

ECOLOGICAL NICHE MODELING APPROACHES TO CONSERVATION OF ENDANGERED AND THREATENED BIRDS IN CENTRAL AND EASTERN EUROPE

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Abstract.— Comprehensive biodiversity surveys are unavailable for most Central and Eastern European countries. Although birds in general are well-studied, distributional information in the region is sparse and largely out-of-date; I used museum specimen locality records and raster GIS data layers summarizing environmental dimensions to produce distributional hypotheses for the 36 threatened and endangered bird species in the region using ecological niche modeling. These ecological niche models were also used to predict likely future (2055) distributional shifts owing to global climate change. The entire suite of distributional information that resulted was used to evaluate strategies for conservation via simple heuristic place-prioritization algorithms based on complementarity and rarity considerations. These analyses identified priority areas in southern and eastern Romania, as well as other areas across the region, as priority targets for conservation action in the region.

Key words.— central and eastern Europe, conservation priority, distribution, endangered bird species.

Europe is generally viewed as fortunate regarding documentation of its biodiversity, with populations monitored in a few instances even over centuries (Haslett 2002). However, comparatively little has been accomplished in the past 50 yr in documenting biodiversity in former communist block countries, which have seen comparatively little priority placed on study or conservation of their biodiversity. Such work has advanced thanks only to individual researchers, with little governmental support; in the Balkans, this situation has been worsened by recent ethnic conflicts.

Birds rank among the better-studied taxonomic groups, with roughly half of European countries having long-established regular bird censuses; the half lacking such censuses is concentrated in Central and Eastern Europe (CEE). The European Bird Census Council (EBCC) Atlas of European Breeding Birds (Hagemeijer & Blair 1997) provided an important summary, but did not establish routine censuses regionwide. A follow-up publication updated the EBCC data for 1996-1999 (BirdLife International/European Bird Census

Council 2000), but additions mainly concerned Western Europe.

To address this information gap for CEE, two options are available: one is to establish new monitoring programs (e.g., as is occurring now in Bulgaria, Croatia, and Romania). Such efforts, however, take time, and may not provide efficient solutions to presently urgent questions, such as which areas are key for protection to promote biodiversity conservation. A second, complementary, approach is that of using existing information to infer distributional areas for species. Clearly, this method can and should be integrated with the previous one, but it provides quantitative information in for situations in which assembly of on-the-ground dataset may take too long-scale on-ground surveys may not be feasible. In particular, this approach can be used to target on-ground survey efforts more efficiently (Raxworthy et al. 2003); conversely, on-ground field surveys present an ideal test of the model-based predictions of species' distributions.

When threatened species are considered, the lack of information is even more acute. The sporadic, general monitoring programs are less

likely to capture the much needed information regarding these species distributions. As such, a method that can generate predictive distributions is even more valuable in this situation. To summarize CEE threatened and endangered bird species' distributions, I used tools from the field of ecological niche modeling (ENM), and produced predictive models of species' distributions based on known occurrences of species and raster GIS databases summarizing relevant environmental parameters across the CEE landscape. I used the Genetic Algorithm for Rule-set Prediction (GARP) (Boston & Stockwell 1994) to relate known occurrences of each species ecological features of landscapes across Europe and western Asia. I focused results and analyses on CEE as the region most in need of such information.

Closely connected with gaps in distributional information is the issue of designing protected areas based on distributional patterns of species (Prendergast et al. 1999, Kelley et al. 2002, Midgley et al. 2003, Moore et al. 2003). Prioritization of areas for conservation is crucial because human presence in landscapes continues to increase, so less land retains natural features and is available for biodiversity protection. Moreover, initial creation of reserves was frequently for reasons little related to preserving biodiversity; rather, scenic and recreational features or even lack of commercial or urban value determined reserve locations (Pressey 1994), and such reserves selected on an ad hoc basis will often not be optimal for biodiversity conservation (Gambino 2002). Identifying biologically richest areas is difficult, especially when distributional and abundance data are unavailable.

ENM, however, can provide quantitative distributional information on which place-prioritization analyses can be based (Sánchez-Cordero et al. 2005). The purpose of this study is to use known occurrences of CEE threatened and endangered birds and ENM tools to prioritize areas important for biodiversity conservation in the region. Planning for conservation of threatened species, even though these represent a small sample of regional biodiversity, is a necessary task that requires innovative approaches; current system of reserves can be optimized to ensure survival of these species.

METHODS

Species for analysis

I chose 36 bird species for study, based both on the Species of European Conservation Concern list (Tucker & Heath 1994) and on the IUCN classification of threatened birds (BirdLife International 2000). Specifically, species included (Table 1) either breed or winter in CEE, and are categorized as Species of European Conservation Concern category 1 or 2 ("SPEC1" and "SPEC2," respectively, hereafter; Tucker & Heath 1994): SPEC1 includes species that are globally threatened, conservation-dependent, or data deficient, whereas SPEC2 includes species with global populations concentrated in Europe that have unfavorable conservation status in Europe (Tucker & Heath 1994). In 3 cases, IUCN and SPEC categories disagreed. *Aegyptus monachus* and *Haliaeetus albicilla* are listed as SPEC3 (species not centered in Europe, but with an unfavorable conservation status in Europe; Tucker & Heath 1994), but IUCN lists them as near-threatened (BirdLife International, 2000). *Phalacrocorax pygmeus* is listed as near-threatened by IUCN (BirdLife International 2000), but as SPEC2 (instead of SPEC1; Tucker and Heath 1994). These disagreements likely result from the time elapsed between the two publications, but all 3 were included in the study, for a total of 36 species in this study.

Occurrence information was accumulated for these species from diverse sources, including natural history museums, census data (as available), and the scientific literature citations (see Acknowledgements). Textual locality references were assigned coordinates to the nearest 1' of latitude and longitude via the GEONet Names Server¹. The final occurrence datasets consisted of 6-81 localities per species (Table 1).

Study region and geographic information.

My analyses covered the following CEE countries: Albania, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Macedonia, Poland, Romania, Slovakia, Slovenia, and Yugoslavia. As most species of interest had geographic distributions extending outside of CEE, and given the sparse distributional information available from within CEE, I

¹ <http://earth-info.nga.mil/gns/html/index.html>

Table 1. List of species studied and number of point occurrences used in analyses, with habitat characteristics and conservation status (Tucker and Evans 1997)

Species	Nr. of localities	Habitat	SPEC category	IUCN category
<i>Alectoris graeca</i> (Rock Partridge)	37	grassland	2	n/a
<i>Oxyura leucocephala</i> (White-headed Duck)	10	water bodies	1	endangered
<i>Anser erythropus</i> (Lesser White-fronted Goose)	6	grassland	1	vulnerable
<i>Branta ruficollis</i> (Red-breasted Goose)	13	grassland	1	vulnerable
<i>Aythya nyroca</i> (Ferruginous Duck)	28	water bodies	1	near threatened
<i>Picus viridis</i> (Green Woodpecker)	81	old deciduous forest, woodlands; grassland	2	n/a
<i>Coracias garrulus</i> (European Roller)	47	meadows, steppes (grasslands), scattered mature trees (wooded grasslands), perennial crops	2	n/a
<i>Otus scops</i> (Scops Owl)	32	woodland, arable grassland, crops, riverine forest	2	n/a
<i>Caprimulgus europaeus</i> (European Nightjar)	52	boreal and lowland temperate forests, woodlands	2	n/a
<i>Otis tarda</i> (Great Bustard)	23	arable and improved grassland; grasslands	1	vulnerable
<i>Crex crex</i> (Corncrake)	56	arable and improved grassland, wet grassland, montane grassland	1	vulnerable
<i>Limosa limosa</i> (Black-tailed Godwit)	48	coastal habitat, inland wetlands (marshes), tundra, wet grassland, rice cultivation	2	n/a
<i>Numenius tenuirostris</i> (Slender-billed Curlew)	12	coastal habitat, inland wetlands (lakes), steppic habitat (coastal, upland grassland)	1	critical
<i>Tringa totanus</i> (Redshank)	48	coastal habitat, wet grassland	2	n/a
<i>Larus canus</i> (Common Gull)	58	coastal habitat, grassland (arable and improved; wet)	2	n/a
<i>Sterna sandvicensis</i> (Sandwich Tern)	31	coastal habitat	2	n/a
<i>Aegypius monachus</i> (Cinereous Vulture)	23	mediterranean habitat (broadleaved forest, dense shrub, open habitats), pastoral woodland	3	near threatened
<i>Haliaeetus albicilla</i> (White-tailed Eagle)	29	coastal habitat, inland wetlands, boreal forests, lowland temperate forests, riverine forests	3	near threatened
<i>Accipiter brevipes</i> (Levant Sparrowhawk)	16	lowland temperate forest, riverine forest, mediterranean habitats (coniferous, broadleaved forests), arable and improved grassland	2	n/a
<i>Aquila clanga</i> (Great Spotted Eagle)	29	inland wetlands, boreal forests, lowland temperate forests, riverine forests, wet grasslands	1	vulnerable
<i>A. heliaca</i> (Imperial Eagle)	23	lowland temperate forest, mediterranean habitats (coniferous, broadleaved forests), arable and improved grassland, steppic habitats, wet grassland	1	vulnerable
<i>Falco eleonora</i> (Eleonora's Falcon)	12	coastal habitats, mediterranean habitats (garrigue and rocky habitats)	2	n/a
<i>F. naumanni</i> (Lesser Kestrel)	30	arable and improved grassland, steppic habitats	1	vulnerable
<i>Phalacrocorax pygmeus</i> (Pygmy Cormorant)	9	coastal habitats, inland wetlands	2	near threatened
<i>Pelecanus crispus</i> (Dalmatian Pelican)	6	coastal habitats, inland wetlands, riverine forests	1	conservation dependent
<i>Platalea leucorodia</i> (Spoonbill)	15	coastal habitats, riverine forests	2	n/a
<i>Ciconia ciconia</i> (White Stork)	48	arable and improved grassland, steppic habitats, wet grassland, pastoral woodland	2	n/a
<i>Lanius minor</i> (Lesser Grey Shrike)	35	arable and improved grassland, steppic habitats	2	n/a
<i>Lanius senator</i> (Woodchat Shrike)	45	mediterranean habitat (broadleaved forest, maquis), perennial crops, pastoral woodland	2	n/a
<i>Phoenicurus phoenicurus</i> (Redstart)	56	boreal and lowland temperate forests, montane forest	2	n/a
<i>Oenanthe hispanica</i> (Black-eared Wheatear)	31	mediterranean habitats (garrigue, rocky habitats), arable and improved grassland, steppic habitat	2	n/a
<i>Acrocephalus paludicola</i> (Aquatic Warbler)	29	coastal habitats, inland wetlands, wet grassland	1	vulnerable
<i>Hippolais olivetorum</i> (Olive-tree Warbler)	12	mediterranean habitats (maquis, broadleaved forests), perennial crops	2	n/a
<i>Lullula arborea</i> (Woodlark)	56	boreal forest, lowland temperate forest, montane forest, mediterranean habitats (coniferous and broadleaved forests, garrigue), arable and improved grasslands, perennial crops, pastoral woodland	2	n/a
<i>Emberiza hortulana</i> (Ortolan Bunting)	36	mediterranean habitats (coniferous and broadleaved forests, garrigue), arable and improved grassland, perennial crops	2	n/a
<i>E. melanocephala</i> (Black-headed Bunting)	30	mediterranean habitats (maquis, garrigue, rocky habitats), arable and improved grassland	2	n/a

developed ENMs based on occurrence data from across Europe and western Asia; in this way, I assured full representation of species' ecological potential in ENMs (Pearson & Dawson 2003).

I used 12 raster GIS coverages to summarize the ecological landscape: 8 climatic layers (diurnal temperature range, ground frost frequency, annual mean precipitation, annual mean maximum temperature, annual mean temperature, annual mean minimum temperature, vapor pressure, and wet day frequency; source: Intergovernmental Panel on Climate Change²; and 4 aspects of topography (elevation, slope, aspect, and topographic index; source: US Geological Survey, Hydro-1K dataset³). All environmental coverages were resampled (nearest neighbor method) to a 0.1° spatial resolution for analysis. Because available locality data were drawn principally from the late 1800s through the early 1950s, I used climatic data for the period 1931-1960.

I based interpretation of my distributional modeling and place-prioritization results on a vector GIS dataset of current protected areas (IUCN reserve categories I-V) in CEE. This dataset was obtained by merging a dataset summarizing protected areas of Austria, Czech Republic, Germany, Hungary, Macedonia, Poland, Slovakia, Slovenia, and Yugoslavia (UNEP-WCMC 2002) with one summarizing current protected areas in Romania (obtained from the Romanian Ministry of Water, Forestry, and Environment⁴) in ArcView 3.2. As such, the final protected areas dataset did not include information regarding reserves in Albania, Bulgaria, Bosnia and Herzegovina, or Croatia, for which detailed information was unavailable.

Ecological niche modeling

The ecological niche of a species can be defined as the set of ecological conditions within which it is able to maintain populations without immigration (Grinnell 1917). Several approaches have been used to approximate species' ecological niches (Austin et al. 1990; Walker and Cocks 1991; Carpenter et al. 1993); of these, a robust option is the Genetic Algorithm for Rule-set Prediction

(GARP⁵), which includes several inferential approaches in an iterative machine-learning approach (Stockwell and Peters 1999).

Within the GARP program's processing, available occurrence points are divided into data sets for model building (training data) and model testing (extrinsic test data). GARP is designed to work based on presence-only data; absence information is included in the modeling exercise via sampling of points from the set of pixels where the species has not been detected—these 'pseudoabsence' points usually include some actual presences (unsampled), but are useful as their prior probability of presence is decidedly below unity. GARP works in an iterative process of rule selection, evaluation, testing, and incorporation or rejection: first, a method is chosen from a set of possibilities (e.g., logistic regression, bioclimatic rules), and then is applied to the training data and a rule developed; rules may evolve by a number of means (e.g., truncation, point changes, crossing-over among rules) to maximize predictivity. Predictive accuracy is evaluated based on 1250 points resampled from the test data and 1250 points sampled randomly from the study region as a whole. The change in predictive accuracy from one iteration to the next is used to evaluate whether a particular rule should be incorporated into the model, and the algorithm runs until it converges and predictive accuracy ceases to change.

Projection of GARP models onto landscapes provides an estimate of the geographic distribution of suitable conditions, and allows tests of model predictivity. In general, extrinsic test data are overlaid, and observed correct predictions are tallied. I used recent best-practices recommendations (Anderson et al. 2003) to select a 'best subset' of 100-1000 random replicate models based on error component distributions, and summed the resulting models to produce a grid summarizing model agreement in predicting presence or absence from 0 (all models predict absence) to 10 or 20 (all models agree in predicting presence). Because species' distributions are limited by combined effects of ecological and historical factors (e.g., barriers to dispersal; Peterson et al. 1999), I compared present-day predictions with summary information available (at

² <http://www.ipcc.ch/>

³ <http://edcdaac.usgs.gov/gtopo30/hydro/>

⁴ <http://www.mmediu.ro/home/home.php>

⁵ <http://www.lifemapper.org/desktopgarp>

the country level) on present distributions of the species included in this analysis (Cramp and Simmons 1977; Cramp and Simmons 1982; Cramp and Simmons 1985a; Cramp and Simmons 1985b; Cramp 1988; Cramp and Perrins 1993; Hagemeyer and Blair 1997). Areas of overprediction were trimmed from model predictions prior to place prioritization analyses. Finally, I reduced predictions to binary predictions (i.e., “yes” versus “no”) using an arbitrary threshold of 10% of models predicting presence.

Given temporal discords between occurrence data and land use information available could not be included directly in model development (Chapman et al, 2005); hence, following Peterson & Kluza (2003), I reduced model predictions to those land use/land cover (LULC) types (raster format, 1 km² spatial resolution, University of Maryland Global Land Cover Facility⁶) adequate for each species (based on Tucker & Evans 1997).

Climate change scenarios

ENMs, which exist as sets of rules as to which portions of environmental space are potentially habitable, can be projected onto modeled future landscapes to identify areas meeting species’ niche requirements under future climate scenarios (Peterson et al. 2001, 2002). Because existing climate change data sets do not include all of the climatic parameters used in the analyses described above for predicting present species distributions, a second round of GARP models was run for predicting future (post-climate change) potential distributions, based only on annual mean minimum temperature, annual mean temperature, annual mean maximum temperature, annual mean precipitation, topographic index, slope, and aspect. These models, trained based on the 1931-1960 climate data described above, were projected onto two climate change scenarios drawn from the Intergovernmental Panel on Climate Change (2050 time frame⁷). The first scenario (HadCM3_A2) is based on assumptions of high population growth and high CO₂ emissions, whereas the second (HadCM3_B2) is based on assumptions of slower population growth and lower CO₂ emissions (Houghton et al. 2001). For each species, the 10 best models were summed, averaged over the two

scenarios, and areas predicted present by >5 of the 10 models were classified as present. I set this threshold to a more conservative value (as compared to that for present day models) due to the coarse scale of the climate change modeling and the reduced number of environmental layers used. Finally, under an assumption of no dispersal ability (Peterson et al. 2001), which is likely the most appropriate assumption for the present study, which focuses on rare, endangered, or declining species, I intersected present and future model predictions to identify portions of the present-day range that will remain habitable.

Place prioritization analysis

The areas identified by the ENMs as suitable under present and future conditions were used to identify concentrations of bird species richness, rarity, and highest threat. A heuristic approach (Pressey et al. 1996) was used, seeking highest numbers of new species or of rare species that can be added to the system with each new area. Although this approach can lead to decisions that do not lead to the globally optimal solution for representing species in a network of places, the simplicity of patterns treated in this study made more complex approaches unnecessary (Church et al. 1996, Pressey et al. 1996, Csuti et al. 1997), and I thus could take advantage of the computational simplicity of heuristic algorithms (Pressey et al. 1996).

My heuristic complementarity approach was thus as follows (after Peterson et al. 2000): areas holding highest numbers of species (i.e., sum of equally weighted distributional predictions for species), or of rarest species (i.e., sum of distributional predictions for species weighted by the multiplicative inverse of range size; Williams et al. 1996) were identified. If multiple areas of equal richness were identified in the first step, the largest and most entire area was chosen; next, areas holding maximum numbers of species (or maximally rare suites of species) not represented in the initial area were added; the process was repeated until all species were included or until the remaining species did not overlap distributionally. “Rarity” in this study thus refers to species of restricted range, and not to abundance of individuals. To take into account existing protected areas, I counted species as present in a given protected area if >10% of the protected area was

⁶ <http://www.glcf.umd.edu/data/landcover>

⁷ <http://www.ipcc.ch>

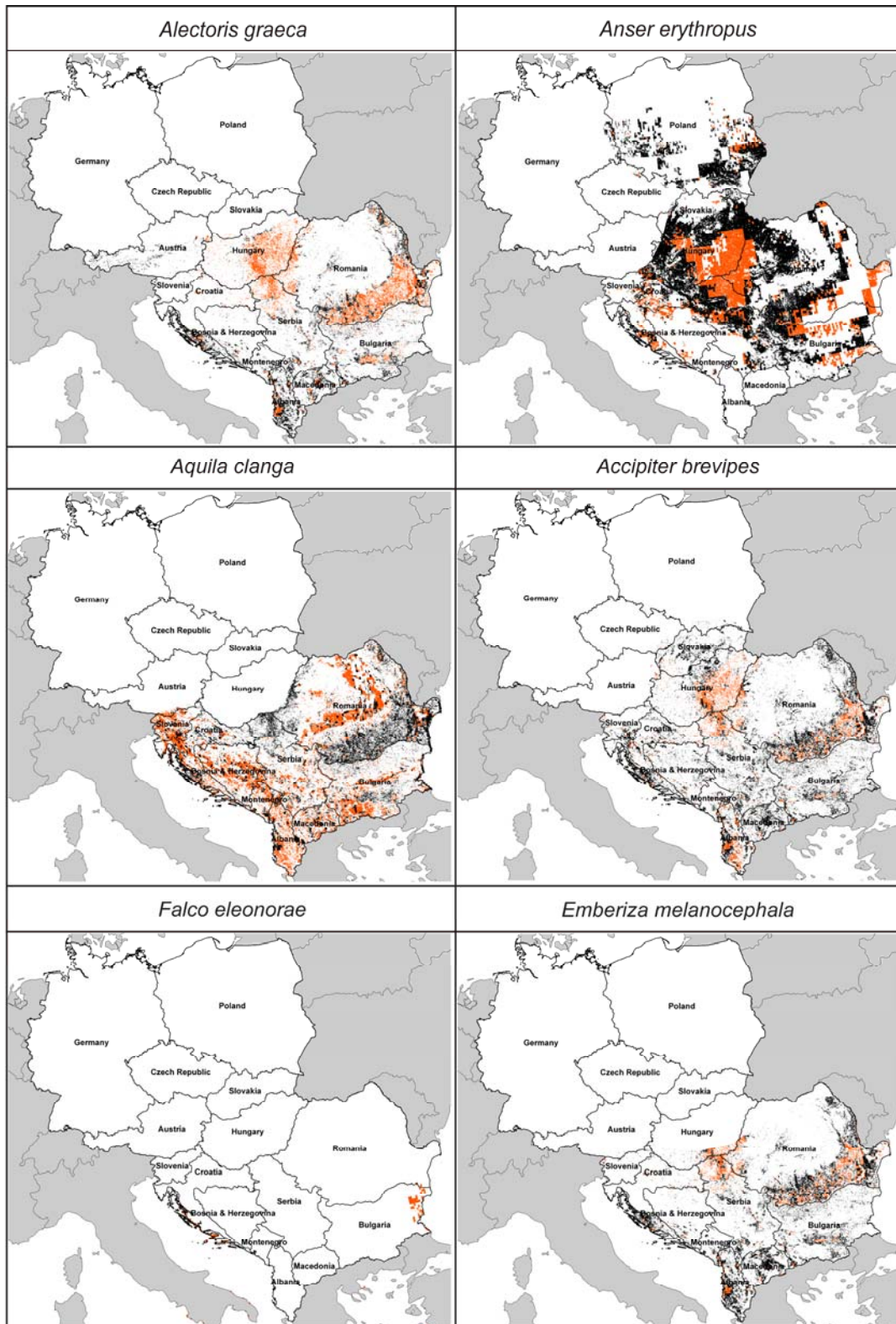


Figure 1. Comparison between present-day (orange) and future-climate (black) predicted distributional areas for 6 bird species. Because future-climate predictions are shown on top of present-day predictions, visible orange areas are predicted to be uninhabitable under future climate conditions.

predicted present for the particular species, an approach that probably overstates the importance of the current reserve system to the conservation of threatened birds.

RESULTS

Distributional predictions

All ENMs (on which all subsequent analyses were based) were statistically significantly better than random predictions for all species (all $P < 0.02$). Species' distributions reconstructed using this procedure ranged from broadly distributed across CEE (e.g., *Anser erythropus*) to narrowly restricted to small parts of the region (e.g., *Falco eleonora*; Fig. 1).

Likely climate change effects on species' potential distributions, as predicted by my ENMs, were variable. One species (*Falco eleonora*) was predicted to lose all of its potential distributional area in CEE, whereas others (e.g., *Caprimulgus europaeus*) were predicted to see only minor losses (0.06%). Indeed, predicted distributions post-climate change in CEE decreased appreciably only for 6 species: *Alectoris graeca*, *Anser erythropus*, *Falco eleonora*, *Aquila clanga*, *Accipiter brevipes*, and *Emberiza melanocephala* (Fig. 1). Such variable effects of climate change agree well with results of parallel studies in other regions (Peterson 2003a; Peterson 2003b; Peterson et al. 2002); in general, previous studies also showed low levels of extinction of bird species in Europe and Mexico under both assumptions of dispersal and no dispersal possible (Thomas et al. 2004). These findings are in contrast with the severe losses predicted for more diverse environments, such as tropical rainforest (Williams et al. 2003).

Complementarity analysis

Because preliminary analyses indicated that 34 of the 36 species were represented in at least one protected area (Fig. 2), I did not explore the trivial case of simple species representation. Hence, I developed 4 separate place-prioritization analyses based on species richness versus rarity, and including distributions under future versus present-day climates.

Prioritizations based on present-day distributional models generally identified a single area that included almost all of the species. The species richness/present day prioritization identified a single area (Fig. 3A) holding 34

species, with *Aegypius monachus*, *Falco eleonora*, and *Caprimulgus europaeus* only marginally represented (just a few pixels) in the area; no areas of overlap were found between *Hippolais olivetorum*, *Phoenicurus phoenicurus*, and the rest of the species. Prioritization with weighted representation by rarity (present-day climates) was swayed by representation of the rarest species, *Hippolais olivetorum*, so the first area represented only 25 species, and a second area added 8 more (Fig. 3B); finally, the predicted distribution of *Aegypius monachus* did not overlap with any of the first 2 areas.

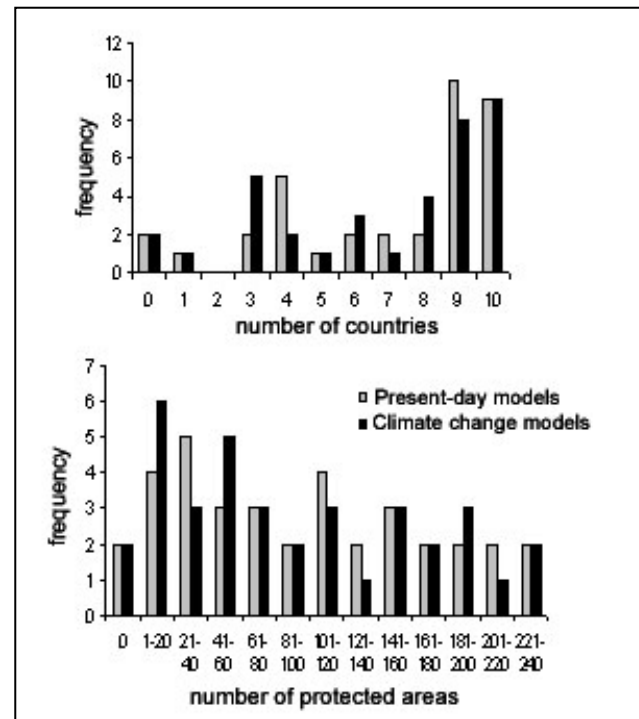


Figure 2. Frequency of representation of species in protected areas in Central and Eastern European countries.

When climate change effects on species' distributions were considered, effectively rendering the models into prioritizations of portions of species' distributional areas likely to remain habitable over the next 50 yr, results were somewhat different, in that prioritizations required more areas to represent most species, suggesting that climate change processes may act to reduce distributional coincidence among species. Hence, a prioritization based on maximizing species richness in future potential distributional areas identified a single area holding 33 of the 36 species

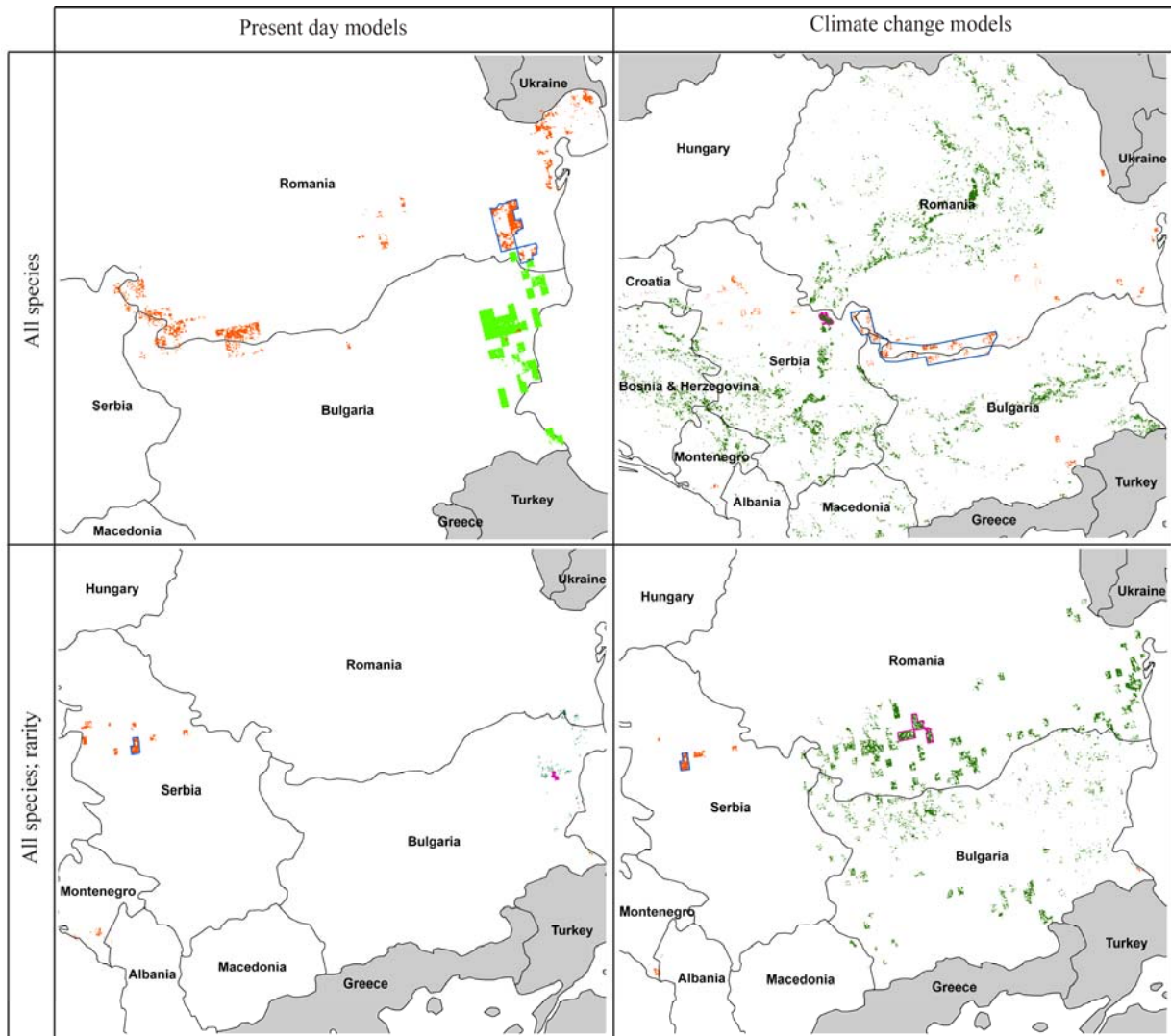


Figure 3. Summary of results of place-prioritization analyses: (A) species richness in present-day climates, (B) rarity representation in present-day climates, (C) species richness under future-climate conditions, and (D) rarity representation under future-climate conditions. First priority areas are outlined in blue, and subsequent ones in purple; representation of species diversity or rarity are depicted as color ramps from white (none) to orange (high); sums of species not included in prioritization areas identified first are shown in white-to-green color ramps; also, in (A), the predicted distribution of *Falco eleonorae* is shown in light green.

(Fig. 3C), although 2 (*Caprimulgus europaeus* and *Aegypius monachus*) were only represented marginally. Maximizing representation of rarity among future-climate potential distributions (Fig. 3D), a first area included 25 species and the second added 7 more.

Most species' modeled geographic distributions overlapped at least one existing protected area in the CEE region. Indeed, the intersection of either present-day and future-climate maps indicated that only *Hippolais olivetorum* and *Falco eleonorae* do not intersect

any of the protected areas; all other species are expected to be represented in one or more protected areas (Fig. 2).

DISCUSSION

The relative lack of detailed, modern, point-based distributional data represented the main limitation in the development of this project. Observational data sets were extensive for Western Europe, but sources for CEE were very few. A reliable source of occurrence localities is the large base of natural history museum specimens (Peterson et al. 1998,

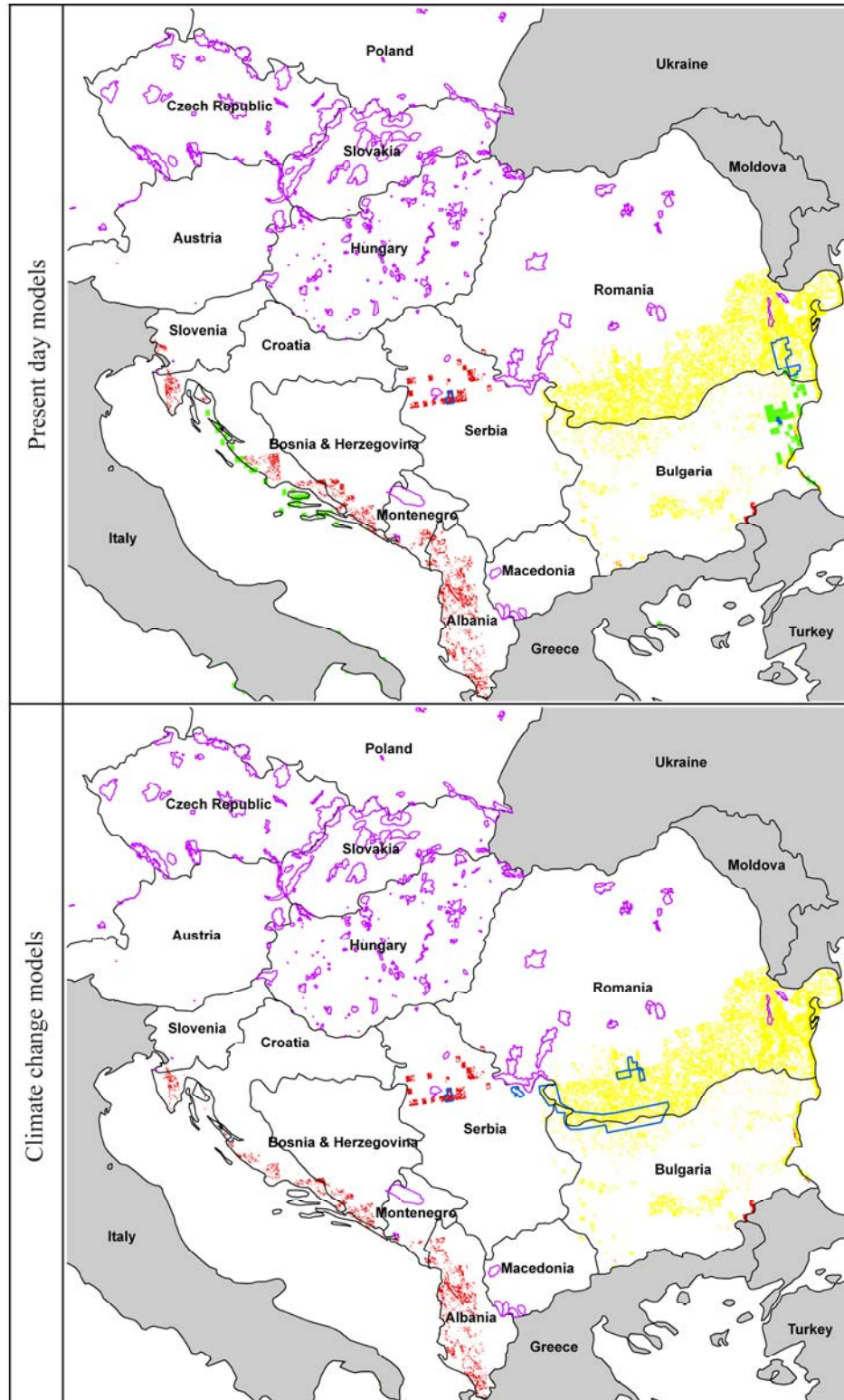


Figure 4. Location of reserves (purple) in CEE with respect to the distributional predictions of *Branta ruficollis* (yellow), *Falco eleonora* (green), and *Hippolais olivetorum* (red), and priority areas (blue) under present-day and future-climate conditions.

Collar et al. 2003, Peterson et al. 2005); nonetheless, because little recent specimen acquisition (e.g., salvage for threatened species) has occurred, it proved difficult to assemble large suites of point-occurrence information. Because of these limitations, full validation of models (e.g., Peterson 2001) based on predictions into unsampled regions was not always possible, so some models may not prove to be as robust as would be desired.

The ENM approach used herein has been tested in numerous studies (e.g. Peterson & Cohoon 1999; Peterson et al. 1999; Peterson 2001; Peterson & Vieglais 2001; Peterson et al. 2001; Stockwell & Peterson 2002; Anderson et al. 2003), and has been shown to produce robust distributional predictions under most conditions. The predictions are based on models of ecological niches and as such--as with any model--are subject to the assumptions outlined earlier in this paper. It must be borne in mind that I focused on identifying potential areas where threatened or/and rare species may occur in CEE. Because models were based on occurrences across Europe and western Asia, I avoided problems with incomplete representation of species' ecological potential as much as possible (Pearson & Dawson 2003).

Predicted distributions obtained from ENM approaches offer several clear advantages over raw occurrence information when used in synthetic analyses such as the place-prioritization analyses herein (Rojas-Soto et al. 2003, Sánchez-Cordero et al. 2005). Whereas raw occurrence data have biases of detectability and sampling effort, and may focus attention on historically surveyed areas that no longer hold populations of species, modeled distributions as input information for these models can overcome these biases to an impressive degree (Soberón & Peterson 2004). The cost, of course, is that any results from this model-based prioritization exercise should be validated and supplemented by targeted field validation (Pressey & Cowling 2001). As such, this approach helps to compensate for the lack of comprehensive distributional data in regional conservation planning.

In general, overlap between species' modeled distributions and existing protected areas was extensive (Fig. 2), suggesting that most species already see some degree of protection. Exceptions were *Falco eleonora* and *Hippolais olivetorum*,

which were not predicted to be present in any reserve, and *Branta ruficollis*, which was predicted to occur in only one. Hence, if the existing reserve system were a reliable protector of species distributed in each reserve, much of the challenge would have been met. Over half of the 36 species were predicted to be present in reserves in >9 countries. Of course, given the need for on-ground model validations, and given variable levels of intersection between reserve boundaries and species' distributions, actual protection afforded may be less. Broadening the summary of protected areas I used, which omitted reserves in Albania, Bulgaria, Bosnia and Herzegovina, and Croatia, would improve this picture somewhat.

The results of this study identified focal areas for threatened birds in CEE. All were situated along the lower Danube River, in areas little covered by existing protected areas (Fig. 4). Basically, foci were identified that included the bulk of the species; special additional areas were necessary to include the problematic *Branta ruficollis*, *Falco eleonora*, and *Hippolais olivetorum*. Judging by the results obtained, and particularly comparing potential distributions under present-day and future-climate conditions, the whole lower Danube River basin is identified as 'of special interest' for a regional conservation scheme. Targeted data collection in the areas identified herein would be key in validating model predictions for each species, and (more importantly) in verifying the importance of focal areas identified in this study.

Another important issue is that of land use changes that have occurred in the past couple of decades in this region due to important political and social changes. To my knowledge, a comprehensive analysis of these transformations is not yet available; however, other studies assessing the possible future land use change in western and central Europe (Rounsevell et al. 2006; Verburg et al. 2006) based on climate change economic scenarios show large reduction in cropland and grassland areas due to extensive technological development. At a more regional (western and eastern Carpathian mountains) and shorter time (last decade) scale, it was observed that both forest and cropland areas decreased while the non-forest natural vegetation and cropland/natural vegetation mosaic areas increased (Dezso et al. 2005). These studies also identified land abandonment to be a

common phenomenon. All these findings emphasize the need for conservation planning along the lower Danube River.

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