Evaluating a focal-species approach for tidal marsh bird conservation in the northeastern United States

Authors: Klingbeil, Brian T., Cohen, Jonathan B., Correll, Maureen D., Field, Christopher R., Hodgman, Thomas P., et al.

Source: The Condor, 120(4) : 874-884

Published By: American Ornithological Society

URL: https://doi.org/10.1650/CONDOR-18-88.1

THE CONDOR
Ornithological Applications
AmericanOrnithology.org

Volume 120, 2018, pp. 874–884
DOI: 10.1650/CONDOR-18-88.1

RESEARCH ARTICLE

Evaluating a focal-species approach for tidal marsh bird conservation in the northeastern United States

Brian T. Klingbeil,[1a]* Jonathan B. Cohen,[2] Maureen D. Correll,[3] Christopher R. Field,[1] Thomas P. Hodgman,[4] Adrienne I. Kovach,[5] Brian J. Olsen,[3] W. Gregory Shriver,[6] Whitney A. Wiest,[6,7] and Chris S. Elphick[1]

[1] Department of Ecology and Evolutionary Biology, Center for Conservation and Biodiversity and Institute of Biological Risk, University of Connecticut, Storrs, Connecticut, USA
[2] SUNY College of Environmental Science and Forestry, Department of Environmental and Forest Biology, Syracuse, New York, USA
[3] School of Biology and Ecology, University of Maine, Orono, Maine, USA
[4] Maine Department of Inland Fisheries and Wildlife, Bird Group, Bangor, Maine, USA
[5] Department of Natural Resources and the Environment, University of New Hampshire, Durham, New Hampshire, USA
[6] Department of Entomology and Wildlife Ecology, University of Delaware, Newark, Delaware, USA
[7] South Carolina Field Office, U.S. Fish and Wildlife Service, Charleston, South Carolina, USA
[a] Current address: School of Forestry and Wildlife Sciences, Auburn University, Auburn, Alabama, USA
* Corresponding author: brian.klingbeil@auburn.edu

Submitted June 11, 2018; Accepted August 19, 2018; Published October 24, 2018

ABSTRACT

Insufficient time and funding remain obstacles to collecting data across broad spatial scales on the fine-scale distribution of multiple species, their life histories, and interactions with other species and the environment. This often necessitates the use of focal species to inform conservation and management decisions. We used the systematic conservation-planning software Marxan to assess quantitatively whether a focal species can aid in conservation and management of tidal marsh birds. Using a metric of relative cost in the region and current protected areas, we identified priority areas for conservation of 5 specialist taxa—Clapper Rail (*Rallus crepitans*), Eastern Willet (*Tringa semipalmata semipalmata*), Acadian Nelson's Sparrow (*Ammospiza nelsoni subvirgatus*), Saltmarsh Sparrow (*A. caudacuta*), and Seaside Sparrow (*A. maritima*)—that nest primarily in tidal marshes in the northeastern United States. We compared the spatial prioritization of sites and cost-effectiveness of alternative protection scenarios that considered individual species, groups of species, and all species simultaneously to evaluate the appropriateness of a focal-species approach. Scenarios that prioritized areas for conservation based on single-species targets were poorly correlated across species. Scenarios based on Saltmarsh Sparrow conservation were most strongly related ($r_s = 0.759$) to site prioritizations that considered all 5 tidal marsh specialists simultaneously. When comparing multispecies combinations to prioritizations based on the Saltmarsh Sparrow alone, the estimated costs, area of land protection, and number of individuals of each species protected were similar. These results suggest that no species is a good surrogate for another but that the Saltmarsh Sparrow may be a viable focal species for conservation planning to protect tidal marsh birds as a group. By evaluating protection scenarios for all species, we were able to identify areas where conservation is likely to have little or no effect, which could be as important for decision making as identifying the best sites.

Keywords: avian, Marxan, protected areas, salt marsh, systematic conservation planning

Évaluation de l'approche par espèce focale pour la conservation des oiseaux de marais côtiers dans le nord-est des États-Unis

RÉSUMÉ

Le manque de temps et de financement demeurent des obstacles à la collecte de données à grande échelle sur la distribution à fine échelle de plusieurs espèces, leur histoire naturelle et les interactions avec d'autres espèces et l'environnement. Cela nécessite souvent l'utilisation d'espèces focales pour permettre des décisions éclairées pour la conservation et la gestion. Nous avons utilisé le logiciel de planification systématique de conservation Marxan afin d'évaluer quantitativement si une espèce focale peut aider dans la conservation et la gestion des oiseaux de marais côtiers. Nous avons identifié des aires prioritaires pour la conservation de cinq taxons de spécialistes (*Rallus crepitans*, *Tringa semipalmata semipalmata*, *Ammospiza nelsoni subvirgatus*, *Ammospiza caudacuta et Ammospiza maritima*) qui nichent principalement dans les marais côtiers à l'aide d'une mesure du coût relatif pour la région et des aires protégées actuelles. Nous avons comparé la priorisation spatiale des sites et le rapport coût-efficacité de scénarios de protection alternatifs qui considèrent les espèces individuelles, les groupes d'espèces et toutes les espèces simultanément pour évaluer la pertinence d'une approche par espèce focale. Les scénarios qui priorisaient les aires pour la conservation sur la base d'une seule espèce cible était peu corrélés parmi les espèces. Les scénarios basés sur la conservation d'*A. caudacuta* étaient les plus reliés ($r_s = 0{,}759$) aux priorisations de sites qui considéraient les cinq spécialistes des marais côtiers simultanément. En comparant les combinaisons multi-spécifiques aux priorisations basées sur *A. caudacuta* seulement, les coûts estimés, l'aire de protection et le nombre d'individus de chaque espèce protégée étaient similaires. Ces résultats suggèrent qu'aucune espèce n'est un bon substitut pour une autre mais qu'*A. caudacuta* peut être une espèce focale viable pour la planification de la conservation afin de protéger le groupe des oiseaux de marais côtiers. En évaluant des scénarios de protection pour toutes les espèces, nous avons été en mesure d'identifier les zones où la conservation est susceptible d'avoir peu ou pas d'effet, ce qui pourraient être aussi important pour la prise de décision que d'identifier les meilleurs sites.

Mots-clés : aires protégées, aviaire, marais salé, Marxan, planification systématique de la conservation

INTRODUCTION

Covering just 9% of the Earth's surface but supporting >25% of humans (Kummu et al. 2016), coastal environments are among the most economically important yet vulnerable ecosystems (Barbier et al. 2011, Arkema et al. 2013). People have long relied on coastal wetlands for highly productive farmland and easy access to the sea for food, travel, and commerce, making them ideal for human settlement. Coastal wetlands also sequester carbon, filter pollutants, buffer against storms, support fisheries, and provide recreational opportunities (Gedan et al. 2009). Despite their importance, ≥25% of the world's coastal wetlands have been lost through conversion for human use (McLeod et al. 2011), and much of the remaining area is vulnerable to sea-level rise.

Tidal marshes are a type of coastal wetland restricted to a narrow strip along temperate coasts (Chapman 1977). Many are situated near areas of high human development, making them among the most economically important yet vulnerable ecosystems, with this vulnerability exacerbated by sea-level rise (Arkema et al. 2013). The eastern coast of North America is home to over one-third of the global extent of tidal marsh and the highest level of vertebrate endemism of any tidal marsh region worldwide (Greenberg and Maldonado 2006). Tidal marshes in the Northeast support a wide range of habitat specialist and generalist avian species throughout the year, but not all birds are equally vulnerable to habitat loss and degradation (Greenberg and Maldonado 2006, Correll et al. 2017). The negative relationship between population trend and degree of tidal marsh specialization indicates that the more specialized a species is to tidal marsh habitat, the less likely it is to persist in this ecosystem over time (Correll et al. 2016). This relationship exemplifies the tradeoffs between specialist and generalist life history strategies, with specialists reaching higher densities than generalists within their defined niche space but being outperformed in degraded or fragmented habitats (Dennis et al. 2011). Over 100 species were observed in a recent survey of northeastern tidal marshes, yet 5 species in particular—Clapper Rail (*Rallus crepitans*), Eastern Willet (*Tringa semipalmata semipalmata*), Acadian Nelson's Sparrow (*Ammospiza nelsoni subvirgatus*), Saltmarsh Sparrow (*A. caudacuta*), and Seaside Sparrow (*A. maritima*)—were identified to have a high degree of marsh specialization (Correll et al. 2016). These taxa use coastal marshes almost exclusively as breeding habitat, usually nesting within a few centimeters of the ground (Cornell Lab of Ornithology 2015), making them particularly vulnerable to habitat loss or degradation and to sea-level rise. Indeed, long-term population declines have recently been identified in 3 of the 5 species (Correll et al. 2017), suggesting that increased attention from the conservation community is necessary.

Current efforts to prioritize action for bird conservation in North America are at least partly determined with a focal-species strategy (USFWS 2011, Atlantic Coast Joint Venture 2017). The focal-species approach attempts to incorporate processes that threaten species viability, such as fragmentation or loss and degradation of habitat, into conservation assessments (Lambeck 1997). Focal species are often species of high conservation concern that are vulnerable to key threats. Their management is expected to confer protection to other co-occurring species facing similar threats (Fleishman et al. 2000, Favreau et al. 2006, Nicholson et al. 2013, Lindenmayer et al. 2014). To enhance the likelihood of success and engagement of stakeholders, the role of the species as a potential unifier for partnerships and the likelihood that factors affecting its status can be realistically addressed are also primary considerations for the U.S. Fish and Wildlife Service (USFWS) (Lindenmayer et al. 2002, USFWS 2011). Based on these criteria, each of the 5 species characterized as being tidal marsh specialists have potential to guide conservation because their fates are closely linked to the future of tidal marshes. Considering secondary factors, the Saltmarsh Sparrow and Clapper Rail appear to be especially strong candidates and potentially work as a pair because they partially segregate by marsh elevation. Both species are of management interest, but for distinct reasons. The Saltmarsh Sparrow faces near-term extinction (Field et al. 2017, 2018), whereas the Clapper Rail is a more abundant, but declining, popular game species (Correll et al. 2017). Together, they represent the full range of marsh habitat and could bring together different stakeholders needed to achieve conservation success at regional scales (e.g., Powell et al. 2017). Despite this reasoning, a danger exists in relying principally upon value-laden choices or predefined criteria rather than systematically evaluating all potential possibilities (Fleishman et al. 2000, Branton and Richardson 2011). The effectiveness of a focal-species approach is contingent upon the assumption that management interventions aimed at conserving those focal species will confer protection on a number of co-occurring species and will not compromise the protection of others (Lambeck 1997, USFWS 2011, Lindenmayer et al. 2014). Consequently, the use of focal species to delineate areas for conservation may be ineffective if focal species do not reliably co-occur with other species of interest (Andelman and Fagan 2000). The assumption that other species are receiving protection as a result of the protection of a focal species, therefore, needs to be evaluated (Lindenmayer et al. 2014).

We used systematic conservation planning methods to evaluate use of a focal-species approach to planning for the protection of multiple, co-occurring tidal marsh species. Systematic conservation planning was developed specifically to identify priority area networks that ensure the representation and persistence of biodiversity. This approach is widely considered the standard for identifying spatial priorities for conservation investment (Margules and Pressey 2000, Kukkala and Moilanen 2013). To determine whether a focal species can aid in conservation and management of tidal marsh birds, we (1) used systematic conservation planning to identify priority areas for 5 species that rely on tidal marsh for breeding in the Northeast; (2) explicitly compared the cost-effectiveness of planning options focused on alternative focal species; (3) examined a mixed-species strategy, stratifying specialists by subhabitat and stakeholder interests; and (4) compared focal-species approaches to an alternative that prioritized areas for protection for all 5 species simultaneously. These results can be applied to real-world management of tidal marsh birds throughout the northeastern United States.

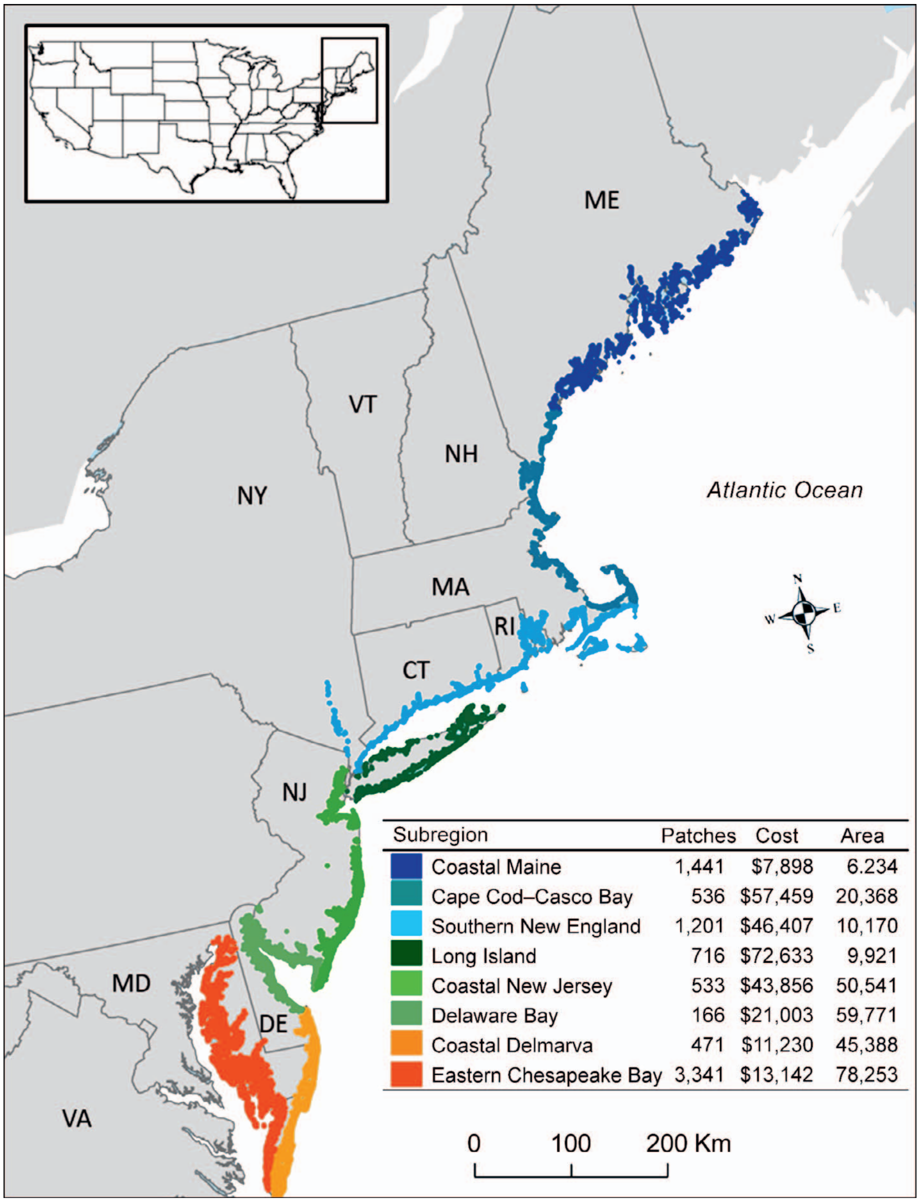
METHODS

We used Marxan 2.43 (Ball et al. 2009) to identify priority areas for protection of the 5 study species. We prioritized 8,405 saltmarsh patches between Maine and Virginia, USA (Figure 1), based on scenarios (i.e. species and their associated population targets) described below. Saltmarsh patches between Maine and Virginia were delimited by creating a 50 m buffer around Estuarine Intertidal Emergent Wetland polygon features (Cowardin et al. 1979) identified in the National Wetlands Inventory (USFWS 2010). Polygons with buffers that intersected were joined into a single patch. Selection of the buffer distance between patches was based on home range size and movement estimates for Acadian Nelson's and Saltmarsh sparrows verified in the field within the study region (Shriver et al. 2010). Home range information was not available for the other species, but sizes are likely to be similar or larger, meaning that use of the other species would, if anything, reduce the resolution of the analysis. Full details of saltmarsh patch creation appear in Wiest et al. (2016). Saltmarsh patches were preferred over a regular grid for spatial prioritization because they are biologically relevant spatial units restricted to the habitat of interest that provide a direct link between conservation prioritization and the location and extent of a particular marsh and its inhabitants.

Each saltmarsh patch was associated with estimates of density for each of the 5 species derived from a comprehensive regional survey of marsh birds in 2011 and 2012 (Wiest et al. 2016). A Bayesian network model incorporated a suite of environmental covariates and survey results that were adjusted to account for imperfect detection in order to estimate population density in all 8,405 saltmarsh patches found in the region (Wiest et al. 2018). Density estimates indicated that Clapper Rails, Eastern Willets, and Seaside Sparrows had population sizes $>$100,000 in the northeastern United States, whereas Saltmarsh ($<$60,000) and Acadian Nelson's ($<$7,000) sparrows had much lower population sizes in the region (Wiest et al. 2016, 2018).

To account for current protected areas in our spatial prioritization, we used the Protected Areas Database (USGS Gap Analysis Program 2012) and our saltmarsh patch layer (Wiest et al. 2016) to identify the overlap between existing protected areas and saltmarsh patches. We considered only areas with permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state (i.e. GAP status 1 or 2). Areas with a GAP status of 3 or 4 were not included because they may be subject to extractive uses. Protected areas and saltmarsh patches rarely overlapped perfectly, so the percentage of each saltmarsh patch protected was quantified.

As a measure of the relative expense of conservation for each patch, we estimated the land cost for each patch from county-level asset values (U.S. dollars ha^{-1}) of agricultural land including buildings (U.S. Department of Agriculture 2012). Although the actual cost associated with purchasing saltmarsh patches will most likely differ from the average county value, and outright purchase is not the only conservation option available to managers, this approach provides an index of relative costs across the region. Patches that spanned multiple counties received an average of the county estimates. Final cost estimates incorporated protected-area information and reflected



Subregion	Patches	Cost	Area
Coastal Maine	1,441	$7,898	6.234
Cape Cod–Casco Bay	536	$57,459	20,368
Southern New England	1,201	$46,407	10,170
Long Island	716	$72,633	9,921
Coastal New Jersey	533	$43,856	50,541
Delaware Bay	166	$21,003	59,771
Coastal Delmarva	471	$11,230	45,388
Eastern Chesapeake Bay	3,341	$13,142	78,253

Figure 1. Delineation of 8 tidal marsh subregions in northeastern North America (after Wiest et al. 2016), with location of the study region in the United States (inset). The table shows total number of patches, mean cost of land purchase (U.S. dollars ha^{-1}), and area (ha) for each subregion.

only the relative cost of adding unprotected land within a patch.

Marxan was used to identify priority areas for protection based on percentage-based targets that range from 10% to 100% of the current population estimate, at 10% intervals. We examined these targets for each species individually and for all 5 species simultaneously. Marxan offers a number of heuristic algorithms to identify a reserve system that minimizes the total cost of sites in a network, while meeting a set of targets for conservation features (Ball et al. 2009). We evaluated all scenarios using a simulated annealing algorithm followed by a 2-step iterative improvement algorithm. An optional parameter, the boundary length modifier, promotes selection of contiguous planning units by attempting to reduce the total boundary length of the full reserve network. We set this parameter equal to zero because we had no reason to favor selection of spatially clustered sites. Marxan also includes the option to force planning units into or out of a solution a priori, based on information available to the user (e.g., to reflect currently protected areas or areas that are known to be unavailable for selection). We used this option to force all saltmarsh patches with ≥99% of their area overlapping current protection to be represented in solutions. Patches with only partial protection were not forced into solutions, because doing so can lead to more costly reserve systems that do not support larger populations of target species (see Supplemental Material).

We constrained all analyses so that each species had to be represented by at least the minimum population target in all runs. To force targets to be met, a species penalty factor was incorporated to make potential solutions that did not meet targets more costly than solutions for which targets were represented. The species penalty factors were set to 100 in individual species scenarios and to 1,000 for Saltmarsh Sparrow and Acadian Nelson's Sparrow in some multispecies analyses to ensure that targets were achieved. The penalty factor is a setting in Marxan that facilitates meeting the target for rare or "costly" species when they are included in scenarios with widely distributed or "inexpensive" species. These penalty factors were the lowest possible values that allowed Marxan flexibility to find an efficient solution, while ensuring that at least the minimum targets were met in all runs for all species (Ball et al. 2009, Ardron et al. 2010).

Marxan output provides a selection frequency that shows the number of times each planning unit was selected in the optimal solution of a run, out of all runs of a given scenario. To quantify selection frequency, we ran each percentage-based scenario 10,000 times with 1 million simulated annealing algorithm iterations in each run. Sensitivity analysis showed that scenarios run with at least 1 million iterations and 10,000 runs would be highly similar to those run with more iterations yet still provide flexibility to explore alternative solutions, but that fewer iterations could lead to substantially different results (see Supplemental Material). We used Spearman rank correlations and the selection frequency from each scenario to determine whether scenarios that prioritize conservation of different species ranked sites in a similar way, which would suggest they are interchangeable from the perspective of site selection. For example, we compared the selection frequency of Saltmarsh Sparrow, with a target of protecting 50% of the current population, to the selection frequency of Clapper Rail, with a target of protecting 50% of the current population. These comparisons allowed us to determine how well each species represented each other species at a particular population target, as well as the maximum strength of association between each species pair. We also quantified the average correlation of each species pair across all 10 population targets (i.e. 10–100%). To determine how well a single species represents the suite of 5 species, we used the same process to quantify the maximum and average Spearman rank correlations between the selection frequency of sites prioritized by each species and that based on all species combined. To identify patterns relevant for species conservation in the Northeast, we used the selection frequency to characterize the relative importance of particular patches and determined the corresponding area in each subregion (Figure 1) that was required to achieve a particular conservation target. We classified saltmarsh patches in the region by the number of times they were selected in 10,000 near-optimal solutions. We distinguished patches that were (1) selected in all 10,000 optimal solutions; (2) selected in at least one, but not all, optimal solutions; and (3) not selected in any optimal solution. We chose this classification scheme to facilitate interpretation and avoid any arbitrary designation of importance (for all results, see https://databasin.org/galleries/545d42aee349487baf5fa5586d647fe5#expand=100981).

To directly inform management decisions in the region and determine how single-species approaches perform compared to multispecies approaches, we used Marxan to estimate the number of birds represented, the number of saltmarsh patches, area protected, and the relative cost of the lowest cost solutions for 5 scenarios with predetermined combinations of species. We identify a scenario by its constituent species because comparisons were made with a population target of 50,000 individuals for each species (except Acadian Nelson's Sparrow; see below): (1) Saltmarsh Sparrow (SALS); (2) Clapper Rail (CLRA); (3) Saltmarsh Sparrow and Clapper Rail (SALS + CLRA); (4) Saltmarsh Sparrow, Clapper Rail, Eastern Willet, and Seaside Sparrow (4TMB; i.e. tidal marsh birds); and (5) Saltmarsh Sparrow, Clapper Rail, Eastern Willet, Seaside Sparrow, and Acadian Nelson's Sparrow (5TMB). This represents a reasonable population target for conservation planning in the region that provides a clear buffer, beyond that likely needed to ensure long-term viability, allowing for strong protection to ensure that subpopulations can be spread across the region to provide geographic representation (Tear et al. 2005, Traill et al. 2010). We explore scenarios with and without Acadian Nelson's Sparrow because it has a distinctly northern geographic distribution in relation to the other species and it hybridizes with Saltmarsh Sparrow within a portion of our study region (Walsh et al. 2015), but it is still a species of management concern. In order to include Acadian Nelson's Sparrow, we use a population target equal to 99.9% of the current population estimate (6,617 individuals), in addition to 50,000 individuals for each of the other 4 species, because the current population size is much smaller than 50,000 individuals within the study region.

Marxan was used to identify a single "best" solution that minimizes cost compared to all other solutions identified from each run. The lowest-cost solutions were more sensitive to the number of iterations than to the number of runs, and a greater number of iterations generally identified a more efficient reserve system, often with a significantly lower cost (see Supplemental Material).

Table 1. Mean (lower triangle) and maximum (upper triangle) of 10 Spearman rank correlation coefficients for association between site prioritizations of percentage-based targets (10–100% of current population) that differ in the target (species) identity but not the target amount. Associations are based on selection frequency of Marxan output with 10,000 runs and 1 million iterations.

Target	CLRA	SALS	SESP	NESP	WILL	SALS + CLRA + NESP + SESP + WILL
Clapper Rail (CLRA)		0.202 (50%) [a]	0.383 (100%)	0.093 (10%)	0.535 (20%)	0.497 (10%)
Saltmarsh Sparrow (SALS)	0.192		0.304 (80%)	−0.010 (30%)	0.438 (100%)	0.759 (90%)
Seaside Sparrow (SESP)	0.359	0.295		0.027 (50%)	0.427 (100%)	0.579 (10%)
Nelson's Sparrow (NESP)	0.072	−0.026	0.011		0.005 (20%)	0.276 (10%)
Eastern Willet (WILL)	0.511	0.415	0.382	−0.048		0.657 (80%)
SALS + CLRA + NESP + SESP + WILL	0.411	0.719	0.438	0.261	0.642	

[a] Value in parentheses indicates species target amount (10–100% of current population) where highest correlation coefficient occurred.

Therefore, we used 100 million iterations of the simulated annealing algorithm and 100 repeat software runs to identify the lowest-cost solution for each of the 5 management scenarios with a population target of 50,000 for each species (except Acadian Nelson's Sparrow; see above). To quantify uncertainty, we repeated this process (100 million iterations of the simulated annealing algorithm, and 100 repeat software runs) 10 times for each scenario and identified the lowest-cost solution from each of the 10 groups of 100 runs. We take this approach, rather than use the selection frequency from a single set of 100 runs, to ensure that we are using a distribution of the best possible scenarios, given the data. We calculated the minimum, mean, and 95% confidence intervals based on the 10 lowest-cost solutions for the number of birds represented, the number of saltmarsh patches, the area protected, and the metric of relative cost (based on land values in U.S. dollars) of the lowest-cost solutions. We compare these 4 characteristics among the 5 scenarios to determine whether a single focal species (scenario 1: SALS or scenario 2: CLRA) provides equivalent representation as scenarios that evaluate multiple focal species (scenario 3: SALS + CLRA and scenario 4: 4TMB) or all species (scenario 5: 5TMB).

RESULTS

Correlations of single-species site prioritizations suggest that those for Clapper Rail and Eastern Willet were most similar, although the strength of this association was low, as were all other single-species comparisons (maximum $r_s < 0.535$; Table 1). Of the 5 species, site prioritization based on Saltmarsh Sparrow conservation was most strongly associated with prioritization based on all 5 species combined (maximum $r_s = 0.759$; Table 1).

Comparison of alternative suites of focal-species targets to be used in conservation plans further indicated that site selection decisions based on Saltmarsh Sparrow alone have high potential to serve as an effective surrogate for tidal marsh bird conservation (Figure 2). For example, the optimal solution for protecting 50,000 Saltmarsh Sparrows will also protect at least that many Clapper Rails and Eastern Willets, as well as >175,000 Seaside Sparrows. Protection for Nelson's Sparrow was less adequate but still ensured that >45% of the U.S. population would be in protected patches. The best scenario for Clapper Rail, by contrast, failed to protect >27,000 individuals of any of the other species, although the cost was substantially lower. Comparing the scenario for Saltmarsh Sparrows to the 3 multispecies scenarios shows few additional benefits in numbers of birds protected, area required, or difference in cost (Figure 2). Acadian Nelson's Sparrow did not reach target population sizes in any scenario in which it was not included (Figure 2).

The proportion of marshland identified as most valuable varied among species, among regions, and with the population goal levels (Figure 3). When the goal was to protect 90% of a population, relatively large areas (up to half, or more) were selected in every model run for several scenarios. For all species except Nelson's Sparrow, such areas were especially common in the southern regions, such as Delaware Bay and coastal New Jersey. For lower population goals (e.g., protecting only 50% of the population), there was more flexibility as to which sites were selected, with very few appearing in every model run.

Across the different scenarios, there was considerable variation in the proportion of marsh area that never contributed to the chosen solution (Figure 3). Areas were more likely to be selected at least sometimes in the more southern subregions. Nonetheless, there were patches that were never selected in any solution, regardless of the target species (Figure 4). Subregions differed in the percentage of saltmarsh patches that never contributed to an optimal solution, with few in southern New England, Long Island, Delaware Bay, or coastal Delmarva.

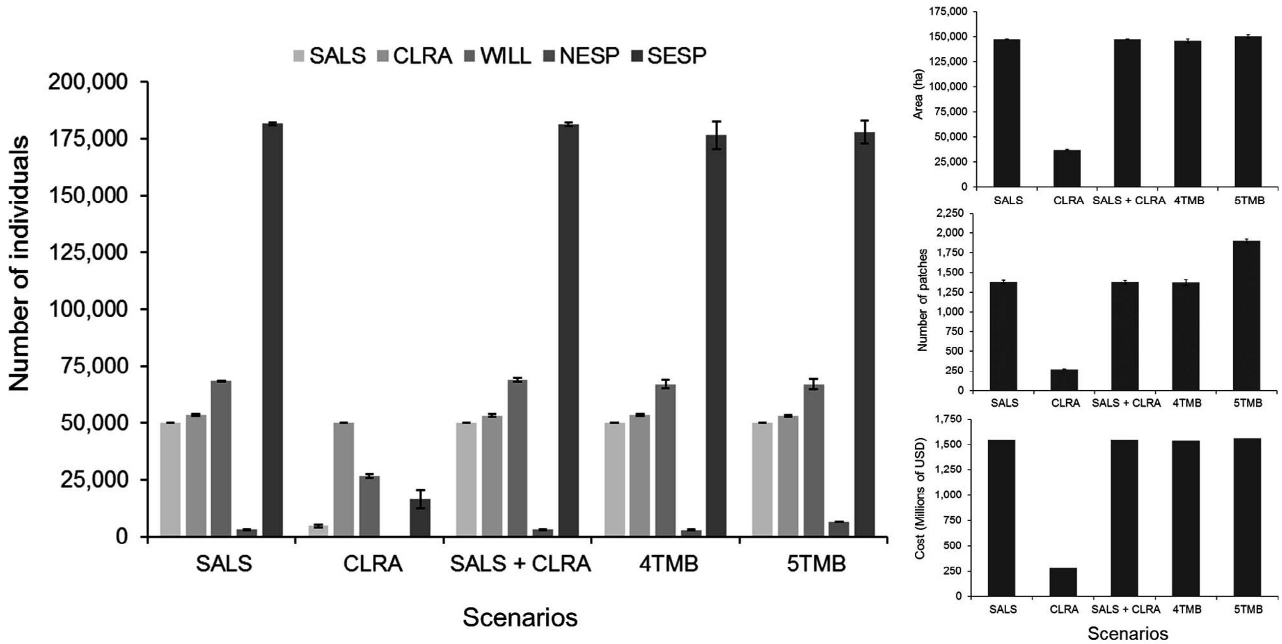


Figure 2. Level of protection for each of 5 management scenarios, with 2 single-species scenarios (Saltmarsh Sparrow [SALS]; Clapper Rail [CLRA]) and 3 multispecies combinations (SALS + CLRA; 4TMB: Saltmarsh Sparrow, Clapper Rail, Eastern Willet [WILL], and Seaside Sparrow [SESP]; and 5TMB: SALS, CLRA, WILL, SESP, and Acadian Nelson's Sparrow [NESP]). In each scenario, Marxan was used to ensure representation of 50,000 individuals of each target species, except NESP, for which the goal was set at 99.9% of current population size (6,617 individuals). For each protection scenario, we present mean and 95% confidence interval of (**A**) number of individuals, (**B**) saltmarsh area, and (**C**) number of saltmarsh patches protected, as well as (**D**) minimum cost index (see text and Supplemental Material regarding interpretation of cost) based on 100 runs in Marxan using 10 million simulated annealing iterations, repeated 10 times.

DISCUSSION

Many stated objectives for conservation (e.g., maximize biodiversity) are too vague to be useful within a decision-making framework and often less effective at garnering support from the public than a single "flagship" species (Tear et al 2005, Caro 2010, Thomas-Walters and Raihani 2017). Management that only considers a single species-specific outcome (e.g., game species), however, may be too restrictive and inefficient to achieve the broad conservation goals of many organizations (Laitila and Moilanen 2012, Gallo and Pejchar 2016). A compromise is to find a species that can be used to garner support, while also functioning as a focal species, such that management interventions aimed at conserving the focal species will confer protection on a large number of co-occurring species (Lambeck 1997, Lindenmayer et al. 2014). We show that spatial prioritization software widely used for conservation is also an effective tool to evaluate the potential for species or species groups to function as focal species for conservation (e.g., Nicholson et al. 2013, Jones et al. 2016).

For tidal marsh bird conservation in the Northeast, multiple factors suggest that the Saltmarsh Sparrow and Clapper Rail are ideal candidates for focal species. Comparison of single-species site prioritizations with a comprehensive prioritization based on all species identified the Saltmarsh Sparrow, but not the Clapper Rail, as the best option considered for a representative focal species to prioritize land for protection. However, prioritizing for the conservation of one species necessarily limits the resources for conservation of other species, so it is critically important to understand how a focus on Saltmarsh Sparrow would affect planning for other species of interest. We found that the relative costs, area of land protection, and numbers of individuals of nonfocal species on protected land were similar when planning for Saltmarsh Sparrow compared to any of the 3 scenarios that evaluated multispecies combinations of saltmarsh birds. These results suggest that if increased attention and funds are focused on protecting and managing Saltmarsh Sparrow populations, other species are unlikely to suffer. By contrast, planning focused solely on the Clapper Rail, the other species identified by predefined criteria, failed to protect population targets for any additional species, although the lower relative cost of this scenario may allow for additional protection elsewhere.

Identification of a focal species, like the Saltmarsh Sparrow, that can act as a surrogate for a group of species has advantages and limitations (Rodrigues and Brooks

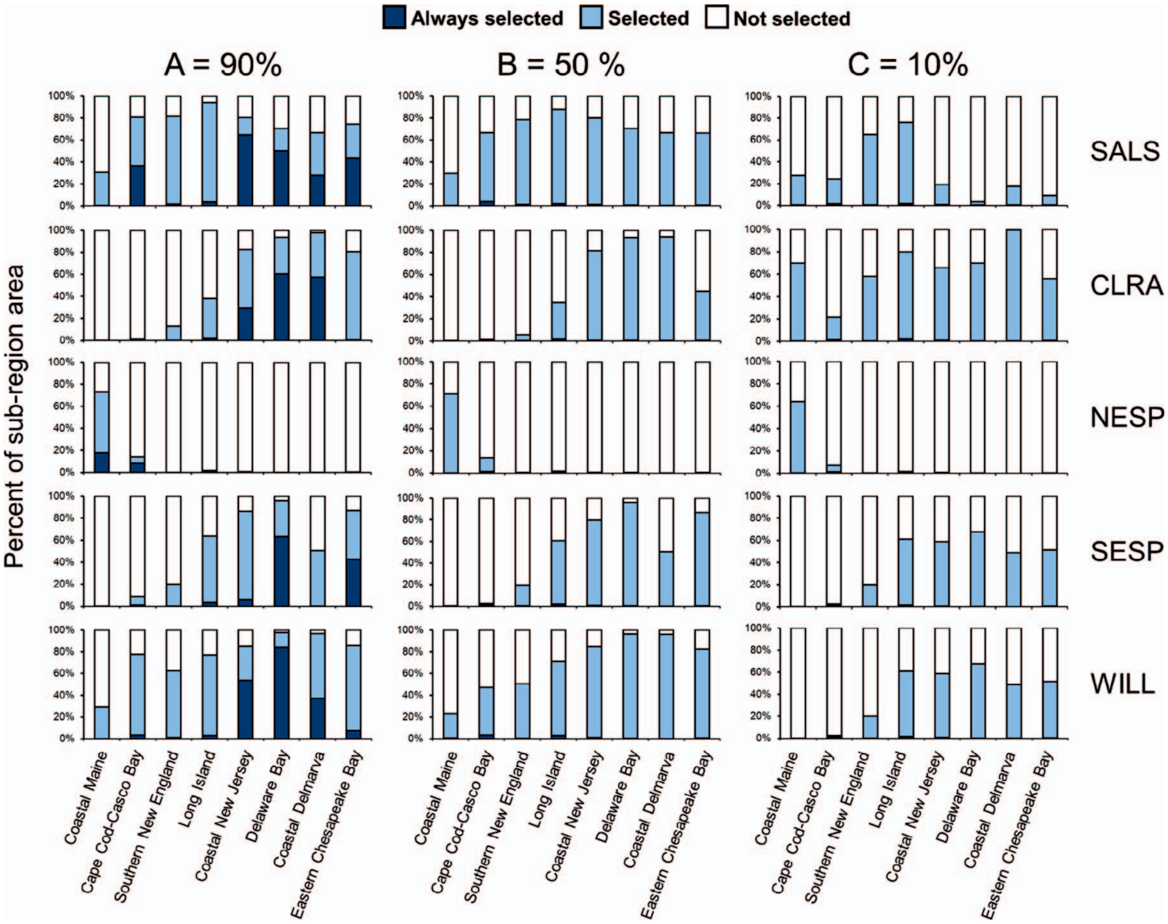


Figure 3. Relative importance of marsh area in each subregion for conserving each of 5 tidal marsh birds (Saltmarsh Sparrow [SALS], Clapper Rail [CLRA], Acadian Nelson's Sparrow [NESP], Seaside Sparrow [SESP], and Eastern Willet [WILL]) at 3 population targets (**A**: 90% of the current population; **B**: 50% of the current population; **C**: 10% of the current population). Percentage of area in each subregion is identified as always selected (patches occurred in solutions for all 10,000 Marxan software runs), selected (patches occurred in solutions for 1–9,999 Marxan software runs), and not selected (patches did not occur in a solution for any of 10,000 Marxan software runs).

2007, Caro 2010, Branton and Richardson 2011). In the current conservation climate, in which time and resources are in short supply, a focal species may be a useful starting point for decision making that can facilitate rapid and efficient land management. For example, the Atlantic Coast Joint Venture—a collaboration among agencies and other organizations engaged in bird conservation along the U.S. East Coast—has identified Saltmarsh Sparrow as a focal species for coastal marsh conservation (ACJV 2017). Moreover, it may be cost effective to focus time and effort on monitoring a single species rather than a suite of species. However, a focal-species approach can be ineffective if the species fails to capture the conservation needs of the species group of interest (Andelman and Fagan 2000, Lindenmayer et al. 2002). Populations of all specialist marsh species face similar threats of habitat loss (e.g., human modification, sea-level rise), although they may differ in sensitivity to other factors such as predation, inbreeding, and stressors on wintering grounds. Spatial prioritization that incorporates information about additional species for the same saltmarsh patches used in the current analysis and that evaluates the use of cost estimates for other conservation methods could be used to evaluate whether the Saltmarsh Sparrow is an adequate focal species for tidal marsh species in general. Our approach, with freely available software, enables easy recalculation and data sharing, facilitating coordination between local, regional, and national efforts to guide land purchases that maximize efficiency.

Deciding when to purchase land and when to hold on to limited resources is one of the most important conservation decisions. Availability of land is often unpredictable, requiring quick investment decisions (for an approach that incorporates scheduling of priority area acquisition, see Alagador et al. 2014). Spatial prioritization and systematic conservation planning were developed in response to the

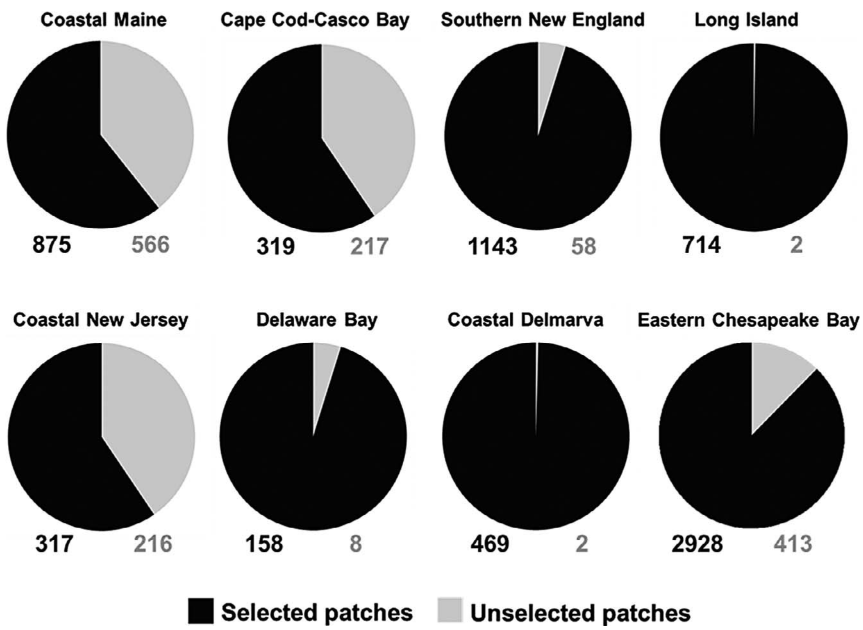


Figure 4. Number of selected and unselected saltmarsh patches in each of 8 subregions (mapped in Figure 1). Patches were classified as unselected if they were never included in any solution from 10,000 Marxan runs of 6 scenarios designed to protect 100% of the current population of each of 5 tidal marsh specialists individually or all 5 species combined.

criticism that protecting biodiversity in an ad hoc fashion was an inefficient use of limited funding (Pressey 1993). In general, however, the approach has been used largely to identify just the very best sites. Analyses can also be used to identify sites that are least likely to contribute to conservation planning goals, which would be poor conservation investments. Our analysis identified a substantial number of saltmarsh patches that were never selected in scenarios that protect each species at their current population size. Identifying low-priority patches where conservation is likely to have little or no effect is another valuable benefit of spatial prioritization that can reduce risks associated with conservation investments, yet this information is often unavailable.

Our results highlight the importance of incorporating a quantitative spatial prioritization approach into systematic conservation planning. However, our study is not without limitations and hurdles to widespread implementation. First, our study relied on high-quality distribution data to estimate the density of each species in every patch. This allowed us to quantify differences in the number of birds protected in alternative site prioritizations. A common critique of focal-species approaches is that these data are rarely available for many taxa or regions of conservation interest (Lindenmayer et al. 2002, Pimm et al. 2014). Second, our study was narrowly focused on 5 species from a restricted taxonomic subset in a single habitat. Many studies assess how well focal species represent large subsets of diverse groups of species in multiple habitats or even biodiversity as a whole (e.g., Favreau et al. 2006, Rodrigues and Brooks 2007, Larsen et al. 2009). It would be difficult to assess all possible combinations of a large suite of species with the approach we undertook, although advances in cloud computing and parallel processing (e.g., http://marxan.net; Watts and Possingham 2013) may increase the numbers of species and systems to which this approach can be applied. Third, prioritizing land for conservation on the basis of minimizing a relative index of cost is only one of many important aspects that need to be considered within the larger context of conservation. Ideally, this step occurs within the framework of strategic conservation planning, after it has been identified as a necessary complement to other sources of data. This is because, for many species, opportunities to conserve areas and protect species exist beyond simply purchasing land. For tidal marsh birds, some regions with extensive marsh area, such as along the U.S. Gulf Coast, have substantial land that may be relatively safe from development but are threatened by other activities (e.g., pollution, energy extraction and production). Fourth, sea-level rise and increased intensity of storms are likely to be dominant threats to the persistence of tidal marsh birds in the Northeast in the future (Powell et al. 2017). Our spatial prioritizations are based on current conditions and do not reflect projections of sea-level rise or possible synergistic effects that could greatly reduce demographic rates due to increased frequency of flooding events (Field et al. 2017) or increased predation rates (Hunter 2017). Integrating models of sea-level rise with the spatial prioritizations developed for the present study could enhance long-term conservation efforts by identifying high-priority areas that are at risk of inundation, areas likely to be safe from inundation, and areas in which the future state is uncertain.

ACKNOWLEDGMENTS

Funding statement: This work was primarily funded by a grant from the U.S. Department of the Interior, Fish and Wildlife Service (USFWS) and North Atlantic Landscape Conservation Cooperative through the Disaster Relief Appropriations Act of 2013 (award no. F14AC00965) and relied heavily on data collected using a Competitive State Wildlife Grant (U2-5-R-1) via USFWS, Federal Aid in Sportfish and Wildlife Restoration to the states of Delaware, Maryland, Connecticut, and Maine. We received additional funding that supported the work from USFWS (Cooperative Agreement Award Fl5AC00163) and the National Science Foundation (DEB-1340008). Funders had no input into the content of the manuscript and did not require their approval before submission or publication. The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of USFWS.

Ethics statement: No live birds were used in this study.

Author contributions: B.T.K., J.B.C., C.S.E., T.P.H., A.I.K., B.J.O., and W.G.S. conceived the idea. M.D.C., C.R.F., and W.A.W. collected the data. B.T.K. and W.A.W. analyzed the data. B.T.K. and C.S.E. wrote the paper with input from all other authors.

Data deposits: ArcGIS shapefiles of spatial prioritization scenarios for each species will be uploaded to a freely accessible online database (https://databasin.org/galleries/545d42aee349487baf5fa5586d647fe5).

LITERATURE CITED

Alagador, D., J. O. Cerdeira, and M. B. Araújo (2014). Shifting protected areas: Scheduling spatial priorities under climate change. Journal of Applied Ecology 51:703–713.

Andelman, S. J., and W. F. Fagan (2000). Umbrellas and flagships: Efficient conservation surrogates or expensive mistakes? Proceedings of the National Academy of Sciences USA 97: 5954–5959.

Ardron, J. A., H. P. Possingham, and C. J. Klein (2010). Marxan Good Practices Handbook. Pacific Marine Analysis and Research Association, Vancouver, BC, Canada.

Arkema, K. K., G. Guannel, G. Verutes, S. A. Wood, A. Guerry, M. Ruckelshaus, P. Kareiva, M. Lacayo, and J. M. Silver (2013). Coastal habitats shield people and property from sea-level rise and storms. Nature Climate Change 3:913–918.

Atlantic Coast Joint Venture (2017). Flagship Species Initiative. http://acjv.org/flagship-species-initiative/

Ball, I. R., H. P. Possingham, and M. Watts (2009). Marxan and relatives: Software for spatial conservation prioritisation. In Spatial Conservation Prioritization: Quantitative Methods & Computational Tools (A. Moilanen, K. A. Wilson, and H. Possingham, Editors). Oxford University Press, Oxford, UK.

Barbier, E. B., S. D. Hacker, C. Kennedy, E. W. Koch, A. C. Stier, and B. R. Silliman (2011). The value of estuarine and coastal ecosystem services. Ecological Monographs 81:169–193.

Branton, M., and J. S. Richardson (2011). Assessing the value of the umbrella-species concept for conservation planning with meta-analysis. Conservation Biology 25:9–20.

Caro, T. (2010). Conservation by Proxy: Indicator, Umbrella, Keystone, Flagship, and Other Surrogate Species. Island Press, New York, NY, USA.

Chapman, V. J. (1977). Introduction. In Wet Coastal Ecosystems (V. J. Chapman, Editor). Elsevier, New York, NY, USA.

Cornell Lab of Ornithology (2015). Birds of North America Online. http://bna.birds.cornell.edu/bna/

Correll, M. D., W. A. Wiest, T. P. Hodgman, W. G. Shriver, C. S. Elphick, B. J. McGill, K. M. O'Brien, and B. J. Olsen (2017). Predictors of specialist avifaunal decline in coastal marshes. Conservation Biology 31:172–182.

Correll, M. D., W. A. Wiest, B. J. Olsen, W. G. Shriver, C. S. Elphick, and T. P. Hodgman (2016). Habitat specialization explains avian persistence in tidal marshes. Ecosphere 7:e01506.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe (1979). Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. U.S. Fish and Wildlife Service, Washington, DC, USA.

Dennis, R. L. H., L. Dapporto, S. Fattorini, and L. M. Cook (2011). The generalism–specialism debate: The role of generalists in the life and death of species. Biological Journal of the Linnean Society 104:725–737.

Favreau, J. M., C. A. Drew, G. R. Hess, M. J. Rubino, F. H. Koch, and K. A. Eschelbach (2006). Recommendations for assessing the effectiveness of surrogate species approaches. Biodiversity & Conservation 15:3949–3969.

Field, C. R., T. S. Bayard, C. Gjerdrum, J. M. Hill, S. Meiman, and C. S. Elphick (2017). High-resolution tide projections reveal extinction threshold in response to sea-level rise. Global Change Biology 23:2058–2070.

Field, C. R., K. J. Ruskin, B. Benvenuti, A. Borowske, J. B. Cohen, L. Garey, T. P. Hodgman, R. A. Kern, E. King, A. R. Kocek, A. I. Kovach, et al. (2018). Quantifying the importance of geographic replication and representativeness when estimating demographic rates, using a coastal species as a case study. Ecography 41:971–981.

Fleishman, E., D. D. Murphy, and P. F. Brussard (2000). A new method for selection of umbrella species for conservation planning. Ecological Applications 10:569–579.

Gallo, T., and L. Pejchar (2016). Improving habitat for game animals has mixed consequences for biodiversity conservation. Biological Conservation 197:47–52.

Gedan, K. B., B. R. Silliman, and M. D. Bertness (2009). Centuries of human-driven change in salt marsh ecosystems. Annual Review of Marine Science 1:117–141.

Greenberg R. G., and J. E. Maldonado (2006). Diversity and endemism in tidal-marsh vertebrates. Studies in Avian Biology 32:32–53.

Hunter, E. A. (2017). How will sea-level rise affect threats to nesting success for Seaside Sparrows? The Condor: Ornithological Applications 119:459–468.

Jones, K. R., A. J. Plumptre, J. E. M. Watson, H. P. Possingham, S. Ayebare, A. Rwetsiba, F. Wanyama, D. Kujirakwinja, and C. J. Klein (2016). Testing the effectiveness of surrogate species for conservation planning in the Greater Virunga Landscape, Africa. Landscape and Urban Planning 145:1–11.

Kukkala, A. S., and A. Moilanen (2013). Core concepts of spatial prioritisation in systematic conservation planning. Biological Reviews of the Cambridge Philosophical Society 88:443–464.

Kummu, M., H. de Moel, G. Salvucci, D. Viviroli, P. J. Ward, and O. Varis (2016). Over the hills and further away from coast: Global geospatial patterns of human and environment over the 20th–21st centuries. Environmental Research Letters 11: 034010.

Laitila, J., and A. Moilanen (2012). Use of many low-level conservation targets reduces high-level conservation performance. Ecological Modelling 247:40–47.

Lambeck, R. J. (1997). Focal species: A multi-species umbrella for nature conservation. Conservation Biology 11:849–856.

Larsen, F. W., J. Bladt, and C. Rahbek (2009). Indicator taxa revisited: Useful for conservation planning? Diversity and Distributions 15:70–79.

Lindenmayer, D. B., P. W. Lane, M. J. Westgate, M. Crane, D. Michael, S. Okada, and P. S. Barton (2014). An empirical assessment of the focal species hypothesis. Conservation Biology 28:1594–1603.

Lindenmayer, D. B., A. D. Manning, P. L. Smith, H. P. Possingham, J. Fischer, I. Oliver, and M. A. McCarthy (2002). The focal-species approach and landscape restoration: A critique. Conservation Biology 16:338–345.

Margules, C. R., and R. L. Pressey (2000). Systematic conservation planning. Nature 405:243–253.

McLeod, E., G. L. Chmura, S. Bouillon, R. Salm, M. Björk, C. M. Duarte, C. E. Lovelock, W. H. Schlesinger, and B. R. Silliman (2011). A blueprint for blue carbon: Toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2. Frontiers in Ecology and the Environment 9:552–560.

Nicholson, E., D. B. Lindenmayer, K. Frank, and H. P. Possingham (2013). Testing the focal species approach to making conservation decisions for species persistence. Diversity and Distributions 19:530–540.

Pimm, S. L., C. N. Jenkins, R. Abell, T. M. Brooks, J. L. Gittleman, L. N. Joppa, P. H. Raven, C. M. Roberts, and J. O. Sexton (2014). The biodiversity of species and their rates of extinction, distribution, and protection. Science 344:1246752.

Powell, E. J., M. C. Tyrrell, A. Milliken, J. M. Tirpak, and M. D. Staudinger (2017). A synthesis of thresholds for focal species along the U.S. Atlantic and Gulf Coasts: A review of research and applications. Ocean & Coastal Management 148:75–88.

Pressey, R. L., C. J. Humphries, C. R. Margules, R. I. Vane-Wright, and P. H. Williams (1993). Beyond opportunism: Key principles for systematic reserve selection. Trends in Ecology & Evolution 8:124–128.

Rodrigues, A. S. L., and T. M. Brooks (2007). Shortcuts for biodiversity conservation planning: The effectiveness of surrogates. Annual Review of Ecology, Evolution, and Systematics 38:713–737.

Shriver, W. G., T. P. Hodgman, J. P. Gibbs, and P. D. Vickery (2010). Home range sizes and habitat use of Nelson's and Saltmarsh sparrows. The Wilson Journal of Ornithology 122: 340–345.

Tear, T. H., P. Kareiva, P. L. Angermeier, P. Comer, B. Czech, R. Kautz, L. Landon, D. Mehlman, K. Murphy, M. Ruckelshaus, J. M. Scott, and G. Wilhere (2005). How much is enough? The recurrent problem of setting measurable objectives in conservation. BioScience 55:835–849.

Thomas-Walters, L., and N. J. Raihani (2017). Supporting conservation: The roles of flagship species and identifiable victims. Conservation Letters 10:581–587.

Traill, L. W., B. W. Brook, R. R. Frankham, and C. J. A. Bradshaw (2010). Pragmatic population viability targets in a rapidly changing world. Biological Conservation 143:28–34.

U.S. Department of Agriculture (2012). Data generated by National Agricultural Statistics Service. https://www.nass.usda.gov

U.S. Fish and Wildlife Service (2010). Data generated by National Wetlands Inventory. http://www.fws.gov/wetlands/Data/State-Downloads.html

U.S. Fish and Wildlife Service (2011). Migratory Bird Program. https://www.fws.gov/birds/management/managed-species/focal-species.php

USGS Gap Analysis Program (2012). Protected Areas Database of the United States. http://gapanalysis.usgs.gov/padus/

Walsh, J., W. G. Shriver, B. J. Olsen, K. M. O'Brien, and A. I. Kovach (2015). Relationship of phenotypic variation and genetic admixture in the Saltmarsh–Nelson's sparrow hybrid zone. The Auk: Ornithological Advances 132:704–716.

Watts, M. E., and H. P. Possingham (2013). Marxan.net: Cloud infrastructure for systematic conservation planning. http://marxan.net

Wiest, W. A., M. D. Correll, B. G. Marcot, B. J. Olsen, C. S. Elphick, T. P. Hodgman, G. R. Guntenspergen, and W. G. Shriver (2018). Estimates of tidal marsh bird densities using Bayesian networks. The Journal of Wildlife Management 82. In press.

Wiest, W. A., M. D. Correll, B. J. Olsen, C. S. Elphick, T. P. Hodgman, D. R. Curson, and W. G. Shriver (2016). Population estimates for tidal marsh birds of high conservation concern in the northeastern USA from a design-based survey. The Condor: Ornithological Applications 118:274–288.