The use of digital photography in censuses of large concentrations of passerines: the case of a winter starling roost-site

Juan M. Pérez-García

Communal roosting occurs in birds of many different taxa and takes place in highly diverse habitats. Some of these concentrations may contain thousands or even millions of individuals. Accurate estimates of bird numbers at large roost sites are important for understanding their biology, establishing population trends and implementing management and conservation actions. This paper describes the use of a low-cost methodology for conducting censuses of large concentrations of passerines based on digital photos that can be processed with a standardized automatic image analysis program. This technique was applied to estimate the number of birds in a mixed starling roost in south-east Spain, which estimated a total of 125,197 birds (CI $_{95\%}$ 122,829 -130,036). The software showed a mean error of 2.85% ± 3.75%, which was directly related to the number of individuals per photograph. The results indicate that this methodology is not only simpler and less expensive than previously used techniques, but can also provide accurate, comparable quantitative data on the number of individuals in large roosts.

Key words: automatic count software, estimates, low-cost method, flock size, *Sturnus vulgaris*, starling roost-site.

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Communal roosting occurs in birds of different taxa and can take place in highly diverse habitats (Emlen 1952). Some such concentrations may contain thousands or even millions of individuals and the estimating of the number of birds that use such large roosts is highly challenging. Observers generally overestimate the size of small groups and underestimate the size of large ones, especially when they exceed a thousand individuals or involve smaller species (Prater 1979, Erwing 1982, Tellería & Cantó 1990, Sutherland 1996, Bibby *et al.* 2000). Indirect counting methods have been used as an alternative to visual censuses (Sutherland 1996). Faecal counts (e.g. Stewart 1973) have proved to be effective and cheap, but are not applicable when the roost is in an inaccessible area such as a wetland or a flooded area. For almost fifty years, photographs have been used to count animals (Meanley 1965), especially when study areas are very large or are of difficult access. Birds in aerial photographs taken from planes can be counted manually (e.g. Glimer *et al.* 1988). Nonetheless, computer software is increasingly able to recognise and count objects in digital photographs automatically (Bajzak & Piatt 1990, Cunningham *et al.* 1996, Hamilton *et al.* 2009). This technique has been successfully used to count large-sized birds such as Snow Geese *Chen caerulescens*, Canada Geese *Branta canadensis* (Strong *et al.* 1991, Laliberte & Ripple 2003) and Lesser Flamingos *Phoeniconaias minor* (Groom *et al.* 2011) in their breeding areas, and also large mammals such as Caribous *Rangifer tarandus* (Laliberte & Ripple 2003) and bat colonies (Hamilton *et al.* 2009). These studies show that this type of bird count is very accurate, with error rates between 3% and 10% (Laliberte & Ripple 2003, Groom *et al.* 2011). In the Iberian Peninsula, of all passerine species the Common Starling *Sturnus vulgaris* forms the largest roosts. After the breeding season (from June to late

March) starlings congregate in roosting groups whose numbers range from a few dozen to several millions of birds (Bernis 1989, del Hoyo *et al.* 2010). Accurate estimates of winter populations are important for understanding temporal and spatial population trends and could be useful for implementing conservation actions or helping to manage and to reduce the negative impact of these roosts on agriculture and other human practices (Sutherland 1996, Bibby *et al.* 2000).

This study aimed to develop a simple, low-cost and accurate technique for counting the number of starlings using a roost based on the use of digital photographs and a free automatic image-counting program. An example estimating the size of a mixed starling aggregation at a roost site in south-east Spain is provided.

Material and Methods

Study Area

The Elche reservoir, located in the Levante region (SE Spain 38º19'N 0º43'W), covers 7.1 ha and was created in the late seventeenth century by the construction of a dam. However, it is now silted up and covered by Common Reed *Phragmites australis* and Giant Reed *Arundo donax* beds. This vegetation is used as a winter roost by several songbird species such as Chaffinches *Fringillia coelebs*, White Wagtail *Motacilla alba* and, above all, by large numbers of European and Spotless Starlings. In the mid-twentieth century this location was considered to be one of the most important known roost sites in Spain for these species (Bernis 1960). Nevertheless, no estimates have ever been made of the number of birds that roost there. For several days before conducting the census, I studied the behaviour of the birds entering the roost to determine the approximate direction taken by birds and the best position for an observer. It became clear that, although the available habitat was large, birds consistently over the years have only used a very small part of it (*ca.* 4% of the total) (pers. obs.).

Field census

On 4 February 2010, two observers conducted a census from three hours before sunset to one hour afterwards. During that period, all the individuals entering the roost were counted in groups in 15-minute blocks. Only the birds entering the roost were counted. To avoid duplications, one of the observers checked that already counted flocks did not return over a previously established line. Small flocks (up to *ca.* 50 birds) were counted individually using a tally counter while larger flocks were photographed using a Canon 450D with a 28–300 mm zoom lens. The camera zoom was adjusted to the flock size to optimize the resolution. Nevertheless, some flocks (*ca.* 4,000 birds) were too large to be photographed without any individual overlap. To solve this bias, general and detailed photographs of the flock were taken. For the detailed photograph (zoom greater than 100 mm) the centre and one edge of the flock were included in the same picture to give a representative image of the gradual density pattern inside the flock (Bibby *et al.* 2000).

Finally, when all the birds were settled in the roost, in order to determine the ratio of *Sturnus unicolor* and *S. vulgaris* I used a field telescope (Swarovski 20 x 60 HD) to conduct seven random samples over the whole of the roost site, from which the number of individuals of each species within the telescope's field of view were counted.

Image processing

To count the birds in each photograph, I employed UHTSCSA Image Tool 3.0 (http://ddsdx.uthscsa.edu/dig/itdesc.html), a freeware program for processing and analyzing images. I used the *Automatic Threshold Method* in the *Find Object Tool* options to count the birds and obtain results that were comparable between photographs regardless of who processes them.

Next, I calculated the proportion of the area sampled in the detailed photograph by comparing with the total size of the flock in the general photo. To calculate this I used the *Spatial Measurements Calibrate* tool. Finally, I counted the birds in the detailed photograph using the software's automatic tool and the result was extrapolated to the total size of the flock.

To estimate the instrumental programming error, I selected ten photographs featuring between 50 and 5,000 individuals. Each photo was divided into 12 equally sized segments (Figure 1), of which three segments were randomly selected

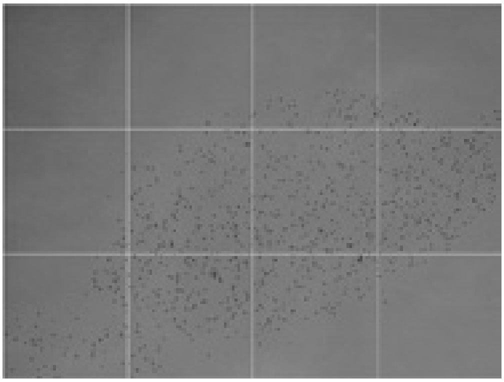

Figure 1. Example of a photograph of a flock of starlings divided into 12 sections used to estimate the programming error.
Exemple d'una fotografia d'un estol d'estornells dividida en 12 seccions utilitzat per estimar l'error del programa.

and the birds therein were counted both manually and automatically by the program. Manual counting was considered to be the best counting method because overlapping or distant birds could be easily detected when visualising the pictures, a task that is sometimes more difficult for the software. I fitted a regression model of the manual versus the automated count data and compared this regression model with the ideal regression line (equal number of birds counted in the automatic and manual counts) in order to test the efficiency of the automatic counts (Laursen *et al.* 2008). I calculated the 95% confidence interval (CI $_{95\%}$) for the fitted regression to obtain the upper and lower limits in each automatic bird count per flock. Finally, I explored the relationship between the program error (manual count–automatic count/manual count), and the number of birds per photo (counted manually).

Statistical procedures

Linear regressions were used to test the relationship between the efficiency of automatic counts versus manual counts and between the average programming error versus the number of birds in each photograph. ANCOVA analyses were used to test differences between methods (automatic vs. manual). All statistical calculations were performed on R statistical software (R Development Core Team 2011) and the results are given with mean and standard deviation.

Results

The entry of starlings into the roost site was not constant, although 93.9% of the flocks entered in the quarter hour between 60 and 45 minutes before sunset (Figure 2). No birds were seen to enter after sunset, although I cannot rule out the possibility that a few individuals could have done so. The mean (SD) flock size was of 954.4 (1,598.5) individuals (n=110; Figure 3). The bias (defined as the percentage of non-photographed individuals) in five flocks was of 13.1, 16.7, 16.9, 31.3 and 51.7%, respectively. The total number of starlings automatically

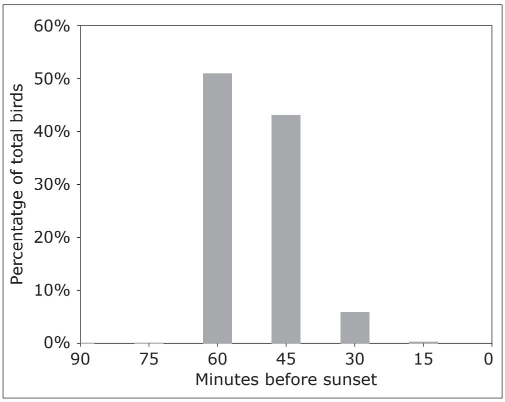

Figure 2. Temporal distribution of the arrival of starlings at the roost in Elche on 4 February 2010.
Distribució temporal de l'arribada d'estornells al dormidor d'Elx el 4 de febrer de 2010.

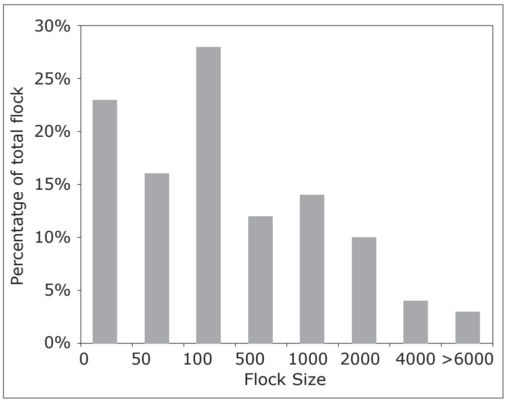

Figure 3. Flock size distribution of starlings at the roost in Elche on 4 February 2010.
Distribució de la mida de l'estol comptabilitzat en el dormidor d'Elx el 4 de febrer de 2010.

counted on photographs was 105,537 individuals. The efficacy of automatic counts (using the manual count as the true value) was very high (r^2 = 0.99, n=34, P < 0.001). In fact, differences between methods were not statistically significant (ANCOVA Test of slope $F_{3, 31}$=0.03, NS; Test of intercept $F_{3, 31}$= 0.54, NS). The average programming error was 2.85 ± 3.75%, n=34 and was directly related to the number of birds in each photograph (r^2 = 0.42, n=34, P < 0.05; Figure 4). Finally, when including both errors (the larger flock photo-biased error and the instrumental programming error), the total number of starlings at the roost site was estimated at 125,197 birds with a CI $_{95\,\%}$ of 122,829–130,036 birds; the proportion of *S. unicolor* was 1.1 ± 1.8% (two *S. unicolor* vs. 211 *S. vulgaris*).

Discussion

Accurate counts of bird concentrations in wintering areas are useful for evaluating population trends (Sutherland 1996, Bibby *et al.* 2000). Currently, the Common Starling is declining throughout Europe, a fact that has been related to the large-scale changes occurring in agriculture (del Hoyo *et al.* 2010). The extensive use of this methodology may provide a quantitative, accurate and comparable source of data for the numbers of birds using winter roost sites. Since these concentrations may have human consequences (e.g. air-strike risk and crop damage, del Hoyo *et al.* 2010, Somers & Morris 2002), these techniques could also be useful as management solutions when local conflicts arise.

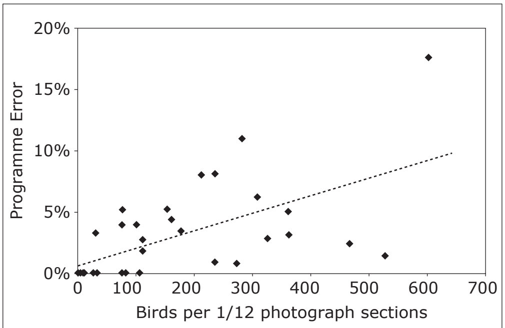

Figure 4. Relationship between the program counting error [(manual counts – automatic) / manual] and the number of birds in the 12 photograph sections.
Relació entre l'error comès pel programa [(comteigs manuals – automàtics) /manuals] i el nombre total d'aus comptabilitzades en 12 seccions de cada fotografia.

This study presents a standardised methodology for counting large roosts using an automatic image analysis program. It is easy and cheap to apply, and the simplicity of its calculations contrasts favourably with more advanced techniques such as videotaping, multispectral images, infrared thermal cameras and radar (Strong *et al.* 1991, Sabol & Hudson 1995, Hamilton *et al.* 2009). The studied approach is more accurate and independent of roost site characteristics and location than indirect methods such as faecal counting (Stewart 1973).

Nevertheless, the protocol has certain drawbacks. To achieve consistent results, it is necessary to select an appropriate observation point because birds tend to arrive at the roost in large numbers from only one direction (Stewart 1973). Moreover, estimates may be highly subjective in situations where the entry to the roost is multidirectional, in which case more observers are required and the likelihood of double counting is greater.

The programming error was similar to other studies, including those using programs that are not freeware (Laliberte & Ripple 2003, Hamilton *et al.* 2009). The principal sources of error were caused by a) an inability to recognise far-off individual objects in the image and b) a failure to separate objects that are in fact overlapping birds in the image. The latter source of error is likely to increase with flock density because individuals are more likely to overlap in such circumstances, resulting in composites being recognised as single birds. The programming error can be minimised by changing the threshold selection method in the software to the manual option. This allows for accurate adjustments such as when photographs present subtle differences in contrast or brightness between birds and the background. The problem with the manual threshold is the loss of comparability between researchers. Despite this, the programming error when using an automatic threshold is very low and acceptable if compared with those errors that are generated when using other survey methods.

Errors associated with bird overlapping may be important in larger flocks. Although I performed a manual count of the birds in the photographs, in some cases it was impossible to separate all the birds. Thus, it would be interesting to use an additional method – for example, the taking of multiple photographs of each flock in short time frames from different angles – to evaluate this bias. This would provide a finer estimate of the error associated with the measurements.

In contrast, the errors due to non-photographed individuals in larger flocks vary between flocks, ranging from 13.1% to 51.7%. Indeed, this error value is probably responsible for the greatest uncertainty in total bird estimates. Although the method used to estimate the sampling bias seems appropriate, I would still recommend improving it using cameras with a wide-angle lens (e.g. 17–200 mm) to cover a broader area in each photograph to thus capture whole flocks.

Despite the aforementioned slight inaccuracies and drawbacks, this is a simple, inexpensive method of taking censuses of large roosting congregations of passerines and can be applied to other species (e.g. herons, raptors, waders and seabirds) and situations (e.g. breeding colonies, post-breeding, feeding and migratory groups). Finally, the implementation in future studies of the above-mentioned methodological improvements could enhance the accuracy of bird number estimates when conducting censuses of large concentrations of passerines.

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Resum

L'ús de fotografies digitals per censar grans concentracions de passeriformes: el cas d'un dormidor hivernal d'estornells

Alguns tàxons d'aus solen concentrar-se en dormidors comunals que es poden trobar en hàbitats molt diversos. Aquestes concentracions poden arribar a aplegar centenars o fins i tot milions d'individus. Poder realitzar estimacions exactes del nombre d'exemplars que formen aquests grans estols és important per entendre la seva biologia, conèixer les tendències de la població i establir accions de gestió o conservació. En aquest estudi es descriu l'ús d'un mètode senzill i de baix cost per calcular el nombre d'individus en grans concentracions de passeriformes. El mètode es fonamenta en la presa de fotografies digitals dels estols i en el posterior processament estandarditzat amb un programa automàtic d'anàlisi d'imatges. Aquesta tècnica va ser utilitzada per estimar el nombre d'aus en un dormidor mixt d'estornells al sud-est d'Espanya, el resultat va ser 125.197 ocells (IC del 95% 122.829-130.036). El programa d'anàlisi d'imatges va mostrar un error mitjà de 2,85% ± 3,75%, relacionat directament amb el nombre d'individus per foto. Els resultats indiquen que aquesta metodologia proporciona dades precises i comparables per calcular la mida de grans dormidors de passeriformes i, a més, la seva aplicació és més senzilla i menys costosa que les tècniques utilitzades fins ara.

Resumen

Uso de fotografías digitales para censar grandes concentraciones de paseriformes: el caso de un dormidero invernal de estorninos

Algunos taxones de aves suelen concentrarse en dormideros comunales que se pueden encontrar en hábitats muy diversos. Estas concentraciones pueden llegar a contener cientos o incluso millones de individuos. El poder realizar estimaciones exactas del número de aves que forman estos grandes bandos es importante para entender su biología, conocer las tendencias de la población y establecer acciones de gestión o conservación. En este estudio se describe el uso de un método sencillo y de bajo coste para calcular el número de individuos en grandes concentraciones de paseriformes. El método se fundamenta en la toma de fotografías digitales de los bandos y en el posterior procesamiento estandarizado con un programa automático de análisis de imágenes. Esta técnica fue utilizada para estimar el número de aves en un dormidero mixto de estorninos en el sureste de España, el resultado fue 125.197 aves (IC del 95% 122.829 a 130.036). El programa de análisis de imágenes mostró un error medio de 2,85% ± 3,75%, relacionado directamente con el número de individuos por foto. Los resultados indican que esta metodología proporciona datos precisos y comparables para calcular el tamaño de grandes dormideros de paseriformes y además su aplicación es más sencilla y menos costosa que las técnicas utilizadas hasta ahora.

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