REMOTE SENSING AS A TECHNIQUE TO ASSES REEBED SUITABILITY FOR NESTING GREYLAG GEESE ANSER ANSER

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We studied Greylag Goose Anser anser nest distribution in relation to reed stem density in the Tømmerby Fjord reedbed, Denmark, using aerial photography to locate nests. Digitised photographs were used to establish a relationship between spectral signature and reed stem density. This technique classified 71% of calibration nest sites correctly regarding reed stem density, and most misclassifications had stem density values near the boundary between density classes. When applied to all 170 identified nest sites, 84% were located in low-density reedbeds.

Keywords: Anser anser - nesting - reedbed - remote sensing

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In Denmark, most breeding Greylag Geese Anser anser nest in reedbeds, and the dense vegetation of this habitat may conceal nests and impede detection by predators (Kristiansen 1998ab). Some 700 pairs of Greylag Geese nest in the extensive reedbeds of the Vejlerne Nature Reserve, NW Denmark (Kristiansen 1997). Reed cutting has been carried out at the reserve on a regular basis (Anonymous 1978-1995) and studies show that Greylag Geese nest in reedbeds of a specific age since harvest (Kristiansen 1998b), and hence such selection may be linked to reed stem density. Remote sensing has been used in wetland classification at regional, national and local levels (Finlayson & Van der Valk 1995; Scott & Jones 1995), but the main emphasis has been on broad habitat classification rather than linked directly to animal distribution. In this study, we test the suitability of digitised large-scale aerial photographs to predict reed stem density and use this method to assess the relationship between goose nest sites and stem density.

The study was conducted at Tømmerby Fjord, part of the 6000 ha Vejlerne Nature Reserve. Tømmerby Fjord is a shallow fresh water lake surrounded by 161 ha of Common Reed Phragmites australis dominated reedbed with smaller patches of reed-mace Typha angustifolia and T. latifolia and bulrush Scirpus sp. In some areas willow scrub Salix cinerea and S. aurita occurs.

The majority of geese were considered to be incubating during the second week of April 1994, and on 12 April, the entire Tømmerby Fjord reedbed was photographed from a Cessna 172 airplane. Vertical photographs were taken using a Rollei camera with a 50 mm lens, using Ectachrome 200 ASA 60 mm x 60 mm colour slide film. Flight speed was c. 100 knots (180 km h\(^{-1}\)) at c. 300 m altitude. Lower altitude photography would increase number of individual exposures
and analysis time. A total of 104 slides covered the entire reedbed of Tømmerby Fjord. Each slide covered an area of approximately 300 m x 300 m, with c. 20% overlap between the slides. An additional flight was made on 25 April 1994 at c. 1000 m altitude, using the same equipment and techniques. These slides each covered an area of c. 1000 m x 1000 m, and were used as an aid to identify the exact location of the previously taken slide images. On 12 April the visibility was 8 km, no precipitation or wind, temperature c. 13°C and cloud cover 0/8. On 25 April visibility was 10 km, precipitation zero, wind 4 SE (Beaufort), temperature c. 18°C and cloud cover 7/8. Goose nests could be identified on the slides with an accuracy of 97% (Kristiansen 1997).

From the aerial slides (300 m altitude) 170 nests were identified. Of these, 39 were subsequently visited to measure vegetation cover using the following procedure:

At each nest a 50 x 50 cm quadrat was sampled North, South, East and West of the nest centre. Each quadrat was sampled sufficiently far (up to 2 m) from the nest to avoid areas of reeds damaged by geese. In each quadrat all reed stems extending more than 75 cm above the substrate surface were counted. Of these, 20 were chosen randomly (blindfolded) and their diameter measured 60 cm from the substrate surface using a digital calliper. If there was an internode at this point, the diameter was measured just above the internode. For each nest a mean reed stem diameter and reed stem density (D) was calculated and these were used to provide an area index of the vegetation cover (P_{50} cover), representing each nest (assuming reed stems to be circular, vegetation density index = \pi r^2 D). The mean of these values was taken as being representative of the immediate nest area. In addition, three distinct areas relatively far apart without goose nests were sampled. These areas were subjectively assessed as being representative of the extensive, relatively homogeneous areas with dense vegetation (c. 28% of the entire reedbed, Kristiansen unpubl. data). These areas had not been harvested for at least 16 years before this study. In each of these areas, two transects were placed, and at 8-10 equidistant reference points vegetation cover was sampled in one quadrat following the above procedure. Each transect was placed perpendicular to the edge of the reed bed, starting at a random point in the outer edge of the reedbed.

Slides covering all nests and reference points were scanned using a Microtek Scannmaker II XE scanner at a resolution of 1036 x 1018 pixels, one pixel corresponding roughly to 0.085 m². Each pixel in the images is characterised by a spectral signature, expressed in terms of reflectance measured in a red, a green and a blue channel (RGB-representation). Each channel records reflectance on a scale from 0 to 255 (8 bit resolution). Separation of pixels into vegetation classes is based on this information. Vegetation density at each of the nests visited and at the reference points were given a corresponding RGB-value from the digitised images using the following procedure: the RGB values at nest sites were obtained by sampling the mean of RGB-values in a one pixel wide ring around the nests. This ring had a radius of 7 pixels approximately equivalent to two meters. At the reference points, a circle of the same size was used, but here all pixels within this circle contributed to the mean RGB-value, as there was no central nest, which should be excluded at these points. Reference points were identified on the digitised image with the aid of landmarks.

Considerable variation in brightness level was found both within and between images. Within images, the brightness level decreases from the centre to the edge due to exposure fall-off. The varying sun reflectance angle across an image will cause bi-directional reflectance, where the reeds in the direction of incoming solar radiation expose their shady sides to the camera, whilst those in the opposite direction expose their illuminated side (King 1995; Pellikka 1996). Between images, exposure, light intensity and conditions at development might vary. To minimize classification problems arising from such intensity variation within and between aerial photographs, Petersen & Noer (1993) and Noer et al. (1995) used a relative measurement of spectral signature.
Adopting this procedure, the RGB values were transformed as given below

\[ X_i^s = \frac{X_i^s}{\sum_{j=1}^{n} X_j^s} \]  

(1)

where \( X_i^s \) is reflectance of channel \( i \) in sample \( s \), \( X_j^s \) is reflectance of channel \( j \) in sample \( s \), \( X_i^s \) is transformed reflectance and \( n \) is number of channels (3). This transformation is performed for all samples on the three channels, and removes the intensity variation from the images, because after this transformation, the sum R+G+B is one. This is done at the cost of reducing the information content. We utilised a scaled minimum distance classification algorithm. In its basic form, a minimum distance classifier simply assigns a sample to the class which it resembles most in terms of the lowest distance to the mean value of the class. Equation 2 represents a slight modification (Wilson 1992), which utilises a scaling to make classes with little variation less inclusive.

\[ S_{MD} = \sum_{i=1}^{n} \left( \frac{(X_i^s - \mu_{ci})^2}{\sigma_{ci}^2} \right) \]  

(2)

Where \( S_{MD} \) is distance measure of the present sample, weighted by division with the variance, \( \mu_{ci} \) is mean reflectance on channel \( i \) for class \( c \), and \( \sigma_{ci}^2 \) is variance of the reflectance on channel \( i \) for class \( c \). Each sample is assigned to the class \( c \) where \( S_{MD} \) is lowest. The classification was performed by the means of a program written for this purpose utilising the statistical package SAS (SAS Institute Inc. 1990).

Mean vegetation densities at nest sites was 5.39% (SE = 2.05, \( n = 39 \)) and 7.18% (SE = 2.03, \( n = 27 \)) for the reference points. The intermediate value (6.28%) was arbitrarily chosen as boundary between two vegetation density classes, taken to represent low and high vegetation densities respectively. Twenty-nine of the 39 nests (74%) were located at sites belonging to the low density class. Table 1 presents RGB-values of transformed channels of the two site density classes. By the transformation according to Eq. 1 the spectral data-set has become effectively two-dimensional, as for each sample a given channel value is one minus the sum of the two others. Therefore, one channel should be left out of the analysis. The two channels with the lowest intercorrelation represent the highest information content, and thus only the red and green channel (\( r^2 = 0.70 \)) were used for the classification (red-blue: \( r^2 = 0.95 \); green-blue: \( r^2 = 0.88 \)). The means for red and green in Table 1 represent values for \( \mu_{ci} \) in Equation 2, and the variances represent values for \( \sigma_{ci}^2 \). Using these values, the scaled minimum distance classification algorithm (equation 2) classified 47 out of the total of 66 sites with vegetation measurements (i.e. 39 nest sites and 27 reference points) correctly into the two vegetation density classes, corresponding to a 71% success rate. As the class separation represents an arbitrary discretisation of a continuous variable, the classification distribution of the two classes is shown in Fig. 1. Now having calibrated the classification, it

<table>
<thead>
<tr>
<th>Channel</th>
<th>Low density sites (( n = 39 ))</th>
<th>High density sites (( n = 27 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>variance</td>
</tr>
<tr>
<td>Red</td>
<td>0.340</td>
<td>1.53\times10^{-04}</td>
</tr>
<tr>
<td>Green</td>
<td>0.321</td>
<td>5.40\times10^{-05}</td>
</tr>
<tr>
<td>Blue</td>
<td>0.339</td>
<td>3.60\times10^{-04}</td>
</tr>
</tbody>
</table>
This apparent avoidance of reedbed areas with too high vegetation density is in accordance with Kristiansen (1998b).

Among the sources of potential error are: undesired variation within and between slides, uncertainty in locating calibration points not associated with a nest, the varying height of the reeds and dryness/inundation of the ground, and the fact that the low vegetation density class could possibly also include sites with a reed density below the range preferred by Greylag Goose for nesting. Future analyses would benefit from the inclusion of such sites with very low density, making this a separate third class.

Use of an airborne multispectral scanner would have eliminated the present problems with brightness variation between exposures, and would have facilitated a GIS-based rectification of an image covering the entire study area. This technique was prohibitively expensive to use at the time, but at the current cost, it could become an alternative in future reedbed investigations. False colour infrared film might also prove useful in depicting vegetation cover. Despite these error sources, a clear distinction between the vegetation classes was achieved, and the link between vegetation classes and Greylag Goose nesting was established. It is concluded that image analysis of aerial photography is an efficient technique for vegetation analysis of reedbeds and can serve as an aid for habitat analysis.

We would like to thank Anthony D. Fox for valuable comments on the manuscript, and Jesper Madsen for support and encouragement during the study. Jaap Graveland, Geoffrey Smith and an anonymous referee gave comments that helped to remove the dark mist of an earlier version. We thank M. Zijlstra for advice on flying procedure. The staff at Vejleme was of great help during the fieldwork. This study was partly financed by Aage V. Jensen Foundations.
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SAMENVATTING

De nesten van Grauwe Ganzen Anser anser die in rietvelden in de Tømmerby Fjord in het Vejlerne natuurgebied in Denemarken broeden, werden met luchtfoto's gelokaliseerd. De luchtfoto's werden gedigitaliseerd en gebruikt om een verband tussen spectrale karakteristieken en de dichtheid van het riet vast te stellen. Het is bekend dat de ganzen vooral broeden in rietvelden met een bepaalde leeftijd, waarmee het aantal jaren na de laatste oogst wordt bedoeld. De dichtheid riet varieert mogelijk met de leeftijd van het rietveld. Een belangrijk probleem bij het fotograferen van het riet was dat de lichtintensiteit sterk kon verschillen tussen en binnen foto's. Om dit probleem op te lossen werden de reflecties van de afzonderlijke kleuren gedeeld door de gesommeerde reflectie van alle drie de kleuren, ook wel aangeduid als kanalen. De getransformeerde reflecties varieerden tussen 0 en 1 en waren duidelijk verschillend tussen locaties met een hoge dichtheid aan rietstengels en locaties met een lage dichtheid aan rietstengels. De grensdichtheid tussen hoge en lage dichtheid werd arbitrair op 0,63% stengeloppervlak gesteld. Uitgaande van dit criterium werd de op de grond gemeten dichtheid riet in het merendeel van de locaties correct geclassificeerd op basis van de luchtfoto's. De ganzen bleken vooral in rietvelden te broeden met een lage dichtheid aan rietstengels. Op basis van de gepresenteerde gegevens wordt geconcludeerd dat deze vorm van luchtfotografie een efficiënte manier is om op grote schaal de vegetatie van rietvelden te analyseren en biotopen te onderscheiden, ook al kan er nog het nodige verbeterd worden.

Received: 10 March 1999, accepted 20 March 2000
Corresponding editor: Bruno J. Ens