Dag Vongraven (ed.)

Assessing vulnerability of flora and fauna in polar areas

Symposium proceedings
Assessing vulnerability of flora and fauna in polar areas

Symposium proceedings
Preface
This report constitutes a compilation of proceedings, extended abstracts and abstracts from a symposium held at the Fram Centre in Tromsø, 3-4 November 2014. The symposium was attended by almost 60 experts from 22 different institutions and organizations in eight countries, lending their ears and eyes to 17 presentations on vulnerability of flora and fauna in polar areas. The Norwegian Polar Institute hosted the symposium as a part of the institute’s long-term effort to increase its insights into and oversight over a wide theme that is of substantial importance in decision-making processes for management purposes in the polar regions. The Institute wishes to thank all contributors, and we hope that readers will get inspired by the content of these proceedings. We have included some poems for extra inspiration.

Tromsø, July 2015
Dag Vongraven

Round and round.
Planet Earth is steadily rotating around its central axis.
24 hours a day.

Round and round.
For every 365th time Earth’s rotating around itself, a journey around the sun is completed.
365 solar days.

Round and round.
24 hours a day.
365 solar days.
Where 23.5 degrees makes a world of difference.

23.5 degrees.
That makes all the difference at the top – and bottom – of the world.
23.5 degrees.
Setting the solar angle.
Tuning light and darkness.
Defining life.

And nowhere is the solar angle as defining as at the Earth’s poles.

Spring. Summer. Fall. Winter.
All defined by the solar angel.
At the poles – a question of total darkness or everlasting light.

Kriss Rokkan Iversen, SALT
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## References


Environmental niche modelling for polar species using MaxEnt

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Introduction

Describing species distributions is essential to understanding and quantifying threats, monitoring changes, assessing protected area representation and investigating future impacts, all of which are important to evaluating vulnerability. Knowing the distribution of a species is difficult, especially in remote regions where it is not possible to comprehensively sample. Whilst it would be desirable to estimate species distributions using an explicit understanding of limiting factors, this is often not realistic within the budgets and timescales needed for creating vulnerability assessments. This creates an apparent need for easy to use tools that can be applied to numerous species and perform with a reasonable degree of accuracy, whilst requiring relatively little data.

Environmental Niche Models (ENMs), sometimes referred to as Species Distribution Models, are one such example of this (Elith and Leathwick 2009). These model species’ suitable habitat using an incomplete set of occurrence records coupled with spatially explicit data layers of environmental conditions, assuming that the abiotic factors input into the model determine, or correlate with, locations where populations of the species can persist (Austin 2002; Elith and Leathwick 2009). Many input environmental conditions can be included in ENMs, but often these are not available at the detail necessary, especially at larger spatial scales. Climate data, however, is readily available worldwide at high resolution, meaning climate-driven ENMs can be built for virtually any system, though they require a greater set of assumptions and a more careful application (Araújo and Peterson 2012).

The Polar Regions are particularly well suited to the application of climate-driven ENMs. The climatic extremes present strongly impact species’ distributions, with clear climatic gradients observable in communities. Palaeoclimatic investigations show that climatic changes of the past have strongly impacted polar (Bigelow et al. 2003; Emslie et al. 2007) species distributions. This means that the major assumption of ENMs, that species’ occurrences correlate to environmental conditions, can be met with reasonable confidence. Detection of many species is also relatively easier in Polar Regions due to the low complexity environment, though sampling bias must still be accounted for. The use and interpretation of ENMs requires caution and a consideration of the costs of inaction in comparison with the uncertainties inherent in the modelling approach (Wiens et al. 2009). In the absence of other options however, they provide an invaluable first step for understanding distributions.

I investigated the applicability of ENMs in a group of Arctic breeding species, shorebirds, and used this to assess how well their current suitable habitat is represented by protected areas. Shorebirds are a group of migratory wader species predominantly of the family Charadriidae that rely on coasts and wetlands. Numerous shorebird species breed throughout the Arctic, making them a useful model group for investigating the efficacy of climate-driven ENMs in estimating distributions for a group of species. Furthermore, they are severely threatened throughout their range, especially in staging sites along the migratory route, with many
experiencing dramatic declines in recent years (Kirby et al. 2008). It is therefore important to understand the distribution of suitable breeding habitat for shorebirds, in order to quantify threats and assess the vulnerability of these species.

**Methods**

24 species were selected for study, based on those species that breed primarily in Arctic tundra (Table 1). Models were built using the niche modelling software MaxEnt, which uses a machine-learning algorithm to estimate a probability distribution of maximum entropy, i.e. the closest to uniform, for each species; constrained by the input environmental variables (Phillips and Dudík 2008). MaxEnt was chosen as it is designed to perform without ‘absence’ data and allows the user to account for sampling bias, relevant here due to large variation in sampling effort across the Arctic region. It has been shown to perform well, even with low sample sizes (Elith et al. 2006; Costa et al. 2010), but is sensitive to the tuning parameters used (Merow et al. 2013). Criticisms of MaxEnt largely stem from users failing to account for sampling bias, or incorrect interpretations of model output (Royle et al. 2012; Yackulic et al. 2013). It is therefore important to note that MaxEnt’s output does not suggest occupied space or even a probability of occurrence, rather the presence of habitat that contains conditions similar to where the species is currently known to exist.

**Data**

Occurrence records for the 24 species were gathered from four key sources: the Global Biodiversity Information Facility (GBIF), The International Breeding Conditions Survey on Arctic Birds (www.Arcticbirds.net, last accessed October 2014), The Atlas of Breeding Waders in the Russian Arctic (Lappo et al. 2012) and via David Boertmann for occurrences in Greenland. All records where definite breeding activity was confirmed (e.g. nest occupancy, recently hatched young) were included in the analysis, and for those where breeding status was unknown, acceptable records were those gathered between 15th May and 30th June from 1990 to now, and that fell within expert mapping of the breeding distribution (Cramp et al. 1983; Sibley and Monroe 1990; Del Hoyo et al. 1992).

The study region was Pan-Arctic with the southern limit defined by current estimated distributions of the 24 study species: between 50°N in parts of Canada and 59°N in parts of Russia. Projections were made for all land north of 50°N. 19 bioclimatic variables, together with the standard deviation of elevation were used, with all data obtained from WorldClim (www.worldclim.org, last accessed October, 2014). Standard deviation of elevation was included as a predictor variable in the models because most shorebirds prefer to breed on vegetated flat tundra (Meltofte 2007) and variation in topographic heterogeneity, even for a given set of climatic conditions, is likely to have a significant influence on distribution. This was calculated by downloading the finest scale elevation grid from WorldClim, 30 arc seconds, and finding the standard deviation of these pixels within the 10 x 10km grid cells used for modelling.

**Model Parameters**

A spatial grain size of 10 x 10km was used for analysis, to reflect the approximate resolution of most of the distributional records and a scale at which climate, rather than microhabitat factors, is more likely to be limiting (Mackey and Lindenmayer 2001). Although there are records of breeding shorebirds from all parts of the Arctic, the intensity of survey effort varied markedly, and this was accounted for by selecting background points (a suite of pixels used by MaxEnt with which to compare occupied pixels) only from known sampling locations. In this way the occurrence records and the background have the same sampling bias, removing its effect from model output.
Models were optimally tuned by adjusting the regularisation parameter, which alters

- tightness of fit (Anderson and Gonzalez Jr 2011; Radosavljevic and Anderson 2014). To choose the best regularisation parameter for each species, five-fold cross validated models were run for 12 values of the regularisation parameter at increasing intervals between 0.5 and 5, with the one resulting in highest mean AUC and lowest mean standard deviation selected. The performance of all models was evaluated using null model significance testing as described by Raes and ter Steege (2007), which estimates the probability that each model performed better than 1000 null models based on an equivalent number of occurrence points drawn at random from all surveyed locations. Distributions were also compared to expert derived range maps (Cramp et al. 1983; Sibley and Monroe 1990; Del Hoyo et al. 1992).

A threshold can be set for the model output, converting the logistic probability output that MaxEnt gives to a binary value indicating suitable or unsuitable habitat – useful for assessing protected area coverage. The threshold value was selected as that which balanced specificity and sensitivity, i.e. Type I and Type II errors in the model. Any cells with a logistic output above this value were converted to ‘suitable’ and any below ‘unsuitable’.

Protected areas
Finally, protected area coverage of current distributions was analysed. Boundaries for all protected areas in the Arctic region were downloaded from www.protectedplanet.net (accessed 15th of July, 2014). Of these, UNESCO Biosphere reserves were excluded as they can include areas that have no formal protection (Coetzer et al. 2014). To ascertain whether the protected area network adequately represented a species, target proportions of protection were defined according to Rodrigues et al. (2004). Targets were set such that species with a geographic range size below 1000km² required 100% protection, those with a range size above 250,000km² required 10% protection, and species with intermediate geographic range size were logarithmically interpolated between these two thresholds. All protected area analyses used the total area of climatically suitable conditions from the thresholded MaxEnt output.

Results
Models for all species performed very well, with most AUC > 0.95 and all being significantly better than null (p < 0.001) (Table 1). Even for species with relatively few occurrence points, current distribution models aligned closely with expert-derived range maps. Given that the models are predicting the occurrence of suitable climatic conditions, rather than the species’ distributions themselves, some models inevitably showed suitable climatic conditions in areas far from the current distribution of the species being modelled. A common feature was for North American species to show some areas of high climatic suitability in parts of Russia. Often, these unoccupied but suitable areas are actually occupied by closely related sister species. Example distribution maps are shown in Figure 1.

Most species had fairly large range sizes; meaning protected area target proportions were low. Nevertheless, all species were well represented within protected areas, with all meeting their targets (Table 1).
Table 1  The 24 species used for modelling. Shows model performance metrics (AUC and Null Model p), as well as target and actual proportions of suitable climatic habitat represented by protected areas.

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Common Name</th>
<th>AUC</th>
<th>Null Model p</th>
<th>Target Proportion of Protection</th>
<th>Actual Proportion of Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Arenaria interpres</em></td>
<td>Ruddy turnstone</td>
<td>0.86</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.28</td>
</tr>
<tr>
<td><em>Calidris acuminata</em></td>
<td>Sharp-tailed sandpiper</td>
<td>0.99</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.30</td>
</tr>
<tr>
<td><em>Calidris alba</em></td>
<td>Sanderling</td>
<td>0.98</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.30</td>
</tr>
<tr>
<td><em>Calidris bairdii</em></td>
<td>Baird’s sandpiper</td>
<td>0.98</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.22</td>
</tr>
<tr>
<td><em>Calidris canutus</em></td>
<td>Red knot</td>
<td>0.97</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.22</td>
</tr>
<tr>
<td><em>Calidris ferruginea</em></td>
<td>Curlew sandpiper</td>
<td>0.96</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.26</td>
</tr>
<tr>
<td><em>Calidris fusciicolis</em></td>
<td>White-rumped sandpiper</td>
<td>0.99</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.12</td>
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<tr>
<td><em>Calidris himantopus</em></td>
<td>Stilt sandpiper</td>
<td>0.99</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.14</td>
</tr>
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<td><em>Calidris maritima</em></td>
<td>Purple sandpiper</td>
<td>0.95</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.25</td>
</tr>
<tr>
<td><em>Calidris mauri</em></td>
<td>Western sandpiper</td>
<td>0.99</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.39</td>
</tr>
<tr>
<td><em>Calidris melanotos</em></td>
<td>Pectoral sandpiper</td>
<td>0.95</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.20</td>
</tr>
<tr>
<td><em>Calidris minutia</em></td>
<td>Little stint</td>
<td>0.94</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.20</td>
</tr>
<tr>
<td><em>Calidris ptilocnemis</em></td>
<td>Rock sandpiper</td>
<td>0.99</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.34</td>
</tr>
<tr>
<td><em>Calidris pusilla</em></td>
<td>Semipalmated sandpiper</td>
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<td>&lt;0.001</td>
<td>0.1</td>
<td>0.17</td>
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<tr>
<td><em>Calidris ruficollis</em></td>
<td>Red-necked stint</td>
<td>0.97</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.18</td>
</tr>
<tr>
<td><em>Eurynorhynchus pygmeus</em></td>
<td>Spoon-billed sandpiper</td>
<td>0.99</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.21</td>
</tr>
<tr>
<td><em>Limnodromus scolopaceus</em></td>
<td>Long-billed dowitcher</td>
<td>0.96</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.25</td>
</tr>
<tr>
<td><em>Limosa haemastica</em></td>
<td>Hudsonian godwit</td>
<td>0.99</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.27</td>
</tr>
<tr>
<td><em>Numenius tahitiensis</em></td>
<td>Bristle-thighed curlew</td>
<td>1.00</td>
<td>&lt;0.001</td>
<td>0.17</td>
<td>0.46</td>
</tr>
<tr>
<td><em>Phalaropus fulicarius</em></td>
<td>Red phalarope</td>
<td>0.95</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.21</td>
</tr>
<tr>
<td><em>Pluvialis dominica</em></td>
<td>American-golden plover</td>
<td>0.97</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.15</td>
</tr>
<tr>
<td><em>Pluvialis fulva</em></td>
<td>Pacific-golden plover</td>
<td>0.94</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.19</td>
</tr>
<tr>
<td><em>Pluvialis squatarola</em></td>
<td>Grey plover</td>
<td>0.93</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.20</td>
</tr>
<tr>
<td><em>Tryngites subruficollis</em></td>
<td>Buff-breasted sandpiper</td>
<td>1.00</td>
<td>&lt;0.001</td>
<td>0.1</td>
<td>0.18</td>
</tr>
</tbody>
</table>
Figure 1  Example suitable climatic habitat maps for a) Purple sandpiper *Calidris maritima*, b) Curlew sandpiper, *Calidris ferruginea* and c) Bristle-thighed curlew, *Numenius tahitiensis*. Black dots represent occurrence points that were input to MaxEnt, and green indicates modelled suitable climatic habitat.

**Discussion**

MaxEnt appears to have given reliable distributions of suitable climatic habitat for all species investigated. Whilst some habitat was identified outside areas of known occupancy, general trends of distributions were good, and model performance statistics confirmed this. The models were built on a broad spatial scale and do not reflect detailed microhabitat choice of species, rather a broader understanding of distribution. More importantly, they rely on the assumption that distributions are constrained by, or correlate with, abiotic factors. If, in reality, the true factors affecting distributions are biotic, such as prey and predator interactions that do not closely correlate with climatic variables, then this assumption may be violated. Therefore the models must be dealt with cautiously, especially when projecting into novel scenarios.

These distributions can be used for identification of spatially explicit threats to species, an important component of assessing vulnerability. Currently, all species appear to have adequate proportions of suitable climatic habitat represented by protected areas, an encouraging result from this analysis. Models can also be used to project future impacts to distributions, such as climate change impacts (Wauchope 2014). This requires a broader set of assumptions, but is once again a useful tool for identifying key species that are particularly at risk to a warming environment.

Whilst Environmental Niche Models and are no substitute for a detailed understanding of species physiological and biological requirements, they provide an excellent first step in understanding distributions that can be built for a number of species using publicly available data and a relatively simple method.