptotic tendency of the graph would surely have been more pronounced.

The aim of this pilot study was to calculate the sampling effort needed for the *Catalan Winter Bird Atlas 2006-2009*, bearing in mind the short period in which the field work will have to be performed and the limited availability of human resources. Each of the three winters will be divided into two independent periods (November 15th to December 31st and January 1st to February 15th) that will reflect any changes that may occur throughout the winter in response to locally important climatic variations. Thus, we will be able to study intra-seasonal variation.

Taking into account the results of this pilot study and given the fact that each winter period will be surveyed independently, eight hours is considered to be the minimum census effort needed per 10x10 km UTM square and per pe-

riod. 71-81% of detected species would seem to be an acceptable percentage for the timed effort surveys and will provide a solid basis for performing robust comparisons between squares, both on a temporal (between and within years) and spatial basis. It seems unrealistic to request more than eight hours of effort in a season as climatologically complex as winter and with so few hours of daylight, especially for such a large project. The atlas will use standardised data from other sources, including the SOCC (ICO 2006), which may help to complete the species checklist in many squares after the timed census are finished. As well, we will use non-standardised data from other sources and the combination of all of these data sources will probably enable us to reach percentages greater than 71-81% for many squares. However, the non-standardised data cannot be used in the comparison between squares.

The percentages thrown up by this pilot study may discourage some enthusiastic collaborators; however, it is very important to convey to participants of any bird monitoring project that there are limitations, but that techniques are available that can overcome these constraints. The knowledge thus gained allows a more rigorous approach to new projects.

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Resum

Estimació de l'esforç de mostratge per quadrat UTM 10x10 km per a l'*Atles dels ocells de Catalunya a l'hivern 2006-2009*

En abordar el disseny de la metodologia de l'*Atles dels ocells de Catalunya a l'hivern 2006-2009* vam realitzar un estudi pilot per conèixer la proporció de les espècies detectades durant un determinat temps de mostratge en relació amb les que realment hi ha en cada quadrat. D'aquesta manera es va establir l'esforç de mostratge necessari per a cada quadrat amb dades quantitatives, i es va adaptar la metodologia de l'atles als recursos humans disponibles per a un projecte d'aquestes dimensions i característiques.

Durant el treball de camp l'únic condicionant necessari per poder fer després les corbes d'esforç era que les dades s'agrupessin en fraccions d'una hora, de manera que en cadascuna de les fraccions s'havia d'anotar la totalitat de les espècies detectades, amb independència de si s'hagués contactat alguna d'elles les hores anteriors, i que idealment es dediqués un mínim de vuit hores efectives de cens per quadrat UTM 10x10 km. Per minimitzar els efectes dels desplaçaments d'ocells dins i fora del quadrat i les variacions al llarg de l'hivern segons les condicions ambientals, es va demanar als col·laboradors que fessin el cens en un sol dia o en dos de consecutius. Les prospeccions es van realitzar majoritàriament a peu, tot i que també és van acceptar les fraccions fetes des de vehicle en aquells sectors oberts en els quals el cotxe permetia una millor cobertura del quadrat, sempre i quan es circulés per camins, a velocitat lenta, amb les finestres obertes i prestant una especial atenció a la detecció dels ocells.

Amb l'objectiu d'estimar l'esforç de mostratge necessari per a cada quadrat es van utilitzar corbes d'acumulació d'espècies. Aquestes corbes extrapolen la riquesa d'espècies a partir de les dades d'una determinada mostra. En aquest cas es van prospectar un total de 24 quadrats UTM 10x10, els quals es van considerar una mostra representativa dels principals ambients de Catalunya, així com dels seus principals gradients climàtics i geogràfics, des del nivell de mar fins a més de 2.000 m.

Els valors de riquesa estimats a partir d'aquests mostratges per als quadrats UTM 10x10 estudiats van oscil·lar, per a l'estimador Chao2, entre 33 i 111 espècies/quadrat (mitjana = 63, SD = 18), mentre que per a l'estimador Jack2 van oscil·lar entre 39 i 120 espècies/quadrat (mitjana = 71, SD = 19). Tenint en compte aquestes xifres es va calcular la corba d'acumulació d'espècies en relació al temps invertit en el mostratge; en vuit hores de cens es van detectar entre el 71% (segons Chao2) i el 81% (segons Jack2) del total d'espècies del quadrat. Tot i que en quatre quadrats es van obtenir dades per a més de vuit hores, la mostra va resultar manifestament insuficient per estimar aquests percentatges de forma mínimament acurada més enllà de les vuit hores.

Els resultats d'aquest estudi mostren la dificultat que suposa trobar totes les espècies d'ocells presents en una zona determinada. Amb un esforç de vuit hores s'arriba, de mitjana, a detectar el 71-81% del total d'espècies estimat al quadrats de 10x10 km, una

xifra que podem considerar acceptable en termes d'eficiència però que posa de manifest fins a quin punt són imperfectes els mostratges de camp habituals en les prospeccions d'un atles.

Un 71-81% d'espècies per a cada mostratge en el quadrat 10x10 km sembla un percentatge acceptable i suposa una base sòlida per fer comparacions robustes entre quadrats en el temps (entre anys i dins un mateix any) i en l'espai. Demanar més hores en una estació meteorològicament tan complexa i amb tan poques hores de llum sembla inviable en un projecte d'aquestes dimensions.

Resumen

Estimación del esfuerzo de muestreo para la cuadrícula UTM 10x10 km del *Atles dels ocells de Catalunya a l'hivern 2006-2009*

En la fase de diseño del *Atles dels ocells de Catalunya a l'hivern 2006-2009* se llevó a cabo un estudio piloto para conocer el porcentaje de especies que se detectan en un intervalo de tiempo determinado con respecto al que hay realmente en una cuadrícula.

Fueron muestreadas 24 cuadrículas UTM 10x10 km representativas de los principales gradientes climáticos y geográficos de Cataluña. A partir de los listados obtenidos independientemente en ocho fracciones de una hora se construyeron curvas de acumulación de especies. La riqueza total de cada cuadrícula se estimó empleando los estimadores Chao2 y Jack2, y ésta se comparó con la riqueza observada.

De esta forma se estableció que con un esfuerzo de 8 horas se alcanzaba a detectar, en promedio, el 71-81% del total de especies estimado para una cuadrícula de 10x10 km. Este porcentaje resulta aceptable para realizar comparaciones robustas entre cuadrículas y para una misma cuadrícula dentro de un año o entre años.

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