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Benefits of Engineered Habitats to Seasonal Bird Communities on the Savannah Harbor Navigation Project, Dredged Material Containment Areas, 1994-2012

Michael P. Guilfoyle, J. Stevan Calver, Sam S. Jackson,
Mary E. Richards, and Richard A. Fischer

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Benefits of Engineered Habitats to Seasonal Bird Communities on the Savannah Harbor Navigation Project, Dredged Material Containment Areas, 1994-2012

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Abstract

This report presents the results of a long-term habitat and trend analyses of bird community data from a monitoring effort conducted on five Dredged Material Containment Areas (DMCAs) from 1994 to 2012. The USACE Savannah District developed and implemented a Long-Term Management Strategy (LTMS) for the DMCAs in 1996 to mitigate lost wetland habitat due to maintenance operations in the Savannah Harbor, and to provide habitat for the floral and faunal communities that otherwise would be available if not for the urban and economic development of the area. Bimonthly surveys were conducted from 1994 to 2012 to assess the effectiveness of the LTMS to provide seasonal habitat for the bird community. Archived quarterly satellite imagery was collected and analyzed from 2001 to 2011 to assess year-round seasonal habitat availability. All bird community data collected were fitted to a negative binomial (mean abundance) or Poisson distribution (mean species richness) and used to assess trends for 180 individual species and 12 species groups for spring, summer, fall, and winter seasons from 1994 to 2012. Results indicate that the Savannah DMCAs support stable to increasing populations of most species and species groups during each season, including many species ranked as regional priority species.

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Preface

This study was conducted by the U.S. Army Corps of Engineers, U.S. Army Research and Development Center, Vicksburg, MS. Funding was provided through the Dredging Operations Environmental Research (DOER) and Engineering With Nature® (EWN) programs, Project No. 485301, Task No. A1000. Fieldwork was funded by the U.S. Army Corps of Engineers, Savannah District, Savannah, GA.

The work was performed by the Ecological Resources Branch, of the Ecosystem Evaluation and Engineering Division, U.S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, Dr. Jennifer Seiter-Moser was the Chief, Ecological Resources Branch; Dr. Mark Farr was Chief, Ecosystem Evaluation and Engineering Division; and Dr. Al Cofrancesco was the Technical Director. The Deputy Director of ERDC-EL was Dr. Jack E. Davis and the Director was Dr. Iker R. Adiguzel.

This work represents more than 4,600 hours of observations by Mr. J. S. Calver during 517 days in the field from February 27, 1994 through September 30, 2012. Ellie Covington (currently with USACE, San Francisco District, California) provided essential reports and archived satellite imagery for this effort. Ms. Katie Percy assisted with data checking and database management and Dr. Jonathon J. Valente performed all statistical analyses in the R 3.1.2 program and created all figures in Appendices C, D, E, F, and G. Drs. Burton Suedel and Jacob Jung, both of ERDC-EL, provided internal reviews. Johanna S. Guilfoyle provided artwork for Figure 3-5.

COL Teresa A. Schlosser was Commander of ERDC, and Dr. David W. Pittman was the Director.

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Executive Summary

This study compiled and analyzed satellite imagery and bimonthly bird community surveys conducted from 1994 to 2012 on the USACE Savannah District, Savannah Harbor Navigation Project (SHNP), Dredged Material Containment Areas (DMCAs), in Jasper County, South Carolina; and on part of the harbor in Savannah, Georgia. Statistical analyses of population trend results are provided from long-term seasonal monitoring of the bird communities using the DMCAs. Implementation of a Long-Term Management Strategy (LTMS) initiated a rotation system where some areas received dredged material for 3 years while other areas remained untouched. This approach was designed to maintain approximately 267 (659 acres) open water habitat and 204 (505 acres) of wetland habitat in mitigation for lost wetlands due to ongoing operations on the SHNP and DMCAs.

We evaluated and confirmed the capability of the LTMS to maintain these habitat types using an ArcGIS iterative self-organizing data analysis (ISODATA) of satellite imagery taken from 2001 to 2011. We used Bayesian community generalized linear models using negative binomial distributions to assess mean seasonal abundance trends for 180 bird species detected during the monitoring effort. Generalized linear mixed models using Poisson distributions were used to test for species richness trends of 12 species groups. Habitat variables determined from the ArcGIS ISODATA were incorporated into generalized mixed linear models where we used abundance data as additive functions of habitat availability for open water, mudflat, shrub-scrub, and barren land.

Monitoring efforts detected 297 species; 180 species represented counts suitable for trend analyses. Total counts of these 180 species were greater than 5.7 million birds over the monitoring period. We focused results on those species regionally identified as Highest, High, and Moderate Priority Species based on their status as rare, sensitive, or in need of conservation attention as identified by Partners in Flight (PIF) in the Southeastern Coastal Plain Bird Conservation Region (BCR). Fifty-one ranked priority species were among 84 waterbirds detected in five species groups (Gulls/Terns, Large Shorebirds, Small Shorebirds, Wading Birds, and Waterfowl). No priority-ranked species experienced significant declines during the monitoring period, and many species showed non-significant trends or increasing trends during some seasons. Among species showing increasing trends were several transient migratory species (e.g., Dunlin

and Semipalmated Plover) and wintering species (e.g., Long- and Short-billed Dowitchers), which showed that the effort to create habitats that provide demonstrable benefits to non-breeding populations is possible. Trend results for non-waterbird species are also presented.

Results of habitat relationship analyses show that many shorebird species and waterfowl species have significant positive relationships to availability of mud flat and open water habitats. Breeding behavior by 11 priority-ranked species on islands created in the DMCAs is documented. Results are discussed in terms of the USACE mission to create, enhance, and manage coastal infrastructure, including maintenance dredging of ports and harbors. Many imperiled waterbirds along the Atlantic Coast are migratory transients or over-wintering species in the region. Future listing of such species under the U.S. Endangered Species Act (ESA) may further compromise the USACE mission along the Atlantic Coast. The construction and management of the SHNP DMCAs represent a prototype approach that incorporates USACE EWN principles and could be replicated in other ports and harbors along the Atlantic Coast and elsewhere.

1 Introduction

1.1 Background

The U.S. Army Corps of Engineers (USACE) is responsible for maintaining our coastal infrastructure, including ports, harbors, and shoreline stabilization features; and for maintaining the Intracoastal Waterway System (ICW) (Guilfoyle et al. 2019). Dredging operations are used regularly to maintain port and harbor depths sufficient to support international and national commerce. Natural coastal sedimentation processes are altered by maintenance dredging and shoreline armoring, both of which may reduce natural formation of coastal habitats, including beaches, sand spits, mud flats, marshes, and other wetland habitats (Guilfoyle et al. 2019). These changes can reduce or degrade important coastal habitat for local and regional floral and faunal species. In addition, maintenance dredging operations can yield significant amounts of sediment material that must be disposed locally, or at nearshore or offshore deposition sites. Dredged material from ports and harbors in large urban areas may also be contaminated by urban and industrial pollutants, including heavy metals and other toxic chemicals used in industrial processes. Contaminated dredged material is required to be placed in confined disposal facilities (CDFs) that reduce exposure to the human population and that are designed to minimize contaminated discharge into the local environment (USACE and USEPA 2003).

Beneficial uses of dredged material for habitat and wetland creation often target coastal and inland waterbirds and comprise an established feature of the USACE dredging operations program (Soots and Landin 1978; Fischer et al. 2004, 2010; Guilfoyle et al. 2006, 2007). Recently, engineering operations that provide environmental benefits have been incorporated into the USACE Engineering With Nature (EWN®) initiative, which seeks to integrate infrastructure development and environmental enhancement to generate both good management and environmental benefits (Banks et al. 2013, Bridges et al. 2018).

Engineering operations and the use of dredged material to create habitat for native floral and faunal species have often been combined to mitigate the loss of habitat that results from coastal engineering projects. However, the USACE EWN initiative is proactive; it works to provide environmental

benefits through regular infrastructure maintenance activities (Bridges et al. 2018). USACE is a national leader in ecological restoration (Thom et al. 2004), and the use of dredged material is often important in beach, wetland, marsh, and mudflat creation and enhancement (Fischer et al. 2004, 2010; Guilfoyle et al. 2006, 2007; Bridges et al. 2018).

On the Savannah Harbor Navigation Project (SHNP), Savannah, Georgia, five Dredged Material Containment Areas (DMCAs) were enhanced via specific management actions in response to mitigation requirements for wetland habitat losses from ongoing deepening of the harbor and maintenance dredging operations. The Long-Term Management Strategy (LTMS), which was implemented in 1996 (USACE 1996), incorporates innovative engineering principles to ensure consistent availability of critical open water, island, wetland, and mudflat habitats for seasonal waterbirds, consistent with the USACE EWN initiative (Guilfoyle et al. 2020, Calver et al. 2016).

The need for mitigation or ecosystem restoration along coastlines is driven by the large-scale changes from urban population growth and residential expansion, industrial development, accumulated waste and pollution, sea-level rise, global climate change, and the continued modification of coastal sediment deposition processes from coastal engineering and shoreline stabilization. However, specific management operations and habitat creation efforts may be limited in their application since long-term post-project monitoring data required to test and evaluate the success or failures of such efforts are often insufficient or nonexistent (Guilfoyle et al. 2019).

However, the development and implementation of the LTMS for management and maintenance dredged material deposition operations in the DMCAs in the Savannah Harbor, Georgia, is different. When the USACE Savannah District developed and implemented the LTMS on the DMCAs, they also proactively worked to perform bimonthly inventories of the seasonal bird community beginning in 1994 (Calver et al. 2016). A prime objective of the LTMS was to ensure the maintenance of approximately 266.7 ha (659 acres) of open water habitat and 204.4 ha (505 acres) of wetland habitat year-round DMCAs (USACE 1996, Calver et al. 2016). In addition, eight, 2-acre islands and one, 4-acre ha island have been created in the DMCAs to provide nesting habitat for breeding shorebirds, colonial waterbirds, terns, and gulls (Calver et al. 2016). These data represent a

unique opportunity to assess the long-term impacts of the LTMS to maintain consistent amounts of open water and wetland habitats and to document the specific species that are benefited by this effort. Calver et al. (2016) provides an introduction to this effort with an initial report on the number and species richness of birds using the DMCAs seasonally, including large numbers of species regionally ranked as priority species by South Atlantic Migratory Bird Initiative (SAMBI) (Watson and Malloy 2008).

1.2 Objectives

Ideally, monitoring and assessment of mitigation or ecosystem restoration efforts should be compared to regional reference sites, where the goal of the effort is to achieve comparable measures of biological metrics between the reference sites and newly created or restored areas. Since the long-term monitoring of habitats created and managed on the DMCAs did not include the identification and monitoring of a reference site, we have chosen to define the success or failure of the LTMS on the DMCAs in two ways, by: (1) using available satellite data to show the consistent habitat availability of open water and wetland habitats as stated in the LTMS, and (2) evaluating long-term abundance and species richness trends of individual bird species and species groups using seasonal habitats on the DMCAs. Successful creation of habitats for seasonal bird communities is assessed by determining whether abundance and richness trends show statistically significant increasing trends, or presence but stable trends (not significantly increasing) during one or more seasons for species identified by SAMBI as regional species of concern. Success of the effort could be described as moderate or poor if regionally identified species are either present in low numbers or show significantly decreasing abundance or richness trends during the monitoring period.

Here, we subject the long-term seasonal bird community data to a rigorous statistical analysis to identify significant trends and habitat relationships for seasonal bird communities. The specific objectives of our efforts are to: (1) use an ArcGIS iterative self-organizing data analysis (ISODATA) algorithm approach to analyze multispectral satellite imagery to assess the seasonal availability of various habitat types (open water, mud flat, barren land, sand, herbaceous wetland, and shrub-scrub areas), (2) to fit Bayesian community generalized linear models with negative binomial regression (for mean abundance models) and Poisson distributed regression (for

mean richness models) to assess and identify significant seasonal trends for individual species and species groups during the monitoring period, and (3) to assess habitat relationships for species and species groups using generalized linear mixed models with abundance and richness metrics as additive functions of habitat availability variables in the analyses.

1.3 Approach

1.3.1 Procure and assess aerial images of SHNP DMCAS

With assistance from USACE Savannah District personnel, we were able to procure 33 hyperspectral satellite images. Only hyperspectral images can be used in the ArcGIS ISODATA and such images were only available from 2001 to 2011. Results from the ISODATA analysis was used to document that the amount of open water and wetland habitats were being sustained as according to the LTMS. Also, amounts of various habitats (open water, mud flat, shrub-scrub, and barren land) available seasonally for the bird community was used in statistical trend analyses to assess relative importance of habitat types contributing to positive, negative, or stable trends for individual species or species groups.

1.3.2 Procure and analyze population trends of the seasonal bird community

Data collected by J. Stevan Calver and colleagues were entered into Microsoft Excel® and checked for accuracy (Calver et al. 2016). We used a Bayesian community generalized linear mixed model approach with bird and species group abundance fitted into a negative binomial distribution, and species richness for each species group fitted into a Poisson distribution. We used the 'jags UI' 1.4.2 package (Kellner 2016) in the R 3.1.1 program (R Core Team 2014) to test for significant increasing or decreasing trends during the monitoring period. Significant seasonal population trends for abundance and species richness, positive, negative, or non-significant, were determined based on overlap of the logarithmic means and confidence intervals.

1.3.3 Statistically assess long-term seasonal bird community data to determine effects of habitat availability on seasonal bird population trends

We used a generalized linear mixed modeling approach to assess the effects of habitat availability on mean abundance and species richness of the seasonal bird community. We modeled abundance (binomial distribution) and species richness (Poisson distribution) as additive functions of available open water, mud flat, shrub-scrub, and barren land habitat attributes. Significant effects of habitat availability on seasonal trends for abundance of individual species and species groups, positive, negative, or non-significant, were determined as with abundance/species richness trends, based on the overlap of the logarithmic means and confidence intervals.

1.4 Scope

This report targets USACE land managers or districts that manage or regulate coastal engineering projects or operations of various CDFs. However, the results of this effort may be of significant interest to all biologists and land managers interested in habitat creation or restoration to benefit seasonal waterbirds, shorebirds, and waterfowl. Results presented and methods described should be considered for monitoring on other USACE project lands or coastal engineering operations, and other state, federal, or private landowners who have an interest and objectives to manage coastal lands for sustained seasonal use by populations of rare, sensitive, or regionally identified avian species of concern.

2 Methods

2.1 Study area

The DMCAs are located along the north shore of the Savannah River, northern coastal area in Jasper County, South Carolina (Figure 2-1). There are additional containment areas located west along the Savannah River (1A and 2A), plus the Jones Oyster Island just east of 14A; however, these areas were not subjected to avian community surveys by USACE and are therefore not considered in this report. When surveys began in 1994, there were six DMCAs (12A, 12B, 13A, 13B, 14A, and 14B), but two of the areas were combined to form one DMCA in 2011 (13A; see Figure 2-1). The areas surveyed in this effort consist of approximately 1,883 hectares (4,529 acres) of land (Figure 2-1) (area determined through ArcGIS mapping and habitat analysis effort; see section below). Along the periphery of the site, exists approximately 60 hectares (148 acres) of woodland, varying in width from about 23 to 91 m (75 to 300 ft.). The remaining 181 hectares (448 acres) is made up primarily of roads, dike slopes, and other open high ground; these areas are usually mowed at least once a year. Further description of the DMCAs, including dominate plant communities, are provided in Calver et al. (2016).

2.2 ArcGIS analysis and habitat mapping

Satellite imagery used in this study was provided by the USACE Savannah District and were obtained from various sources. This was primarily due to the frequency of analyses requiring quarterly assessments every year for each of the DMCAs. High-spectral imagery is required for this analysis; therefore, only imagery from late 2001 to 2011 was used (Table A-1). Quarterly summaries of each DMCA area were made from the best available hyperspectral imagery provided. The imagery sources were Landsat, GeoEye-1, and WorldView (DigitalGlobe).

Figure 2-1. An aerial view of the SHNP, Dredged Material Containment Areas (sections 12A, 13A, 13B, 14A, and 14B), Jasper County, South Carolina.



Environmental Systems Research Institute, Inc. (ESRI) ArcGIS version 10.5 was used to derive spectrally distinct classes within the disposal areas. An unsupervised image classification technique was used for this study. In unsupervised classifications, statistical clustering algorithms were used to analyze the digital values in each band of imagery and to determine the number of statistically distinct features or clusters in the image. Specifically for this study, and because very limited ground truth information was available, an unsupervised ISODATA clustering algorithm was used. ISODATA is a widely used clustering algorithm that makes a large number of passes through an image using a minimum spectral distance formula to form clusters. It begins with either arbitrary cluster means or means of an existing signature set, and each time the clustering repeats, the means of these clusters are shifted. The new cluster means are used for the next iteration. The iterative process continues until statistically distinct class features emerge.

The classification workflow tool in ArcGIS 10.5 was used to perform the ISODATA algorithm. A maximum of 10 sample intervals was specified to have an output of six distinct classes. The minimum class pixel size was 20, so a class had to have at least 20 pixels or more cells to be assigned. The output classes were aggregated to remove small segmented regions and smoothed to remove any speckling noise to produce the final result. Class names and definitions were then assigned to the classification result and named as follows: Open water, Mud Flat, Shrub/Scrub Vegetation, Barren Land, Sand, and Herbaceous Wetland. Efforts to maintain consistent availability of open water and wetland habitat and directed in the LTMS (USACE 1996) can be assessed by determining the average annual amounts of open water, mud flats, and herbaceous wetlands determined during the analysis. Not every class was identified with each classification performed, and in some cases, only four or five final classes were derived depending on the seasonally changing land cover. It is recommended to derive a statistically random number of samples within each class and conduct a site visit to determine and identify each spectrally distinct class that was derived from the unsupervised classification. However, when not accessible, information from other sources such as high-resolution aerial photography, or other photographs, can help assign class definitions to each separate class identified.

2.3 Seasonal bird community monitoring

Calver et al. (2016) provides a detailed description of the monitoring approach used during the bimonthly surveys. In short, the approach consisted of an area search (Guilfoyle and Fischer 2007), where the DMCA's were surveyed and all birds detected by sight or sound were recorded, and start and stop time data were recorded to determine the length of time for all surveys. Surveys were intended to represent complete counts of all birds present; therefore, total time required to conduct the surveys varied depending on time of the year, current weather conditions, number of birds present, among other factors. Surveys were generally conducted twice per month, but on occasion, no surveys were conducted in some months, and occasionally, three or more surveys were conducted in a single month. Summary data presented in Calver et al. (2016) included total counts of all surveys, including surveys in which not all the DMCA's were sampled during a single visit. For this report, only data from survey efforts in which all DMCA's were sampled are included. Surveys began in the early morning hours (generally before 0730 Eastern Standard Time [EST]) and ended at dusk (generally around 1830 EST); surveys periods varied according to time of year and day length available for surveys.

Surveys were conducted during periods of relatively good weather; no surveys were conducted on days with heavy wind, rain, or other precipitation. From 1994 to 1998, vehicle surveys were conducted using a Bausch & Lomb® tripod-mounted scope and 25X eyepiece. During the survey, an observer exited the vehicle and set up the mounted scope to count shorebirds and waterfowl. Beginning on September 14, 1998, a Swarovski® HD80 scope with 60X zoom eyepiece was used. Beginning in 2002, shorebird and waterfowl counts were made primarily using a window-mounted scope. Efforts to count raptors, waders, waterfowl, and shorebirds were designated as “shorebird hours” and efforts to count other passerines and non-passerines were designated as “small bird hours.” A total of 580 surveys were conducted during the monitoring period, with a total of approximately 5,520 hours completed. Approximately 3,546 hours were spent monitoring shorebirds and 1,975 hours spent on small birds during the monitoring period. All birds detected by sight or sound within the DMCA boundaries were counted, whether they were flying or stationary. Survey boundaries were judged to be the boundary of area between property associated with the DMCA and adjacent habitats.

2.4 Statistical trends and habitat relationships data analyses

2.4.1 Trend analyses

2.4.1.1 Mean abundance trends

Surveys were limited to only those that were conducted at all DMCA's. This left us with 580 surveys (91 winter, 170 spring, 164 summer, 155 fall). Any species detected during fewer than 10% of surveys in any season was eliminated (as there simply were not enough data to estimate trends for those birds). This resulted in 180 species recorded during the monitoring period that were then placed into one of 12 species groups:

1. Blackbirds
2. Gulls and Terns
3. Grassland Birds
4. Large Shorebirds
5. Marsh Birds
6. Other Non-Passerines
7. Passerines
8. Raptors
9. Small Shorebirds
10. Wading Birds
11. Warblers
12. Waterfowl.

For each species or species group in each season, a Bayesian community generalized linear mixed model was fixed with time treated as a fixed effect, and year as a random grouping variable. Bird abundance data were fitted to a negative binomial distribution. Community models estimate species-specific trends within a hierarchical framework where estimates are related through community-level hyperparameters (Kéry and Royle 2008, Zipkin et al. 2009). The full advantages of such an approach are detailed elsewhere (Kéry and Royle 2008, Royle and Dorazio 2008, Zipkin et al. 2009, Iknayan et al. 2014), but we chose this approach for two primary reasons. First, by borrowing information from more common species, the approach allows inclusion of rarer species in the analysis (Royle and Dorazio 2008, Zipkin et al. 2009, Iknayan et al. 2014). Second, we were interested in community hyperparameter estimates themselves to summarize overall group trends.

The full model is specified below. The subscript i denotes the season, j denotes the species group, k denotes the specific species in the group, l denotes the year, and m denotes the visit number.

$$y_{ijklm} \sim \text{NegativeBinomial}(p_{ijkl}, r_{ijk})$$

$$p_{ijkl} = \frac{r_{ijk}}{r_{ijk} + \lambda_{ijkl}}$$

$$\log(\lambda_{ijkl}) = B0_{ijkl} + B1_{ijk} * TIME_l$$

$$\log(r_{ijk}) \sim \text{Normal}(\mu. \delta_{ij}, \sigma^2. \delta_{ij})$$

$$B0_{ijkl} \sim \text{Normal}(\mu. B0_{ijk}, \sigma^2. B0_{ijk})$$

$$\mu. B0_{ijk} \sim \text{Normal}(\mu. \mu. B0_{ij}, \sigma^2. \sigma^2. B0_{ij})$$

$$B1_{ijk} \sim \text{Normal}(\mu. B1_{ij}, \sigma^2. B1_{ij})$$

These models were fit in JAGS (Plummer 2003) using the ‘jagsUI’ 1.4.2 package (Kellner 2016) in R 3.1.2 (R Core Team 2014). Vague priors were specified for all community hyperparameters and for each model ran three Markov Chain Monte Carlo (MCMC) chains for 200,000 iterations with a burn-in of 100,000 and thinned by 50. Model convergence was assessed by visually inspecting traceplots, and ensuring that the Gelman-Rubin statistic for monitored parameters was less than 1.1 (Gelman et al. 2004).

Abundance models could not be converged for Raptors or Marsh Birds in any season; therefore, trends for these groups, and individual species will not be presented. In addition, counts for grassland birds during the summer season fell below the 10% threshold; therefore, summer abundance trends for these species are not presented. In some monitoring efforts, data with large numbers of zeroes (0’s) is possible. In these cases, performing a zero-inflated binomial regression may be warranted. However, we could not get such models to converge. Further, the trend estimates were nearly identical between the zero-inflated and regular negative binomial models.

We evaluated trend significance for individual species and species groups based on logarithmic values with 95% confidence intervals for each seasonal

trend during the monitoring period. We determined significant trends based on whether the mean and confidence intervals overlapped with zero; those means and confidence intervals that are above zero indicate significantly increasing trends, while those means and confidence intervals below zero indicate significantly decreasing trends. Means and confidence intervals that overlap with zero indicate non-significant trends during the monitoring period. We also use the SAMBI plan (Watson and Malloy 2008) to identify species on the DMCAs ranked as regional priority species in the Southeastern Coastal Plain including Highest Priority, High Priority, and Moderate Priority Species (Watson and Malloy 2008, Calver et al. 2016). The SHNP DMCAs are located in the Southeastern Coastal Plain BCR as identified and used by Partners in Flight (PIF) and the North American Bird Conservation Initiative (NABCI) for regional bird conservation (NABCI 2019).

2.4.1.2 Mean species richness trends

We placed the species into the same groups as above. For each species group, we fit a generalized linear mixed model where species counts had a Poisson distribution, time was treated as a fixed effect, and year was a random grouping variable. The analysis was conducted in R 3.1.2 using the `glmer()` function in the `lme4` package (Bates et al. 2015). While abundance models for Raptors and Marsh Birds could not converge, species richness models for these groups did converge and results are presented. In addition, species richness values are more constrained with less variation than abundance metrics, so all 180 species detected were used in the analyses. For this reason, species richness for summer grassland birds are presented. We provide a summary of all species groups detected over the course of the 19-year monitoring period (1994 to 2012), focusing only on maximum counts. For clarity on total counts and species richness, we generally only used data on detections that were identified to species. Most observations of groups of birds (e.g., Blackbird sp., Ducks sp.) were removed. Some exceptions include the designation of birds in the genus, *Empidonax*, *Calidris*, *Aythya*, and the family, Scolopacidae. As with abundance trends, significant trends were determined based on the overlap of the logarithmic means and confidence intervals

2.4.2 Habitat relationships analyses

2.4.2.1 *Habitat effects on mean abundance*

We started by identifying exactly what habitat images we had. There were two images from fall of 2008, spring of 2004, and spring of 2005. To arrive at a single value for habitat in each of those year-season combinations, we averaged the values between the two images. This left us with habitat data from seven winters, eight springs, six summers, and nine falls from November 2001 to August 2011 (see Table A-1). We then combined these habitat data with the abundance data described above. Since the bird count data for analyzing habitat is smaller, with less variation, we were able to obtain convergence and present results for the Marsh Birds and Raptors species groups.

Habitat analyses yielded six habitat types: open water, sand, mud flat, shrub-scrub vegetation, herbaceous wetland, and barren land. Since sand and herbaceous wetland habitats were highly correlated with other habitats and other seasons, these were eliminated for comparisons with the bird community data. Time (year) was also highly correlated with barren land in most seasons, so this was eliminated as well. This left us with four explanatory variables: open water, mud flat, shrub-scrub vegetation, and barren land.

The Bayesian hierarchical abundance community models were not used for the analysis of habitat relationships since models could not converge. Therefore, we used a generalized linear mixed model for each species-by-season comparison using the `glmer.nb()` function in R 3.1.2. This model assumes a binomial distribution for abundance data. We modeled the abundance data as additive function of open water, mud flat, shrub-scrub, and barren land habitat attributes. All covariates were standardized before inclusion of the model. Count data were treated as repeated samples and the 'year' variable was included as a random effect. Models of abundance-habitat relationships did not fit the data for approximately 30% to 40% of the comparisons, but these were the best results possible for this analysis.

The models developed in these analyses were difficult to fit because a single measure of each explanatory variable (habitat type availability per season) was compared to multiple measures of the response variable (bird counts). It is recommended that future monitoring efforts collect regular measures of habitat variability each season to further investigate the role

of habitat relationships to long-term trends on the DMCAs. Significant effects of habitat availability on seasonal trends for abundance of individual species and species groups were based on the overlap of the logarithmic means and confidence intervals.

2.4.2.2 Habitat effects on mean species richness

We processed the habitat and bird data as described above (Habitat Relationship Analyses). We then placed the bird species into the same groups as above. For each species group, we fit a generalized linear mixed model where species richness values had a Poisson distribution. Habitat variable covariates (open water, mud flat, shrub-scrub, and barren land) were treated as fixed effects and 'year' was a random grouping variable. As with prior analyses, this analysis was conducted in R 3.1.2 (Bates et al. 2015). Species richness data are much less variable than count data, so there were no issues of fitting the models to the data. Significant effect of habitat availability on seasonal trends for species richness were based on the overlap of the logarithmic means and confidence intervals.

3 Results

3.1 ArcGIS habitat mapping results

Thirty-three hyperspectral satellite images were analyzed using the ArcGIS 10.5 ISODATA algorithm. These analyses provided information on 33 hyperspectral images archived from November 2001 to August 2011. Other archived satellite imagery from earlier years beginning in 1994 were not hyperspectral images and could not be analyzed by the ISODATA algorithm. These data provided estimates of six habitat types available for the seasonal bird community during seven winters, eight springs, nine falls, and six summer seasons (Table A-1). Habitats discerned in the analyses included open water, sand, mud flat, shrub-scrub vegetation, herbaceous wetland, and barren land (Table A-1). Amounts of these habitats varied seasonally due to differences in seasonal rainfall, variations in conditions suitable for vegetative growth, and variable local weather conditions. Generally, the satellite images only offer a brief, one-sample picture of the habitat conditions during each sampled 3-month season.

Future efforts to monitor seasonal bird communities should strive to collect satellite or other overhead multispectral images (e.g., pictures collected from a Video Aerial System [VAS]) to more closely match frequency of bird community survey efforts. Figures 3-1 to 3-4 show examples of seasonal variation determined through the ISODATA algorithm analyses. Results of the habitat analyses show that for the period analyzed, open water and wetland habitats (mud flat and herbaceous wetland) were consistently maintained annually close to, or more than, the stated goal of 266.7 ha (659 acres) of open water and 204.4 ha (505 acres) of wetland habitat (USACE 1996) (see Table A-1).

Figure 3-1. An example of ArcGIS ISODATA habitat classification effort for the Savannah Navigation Harbor Project, Disposal Management Containment Areas, Jasper County, South Carolina, during the winter season. Satellite image dated January 19, 2006.

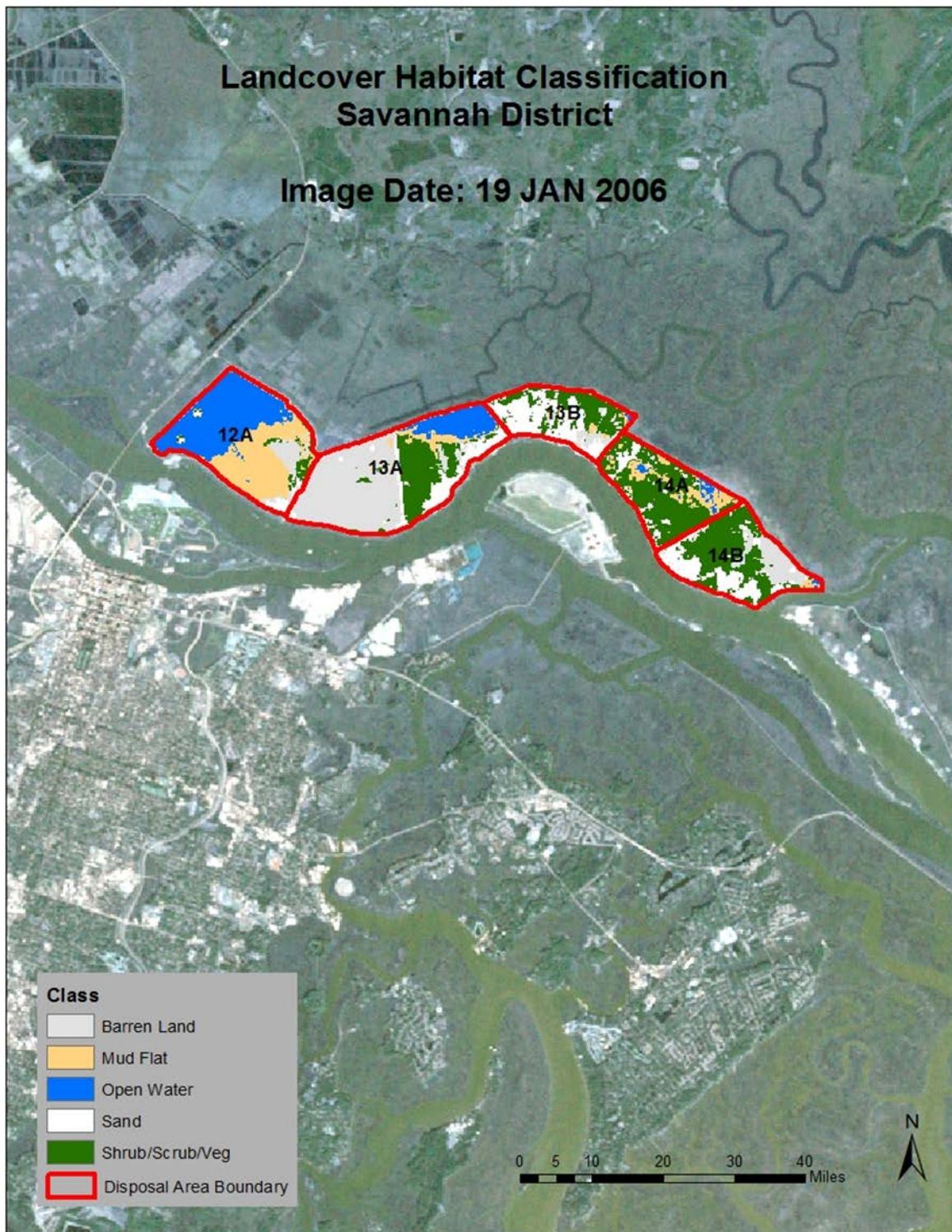


Figure 3-2. An example of ArcGIS ISODATA habitat classification effort for the Savannah Navigation Harbor Project, Disposal Management Containment Areas, Jasper County, South Carolina, during the spring season. Satellite image dated April 30, 2008.

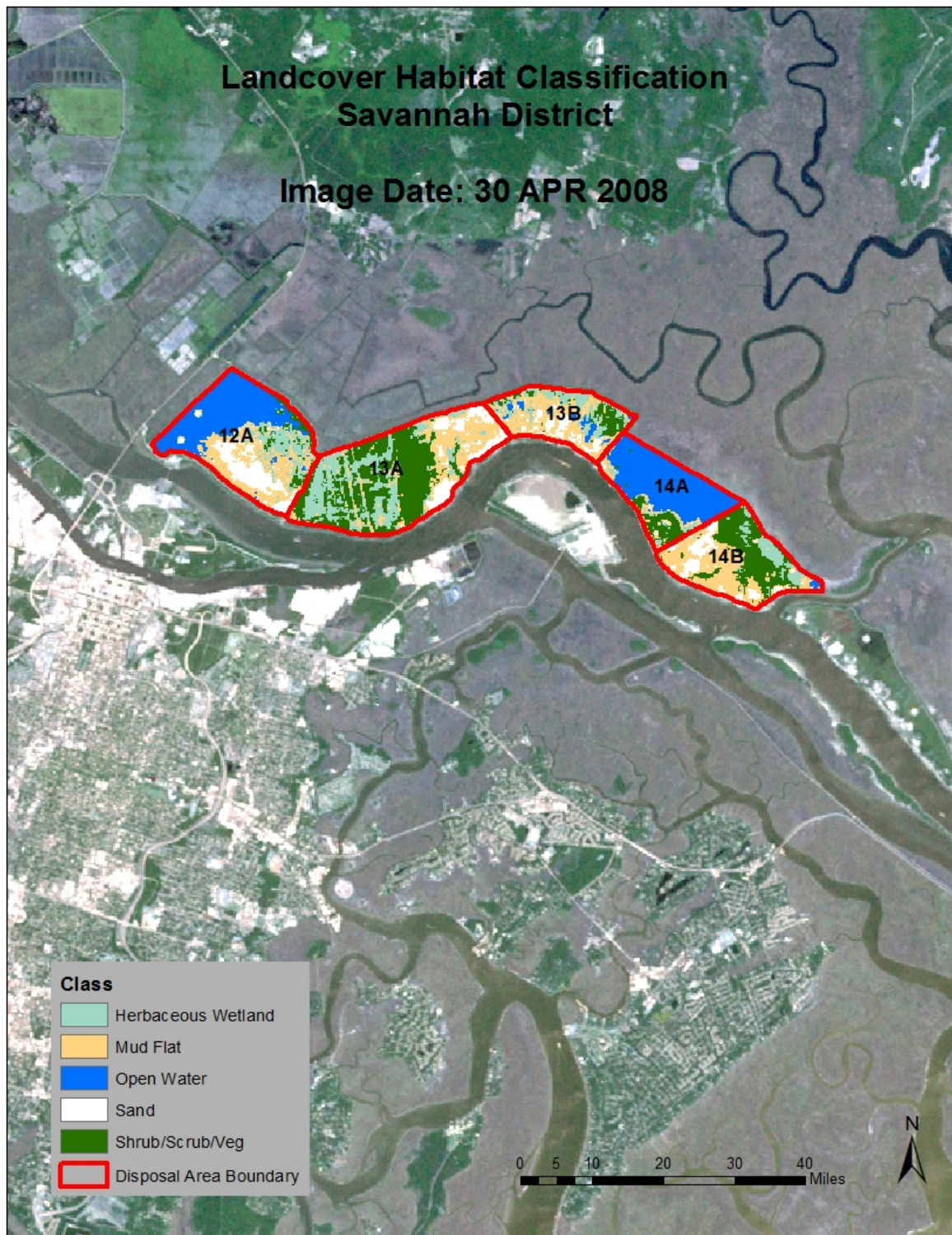


Figure 3-3. An example of ArcGIS ISODATA habitat classification effort for the Savannah Navigation Harbor Project, Disposal Management Containment Areas, Jasper County, South Carolina, during the summer season. Satellite image dated July 27, 2005.

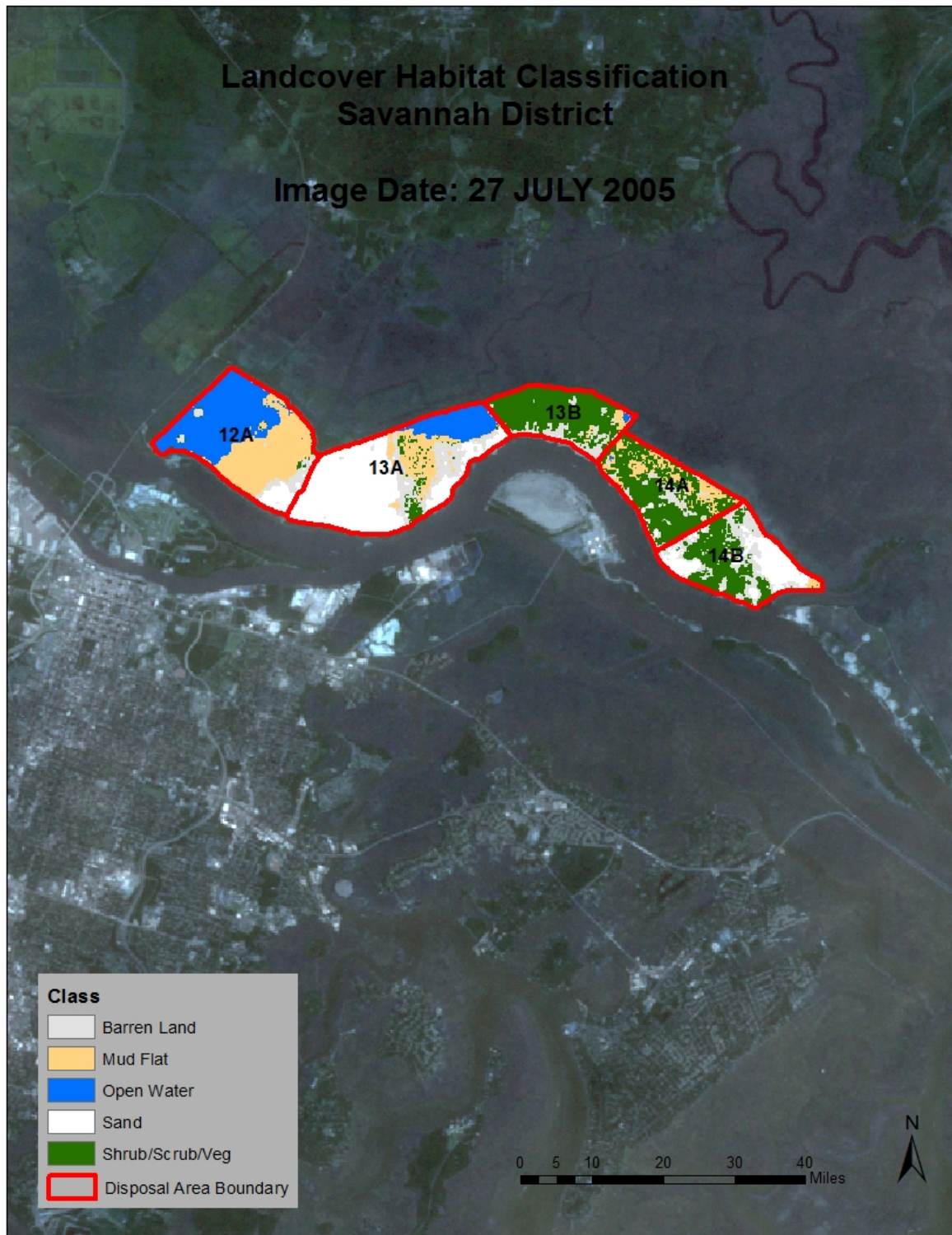
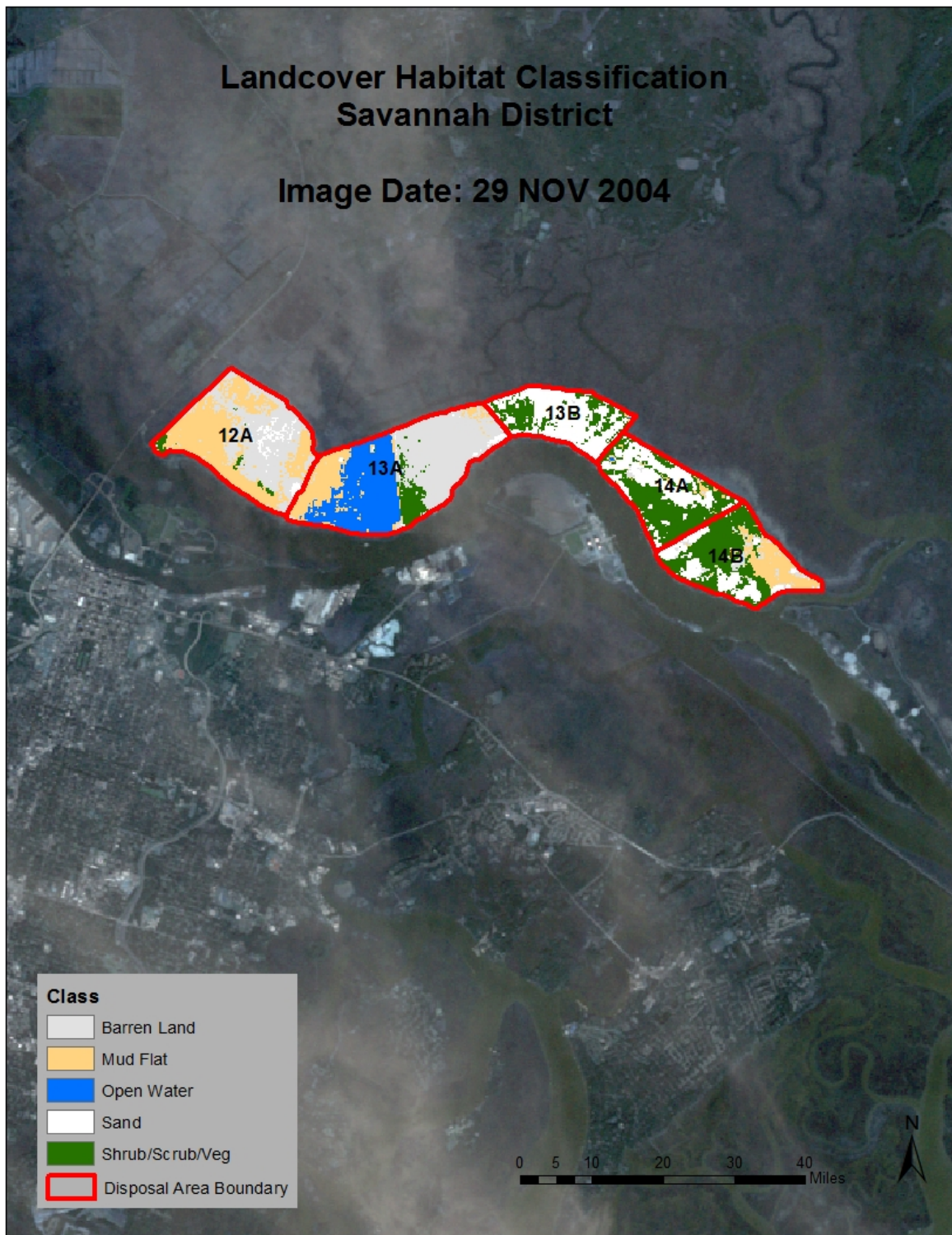


Figure 3-4. An example of ArcGIS ISODATA habitat classification effort for the Savannah Navigation Harbor Project, Disposal Management Containment Areas, Jasper County, South Carolina, during the fall season. Satellite image dated November 29, 2004.



3.2 Seasonal mean abundance and species richness trends

Survey efforts on the six DMCA were completed during the 19-year period from 1994 to 2012. During this time, surveys were conducted on over 700 days (n=746), constituting over 5,500 survey hours (total = 5,539.4 hours). Over 3,500 hours were dedicated to waterbird surveys (total = 3,546.1 hours) and over 1,900 hours were dedicated to small bird surveys (total = 1,975.3 hours) (Calver et al. 2016). A total of 297 species were detected during surveys on days when all DMCA were surveyed. When species detected fewer than 10% of the time were removed, 180 species remained (Table B-1). Between 1994 and 2012, total counts of these 180 species were greater than 5.7 million birds (5,731,153); these surveys consisted of 91 winter surveys during 19 winters, 170 spring surveys during 19 springs, 164 summer surveys during 19 summers, and 155 fall surveys during 18 falls.

Appendix C (Figures C-1 to C-24) gives examples of seasonal trends for individual species. Appendix D (Figures D-1 to D-10) presents the statistical significance of trend results for individual species and species groups. Appendix E (Figure E-1) presents the statistical significance of species richness trends for each species group.

3.2.1 Blackbirds

During the monitoring period, blackbirds as a group did not show any significant increase in trends (Figure D-1). However, no blackbird species experienced significant declines, and several individual species did show significant increases in abundance during specific seasons (Figure D-1). During the winter, significant increases were observed for Boat-tailed Grackles, Common Grackles, Fish Crows, and Red-winged Blackbirds (Figure D-1). During spring migration, significant increases were observed for Boat-tailed Grackles and Red-winged Blackbirds. Trends for Brown-headed Cowbirds, Boat-tailed Grackles, European Starlings, and Red-winged Blackbirds significantly increased during the summer. During fall migration, trends increased significantly for the Common Grackle, European Starling, Fish Crow, and Red-winged Blackbird (Figure D-1). SAMBI ranked priority species, including the Eastern Meadowlark and the Orchard Oriole, did not show any significant trends (Table B-1, Figure D-1). Species richness of blackbirds did not increase significantly during the monitoring period (Figure E-1).

3.2.2 Grassland birds

During the monitoring period, grassland birds as a group did not show any significant increase in trends (Figure D-2). During the winter season, eight grassland species did not show any significant trends, and one species, the White-throated Sparrow experienced a significant decline (Figure D-2). Eight grassland species detected during the spring season did not show any significant trends (Figure D-2) while no data could be tested for the summer season. SAMBI ranked priority species only showed significant trend declines for the White-throated Sparrow during the winter and spring seasons (Table B-1, Figure D-2). Trends for species richness of grassland species increased significantly during the summer season, but no significant trends were observed during the other seasons during the monitoring period (Figure E-1).

3.2.3 Gulls and terns

During the monitoring period, gulls and terns as a group did not show any significant increase in trends (Figure D-3). Only one species, the Caspian Tern, declined significantly during the monitoring period in the winter and summer seasons (Figure D-3). Five other species showed no significant trends during the winter season. During the spring, the Gull-billed Tern and the Laughing Gull showed significant increases, while seven other species showed no significant trends (Figure D-3). Three species experienced a significant increase in trends including the SAMBI priority species the Black Tern, Forster's Tern, Gull-billed Tern, and the Least Tern during the summer and fall seasons (Table B-1, Figure D-3). Laughing Gulls increased during the spring, summer and fall seasons, while two other species did not experience a change in trends (Figure D-3). SAMBI ranked priority species, including the Bonaparte's Gull and the Royal Tern, did not have significant trends during the monitoring period (Table B-1, Figure D-3). Trends for species richness for gull and tern species increased significantly during the spring and summer seasons, but no significant trends were observed during the winter and fall seasons (Figure E-1).

3.2.4 Large shorebirds

During the monitoring period, large shorebirds as a group did not show any significant increase in trends (Figure D-4). Three SAMBI ranked pri-

ority species showed some significant increase in trends during some seasons, including the Black Skimmer (spring, summer, and fall), Short-billed Dowitcher (winter and spring), and the Willet (summer) (Table B-1, Figure D-4). Other priority-ranked species including the Brown Pelican, Greater Yellowlegs, Lesser Yellowlegs, and Wilson's Phalarope, did not exhibit any significant trends during the monitoring period. Only Dowitcher spp. showed a significant declining trend during the fall (Figure D-4). Trends for species richness increased significantly during each season for large shorebirds (Figure E-4).

3.2.5 Other non-passerines

During the monitoring period, other non-passerines as a group did not show any significant increase in trends (Figure D-5). The Common Ground Dove, a SAMBI Highest Ranked priority species, showed significant increases during the monitoring periods for the winter, summer, and fall seasons, while the Northern Bobwhite showed significant declines during the spring, summer, and fall seasons (Table B-1, Figure D-5). No other SAMBI ranked species exhibited any significant trends during the monitoring period (Table B-1, Figure D-5). A non-ranked species, the Yellow-bellied Sapsucker, showed significant increases during the winter season (Figure D-5). Other non-passerines showed an increase in species richness during the winter season, but no significant trends during the other seasons (Figure E-1).

3.2.6 Other passerines

During the monitoring period, other passerines as a group did not show any significant increase in trends (Figure D-6). The SAMBI ranked Highest Priority Species, the Painted Bunting, showed a significant increase during only the spring season (Table B-1, Figure D-6). Other SAMBI ranked species, including the Brown Thrasher, showed a significant increase during the summer, while the ranked Eastern Kingbird showed a significant decline during the summer (Table B-1, Figure D-6). The Moderate Priority Species, the White-eye Vireo, showed significant declines during the spring and summer seasons (Table B-1, Figure D-6). Numerous non-ranked other passerine species showed significant increases during some seasons, including the Blue Grosbeak (fall), Carolina Wren (winter, spring, summer), Eastern Phoebe (winter), Gray Catbird (fall), Loggerhead Shrike (summer and fall), Northern Cardinal (spring and summer), Northern Mockingbird (winter, spring, summer, fall), Ruby-crowned Kinglet

(winter), and Tree Swallow (winter and spring) (Table B-1, Figure D-6). Trends for Species richness of other passerines increased significantly during the winter, summer, and fall seasons, but no significant trend was observed for the spring season (Figure E-1).

3.2.7 Small shorebirds

During the monitoring period, small shorebirds as a group did not show any significant increase in trends (Figure D-7). Some SAMBI ranked species showed significant increases during some seasons, including the Black-bellied Plover (winter and spring), Dunlin (winter and spring), Semipalmated Plover (summer and fall), Semipalmated Sandpiper (Summer), and Western Sandpiper (winter and spring) (Table B-1, Figure D-7). Other SAMBI ranked species did not show any significant trends (Table B-1, Figure D-7); only *Calidris* spp. showed significant declines in the summer and fall season (Table B-1, Figure D-7). The SAMBI Highest Rank Priority Species, the Buff-breasted Sandpiper, did not exhibit any significant trends during the monitoring period (Table B-1, Figure D-7). Small shorebirds showed no significant trends in species richness during the monitoring period (Figure E-1).

3.2.8 Wading birds

During the monitoring period, abundance of wading birds as a group increased significantly during each season (Figure D-8). No wading bird species experienced a significant trend decline during the monitoring period in any season. Some SAMBI ranked species showed a significant increase in trends during some seasons, including the American White Pelican (winter, summer, and fall), Black-crowned Night Heron (winter, spring, summer, and fall), Glossy Ibis (spring), Great Egret (winter), Little Blue Heron (winter and spring), Snowy Egret (winter, spring, and fall), Tricolored Heron (winter, spring, and fall), and the White Ibis (winter, spring, summer, and fall) (Table B-1, Figure D-8). The SAMBI Highest Ranked Priority species, the Wood Stork, did not exhibit any significant trends in any season (Table B-1, Figure D-8). Non-ranked species showed some significant increases during some seasons, including the Anhinga (fall), Black-necked Stilt (winter), Double-crested Cormorant (summer), Great Blue Heron (summer and fall), and the Roseate Spoonbill (spring, summer, and fall) (Table B-1, Figure D-8). Trends for species richness for wading birds increased significantly in each season during the monitoring period (Figure E-1).

3.2.9 Warblers

During the monitoring period, warblers as a group did not show any significant increase (Figure D-9). No warbler species experienced a significant trend decline during the monitoring period. Some SAMBI ranked species showed a significant increase in trends during some seasons, including the Black-throated Blue Warbler (fall), Northern Parula (fall), Palm Warbler (winter, spring, and fall), and Prairie Warbler (summer) (Table B-1, Figure D-9). Some non-ranked species showed a significant increase in trends during some seasons, including the Black-and-White Warbler (winter and fall), Northern Waterthrush (winter, spring, summer, and fall), Orange-crowned Warbler (winter), Yellow Warbler (summer and fall), and the Yellow-rumped Warbler (winter) (Table B-1, Figure D-9). Trends for species richness for warblers increased significantly during the winter and fall migration seasons, but no significant trends were observed for the spring and summer seasons (Figure E-1).

3.2.10 Waterfowl

During the monitoring period, waterfowl as a group did not show any significant increase in trends (Figure D-10). No waterfowl species experienced a significant trend decline during the winter, spring, and summer seasons during the monitoring period. Some SAMBI ranked species showed a significant increase in trends during some seasons, including the Mottled Duck (winter, spring, and summer), Northern Pintail (winter) (Table B-1, Figure D-10). Only one Highest Priority-ranked species, the American Coot, showed a significant decline in trends for the fall season (Table B-1, Figure D-10); however, this species is only listed as a Highest Priority Species during the breeding season (Watson and Mallory 2008). This species is a rare breeder in the region and had non-significant trends during the winter and spring.

The Lesser Scaup is only ranked as a Highest Priority Species during the non-breeding season (Watson and Mallory 2008), but significant declining trends only occurred during the breeding season when this species is largely absent from the region; non-breeding seasons for this species showed non-significant trends during the monitoring period. Other SAMBI ranked waterfowl species did not exhibit significant trends during the monitoring period. Several non-ranked waterfowl species showed significant trends during some seasons, including the Black-bellied Whistling

Duck (spring, summer, and fall), Gadwall (winter), Hooded Merganser (winter), Mallard (winter, spring, summer, and fall), Ring-necked Duck (spring), and Ruddy Duck (summer) (Table B-1, Figure D-10). Trends of species richness for waterfowl increased significantly during the winter season, but no significant trends were observed for the spring, summer and fall seasons (Figure E-1).

3.3 Seasonal mean abundance and species richness habitat relationships

Analyses of bird-habitat relationships were based on surveys completed from fall of 2001 to summer of 2011 when high-quality, multispectral satellite images were available for ArcGIS ISODATA analysis. A total of 277 species were detected during these surveys. The same 180 species were used during the bird-habitat analyses as were used during the trend analyses. Between 2001 and 2011, 2,955,626 birds were recorded; these surveys consisted of 34 winter surveys during seven winters, 71 spring surveys during eight springs, 63 summer surveys during six summers, and 89 fall surveys during nine fall seasons.

The results of the habitat relationships are the most difficult to assess. The timing of the satellite image represents a brief snapshot of habitats available during any specific season, and habitat availability likely varies considerably during a season due to local rainfall and temperature patterns, as well as dredged material deposition operations that were ongoing in some DCMA's during the monitoring period. Therefore, significant effects of habitat availability on the abundance and species richness trends needs to be interpreted with caution; results will need to be evaluated with further collection of monitoring data.

During the monitoring period, we observed 191 significant effects of habitat availability on the species abundance trends (Appendix F; Figures F-1 to F-12). Barren Land was positively associated to trends of 23 species and negatively with trends of 28 species; mud flats were positively associated to trends of 38 species and negatively associated to trends of 19 species; open water areas were positively associated to trends of 35 species and negatively associated to trends of 10 species; shrub-scrub habitat was positively associated to trends of 20 species and negatively associated to trends of 18 species (Figures F-1 to F-12).

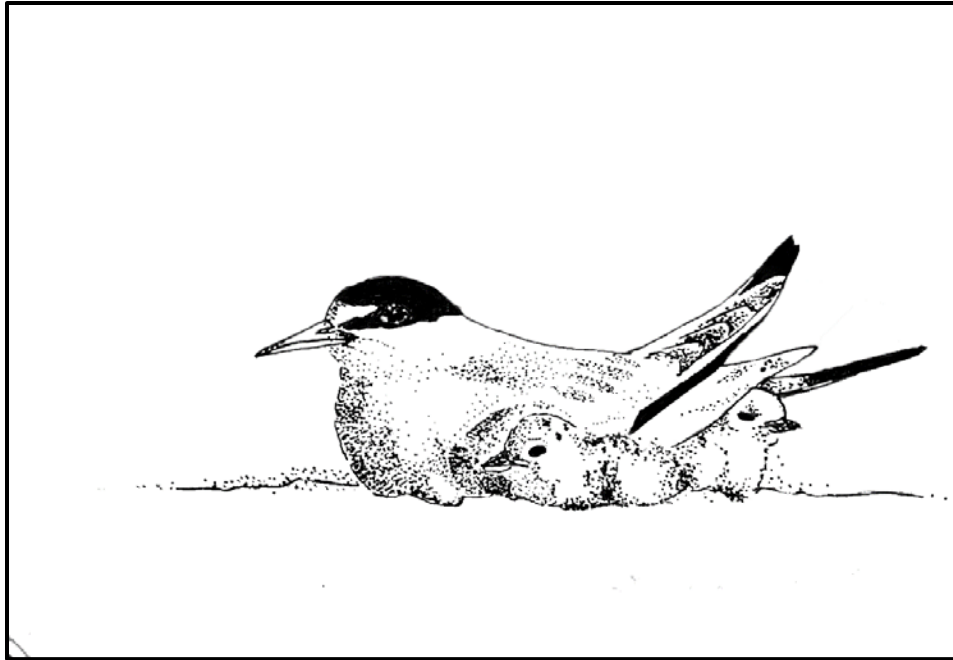
Many waterbird species (gulls and terns, large shorebirds, small shorebirds, wading birds, and waterfowl) revealed positive associations with open water (23 positive relationships), mud flats (25 positive relationships), and shrub-scrub habitat (11 positive relationships) during some seasons (Figures F-1 to F-12). These birds were also had negative relationships with barren land (18 negative relationships). Most terrestrial associated birds (blackbirds, grass-land birds, other non-passerines, passerines, and warblers) revealed significant positive relationships with barren land (15 positive relationships), mud flats (17 positive relationships), and shrub-scrub habitats (eight positive relationships) during some seasons (Figures F-1 to F-12).

Mean species richness for species groups showed few significant relationships to habitat availability from 2001 to 2011 (Figure G-1). Notably, all waterbirds were negatively associated with barren land in the winter, while all landbirds were positively associated to barren land in the summer (Figure G-1). Warblers were positively associated with barren land and shrub-scrub habitat during the summer, while waterfowl were positively associated with open water during the winter (Figure G-1).

3.4 Nesting and reproductive behavior for select species, 1996-2012

Although not an objective of this monitoring effort, 32 species were documented as nesting on the DMCAs from 1996 to 2012 (Tables H-1 to H-3). Sixteen of these species have been ranked as High Priority Species in the SAMBI, and two have been ranked as Moderate Priority Species (Waterson and Malloy 2008) (see Tables H-1 to H-3). Islands in the DMCAs provide nesting habitat for several priority terns, including the Least Tern and the Gull-billed Tern (Figure 3-5, Table H-1). Various priority shorebirds were observed nesting including the Wilson's Plover, Willet, American Avocet, and Black Skimmer (Table H-1). Most of the High Priority birds nesting on the DMCAs included colonial nesters, such as the Snowy Egret, Little Blue Heron and Tricolored Heron (Table H-2). One High Priority marsh bird, the Common Gallinule (*Gallinula chloropus*) was observed nesting, even though counts of this species during the monitoring efforts were too low to include in the trend analyses (Table H-3). Other terrestrial species have also been observed nesting in the DMCAs, including the Red-tailed Hawk and Eastern Towhee (Table H-3).

Figure 3-5. The Least Tern (*Sternula antillarum*) is a regionally identified High Priority Species by the SAMBI that has been documented to nest on the created islands in the SHNP, DMCAs (drawing and copyright ©Johanna S. Guilfoyle).



4 Discussion

Populations of coastal shorebirds and waterfowl, particularly migratory species, have experienced long-term declines (Newton 2004, Kirby et al. 2008). Moreover, since 1970, North American birds have declined by 29%, or over 3 billion birds (Rosenberg et al. 2019). Habitat loss and degradation throughout the breeding, migratory, and wintering ranges form the largest contribution to population declines. Habitats are being continually altered through agricultural practices, increased urbanization, and increased conflict and disturbance by human populations (Stillman et al. 2007, Kirby et al. 2008).

Ongoing habitat changes will also likely occur due to global climate change with increased temperatures and severe storm events that may alter migratory timing, prey availability and increased competition among migratory birds during the fall and spring passage (Kirby et al. 2008). The complexity of migratory bird life-history traits requires that habitat be available during the entire life cycle, both breeding and non-breeding seasons, including the availability of high-quality stopover habitat during migration (Newton 2004, Mehlman et al. 2005, Kirby et al. 2008). The USACE has a disproportionate role influencing coastal habitats along the Atlantic Coast due to its mission in the creation, enhancement and maintenance of coastal infrastructure (Guilfoyle et al. 2019). Maintenance dredging, beach nourishment, shoreline stabilization (Gittman et al. 2015), and other coastal engineering activities are likely to affect the availability and quality of seasonal habitats for waterbirds and other floral or faunal wildlife species. Efforts to mitigate or restore habitats lost or degraded during coastal engineering is often required through legal mitigation processes or through USACE habitat restoration efforts (Guilfoyle et al. 2019).

Here, we reveal seasonal long-term trends of bird populations in open water and wetland habitats created and maintained by a specific management approach applied to the operations of the SHNP DMCAs. The LTMS was designed to maintain specific quantities of open water and wetland habitats and to benefit seasonal waterbirds. The approach used in the construction of the DMCAs and implementation of the LTMS incorporates many features of the USACE EWN initiative (Guilfoyle et al. 2020). In the absence of data from a reference site, we used the results of Calver et al. (2016) to identify

specific species regionally identified as priority species (Watson and Mallory 2008) that are sensitive or rare and in need of conservation management. In contrast to most other pre- and post-project monitoring, the seasonal waterbird community monitoring on the SHNP DMCAs presented in this report represents nearly 20 years of data. Assessment of the success of the LTMS is provided by (1) showing that the goal of maintaining habitat availability of open water and wetland habitats has been met based on ArcGIS ISODATA analyses of archived satellite imagery from 2001 to 2011, and (2) recognizing that seasonal long-term trends of regionally identified priority species indicate stable or significantly increasing trends with no significantly decreasing trends for 51 priority-ranked waterbirds. In addition, observations of nesting behavior documents breeding attempts by 11 High Priority waterbird and colonial waterbird species.

Current U.S. Endangered Species Act (ESA) listed species, including the Piping Plover (*Charadrius melodus*) and Interior Least Tern (*S. a. athalassos*), are known breeding species, and efforts to promote population sustainability in areas of USACE jurisdiction focus on creating suitable breeding habitat (Guilfoyle et al. 2006, 2007; Hunt et al. 2018). However, many imperiled shorebirds currently experiencing significant population declines are species that are migratory transients along the Atlantic Coast during the spring or fall, and other species that over-winter along the Atlantic and/or Gulf Coasts. Recent declines of the migratory *rufa* subspecies of the Red Knot (*Calidris canutus rufa*) led to its listing as a threatened species under the ESA by the U.S. Fish and Wildlife Service (USFWS) in 2014. The USACE is currently in the process of adapting approaches to minimizing impacts of coastal engineering on transient migrant species; future listing of other non-breeding shorebirds could further compromise the USACE mission along the Atlantic Coast (Guilfoyle et al. 2019). On the SHNP DMCAs, we show demonstrable increases in mean abundance trends for several seasonal transient migratory shorebirds that are also ranked priority species in the region (e.g., Dunlin and Semipalmated Sandpiper). Also, we show significant increasing mean abundance trends for ranked over-wintering priority species (e.g., Long-billed and Short-billed Dowitcher, Semipalmated Plover, and Western Sandpiper). These results show that it is possible to create habitat that will benefit non-breeding waterbirds along the Atlantic Coast.

Although non-waterbird species were not a focus of the monitoring effort, species documented during the monitoring effort revealed increasing trends for several Highest Priority Species, including the Common Ground Dove and Painted Bunting. Significant declines for the High Priority Northern Bobwhite on the DMCA likely reflect regional observed declines for this species (Rosenberg et al. 2016) and are probably unrelated to habitat created by the LTMS; this species uses terrestrial and agricultural land (Brennan 1999). A High Priority Species, the wintering White-throated Sparrow, also exhibited significant declines over the course of the monitoring. However, this species is not known to prefer open water and wetland habitats during the winter (Falls and Kopachena 1994) and is not a species likely to benefit from habitats created on the DMCA. The Moderate Priority Species, the White-eyed Vireo, also declined significantly during the spring and summer seasons. While this species could respond positively to wetland habitats, it is also associated with dense vegetation (Hopp et al. 1995). The DMCA are generally flooded or contain shallow water and mudflats and are often denuded of vegetation. Surrounding levees systems are also maintained through regular mowing and vegetation control (USACE 1996); therefore, the habitats provided by the LTMS on the DMCA are also not likely to benefit this species.

Prior research has evaluated artificially created wetland habitats for seasonal waterbird communities, often with mixed results. Non-breeding waterbirds showed similar relationships to new and older created wetlands in the Central Appalachian region (Clipp et al. 2017), while natural tidal wetlands provided better habitat during the spring and autumn, but artificial ponds provided suitable habitat during the winter in China (Ma et al. 2004). Irrigation ponds in Spain have been determined to benefit seasonal waterbirds, but specific attributes, such as pond size, proximity to other wetlands, and overall quality are important, particularly during the breeding season (Sebastian-Gonzalez et al. 2010). In southern France, rice fields have been shown to be poor habitats for waterbirds compared to natural marshes (Tourenq et al. 2001). Natural wetlands subject to disturbance by pollution and tourism in Gujarat, India, showed lower abundance and diversity compared to undisturbed wetlands (Kumar et al. 2007). Wetlands managed for waterbirds supported the highest seasonal diversity and abundance along the Colorado River, Mexico (Hinojosa-Huerta et al. 2004), yet opportunities to improve habitat would be possible with better flood control.

Engineered habitat for breeding Piping Plovers was poor when compared to habitat created through natural flood events on the Missouri River (Hunt et al. 2018). Managed wetlands may also improve habitat during the non-breeding seasons by maintaining differences in water-levels between 30 and 40 cm in the deepest and shallowest portions of the wetland (Taft et al. 2002); such targeted water depths can be maintained through draw-downs in artificial wetlands. On the SHNP DMCAs, areas not receiving dredged material often retain shallow water and mudflat habitat due to the capacity of the DMCAs to hold water, while the areas receiving dredged material often support deeper open water habitat. The rotation-based feature of the LTMS on the DMCAs removes any additional need for artificial manipulation of the water depths. The availability of wetlands and mudflats was important to many seasonal shorebirds and gulls and terns in our study. Also, the open water habitat was important to many wintering waterfowl species. In addition, the SHNP DMCAs are largely inaccessible by the general public; therefore the seasonal bird populations are usually not subjected to frequent disturbance.

Large-scale human modification of coastal wetland systems necessitates an approach to create or restore wetland habitats that provide demonstrable benefits to the native floral and faunal communities. In our opinion, the significant long-term seasonal abundance and diversity trends of multiple regionally identified priority species and bird groups on the SHNP DMCAs during the monitoring period represent a clear benefit to many species in the region. In a heavily modified and urbanized wetland system like the Savannah Harbor, a constructed wetland system like the DMCAs, used either as a CDF or simply as a system to restore lost wetland habitat, could be beneficial to seasonal waterbirds. In this way, the design and construction of the SHNP DMCAs, combined with the LTMS implemented on the DMCAs, represents a prototype approach that could be replicated in many other industrial and urbanized ports and harbors along the Atlantic Coast and elsewhere.

However, future work is needed to investigate, clarify, and expand our understanding of the value and limitations of engineered habitats for seasonal bird populations. First, efforts should promote the comparisons of such engineered systems to seasonal waterbird communities in natural, minimally disturbed wetland systems. Since non-breeding habitat for waterbirds is often tied to the benthic community as a prey base, especially

for migratory shorebirds (Peterson et al. 2006), performing comparisons of benthic organisms in restored and reference sites may be needed. Placement of created wetlands in the landscape (Gillespie and Fontaine 2017), and the interspersed of foraging, roosting, and loafing habitat (Grandeiro et al. 2007), may be important features of the habitat for some waterbird species. Breeding and non-breeding areas may serve as sources or sinks for targeted waterbirds in the region. Therefore, documenting reproductive success during the breeding season, or assessing physiological condition and implementing an integrated population model during the non-breeding seasons may be helpful to further evaluate the value of such areas for waterbirds (Gibson et al. 2018). Finally, even though CDFs are designed to minimize exposure of the environment to toxins, research on the possible effects of toxins and heavy metals ingested by foraging birds in the DMCAs may be needed to ensure that the value of the created seasonal habitats do not represent a danger to existing populations.

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Acronyms and Abbreviations

Term	Definition
BCR	(Southeastern Coastal Plain) Bird Conservation Region
CDF	Confined Disposal Facility
DCMA	Defense Contract Management Agency
DMCA	Dredged Material Containment Areas
ESA	U.S. Endangered Species Act
ESRI	Environmental Systems Research Institute, Inc.
EST	Eastern Standard Time
EWN®	Engineering With Nature
ICW	Intracoastal Waterway System
LTMS	Long-Term Management Strategy
MCMC	Markov Chain Monte Carlo
NABCI	North American Bird Conservation Initiative
PIF	Partners In Flight
SAMBI	South Atlantic Migratory Bird Initiative
SHNP	Savannah Harbor Navigation Project
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VAS	Video Aerial System

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
angstroms	0.1	nanometers
atmosphere (standard)	101.325	kilopascals
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
hectares	1.0 E+04	square meters
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

**Appendix A: Habitat Type Availability for
Seasonal Bird Communities on the
Savannah Harbor Navigation Project,
Dredged Material Containment Areas,
2002-2011**

Table A-1. Date and type of satellite image and results of ArcGIS ISODATA algorithm habitat analyses on satellite images of the Savannah Harbor Navigation Project, Dredged Material Containment Areas, from November 21, 2001 to August 9, 2011. Results show habitat availability (acres) for six habitat types seasonally.

Date	DMCA	Open Water	Sand	Mud Flat	Shrub/Scrub/Veg	Herbaceous Wetland	Barren Land	Total (acres)
11/21/2001	12A	0	202	0	403	0	510	1115
Landsat 30-m multispectral	13A	426	158	644	161	0	28	1417
	13B	0	178	0	30	0	343	551
	14A	0	285	2	391	0	1	679
	14B	32	169	56	315	0	205	777
Total (acres)		458	992	702	1300	0	1087	4539
1/17/2002	12A	75	19	461	0	414	142	1111
IKONOS 1-m pan, 4-m multispectral	13A	672	60	324	0	227	117	1400
	13B	42	17	174	0	270	56	559
	14A	157	12	133	0	239	133	674
	14B	172	19	195	0	236	144	766
Total (acres)		1118	127	1287	0	1386	592	4510
3/29/2002	12A	0	203	58	0	0	854	1115
Landsat 30-m multispectral	13A	578	164	476	117	0	82	1417
	13B	0	298	4	16	0	232	550
	14A	3	254	48	374	0	1	680
	14B	0	191	151	241	0	195	778
Total (acres)		581	1110	737	748	0	1364	4540
7/19/2002	12A	4	348	0	12	116	636	1116
Landsat 30-m multispectral	13A	472	127	0	108	327	383	1417
	13B	0	356	0	16	8	172	552
	14A	1	14	0	483	182	0	680
	14B	0	308	0	107	110	253	778

Date	DMCA	Open Water	Sand	Mud Flat	Shrub/Scrub/Veg	Herbaceous Wetland	Barren Land	Total (acres)
Total (acres)		477	1153	0	726	743	1444	4543
11/24/2002	12A	30	181	252	261	0	393	1117
Landsat 30-m multispectral	13A	406	167	245	286	0	314	1418
	13B	0	247	9	10	0	285	551
	14A	96	30	262	286	0	4	678
	14B	8	147	150	292	0	180	777
Total (acres)		540	772	918	1135	0	1176	4541
1/27/2003	12A	3	545	42	25	0	501	1116
Landsat 30-m multispectral	13A	580	215	118	193	0	311	1417
	13B	0	199	0	2	0	350	551
	14A	205	47	179	246	0	2	679
	14B	5	253	201	177	0	140	776
Total (acres)		793	1259	540	643	0	1304	4539
4/1/2003	12A	2	398	97	165	0	453	1115
Landsat 30-m multispectral	13A	575	183	307	199	0	153	1417
	13B	3	305	20	11	0	212	551
	14A	303	9	150	213	0	3	678
	14B	4	60	248	335	0	130	777
Total (acres)		887	955	822	923	0	951	4538
9/24/2003	12A	0	576	1	64	0	474	1115
Landsat 30-m multispectral	13A	414	323	366	78	0	235	1416
	13B	4	194	6	209	0	138	551
	14A	140	3	136	328	0	72	679
	14B	56	119	244	317	0	41	777
Total (acres)		614	1215	753	996	0	960	4538
3/18/2004	12A	0	123	35	4	0	953	1115

Date	DMCA	Open Water	Sand	Mud Flat	Shrub/Scrub/Veg	Herbaceous Wetland	Barren Land	Total (acres)
Landsat 30-m multispectral	13A	622	294	209	227	0	66	1418
	13B	5	39	355	23	0	129	551
	14A	161	8	98	406	0	7	680
	14B	0	95	221	221	0	240	777
Total (acres)		788	559	918	881	0	1395	4541
5/5/2004	12A	172	443	0	40	0	461	1116
Landsat 30-m multispectral	13A	669	345	0	268	0	135	1417
	13B	17	207	0	23	0	303	550
	14A	269	34	0	306	0	69	678
	14B	180	137	0	223	0	237	777
Total (acres)		1307	1166	0	860	0	1205	4538
7/24/2004	12A	0	2	3	691	0	419	1115
Landsat 30-m multispectral	13A	497	411	423	31	0	54	1416
	13B	0	9	38	117	0	386	550
	14A	0	32	161	113	0	372	678
	14B	0	453	177	15	0	132	777
Total (acres)		497	907	802	967	0	1363	4536
11/29/2004	12A	0	46	522	25	0	523	1116
Landsat 30-m multispectral	13A	485	33	226	90	0	583	1417
	13B	0	394	2	144	0	9	549
	14A	2	294	22	351	0	11	680
	14B	0	193	159	356	0	68	776
Total (acres)		487	960	931	966	0	1194	4538
3/5/2005	12A	0	336	70	396	0	313	1115
Landsat 30-m	13A	686	127	508	26	0	69	1416
	13B	4	322	5	205	0	15	551

Date	DMCA	Open Water	Sand	Mud Flat	Shrub/Scrub/Veg	Herbaceous Wetland	Barren Land	Total (acres)
multispectral	14A	23	113	73	277	0	193	679
	14B	3	287	107	167	0	213	777
Total (acres)		716	1185	763	1071	0	803	4538
5/24/2005 Landsat 30-m multispectral	12A	742	28	230	27	0	89	1116
	13A	119	163	167	111	0	857	1417
	13B	4	171	20	354	0	2	551
	14A	51	66	274	236	0	52	679
	14B	6	243	40	309	0	178	776
Total (acres)		922	671	731	1037	0	1178	4539
7/27/2005 Landsat 30-m multispectral	12A	511	68	435	30	0	73	1117
	13A	186	783	173	60	0	214	1416
	13B	4	12	21	417	0	97	551
	14A	2	12	135	430	0	99	678
	14B	0	235	11	288	0	243	777
Total (acres)		703	1110	775	1225	0	726	4539
11/16/2005 Landsat 30-m multispectral	12A	524	49	316	66	0	160	1115
	13A	117	229	101	303	0	668	1418
	13B	15	291	31	200	0	13	550
	14A	18	26	144	482	0	9	679
	14B	6	164	9	489	0	108	776
Total (acres)		680	759	601	1540	0	958	4538
1/19/2006 Landsat 30-m multispectral	12A	518	48	403	62	0	84	1115
	13A	168	189	68	276	0	715	1416
	13B	2	300	14	187	0	48	551
	14A	30	89	120	437	0	3	679
	14B	4	245	11	368	0	149	777

Date	DMCA	Open Water	Sand	Mud Flat	Shrub/Scrub/Veg	Herbaceous Wetland	Barren Land	Total (acres)
Total (acres)		722	871	616	1330	0	999	4538
4/25/2006 Landsat 30-m multispectral	12A	397	515	0	95	0	108	1115
	13A	0	266	0	254	0	897	1417
	13B	0	109	0	410	0	33	552
	14A	394	28	0	252	0	4	678
	14B	36	112	0	525	0	103	776
Total (acres)		827	1030	0	1536	0	1145	4538
7/14/2006 Landsat 30-m multispectral	12A	407	104	119	47	0	440	1117
	13A	18	213	210	266	0	710	1417
	13B	10	59	413	56	0	13	551
	14A	278	196	92	64	0	48	678
	14B	92	187	213	234	0	51	777
Total (acres)		805	759	1047	667	0	1262	4540
11/19/2006 Landsat 30-m multispectral	12A	226	172	0	40	0	677	1115
	13A	0	384	0	305	0	728	1417
	13B	0	522	0	0	0	28	550
	14A	378	58	0	118	0	125	679
	14B	5	216	0	507	0	49	777
Total (acres)		609	1352	0	970	0	1607	4538
2/7/2007 Landsat 30-m multispectral	12A	131	143	519	17	0	306	1116
	13A	1	348	125	200	0	743	1417
	13B	1	326	33	8	0	184	552
	14A	424	37	84	87	0	47	679
	14B	12	258	15	437	0	55	777
Total (acres)		569	1112	776	749	0	1335	4541
5/14/2007	12A	364	127	338	65	0	222	1116

Date	DMCA	Open Water	Sand	Mud Flat	Shrub/Scrub/Veg	Herbaceous Wetland	Barren Land	Total (acres)
Landsat 30-m multispectral	13A	0	359	0	592	0	465	1416
	13B	0	396	1	28	0	126	551
	14A	314	73	116	72	0	103	678
	14B	23	73	58	403	0	220	777
Total (acres)		701	1028	513	1160	0	1136	4538
8/18/2007 Landsat 30-m multispectral	12A	363	266	329	157	0	0	1115
	13A	0	508	3	906	0	0	1417
	13B	7	405	32	107	0	0	551
	14A	338	107	117	117	0	0	679
Total (acres)	14B	8	265	113	389	0	0	775
		716	1551	594	1676	0	0	4537
2/10/2008 Landsat 30-m multispectral	12A	306	130	497	39	144	0	1116
	13A	0	283	15	356	763	0	1417
	13B	37	229	93	39	153	0	551
	14A	461	32	47	96	44	0	680
Total (acres)	14B	5	250	52	276	0	194	777
		809	924	704	806	1104	194	4541
4/30/2008 Landsat 30-m multispectral	12A	469	169	268	66	144	0	1116
	13A	0	145	304	603	365	0	1417
	13B	32	74	258	73	113	0	550
	14A	489	10	57	85	38	0	679
Total (acres)	14B	9	116	300	259	93	0	777
		999	514	1187	1086	753	0	4539
10/7/2008 Landsat 30-m	12A	417	105	0	0	60	521	1103
	13A	13	80	0	0	1078	212	1383
	13B	193	16	0	0	153	188	550

Date	DMCA	Open Water	Sand	Mud Flat	Shrub/Scrub/Veg	Herbaceous Wetland	Barren Land	Total (acres)
multispectral	14A	411	27	0	0	105	127	670
	14B	142	83	0	0	187	346	758
Total (acres)		1176	311	0	0	1583	1394	4464
11/24/2008 Landsat 30-m multispectral	12A	465	279	0	83	0	288	1115
	13A	0	160	0	819	0	438	1417
	13B	142	145	0	77	0	188	552
	14A	273	72	0	171	0	163	679
	14B	9	403	0	159	0	206	777
Total (acres)		889	1059	0	1309	0	1283	4540
2/12/2009 Landsat 30-m multispectral	12A	616	253	0	97	151	0	1117
	13A	0	359	0	291	767	0	1417
	13B	130	145	0	191	85	0	551
	14A	207	142	0	82	248	0	679
	14B	2	471	0	204	100	0	777
Total (acres)		955	1370	0	865	1351	0	4541
9/8/2009 Landsat 30-m multispectral	12A	350	235	257	90	182	0	1114
	13A	0	82	1	1055	279	0	1417
	13B	180	58	190	56	66	0	550
	14A	81	202	134	128	133	0	678
	14B	16	127	143	219	272	0	777
Total (acres)		627	704	725	1548	932	0	4536
5/19/2010 IKONOS 1-m pan, 4-m multispectral	12A	443	62	190	214	115	86	1110
	13A	19	57	537	165	386	236	1400
	13B	188	25	149	29	97	72	560
	14A	8	3	157	244	156	104	672
	14B	95	27	94	177	230	142	765

Date	DMCA	Open Water	Sand	Mud Flat	Shrub/Scrub/Veg	Herbaceous Wetland	Barren Land	Total (acres)
Total (acres)		753	174	1127	829	984	640	4507
9/11/2010	12A	404	103	234	32	0	343	1116
Landsat 30-m multispectral	13A	0	272	10	753	0	382	1417
	13B	177	95	74	66	0	139	551
	14A	75	333	95	83	0	93	679
	14B	5	245	52	271	0	193	766
Total (acres)		661	1048	465	1205	0	1150	4529
2/18/2011	12A	329	52	462	156	117	0	1116
Landsat 30-m multispectral	13A	0	445	7	362	603	0	1417
	13B	166	72	101	111	101	0	551
	14A	112	165	87	126	188	0	678
	14B	9	365	58	175	169	0	776
Total (acres)		616	1099	715	930	1178	0	4538
8/29/2011	12A	314	76	367	171	188	0	1116
Landsat 30-m multispectral	13A	3	329	343	515	227	0	1417
	13B	109	173	111	72	87	0	552
	14A	0	226	38	129	285	0	678
	14B	4	344	39	83	307	0	777
Total (acres)		430	1148	898	970	1094	0	4540

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**Appendix B: Individual Species and
Species Groups Seasonal Trend Analysis
Results on the Savannah Harbor
Navigation Project, Dredged Material
Containment Areas, 1994-2012.**

Table B-1. Common name, scientific name, species code, and trend estimate (+SD) for mean abundance for individual species and species groups by season on the SHNP, DMCA, 1994-2012. Regional priority rankings for the SAMBI plan are indicated by superscripts (from Watson and Malloy 2008).

Species	Species Code	Winter	Spring	Summer	Fall
Blackbirds	—	0.12±0.12	0.06±0.09	0.08±0.10	0.13±0.11
American Crow <i>Corvus brachyrhynchos</i>	AMCR	- 0.02±0.10	—	—	—
Brown-headed Cowbird <i>Molothrus ater</i>	BHCO	—	0.08±0.04	0.19±0.06	-0.01±0.10
Boat-tailed Grackle <i>Quiscalus major</i>	BTGR	0.09±0.05	0.07±0.03	0.08±0.03	0.07±0.05
Common Grackle <i>Quiscalus quiscula</i>	COGR	0.28±0.14	0.22±0.20	0.14±0.14	0.24±0.09
Eastern Meadowlark ^{**} <i>Sturnella magna</i>	EAME	0.00±0.04	- 0.09±0.06	—	0.00±0.03
European Starling <i>Sturnus vulgaris</i>	EUST	0.05±0.10	0.05±0.07	0.20±0.06	0.29±0.09
Fish Crow <i>Corvus ossifragus</i>	FICR	0.34±0.10	0.04±0.06	- 0.06±0.05	0.17±0.05
Orchard Oriole <i>Icterus spurius</i>	OROR	—	0.04±0.03	- 0.02±0.03	—
Red-winged Blackbird <i>Agelaius phoeniceus</i>	RWBL	0.12±0.04	0.07±0.02	0.07±0.02	0.17±0.03
Grassland Birds	—	0.02±0.07	- 0.05±0.10	—	0.00±0.08
American Pipit <i>Anthus rubescens</i>	AMPI	0.05±0.05	0.10±0.09	—	-0.01±0.09
Bobolink <i>Dolichonyx oryzivorus</i>	BOBO	—	0.09±0.05	—	0.02±0.05
Field Sparrow ^{**} <i>Spizella pusilla</i>	FISP	0.09±0.09	—	—	—
Le Conte's Sparrow ^{**} <i>Ammodramus leconteii</i>	LCSP	0.03±0.11	—	—	—
Savannah Sparrow <i>Passerculus sandwichensis</i>	SAVA	0.04±0.03	- 0.01±0.03	—	0.01±0.03
Song Sparrow <i>Melospiza melodia</i>	SOSP	0.04±0.04	- 0.07±0.06	—	0.02±0.06
Swamp Sparrow [*] <i>Melospiza georgiana</i>	SWSP	0.01±0.04	- 0.01±0.04	—	0.06±0.06
Vesper Sparrow ^{**} <i>Poocetes gramineus</i>	VESP	0.03±0.05	—	—	-0.07±0.07
White-crowned Sparrow <i>Zonotrichia leucophrys</i>	WCSP	0.01±0.06	- 0.11±0.06	—	0.07±0.08
White-throated Sparrow ^{**} <i>Zonotrichia albicollis</i>	WTSP	- 0.11±0.05	- 0.16±0.05	—	-0.14±0.07
Gulls and Terns	—	- 0.02±0.13	0.07±0.08	0.11±0.09	0.07±0.06

Note: *Moderate Priority Species; **High Priority Species;***Highest Priority Species

Species	Species Code	Winter	Spring	Summer	Fall
Black Tern** <i>Chlidonias niger</i>	BLTE	—	—	0.19±0.04	0.14±0.07
Bonaparte's Gull* <i>Chroicocephalus philadelphia</i>	BOGU	- 0.04±0.04	- 0.10±0.05	—	0.04±0.07
Caspian Tern <i>Hydroprogne caspia</i>	CATE	- 0.26±0.10	- 0.05±0.06	- 0.11±0.05	0.04±0.03
Forster's Tern* <i>Sterna forsteri</i>	FOTE	- 0.01±0.05	0.00±0.05	0.12±0.06	0.10±0.04
Gull-billed Tern** <i>Gelochelidon nilotica</i>	GBTE	—	0.25±0.07	0.20±0.04	0.04±0.06
Herring Gull <i>Larus argentatus</i>	HERG	0.11±0.08	0.05±0.11	—	0.05±0.07
Laughing Gull <i>Leucophaeus atricilla</i>	LAGU	0.04±0.06	0.17±0.05	0.20±0.04	0.13±0.04
Least Tern** <i>Sternula antillarum</i>	LETE	—	0.09±0.04	0.08±0.03	0.00±0.08
Ring-billed Gull <i>Larus delawarensis</i>	RBGU	0.03±0.04	0.10±0.07	0.09±0.08	0.14±0.05
Royal Tern* <i>Thalasseus maximus</i>	ROYT	—	0.09±0.07	0.09±0.09	0.04±0.08
Large Shorebirds	—	0.09±0.15	0.10±0.08	0.05±0.09	0.02±0.08
Black Skimmer** <i>Rynchops niger</i>	BLSK	—	0.26±0.08	0.27±0.07	0.07±0.09
Brown Pelican** <i>Pelecanus occidentalis</i>	BRPE	0.03±0.11	- 0.02±0.09	—	-0.11±0.08
Dowitcher spp. <i>Limnodromus spp.</i>	DOWITCH_SP	- 0.09±0.05	0.01±0.04	- 0.02±0.05	-0.16±0.04
Greater Yellowlegs* <i>Tringa melanoleuca</i>	GRYE	0.06±0.04	0.03±0.03	0.03±0.02	0.02±0.02
Long-billed Dowitcher <i>Limnodromus scolopaceus</i>	LBDO	0.36±0.07	0.16±0.05	0.02±0.10	0.28±0.05
Lesser Yellowlegs** <i>Tringa flavipes</i>	LEYE	- 0.11±0.05	0.01±0.03	- 0.06±0.03	-0.06±0.03
Short-billed Dowitcher** <i>Limnodromus griseus</i>	SHDO	0.30±0.12	0.27±0.06	0.10±0.06	0.17±0.06
Willet** <i>Tringa semipalmata</i>	WILL	—	0.05±0.03	0.01±0.03	0.05±0.07
Wilson's Phalarope** <i>Phalaropus tricolor</i>	WIPH	—	0.11±0.08	0.01±0.05	-0.02±0.06
Marsh Birds	—	—	—	—	—
Common Gallinule <i>Gallinula galeata</i>	COGA	—	—	—	—

Note: *Moderate Priority Species; **High Priority Species;***Highest Priority Species

Species	Species Code	Winter	Spring	Summer	Fall
Least Bittern** <i>Ixobrychus exilis</i>	LEBI	—	—	—	—
Sora <i>Porzana carolina</i>	SORA	—	—	—	—
Other Non-Passerines	—	0.08±0.09	- 0.02±0.07	- 0.02±0.08	-0.01±0.09
Common Ground Dove*** <i>Columina passerine</i>	COGD	0.13±0.05	0.03±0.03	0.10±0.04	0.10±0.04
Common Nighthawk <i>Chordeiles minor</i>	CONI	—	0.05±0.03	0.04±0.03	—
Chuck-Will's-Widow** <i>Antrostomus carolinensis</i>	CWWI	—	- 0.01±0.07	—	—
Downy Woodpecker <i>Picoides pubescens</i>	DOWO	0.02±0.04	- 0.08±0.04	- 0.08±0.05	-0.04±0.03
Mourning Dove <i>Zenaida macroura</i>	MODO	0.12±0.04	0.07±0.02	0.09±0.02	0.08±0.03
Northern Bobwhite** <i>Colinus virginianus</i>	NOBO	—	- 0.20±0.06	- 0.19±0.05	-0.29±0.10
Northern Flicker** <i>Colaptes auratus</i>	NOFL	0.03±0.03	- 0.04±0.06	—	-0.03±0.03
Red-bellied Woodpecker <i>Mekaberpes carolinus</i>	RBWO	0.01±0.03	0.01±0.04	- 0.02±0.04	0.00±0.03
Rock Pigeon <i>Columba livia</i>	ROPI	0.12±0.09	- 0.01±0.94	- 0.06±0.04	0.06±0.06
Ruby-throated Hummingbird <i>Archilochus colubris</i>	RTHU	—	—	0.01±0.07	—
Yellow-bellied Sapsucker <i>Sphyrapicus varius</i>	YBSA	0.11±0.05	—	—	0.07±0.05
Other Passerines	—	0.06±0.03	0.01±0.02	0.02±0.03	0.02±0.02
American Goldfinch <i>Spinus tristis</i>	AMGO	0.05±0.08	—	—	—
American Robin <i>Turdus migratorius</i>	AMRO	0.12±0.07	0.00±0.08	—	—
Bank Swallow <i>Riparia riparia</i>	BANS	—	—	0.02±0.07	0.06±0.07
Barn Swallow <i>Hirundo rustica</i>	BARS	—	- 0.04±0.04	0.03±0.02	-0.01±0.05
Belted Kingfisher <i>Megasceryle alcyon</i>	BEKI	0.05±0.03	- 0.04±0.05	0.02±0.04	0.03±0.02
Blue-gray Gnatcatcher <i>Polioptila caerulea</i>	BGGN	0.09±0.05	0.02±0.04	0.01±0.04	-0.01±0.03
Blue-headed Vireo <i>Vireo solitaries</i>	BHVI	0.07±0.05	—	—	—
Blue Grosbeak <i>Passerina caerulea</i>	BLGR	—	0.06±0.04	0.08±0.04	0.01±0.06

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Species	Species Code	Winter	Spring	Summer	Fall
Brown Thrasher** <i>Toxostoma rufum</i>	BRTH	0.02±0.05	0.04±0.02	0.02±0.02	0.01±0.03
Carolina Chickadee <i>Poecile carolinensis</i>	CACH	0.03±0.04	0.03±0.03	0.02±0.04	-0.01±0.03
Carolina Wren <i>Thryothorus ludovicianus</i>	CARW	0.08±0.04	0.08±0.03	0.09±0.03	0.04±0.03
Cedar Waxwing <i>Bombycilla cedrorum</i>	CEDW	0.15±0.07	0.03±0.05	—	—
Chimney Swift <i>Chaetura pelagica</i>	CHSW	—	- 0.03±0.04	0.05±0.05	0.02±0.05
Eastern Bluebird <i>Sialia sialis</i>	EABL	0.04±0.10	—	—	—
Eastern Kingbird** <i>Tyrannus tyrannus</i>	EAKI	—	- 0.04±0.04	- 0.10±0.03	-0.08±0.06
Eastern Phoebe <i>Sayornis phoebe</i>	EAPH	0.05±0.02	- 0.01±0.06	—	0.05±0.03
Eastern Towhee** <i>Pipilo erythrophthalmus</i>	EATO	0.04±0.04	0.04±0.03	0.03±0.03	0.02±0.03
Eastern Wood-Pewee** <i>Contopus virens</i>	EAWP	—	—	—	0.00±0.05
Empidonax spp. <i>Empidonax spp.</i>	EMPID	—	—	—	0.02±0.06
Gray Catbird <i>Dumetella carolinensis</i>	GRCA	0.03±0.04	0.06±0.04	0.08±0.03	0.07±0.04
Great-crested Flycatcher <i>Myiarchus crinitus</i>	GCFL	—	- 0.02±0.05	0.00±0.04	—
Hermit Thrush <i>Catharus guttatus</i>	HETH	0.03±0.04	0.00±0.07	—	-0.02±0.05
House Wren <i>Troglodytes aedon</i>	HOWR	0.03±0.04	0.02±0.05	—	0.04±0.03
Indigo Bunting* <i>Passerina cyanea</i>	INBU	—	0.05±0.04	0.04±0.03	-0.05±0.04
Loggerhead Shrike <i>Lanius ludovicianus</i>	LOSH	0.06±0.06	—	0.14±0.06	0.16±0.04
Marsh Wren* <i>Cistothorus palustris</i>	MAWR	0.01±0.04	- 0.04±0.02	- 0.03±0.03	0.06±0.05
Northern Cardinal <i>Cardinalis cardinalis</i>	NOCA	0.04±0.04	0.06±0.02	0.06±0.03	0.00±0.03
Northern Mockingbird <i>Mimus polyglottos</i>	NOMO	0.10±0.03	0.08±0.02	0.06±0.02	0.06±0.02
Northern Rough-Winged Swallow <i>Stelgidopteryx serripennis</i>	NRWS	—	0.02±0.04	0.01±0.05	—
Painted Bunting*** <i>Passerina ciris</i>	PABU	—	0.07±0.03	0.04±0.02	0.02±0.04

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Species	Species Code	Winter	Spring	Summer	Fall
Purple Martin <i>Progne subis</i>	PUMA	—	- 0.04±0.06	- 0.01±0.04	—
Ruby-crowned Kinglet <i>Regulus calendula</i>	RCKI	0.14±0.04	0.05±0.06	—	0.06±0.06
Red-Eyed Vireo <i>Vireo olivaceus</i>	REVI	—	- 0.03±0.05	- 0.01±0.06	0.00±0.05
Sedge Wren* <i>Cistothorus platensis</i>	SEWR	0.04±0.06	- 0.05±0.06	—	-0.06±0.05
Tree Swallow <i>Tachycineta bicolor</i>	TRES	0.12±0.06	0.17±0.06	- 0.09±0.08	0.03±0.04
White-eyed Vireo* <i>Vireo griseus</i>	WEVI	- 0.09±0.06	- 0.08±0.04	- 0.09±0.04	-0.01±0.03
Yellow-billed Cuckoo** <i>Coccyzus americanus</i>	YBCU	—	- 0.08±0.05	- 0.05±0.03	-0.04±0.06
Raptors	—	—	—	—	—
American Kestrel** <i>Falco sparverius</i>	MAKE	—	—	—	—
Bald Eagle <i>Haliaeetus leucocephalus</i>	BAEA	—	—	—	—
Black Vulture* <i>Coragyps atratus</i>	BLVU	—	—	—	—
Cooper's Hawk* <i>Accipiter cooperii</i>	COHA	—	—	—	—
Merlin <i>Falco columbarius</i>	MERL	—	—	—	—
Mississippi Kite* <i>Ictinia mississippiensis</i>	MIKI	—	—	—	—
Northern Harrier* <i>Circus cyaneus</i>	NOHA	—	—	—	—
Red-tailed Hawk* <i>Buteo jamaicensis</i>	RTHA	—	—	—	—
Sharp-Shinned Hawk <i>Accipiter striatus</i>	SSHA				
Short-eared Owl <i>Asio flammeus</i>	SEOW	—	—	—	—
Turkey Vulture <i>Carthartes aura</i>	TUVU	—	—	—	—
Small Shorebirds	—	0.04±0.06	0.03±0.04	0.02±0.04	0.01±0.04
American Golden Plover** <i>Pluvialis dominica</i>	AMGP	—	- 0.03±0.07	—	-0.01±0.05
Black-Bellied Plover* <i>Pluvialis squatarola</i>	BBPL	0.11±0.04	0.12±0.04	0.06±0.05	0.06±0.04

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Species	Species Code	Winter	Spring	Summer	Fall
Buff-Breasted Sandpiper*** <i>Tryngites subruficollis</i>	BBSA	—	—	—	-0.01±0.08
Calidris spp. <i>Calidris spp.</i>	CALIDRIS_SP	- 0.04±0.10	- 0.07±0.06	- 0.09±0.04	-0.11±0.05
Dunlin** <i>Calidris alpina</i>	DUNL	0.09±0.04	0.13±0.04	- 0.03±0.09	0.02±0.05
Killdeer <i>Charadrius vociferus</i>	KILL	0.00±0.03	0.00±0.02	0.06±0.02	0.00±0.03
Least Sandpiper** <i>Calidris minutilla</i>	LESA	- 0.04±0.04	- 0.02±0.04	0.05±0.04	0.03±0.03
Pectoral Sandpiper* <i>Calidris melanotos</i>	PESA	—	0.00±0.05	- 0.02±0.05	-0.05±0.05
Ruddy Turnstone** <i>Oxyura jamaicensis</i>	RUTU	0.14±0.08	- 0.01±0.07	- 0.06±0.05	0.06±0.07
Sanderling** <i>Calidris alba</i>	SAND	- 0.04±0.09	—	—	-0.02±0.08
Semipalmated Plover* <i>Charadrius semipalmatus</i>	SEPL	0.17±0.06	0.07±0.04	0.08±0.03	0.11±0.04
Semipalmated Sandpiper** <i>Calidris pusilla</i>	SESA	—	0.07±0.06	0.13±0.05	0.09±0.06
Solitary Sandpiper** <i>Tringa solitaria</i>	SOSA	—	0.08±0.06	- 0.04±0.05	-0.04±0.05
Spotted Sandpiper* <i>Actitis macularius</i>	SPSA	—	- 0.03±0.04	0.01±0.03	-0.06±0.03
Stilt Sandpiper** <i>Calidris himantopus</i>	STSA	- 0.03±0.07	0.05±0.04	- 0.02±0.04	-0.01±0.03
Western Sandpiper** <i>Calidris mauri</i>	WESA	0.09±0.04	0.12±0.06	0.10±0.05	0.03±0.05
White-Rumped Sandpiper <i>Calidris fuscicollis</i>	WRSA	—	- 0.08±0.05	0.07±0.06	-0.01±0.06
Wilson's Plover** <i>Charadrius wilsonia</i>	WISP	—	0.03±0.04	0.03±0.03	—
Wilson's Snipe** <i>Gallinago delicata</i>	WISN	- 0.01±0.07	0.01±0.05	—	0.01±0.04
Wading Birds	—	0.17±0.05	0.12±0.04	0.09±0.04	0.10±0.04
American Avocet** <i>Recurvirostra americana</i>	AMAV	0.00±0.03	0.04±0.03	0.05±0.03	0.04±0.02
American White Pelican** <i>Pelecanus erythrorhynchos</i>	AWPE	0.26±0.12	0.12±0.11	0.23±0.11	-0.31±0.08
Anhinga <i>Anhinga anhinga</i>	ANHI	0.09±0.11	0.11±0.05	0.11±0.07	0.04±0.09

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Species	Species Code	Winter	Spring	Summer	Fall
Black-Crowned Night Heron ** <i>Nycticorax nycticorax</i>	BCNH	0.19±0.07	0.20±0.06	0.17±0.05	0.18±0.06
Black-Necked Stilt <i>Himantopus mexicanus</i>	BNST	0.32±0.09	0.00±0.03	0.02±0.02	0.081±0.05
Cattle Egret <i>Bubulcus ibis</i>	CAEG	—	- 0.01±0.05	- 0.02±0.03	0.00±0.05
Double-Crested Cormorant <i>Phalacrocorax auritus</i>	DCCO	0.07±0.06	0.07±0.05	0.08±0.04	0.06±0.06
Glossy Ibis ** <i>Plegadis falcinellus</i>	GLIB	0.14±0.08	0.13±0.06	- 0.00±0.05	0.05±0.05
Great Blue Heron <i>Ardea herodias</i>	GBHE	0.08±0.02	0.06±0.03	0.08±0.02	0.06±0.06
Great Egret * <i>Ardea alba</i>	GREG	0.15±0.05	0.04±0.04	0.03±0.05	0.04±0.04
Green Heron <i>Butorides virescens</i>	GRHE	—	0.09±0.04	0.04±0.03	0.03±0.05
Little Blue Heron ** <i>Egretta garzetta</i>	LBHE	0.19±0.05	0.16±0.06	- 0.04±0.04	0.02±0.03
Reddish Egret * <i>Egretta rufescens</i>	REEG	—	—	0.13±0.10	0.11±0.08
Roseate Spoonbill <i>Platalea ajaja</i>	ROSP	—	0.39±0.08	0.48±0.08	0.47±0.08
Snowy Egret ** <i>Egretta thula</i>	SNEG	0.29±0.05	0.13±0.05	0.06±0.04	0.10±0.04
Tricolored Heron ** <i>Egretta tricolor</i>	TRHE	0.32±0.06	0.16±0.05	0.04±0.05	0.14±0.04
White Ibis ** <i>Eudocimus albus</i>	WHIB	0.16±0.05	0.21±0.09	0.15±0.06	0.09±0.04
Wood Stork *** <i>Mycteria americana</i>	WOST	0.14±0.11	0.16±0.09	0.02±0.06	0.11±0.06
Yellow-Crowned Night Heron ** <i>Nyctanassa violacea</i>	YCNH	—	0.05±0.11	- 0.01±0.07	0.02±0.07
Warblers	—	0.14±0.09	0.03±0.05	0.04±0.08	0.09±0.05
American Redstart <i>Setophaga ruticilla</i>	AMRE	—	- 0.02±0.08	0.03±0.06	0.08±0.04
Black-And-White Warbler <i>Mniotilta varia</i>	BAWW	0.19±0.07	0.05±0.04	- 0.02±0.07	0.10±0.04
Blackpoll Warbler * <i>Setophaga striata</i>	BLPW	—	- 0.09±0.08	—	—
Black-Throated Blue Warbler * <i>Setophaga caerulescens</i>	BTBW	—	—	—	0.13±0.06

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Species	Species Code	Winter	Spring	Summer	Fall
Common Yellowthroat <i>Geothlypis trichas</i>	COYE	0.06±0.05	0.03±0.03	0.03±0.04	0.10±0.03
Magnolia Warbler <i>Setophaga magnolia</i>	MAWA	—	—	—	-0.01±0.05
Northern Parula* <i>Setophaga Americana</i>	NOPA	—	0.01±0.06	0.01±0.06	0.09±0.04
Northern Waterthrush <i>Parkesia noveboracensis</i>	NOWA	0.17±0.06	0.10±0.04	0.13±0.06	0.13±0.04
Orange-Crowned Warbler <i>Oreothlypis celata</i>	OCWA	0.15±0.05	0.11±0.07	—	0.09±0.05
Palm Warbler <i>Setophaga palmarum</i>	PAWA	0.21±0.04	0.17±0.06	—	0.07±0.03
Prairie Warbler** <i>Setophaga</i>	PRAW	0.14±0.08	0.03±0.06	0.14±0.05	0.06±0.04
Prothonotary Warbler** <i>Protonotaria citrea</i>	PROW	—	—	- 0.02±0.07	—
Yellow-Breasted Chat <i>Icteria virens</i>	YBCH	—	- 0.03±0.05	- 0.07±0.04	—
Yellow-Rumped Warbler <i>Setophaga coronata</i>	YRWA	0.09±0.03	0.07±0.05	—	0.09±0.06
Yellow Warbler <i>Setophaga petechia</i>	YEWA	—	- 0.03±0.06	0.18±0.06	0.16±0.04
Waterfowl	—	0.05±0.03	0.07±0.04	0.07±0.10	0.02±0.04
American Black Duck*** <i>Anas rubripes</i>	ABDU	0.05±0.08	—	—	—
American Coot*** <i>Fulica americana</i>	AMCO	- 0.07±0.05	- 0.08±0.06	- 0.08±0.06	-0.11±0.06
American Widgeon** <i>Anas americana</i>	AMWI	0.06±0.07	0.10±0.07	—	-0.04±0.07
Black-Bellied Whistling Duck <i>Dendrocygna autumnalis</i>	BBWD	—	0.35±0.10	0.44±0.10	0.17±0.12
Blue-Winged Teal** <i>Anas discors</i>	BWTE	- 0.05±0.07	- 0.04±0.03	0.08±0.06	0.00±0.04
Bufflehead <i>Bucephala albeola</i>	BUFF	0.08±0.04	0.00±0.08	—	0.06±0.07
Canvasback*** <i>Aythya valisineria</i>	CANS	-0.01±0.10	—	—	—
Common Goldeneye** <i>Bucephala clangula</i>	COGO	- 0.06±0.08	—	—	—
Eared Grebe <i>Podiceps nigricollis</i>	EAGR	0.07±0.05	0.08±0.05	—	0.11±0.04
Gadwall <i>Anas strepera</i>	GADW	0.14±0.06	0.11±0.07	—	0.07±0.07

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Greater Scaup <i>Aythya marila</i>	GRSC	0.14±0.09	0.07±0.07	—	0.05±0.08
Green-Winged Teal <i>Anas crecca</i>	GWTE	0.03±0.04	- 0.01±0.05	—	-0.02±0.05
Hooded Merganser <i>Lophodytes cucullatus</i>	HOME	0.14±0.07	0.17±0.09	—	0.06±0.08
Horned Grebe <i>Podiceps auratus</i>	HOGR	0.02±0.08	0.01±0.08	—	-0.05±0.06
Lesser Scaup *** <i>Aythya affinis</i>	LESC	0.05±0.07	0.06±0.08	- 0.18±0.10	0.05±0.07
Mallard <i>Anas platyrhynchos</i>	MALL	0.20±0.06	0.11±0.03	0.15±0.05	0.08±0.04
Mottled Duck * <i>Anas fulvigula</i>	MODU	0.09±0.03	0.10±0.03	0.08±0.03	0.03±0.04
Northern Pintail <i>Anas acuta</i>	NOPI	0.16±0.06	—	—	0.04±0.06
Northern Shoveler <i>Anas clypeata</i>	MOSH	0.01±0.03	0.02±0.05	- 0.08±0.07	-0.01±0.03
Pied-Billed Grebe ** <i>Podilymbus podiceps</i>	PBGR	0.06±0.07	0.07±0.05	0.00±0.05	0.01±0.09
Red-Breasted Merganser <i>Mergus serrator</i>	RBME	0.00±0.09	0.08±0.09	—	—
Redhead *** <i>Aythya americana</i>	REDH	0.01±0.09	—	—	—
Ring-Necked Duck <i>Aythya collaris</i>	RNDU	0.03±0.09	0.13±0.06	—	0.01±0.08
Ruddy Duck <i>Oxyura jamaicensis</i>	RUDU	0.05±0.07	0.02±0.06	0.18±0.09	-0.01±0.06
Scaup spp. <i>Aythya spp.</i>	SCAUP_SP	0.14±0.09	0.04±0.09	—	0.04±0.09
Scolopacidae spp. <i>Scolopacidae spp.</i>	SCOLOPACIDAE_SP	- 0.09±0.13	—	—	—
Snow Goose <i>Chen caerulescens</i>	SNGO	- 0.02±0.10	—	—	-0.10±0.08

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**Appendix C: Select Individual Species
Seasonal Trend Analysis Results,
Savannah Harbor Navigation Project,
Dredged Material Containment Areas,
1994-2012**

Figure C-1. Seasonal trends analyses for the Boat-tailed Grackle on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

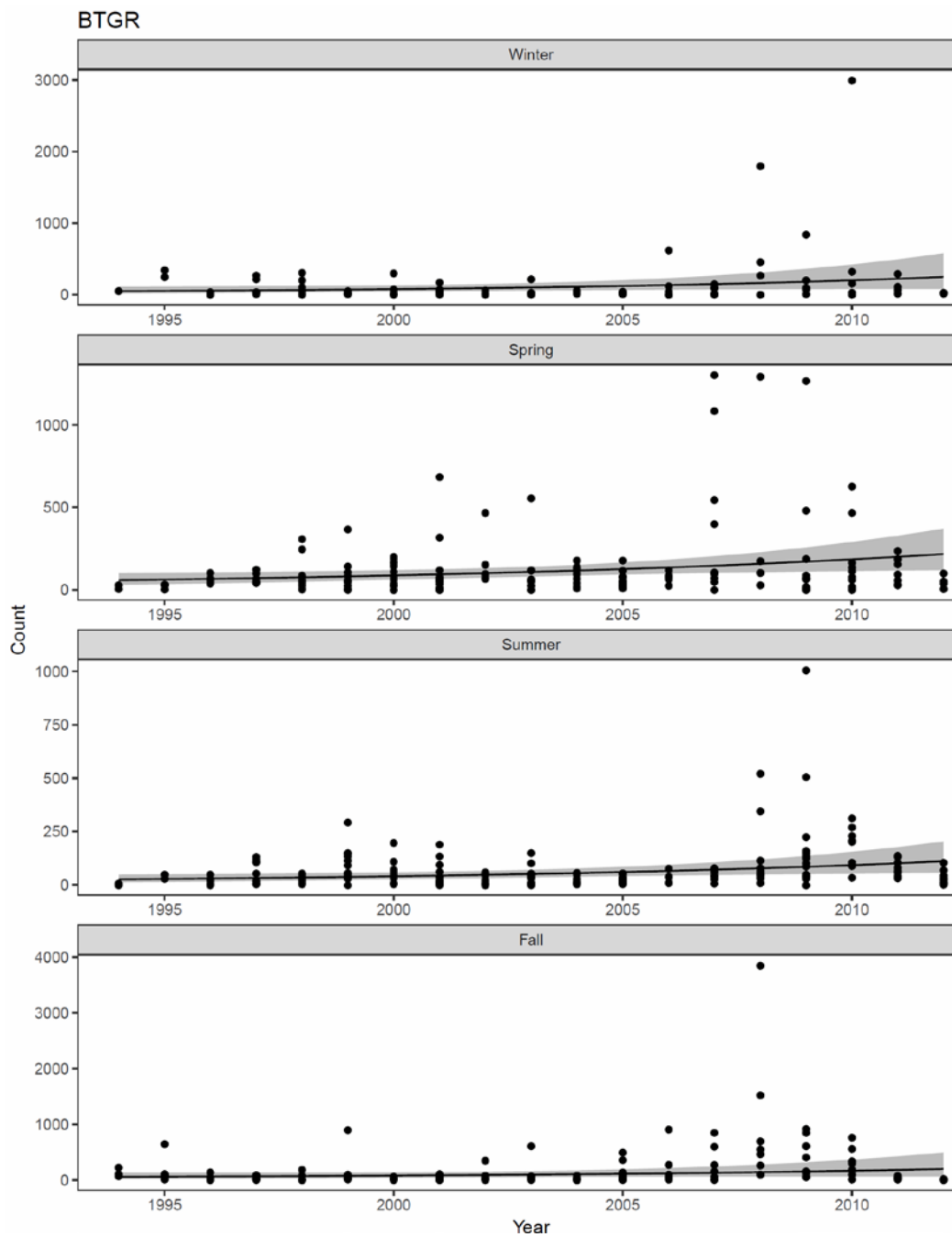


Figure C-2. Seasonal trends analyses for the Common Grackle on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

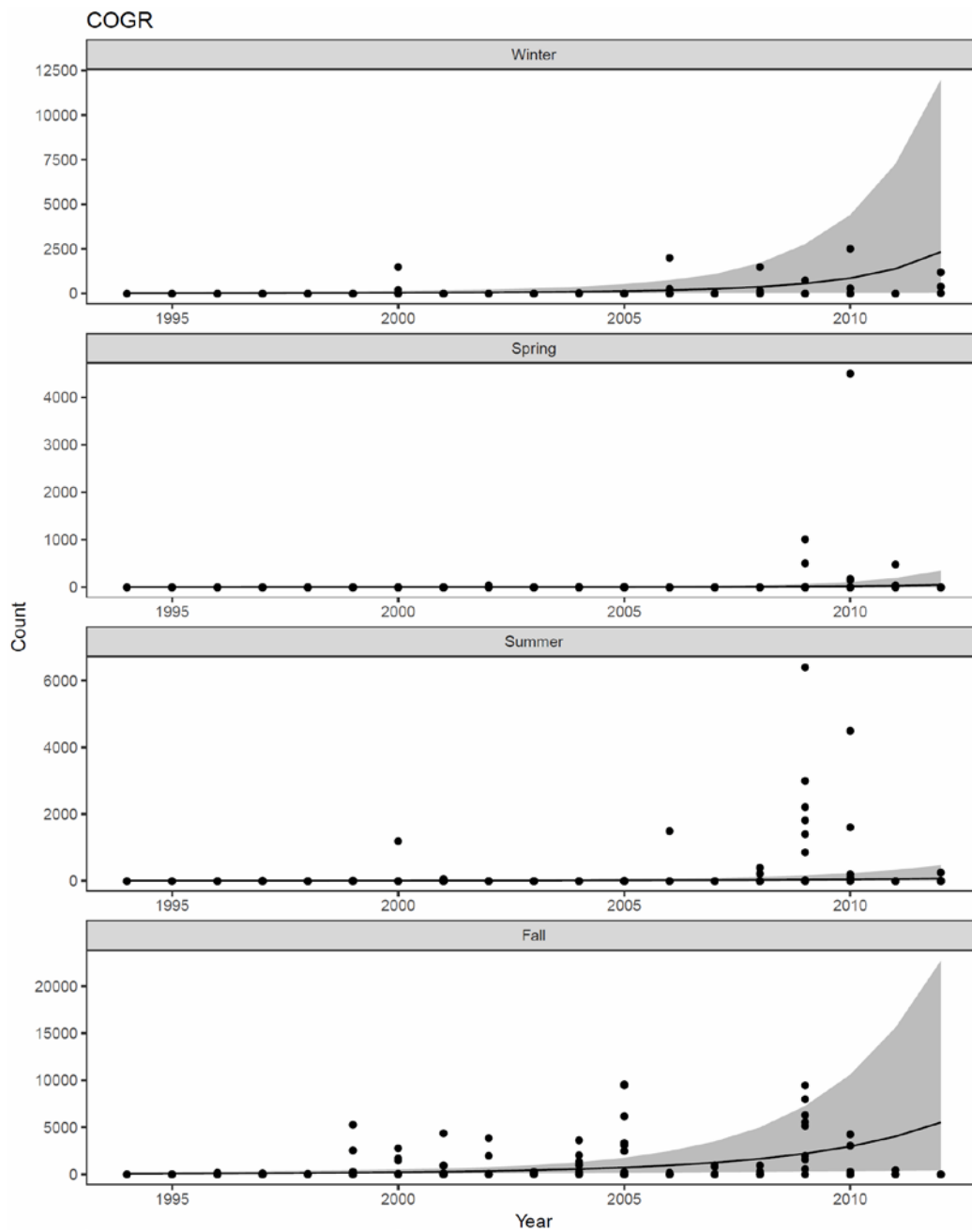


Figure C-3. Seasonal trends analyses for the Least Tern on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

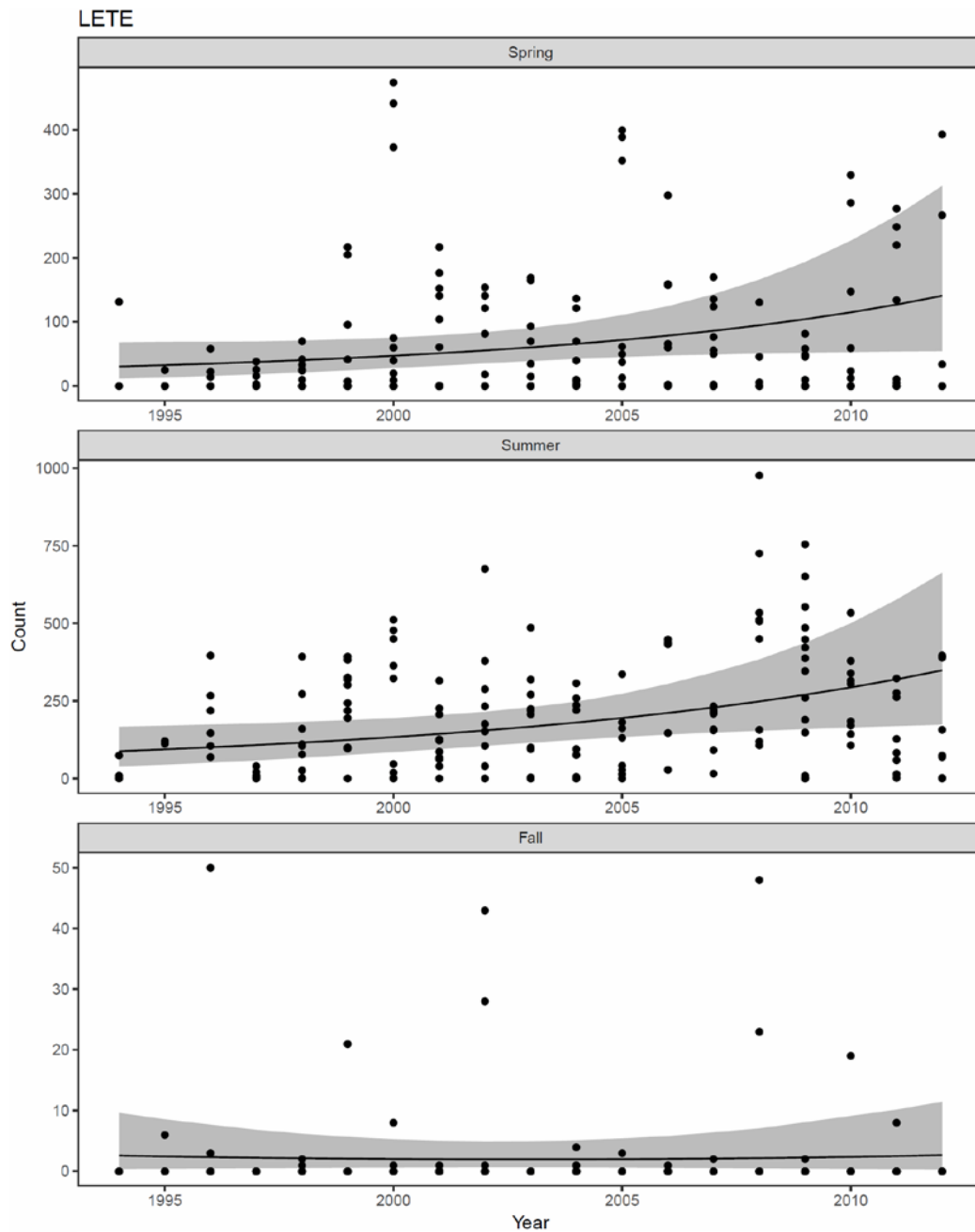


Figure C-4. Seasonal trends analyses for the Gull-billed Tern on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

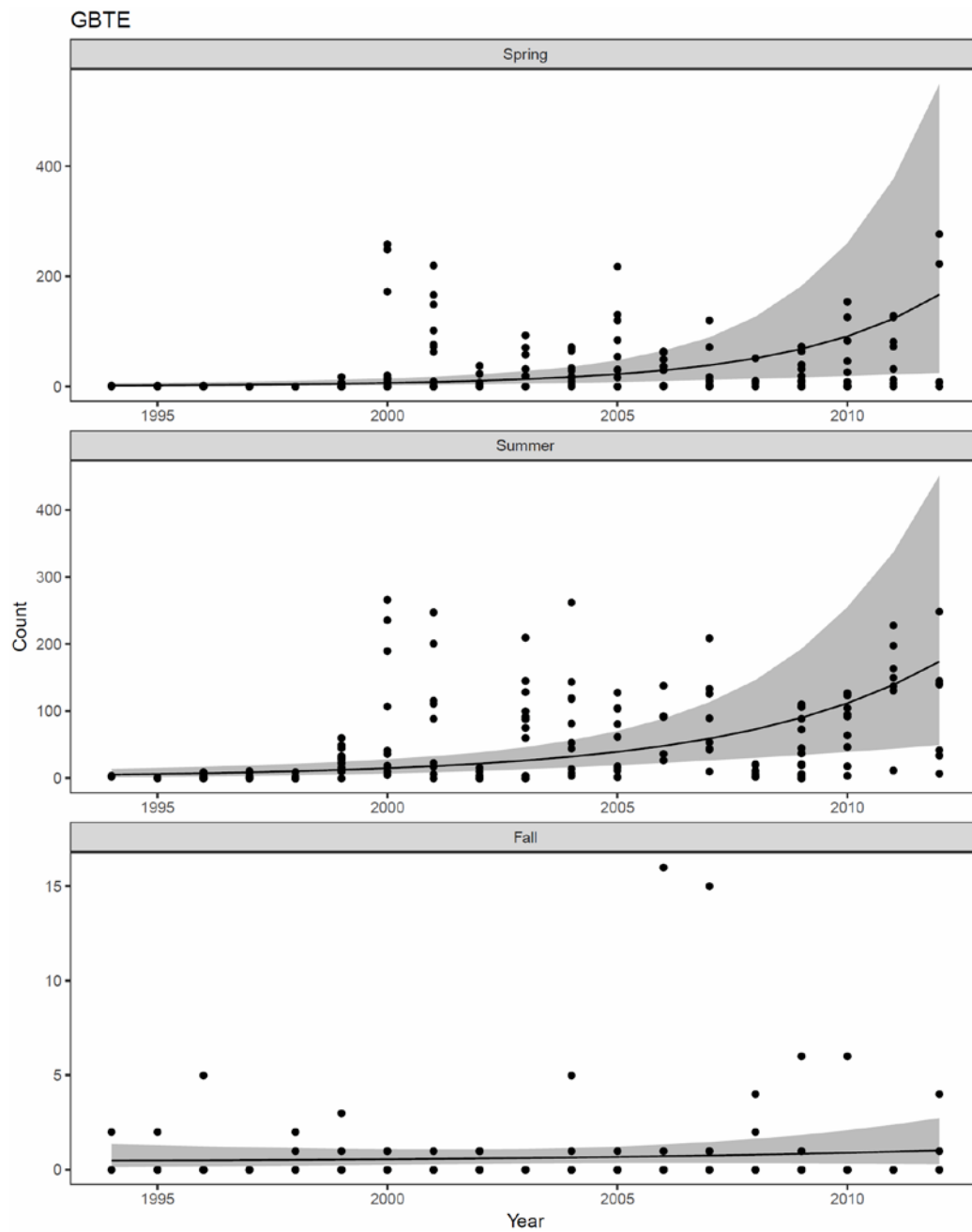


Figure C-5. Seasonal trends analyses for the Ring-billed Gull on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

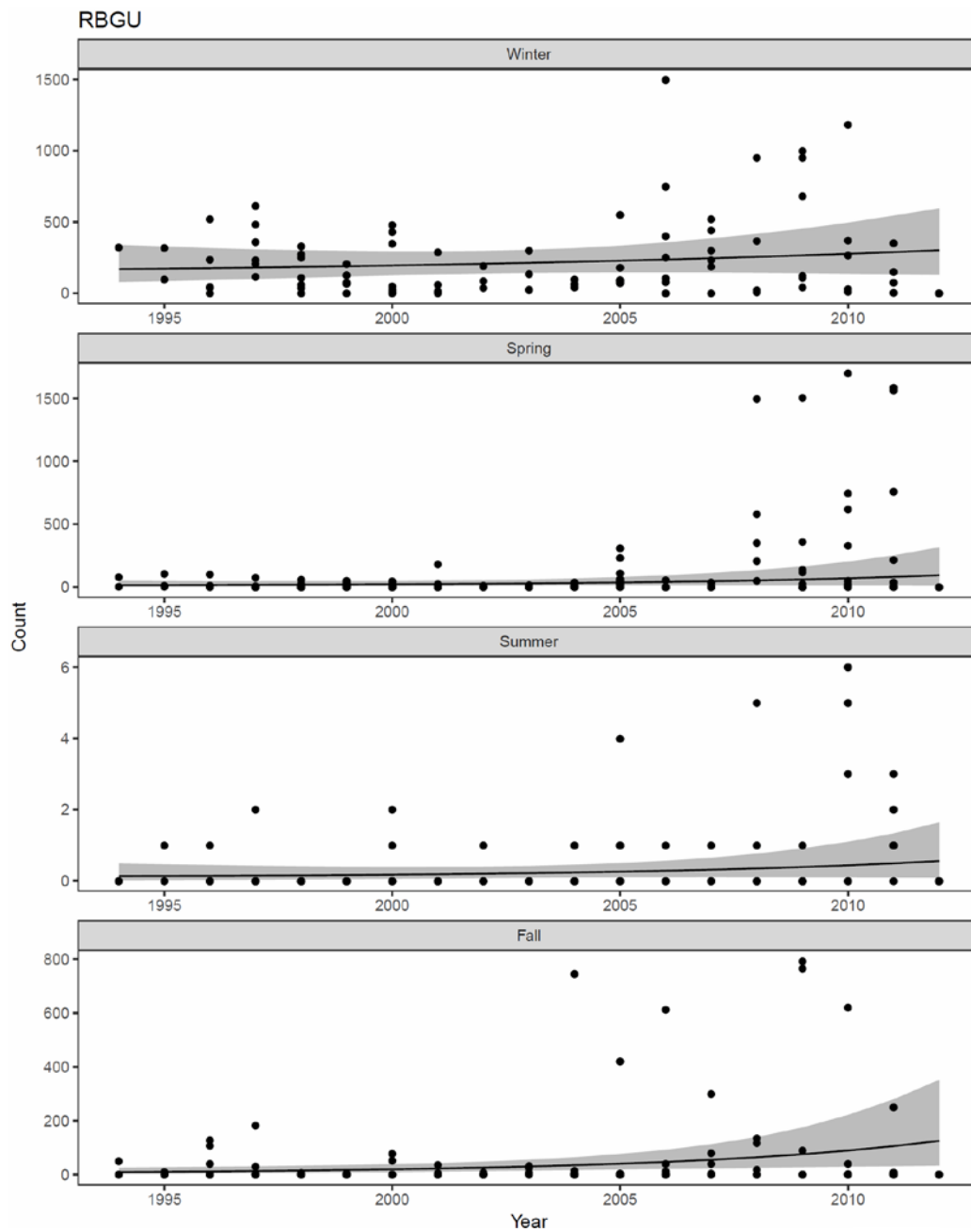


Figure C-6. Seasonal trends analyses for the Savannah Sparrow on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

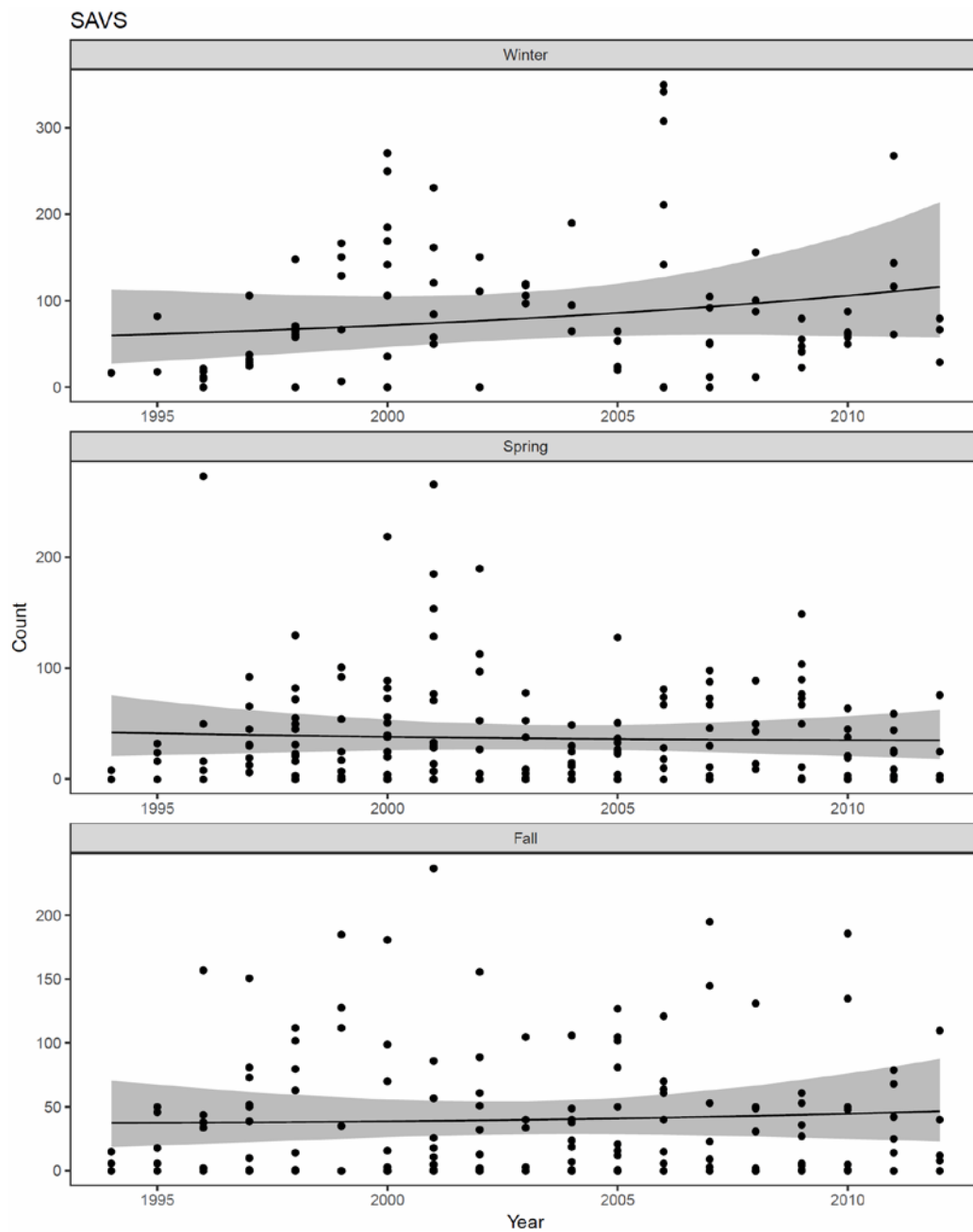


Figure C-7. Seasonal trends analyses for the White-throated Sparrow on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

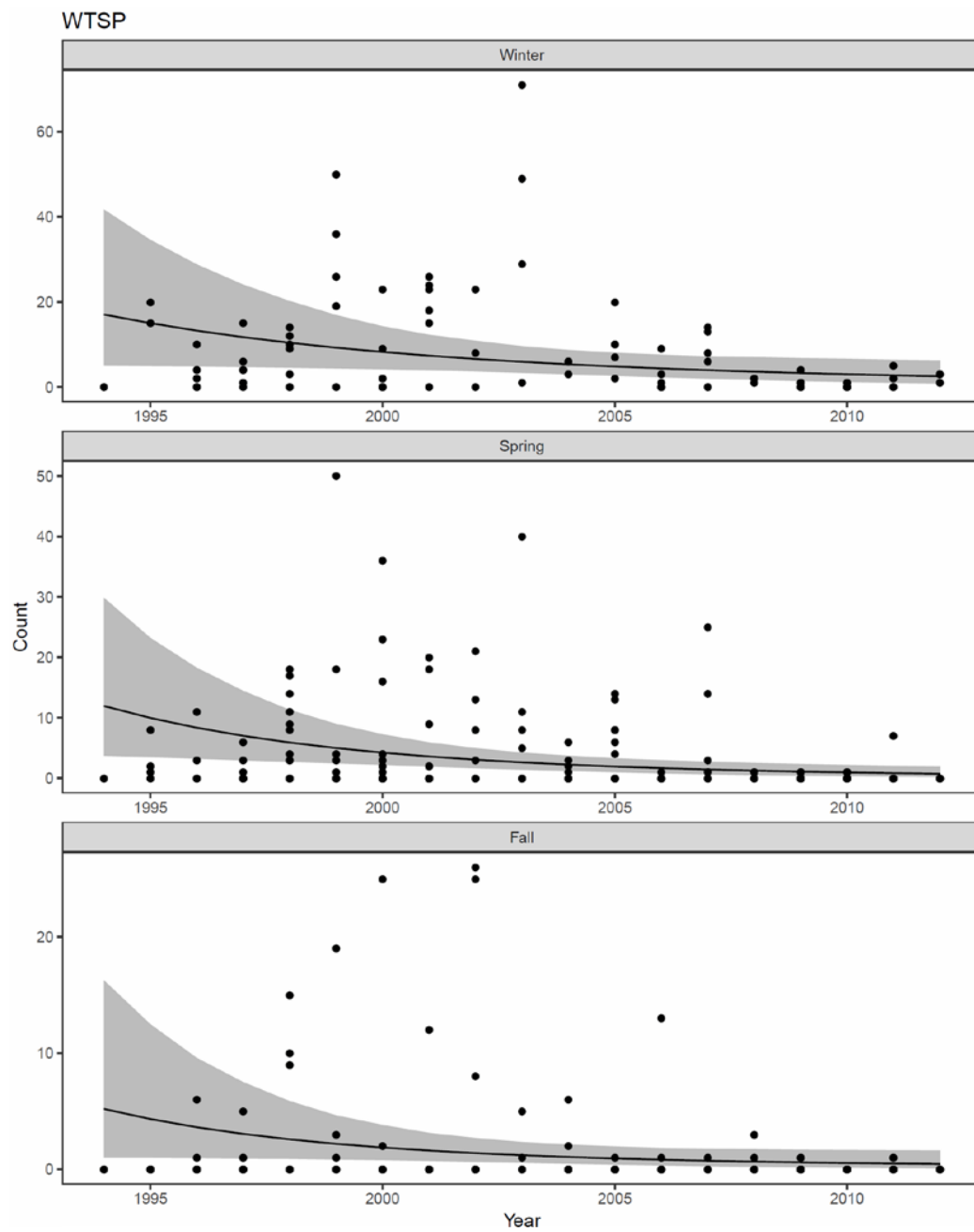


Figure C-8. Seasonal trends analyses for the Greater Yellowlegs on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

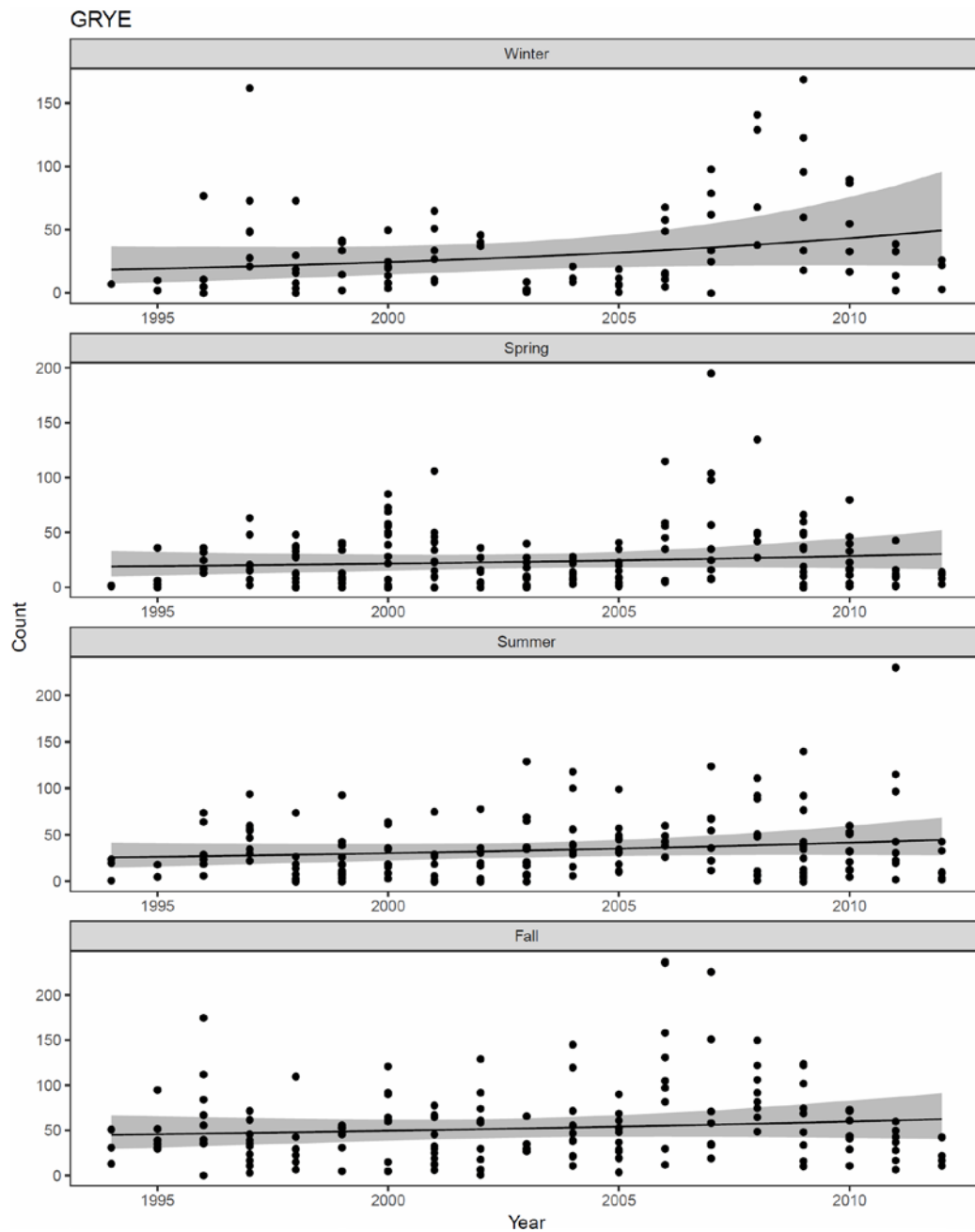


Figure C-9. Seasonal trends analyses for the Lesser Yellowlegs on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

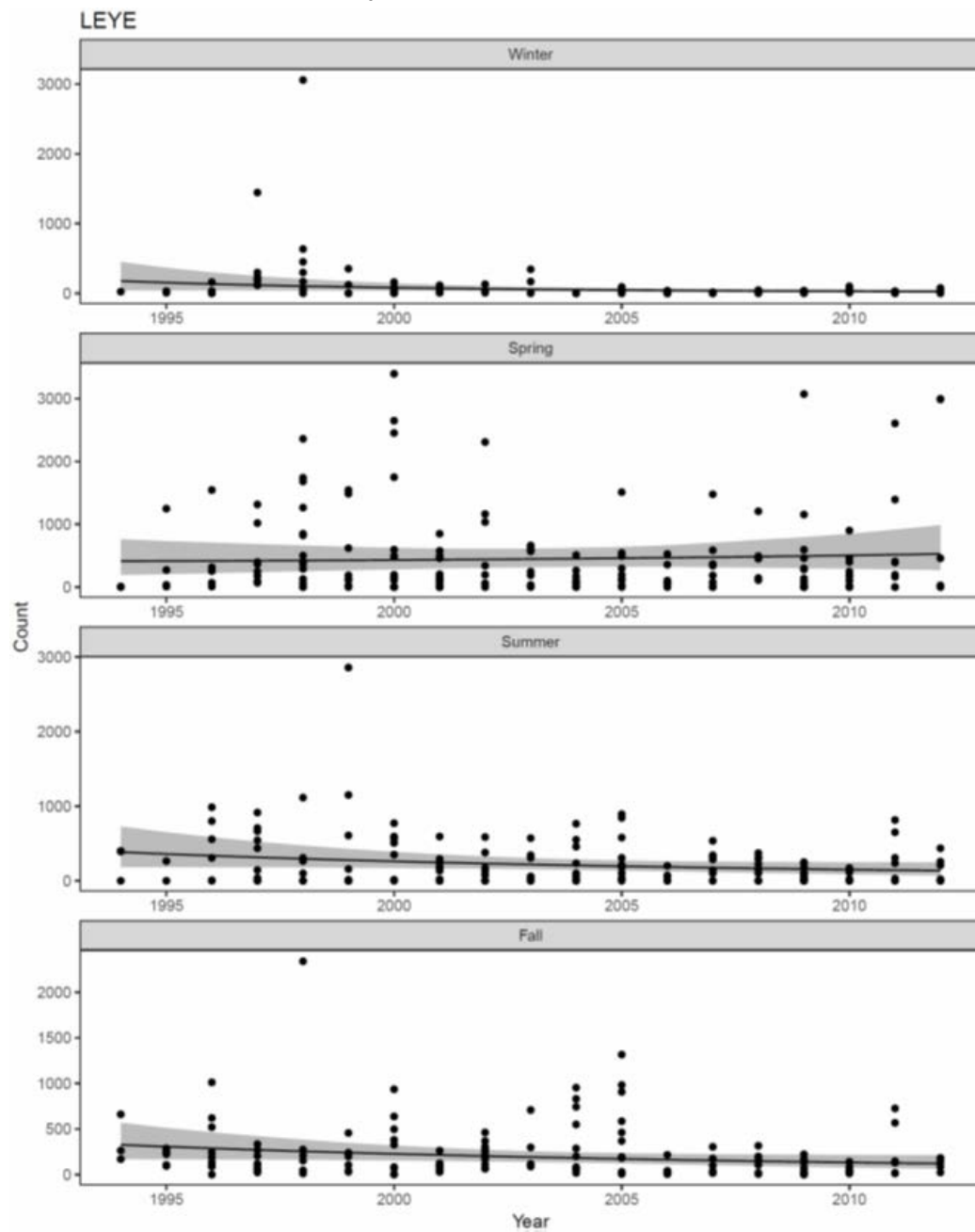


Figure C-10. Seasonal trends analyses for the Black Skimmer on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

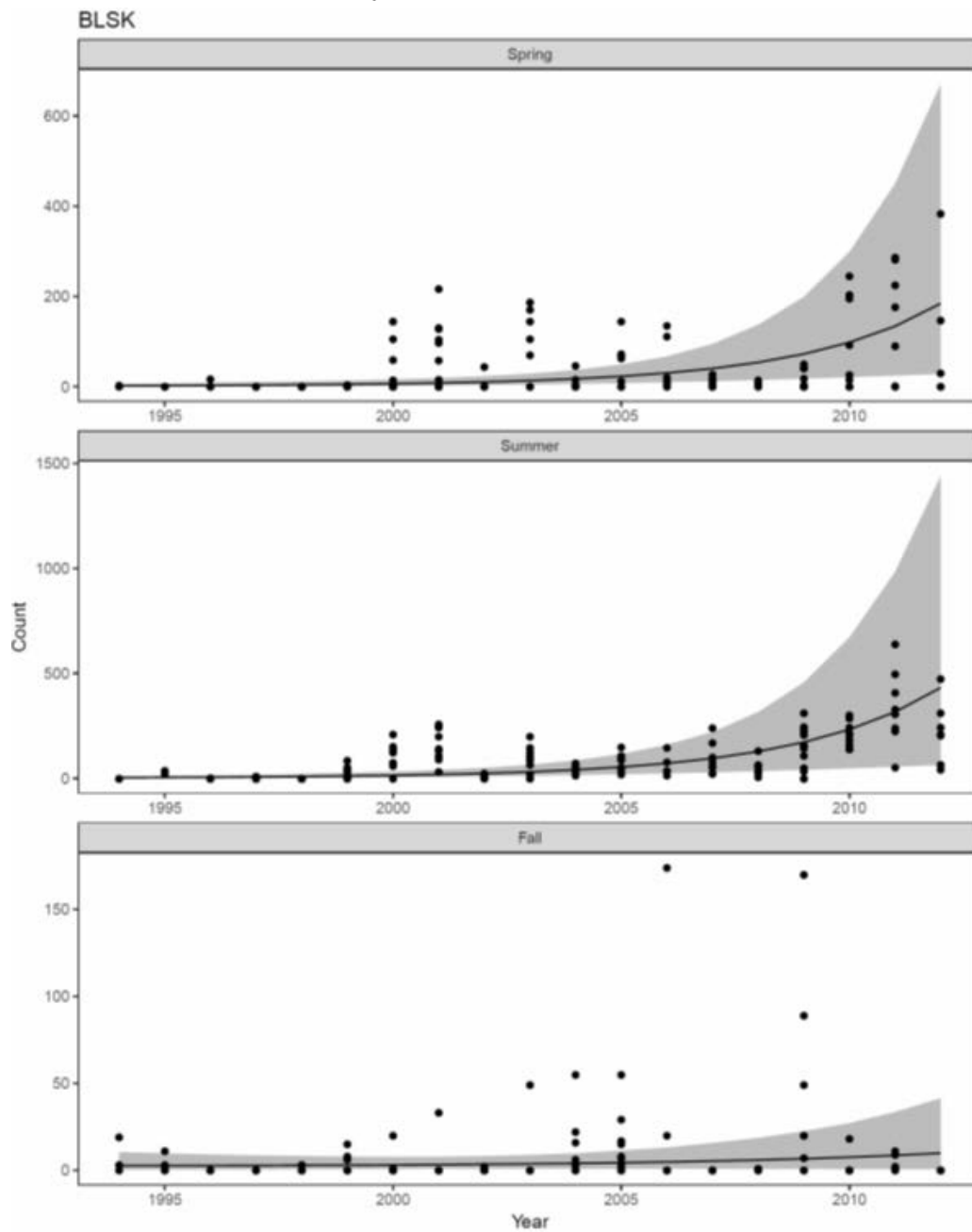


Figure C-11. Seasonal trends analyses for the Mourning Dove on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

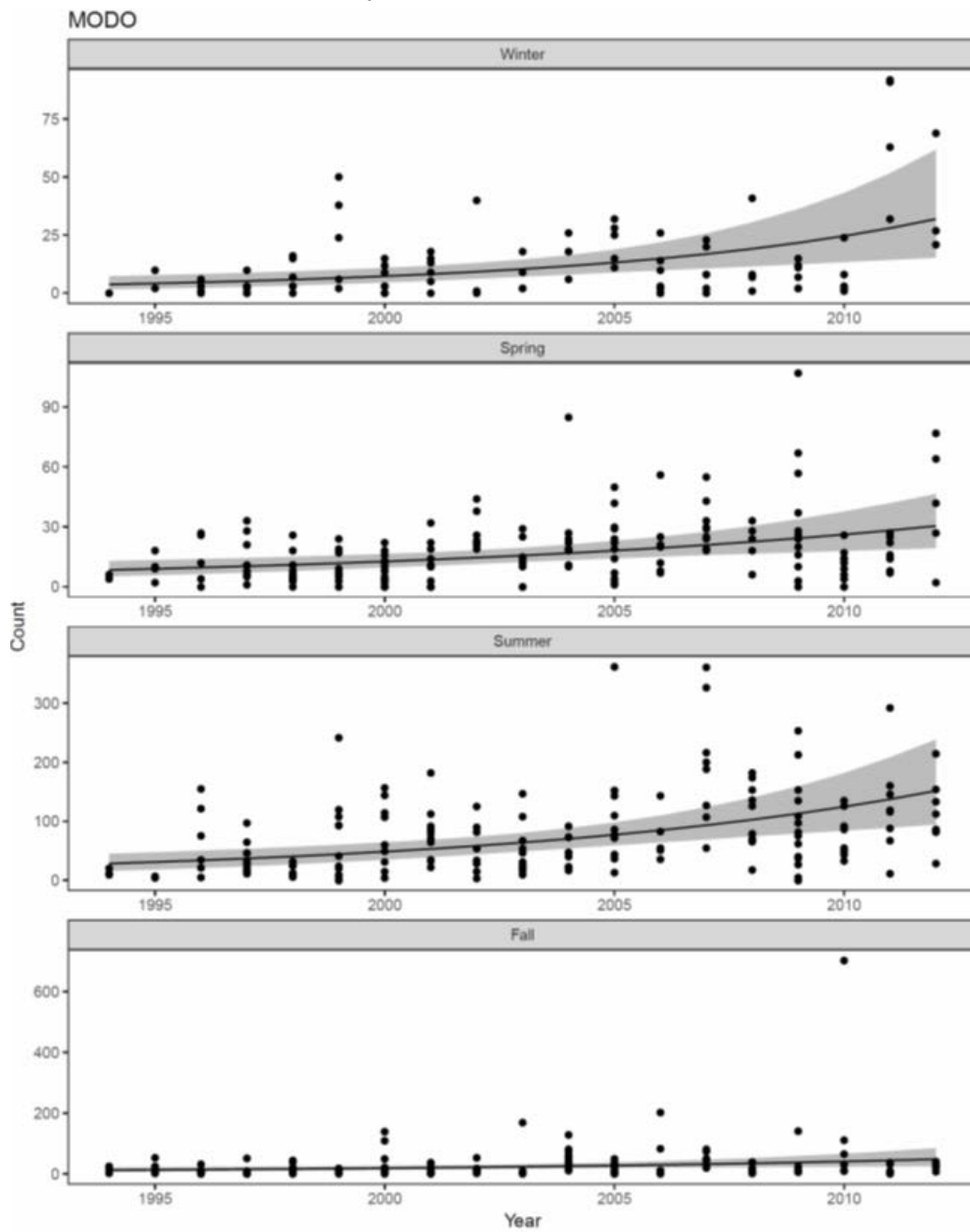


Figure C-12. Seasonal trends analyses for the Red-bellied Woodpecker on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

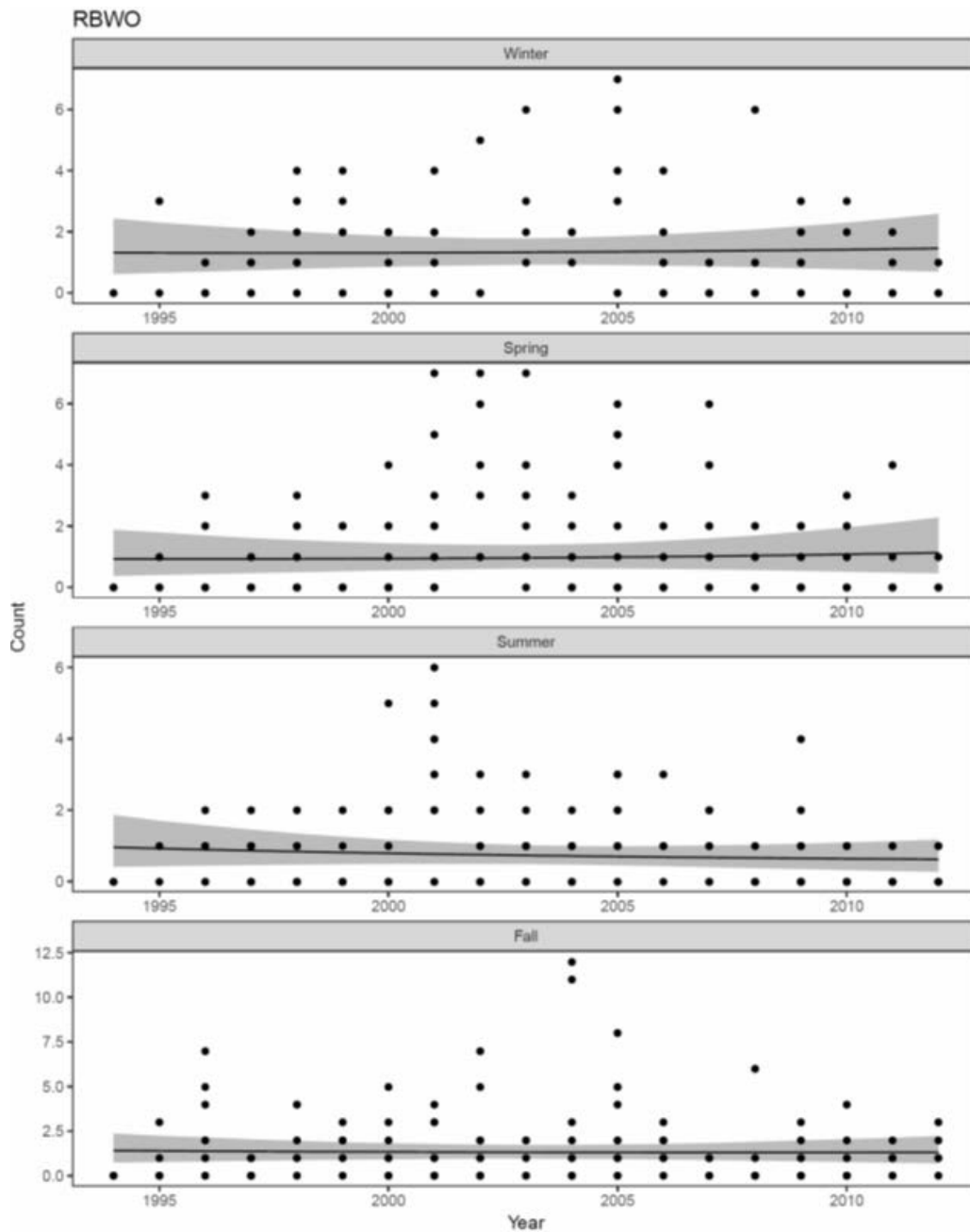


Figure C-13. Seasonal trends analyses for the Blue Grosbeak on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

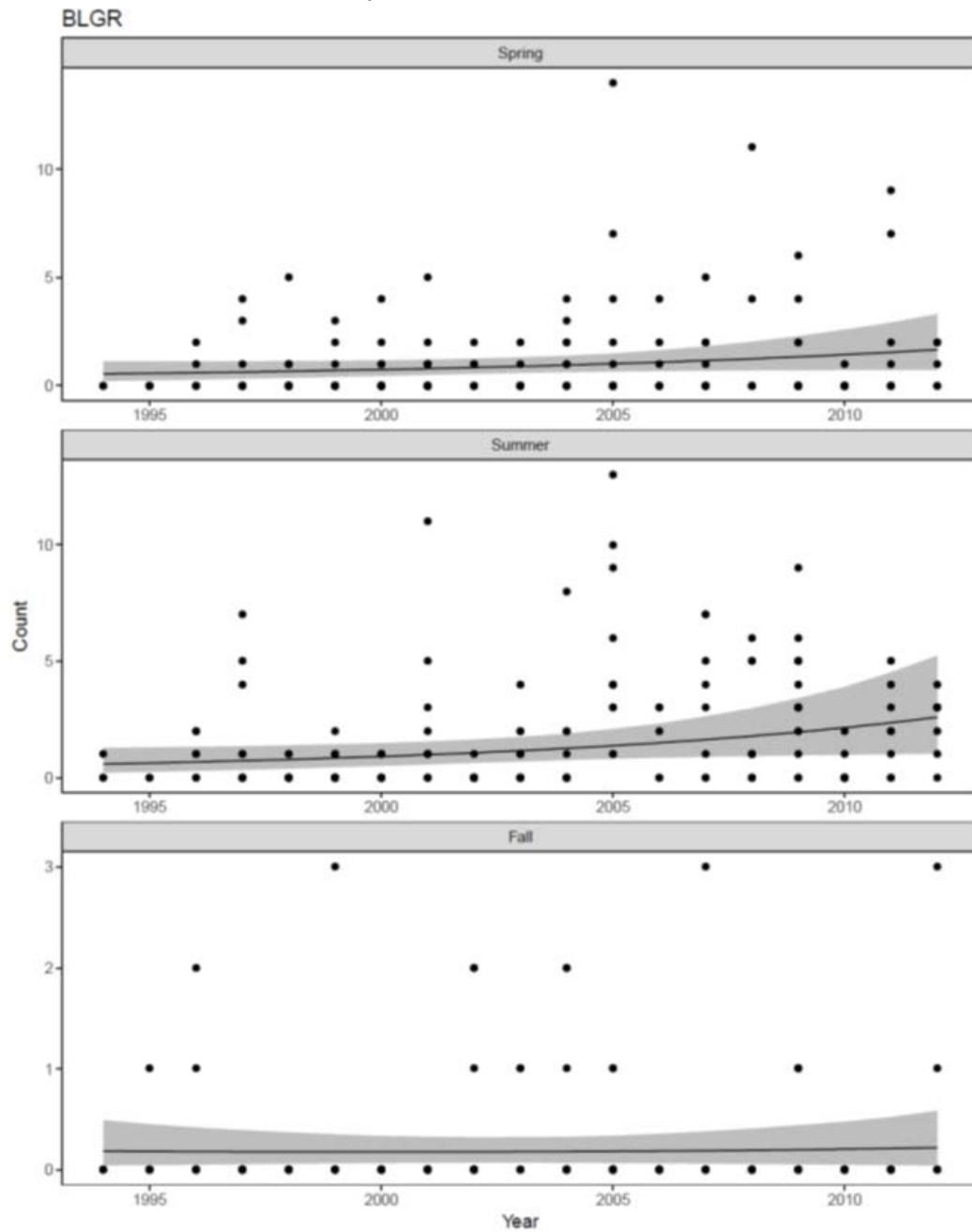


Figure C-14. Seasonal trends analyses for the Eastern Kingbird on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

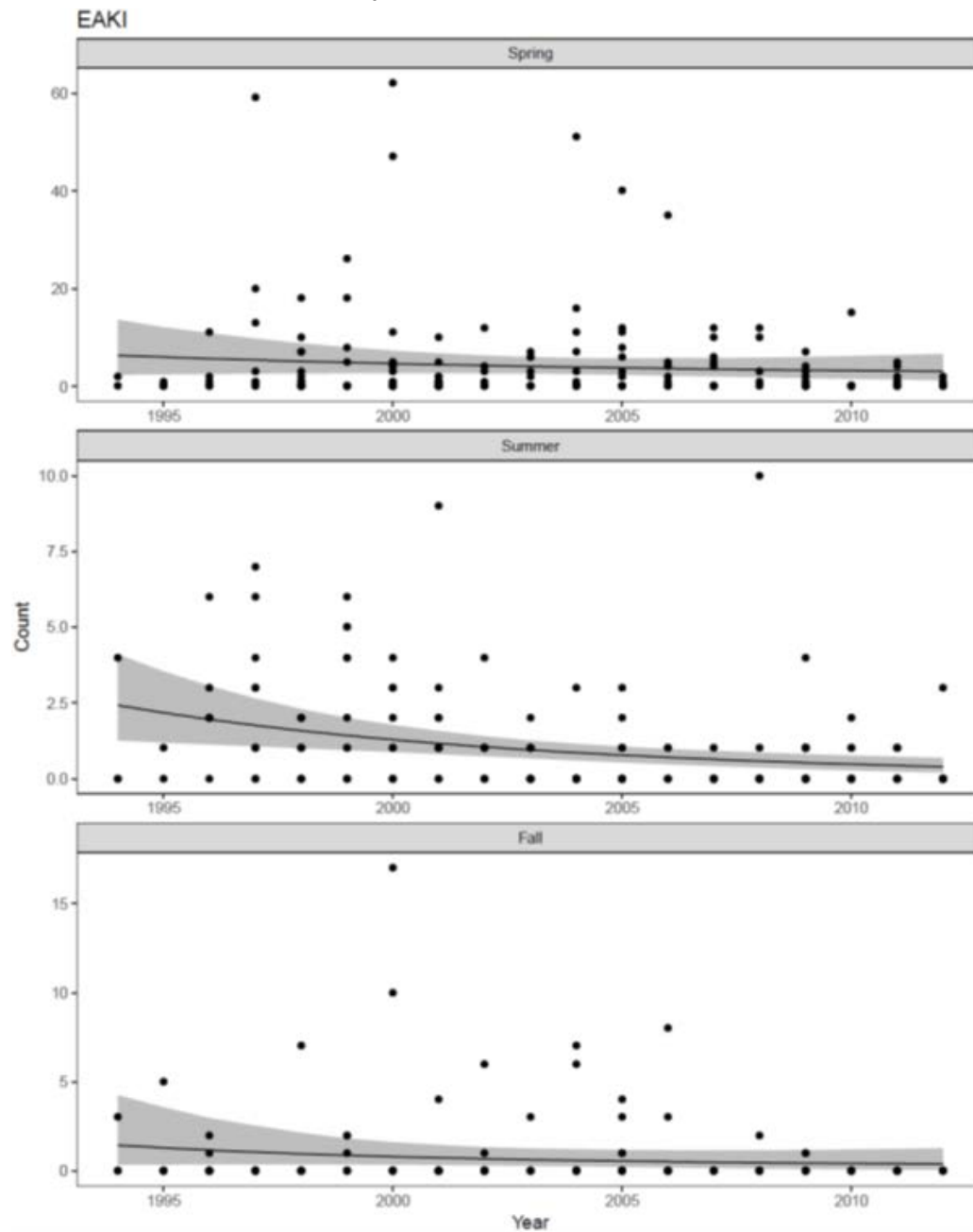


Figure C-15. Seasonal trends analyses for the Belted Kingfisher on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

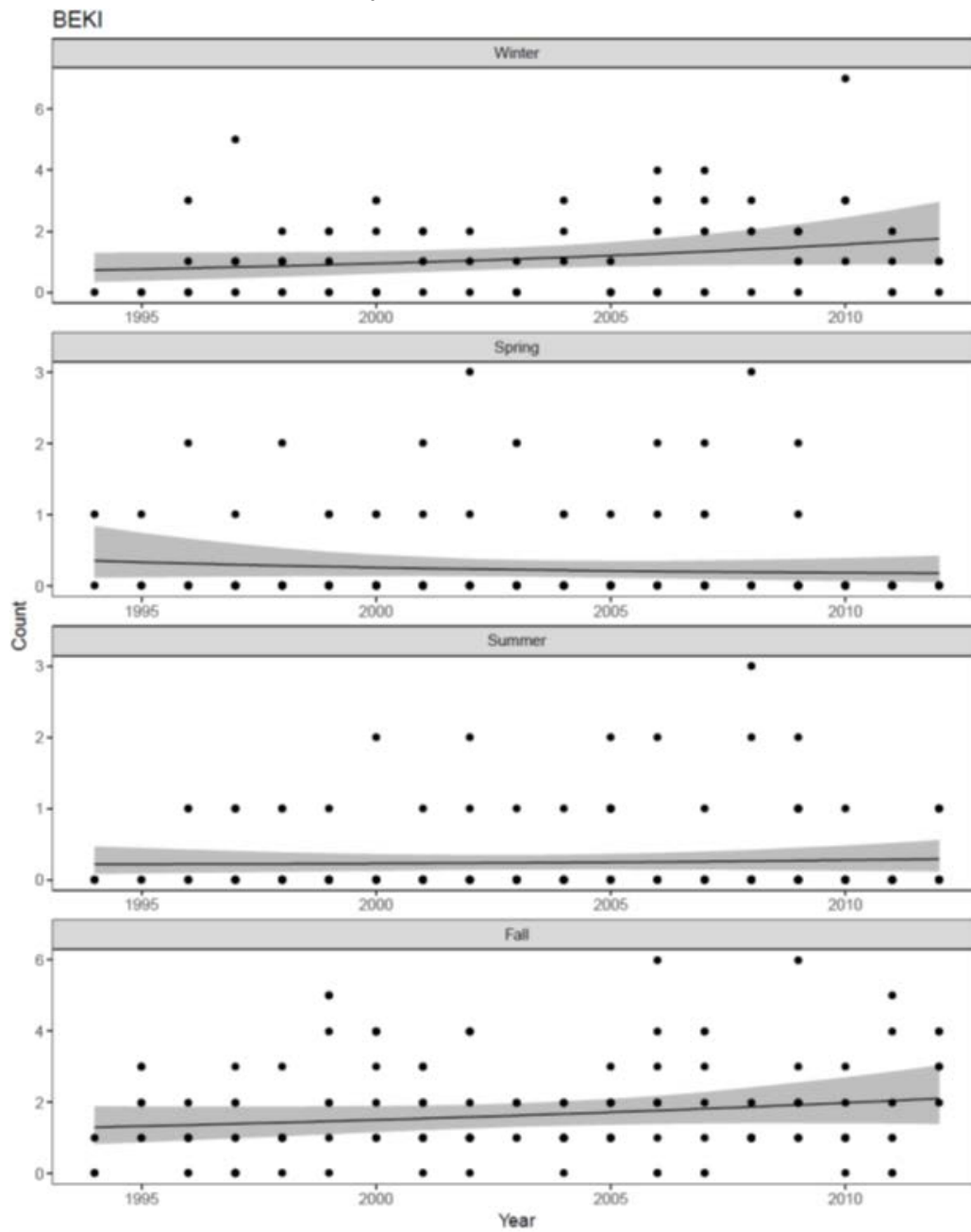


Figure C-16. Seasonal trends analyses for the Least Sandpiper on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

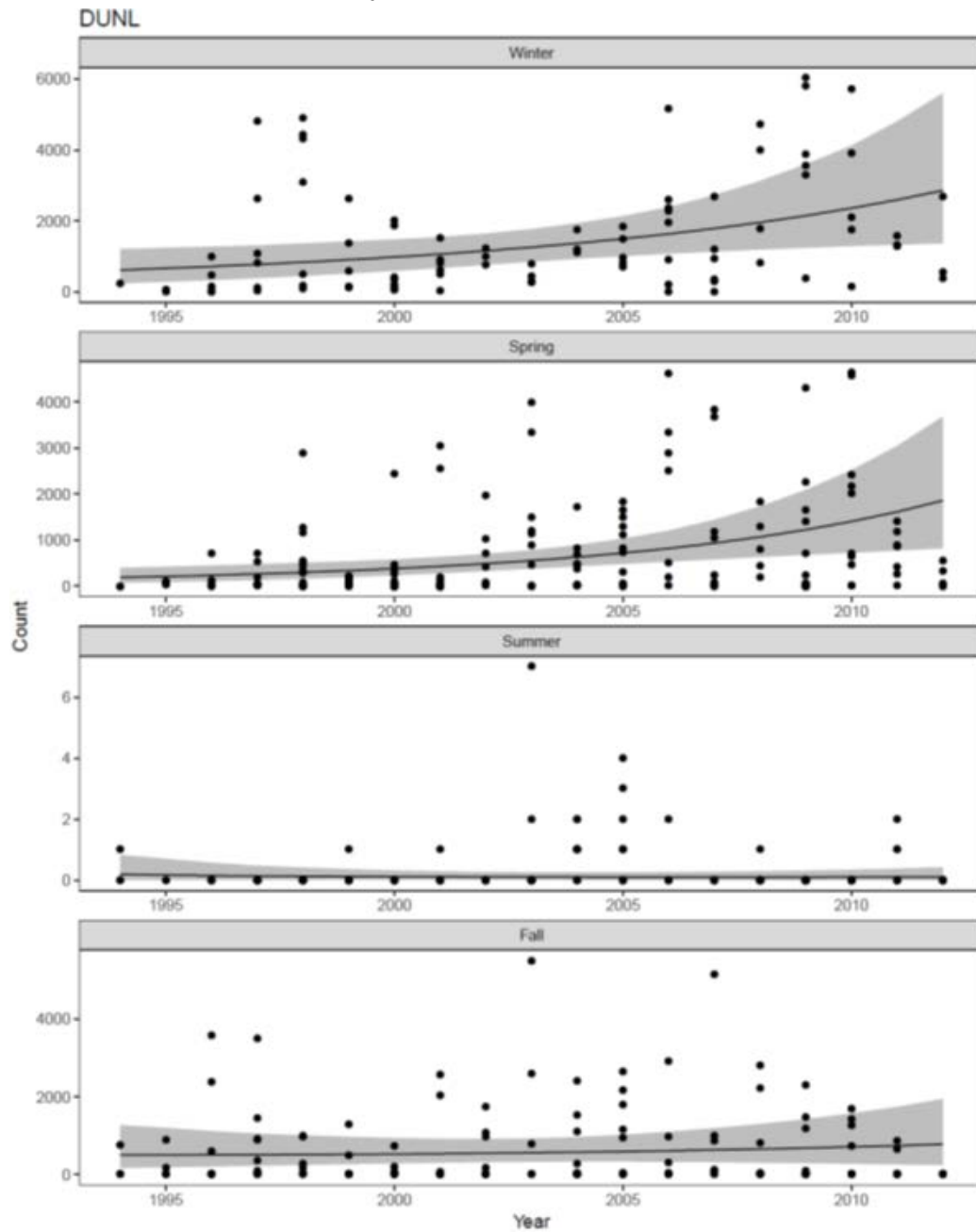


Figure C-17. Seasonal trends analyses for the Dunlin on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

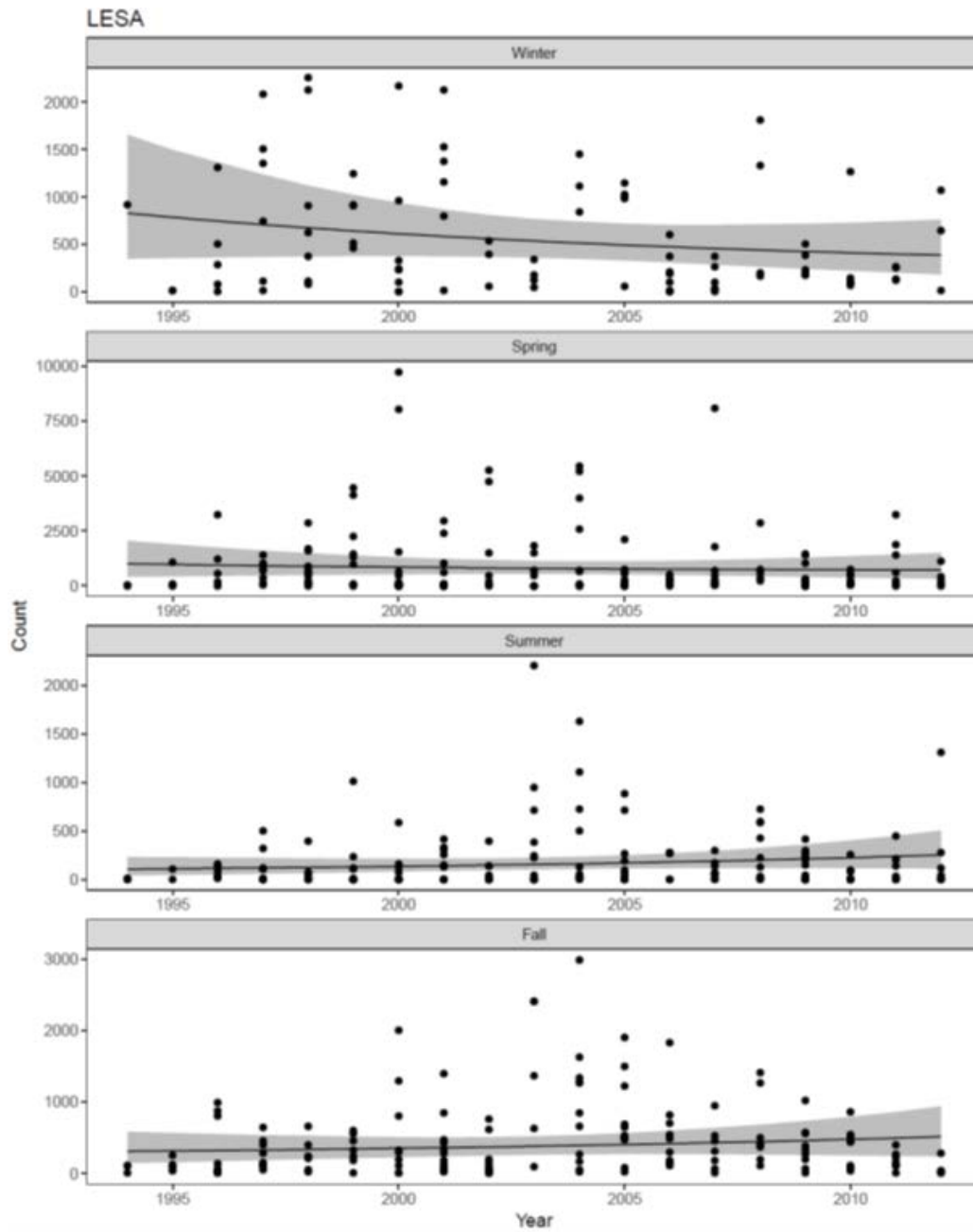


Figure C-18. Seasonal trends analyses for the Semipalmated Plover on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

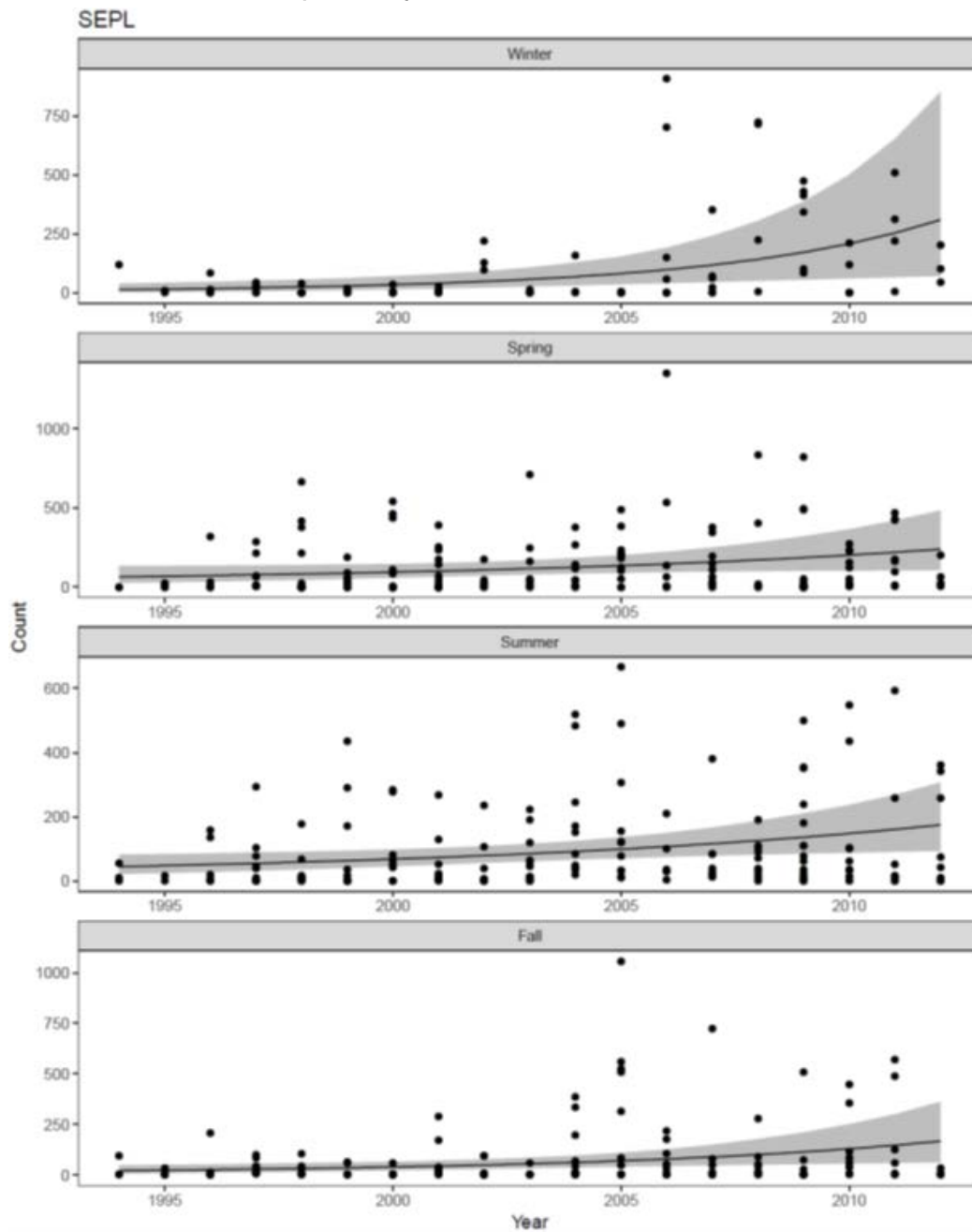


Figure C-19. Seasonal trends analyses for the Great Blue Heron on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

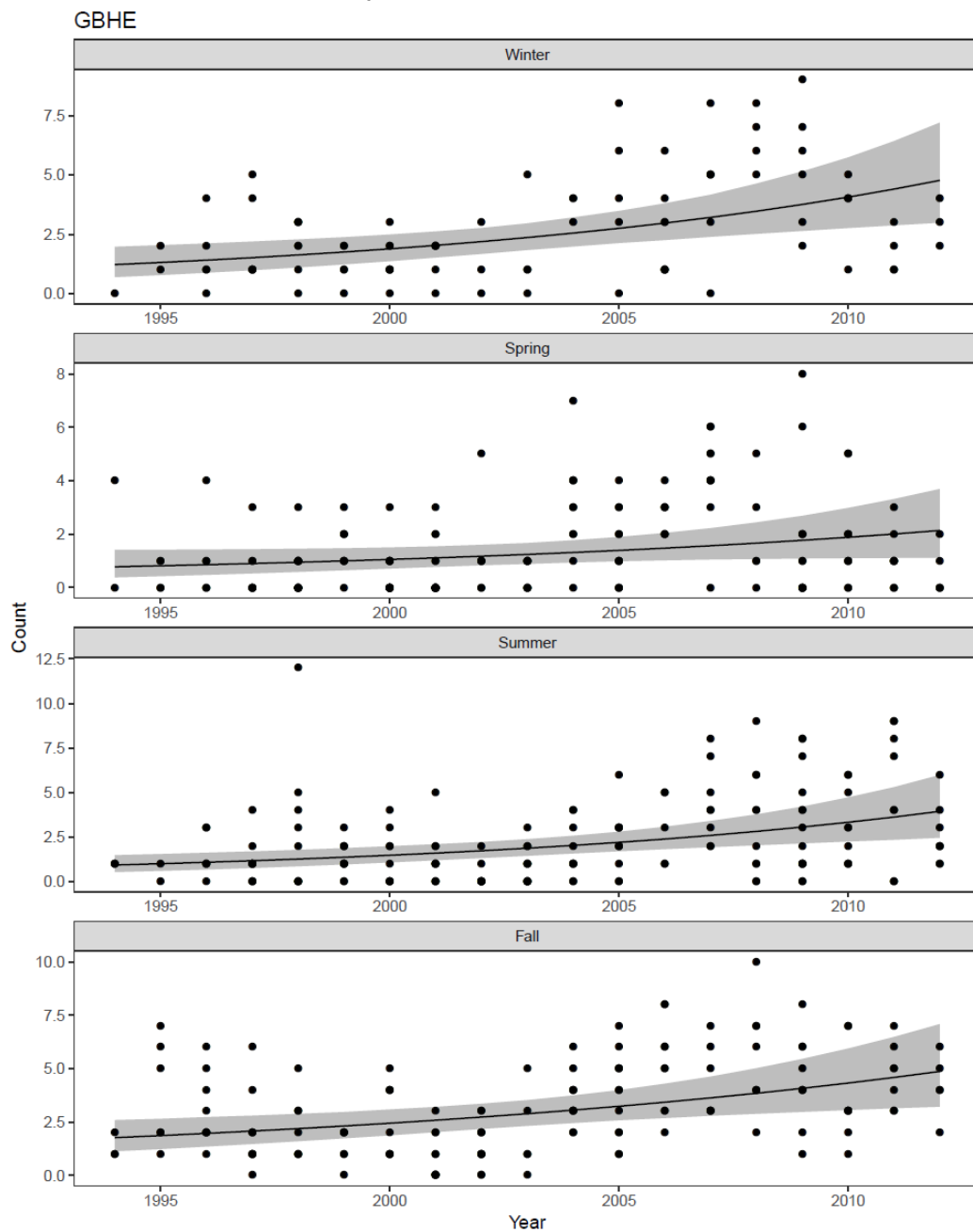


Figure C-20. Seasonal trends analyses for the Black-necked Stilt on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

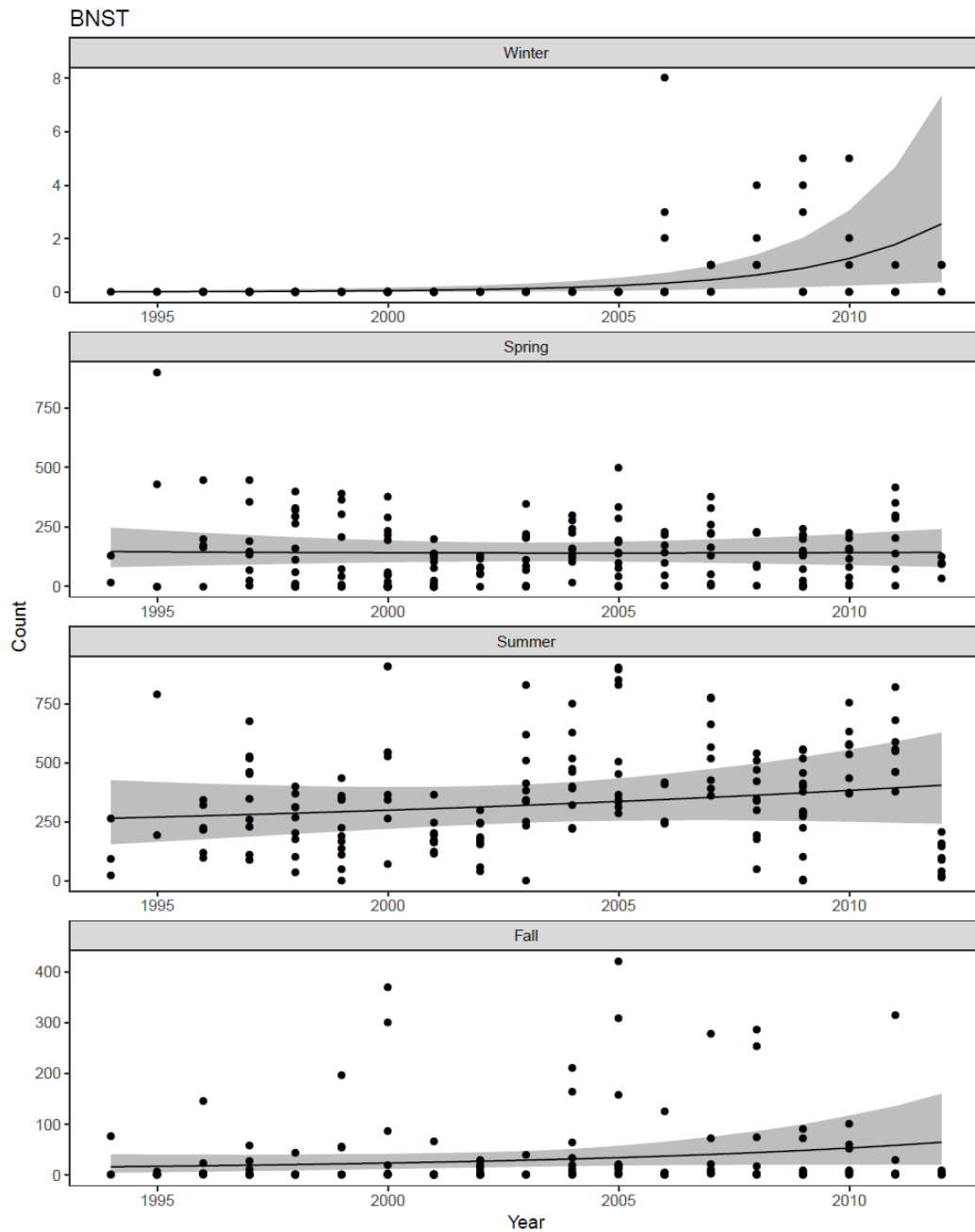


Figure C-21. Seasonal trends analyses for the Northern Parula on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012.

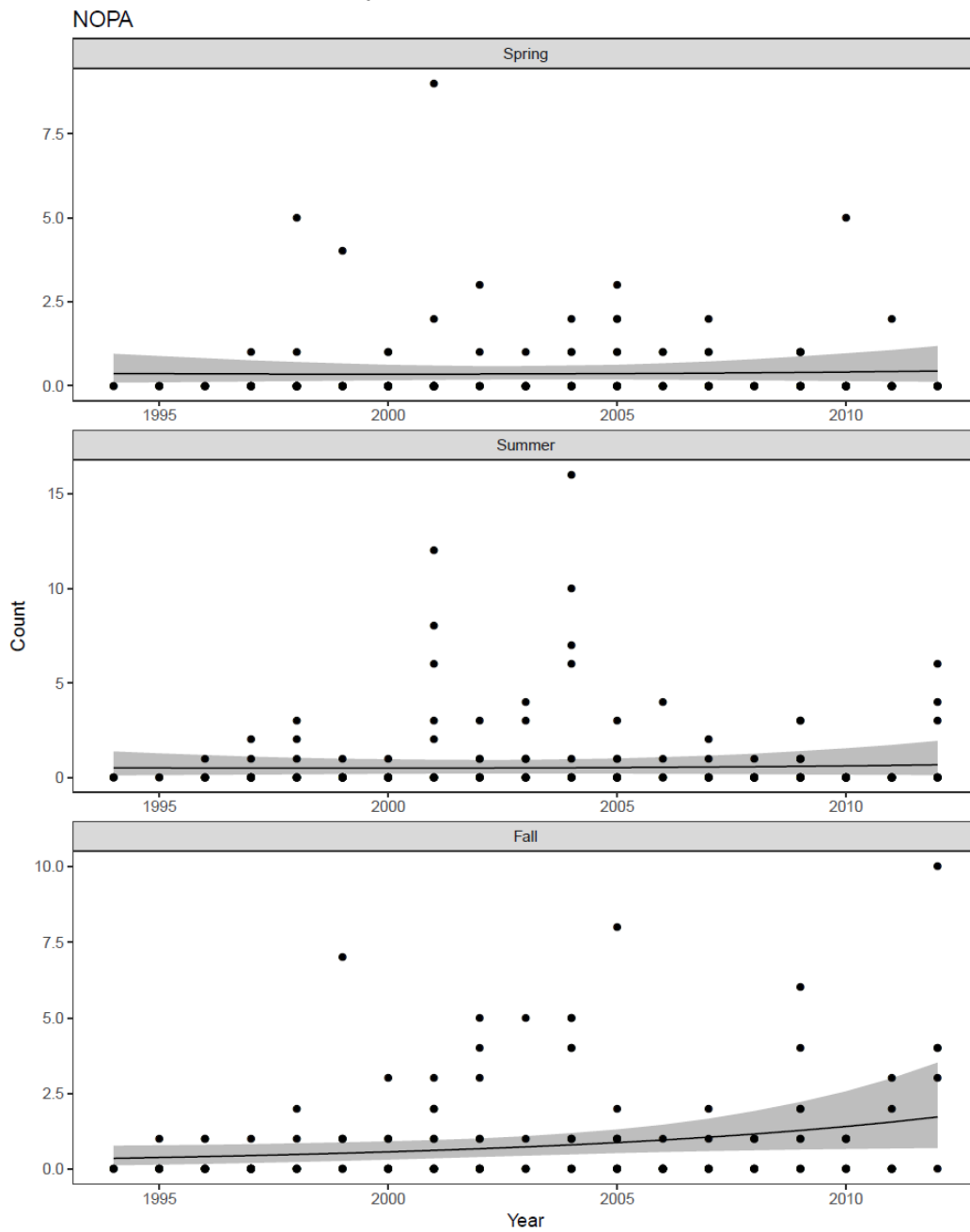


Figure C-22. Seasonal trends analyses for the Yellow-breasted Chat on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

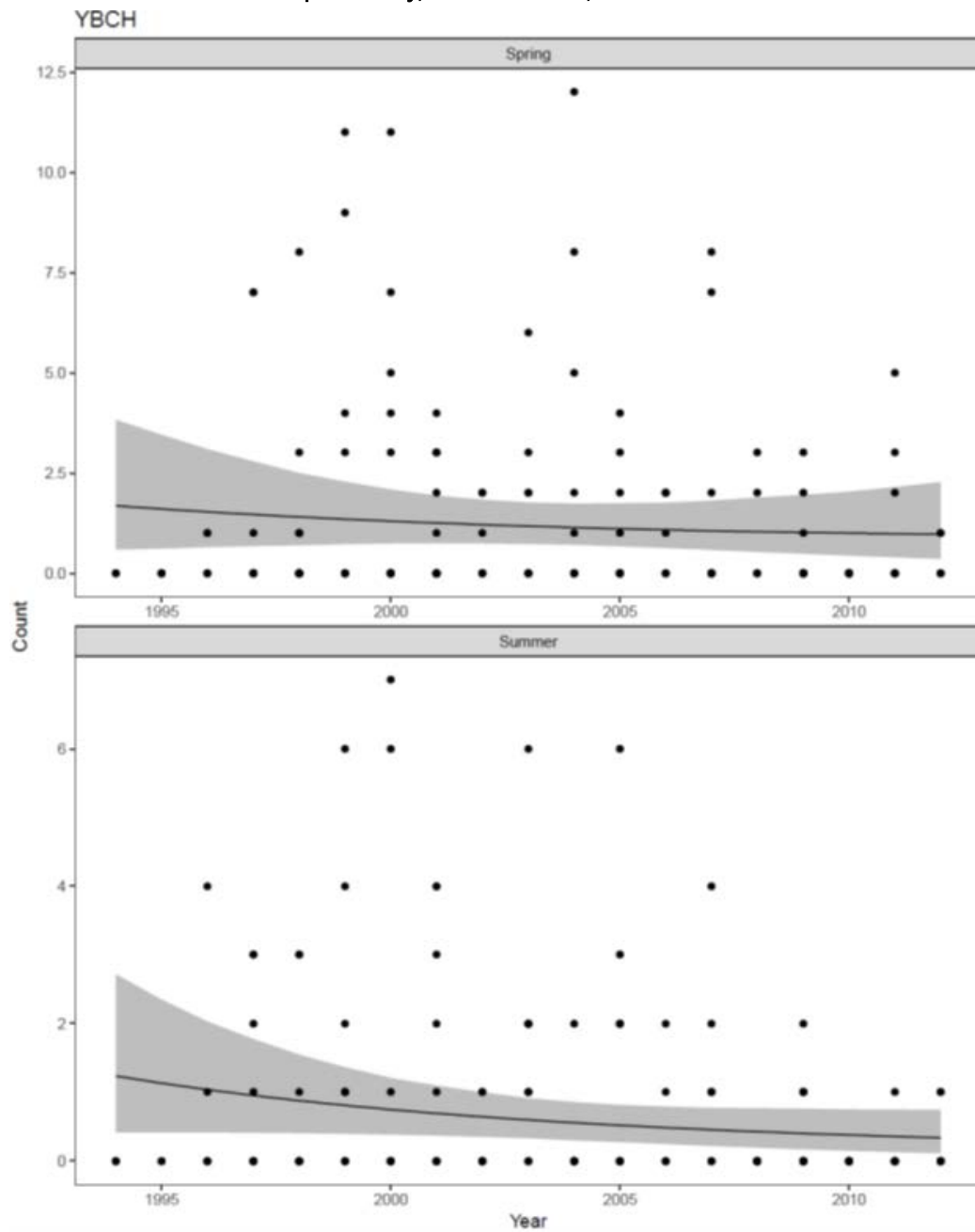


Figure C-23. Seasonal trends analyses for the Gadwall on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.

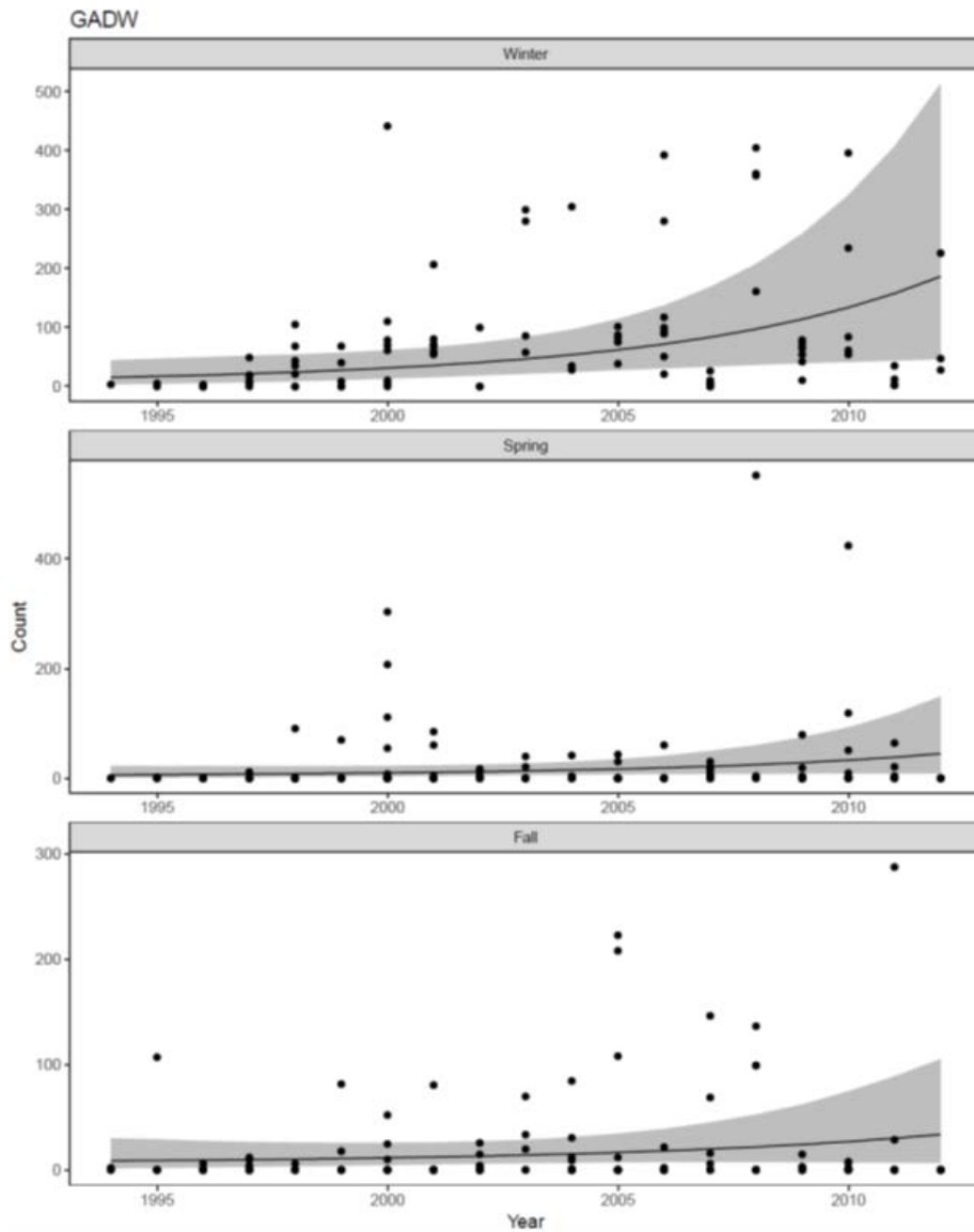
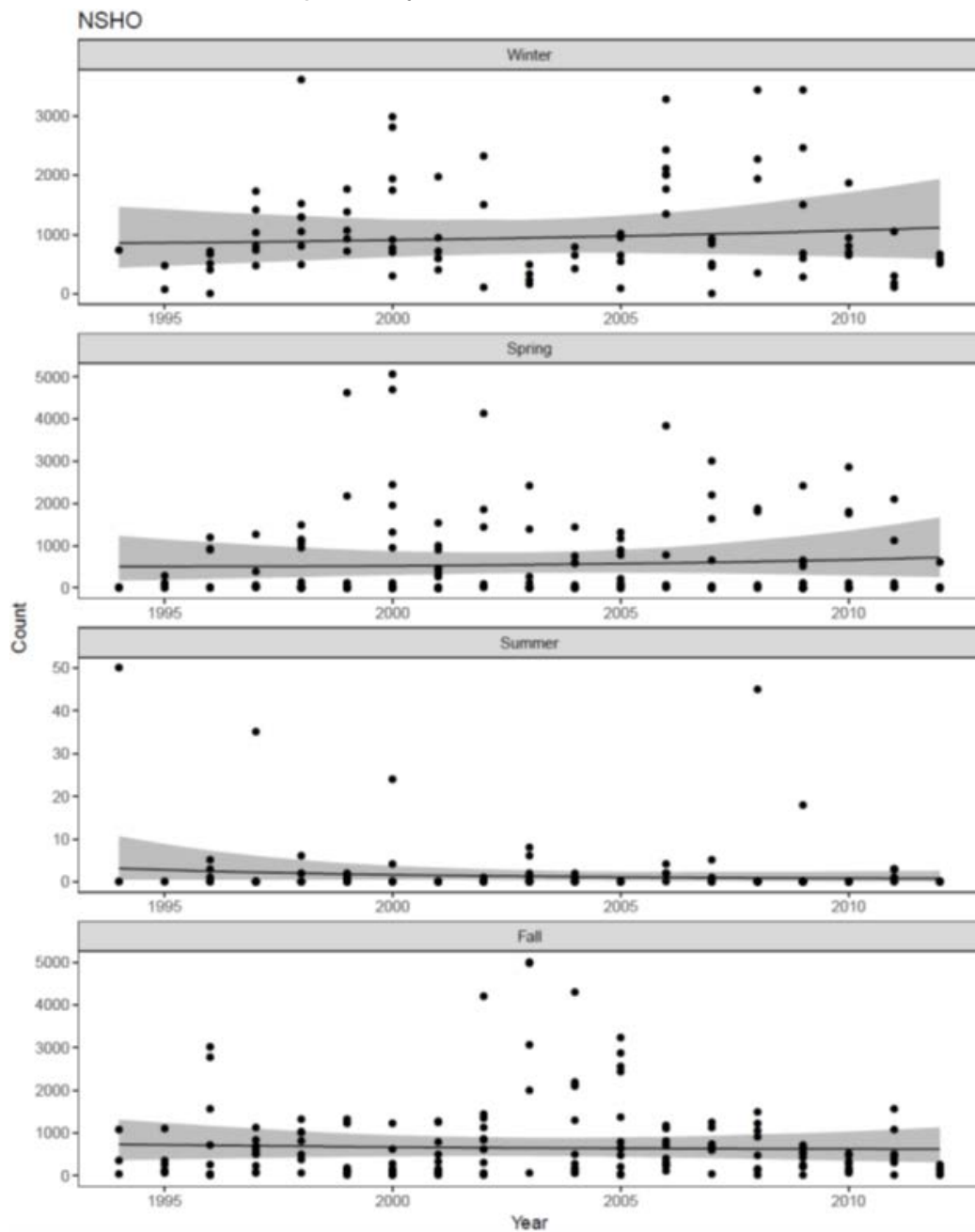


Figure C-24. Seasonal trends analyses for the Northern Shoveler on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012.



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**Appendix D: Species Groups and
Individual Species Seasonal Mean
Abundance Trend Analysis Results,
Savannah Harbor Navigation Project,
Dredged Material Containment Areas,
1994-2012**

Figure D-1. Log-transformed means and 95% confidence intervals of seasonal Blackbird species trends on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

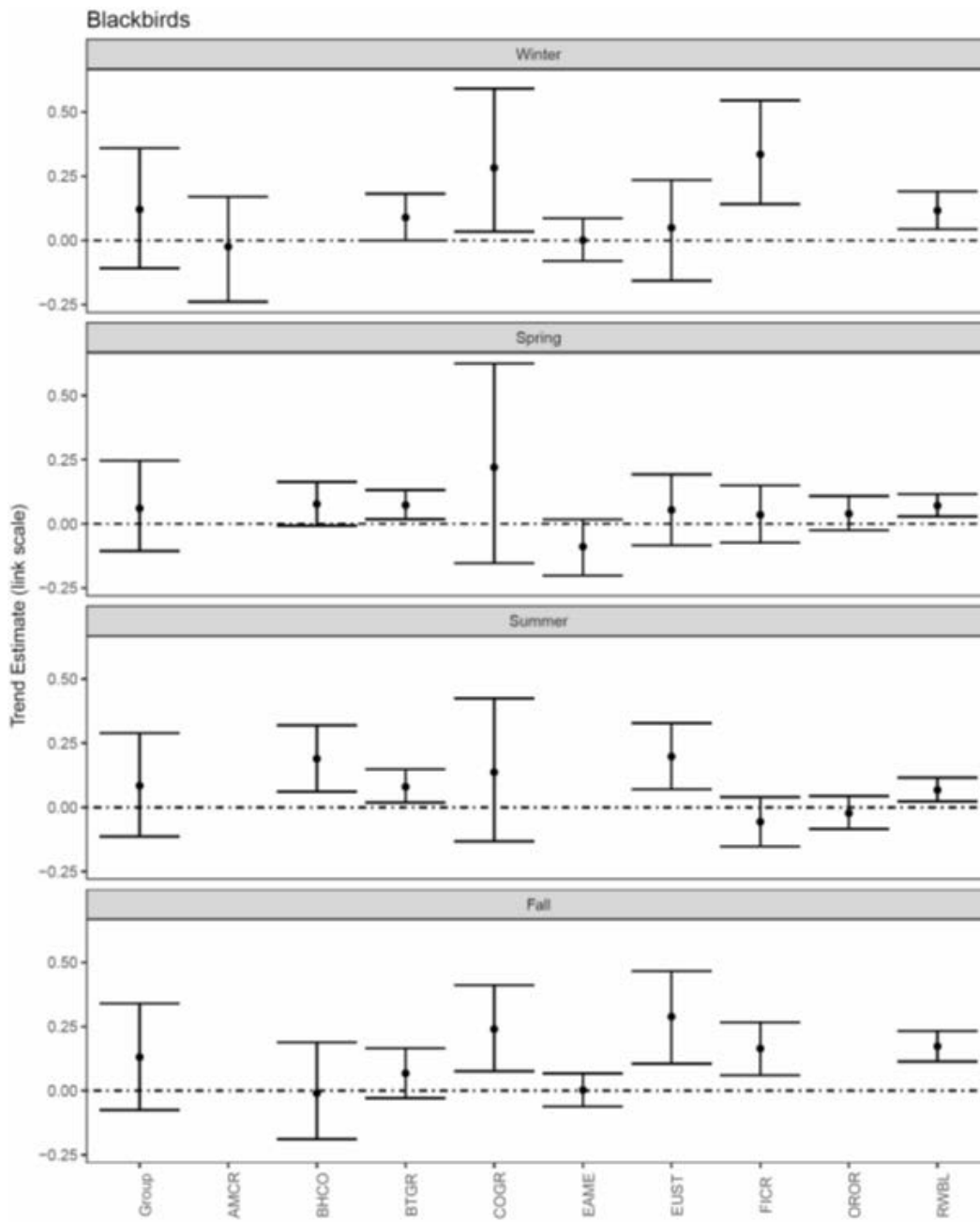


Figure D-2. Log-transformed means and 95% confidence intervals of seasonal Grassland Bird species trends on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

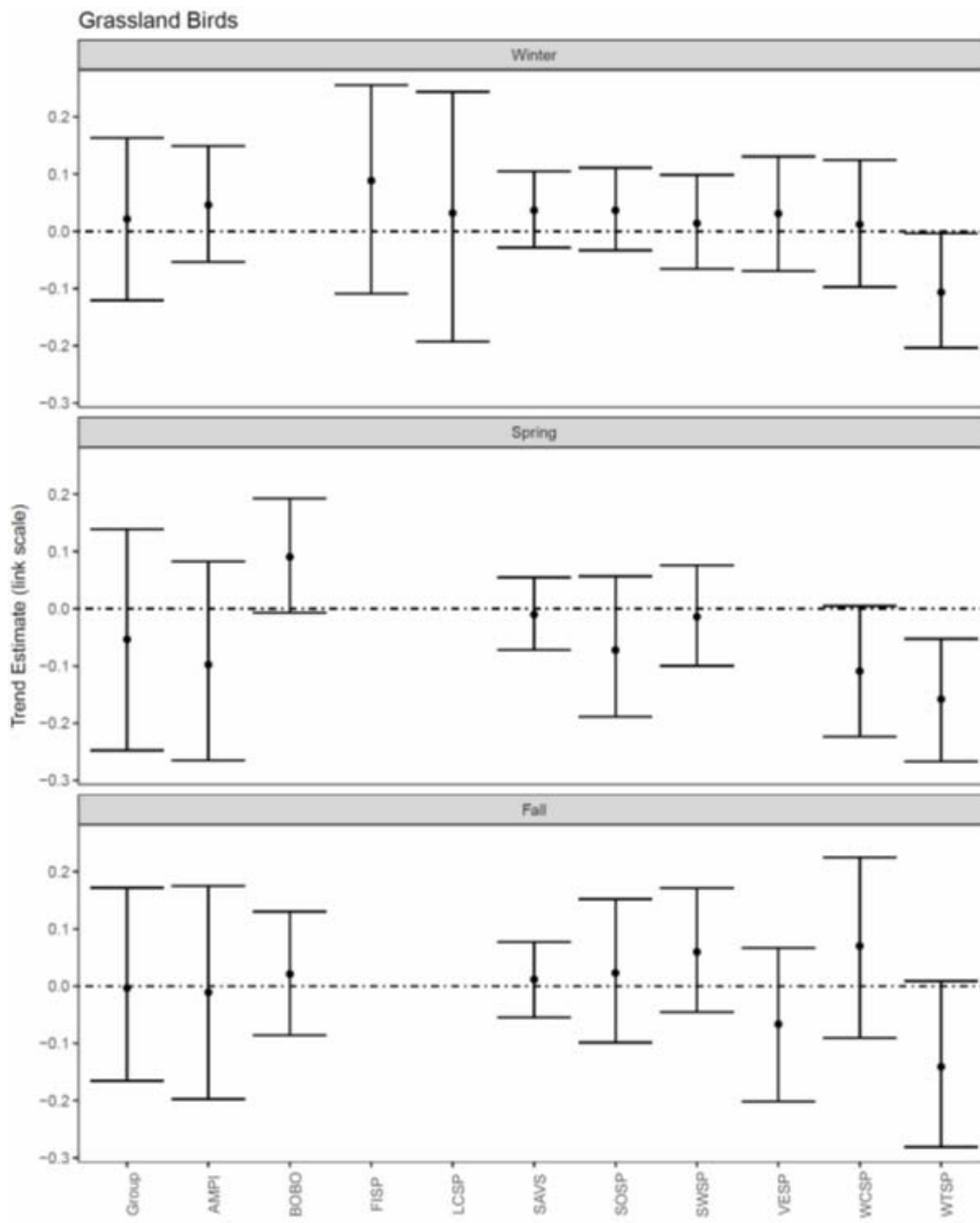


Figure D-3. Log-transformed means and 95% confidence intervals of seasonal Gull and Tern species trends on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

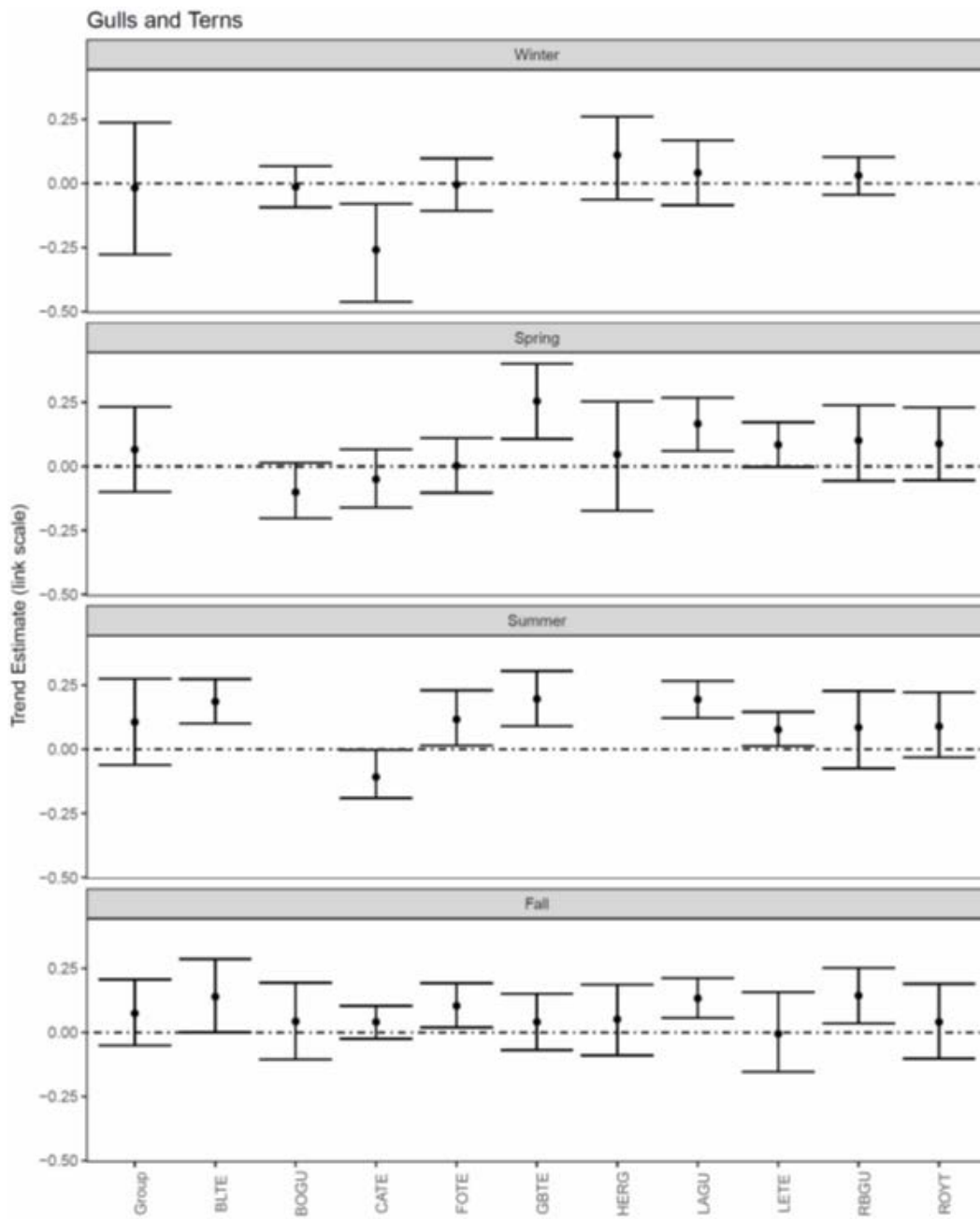


Figure D-4. Log-transformed means and 95% confidence intervals of seasonal Large Shorebird species trends on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

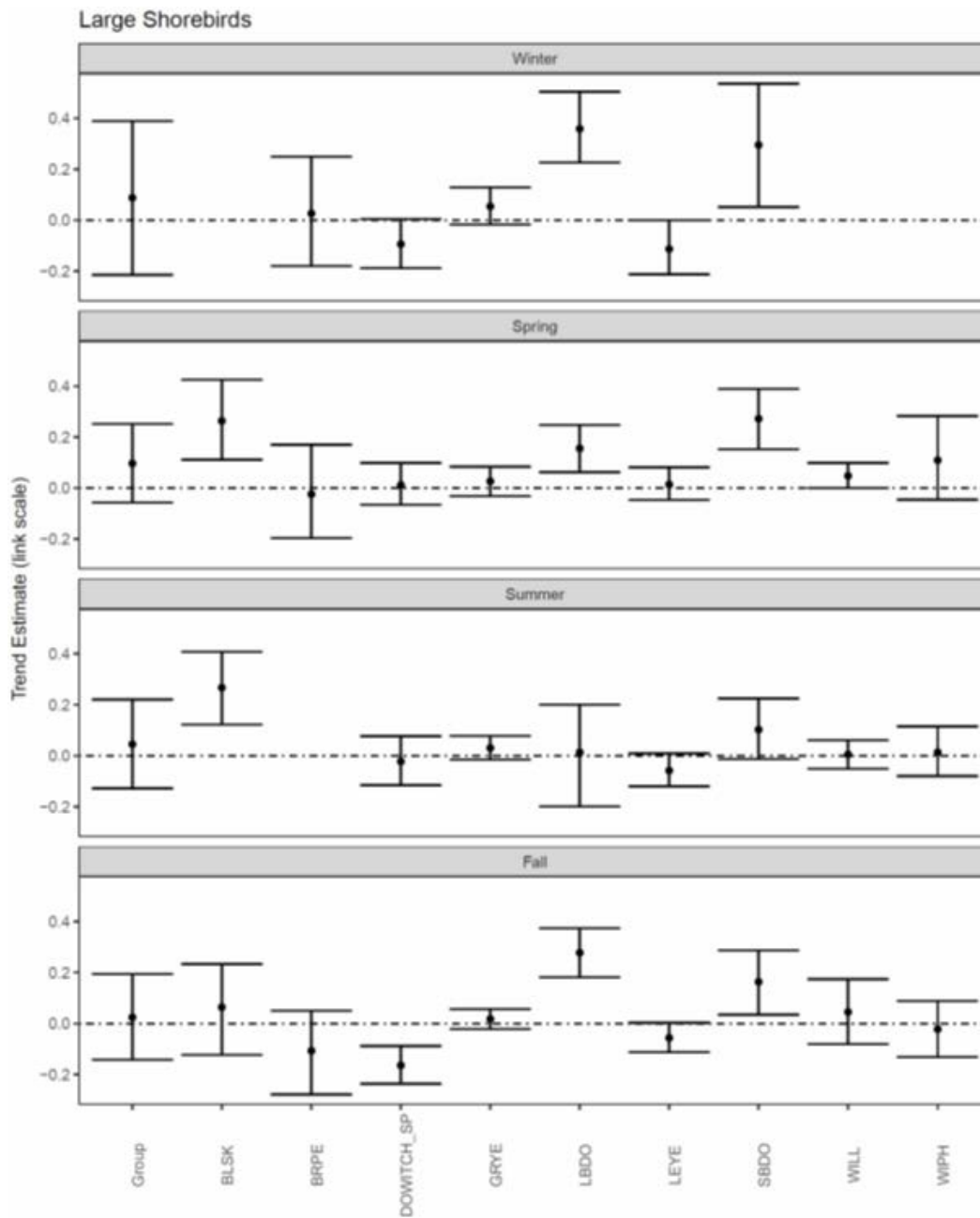


Figure D-5. Log-transformed means and 95% confidence intervals of seasonal Other Non-Passerine species trends on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

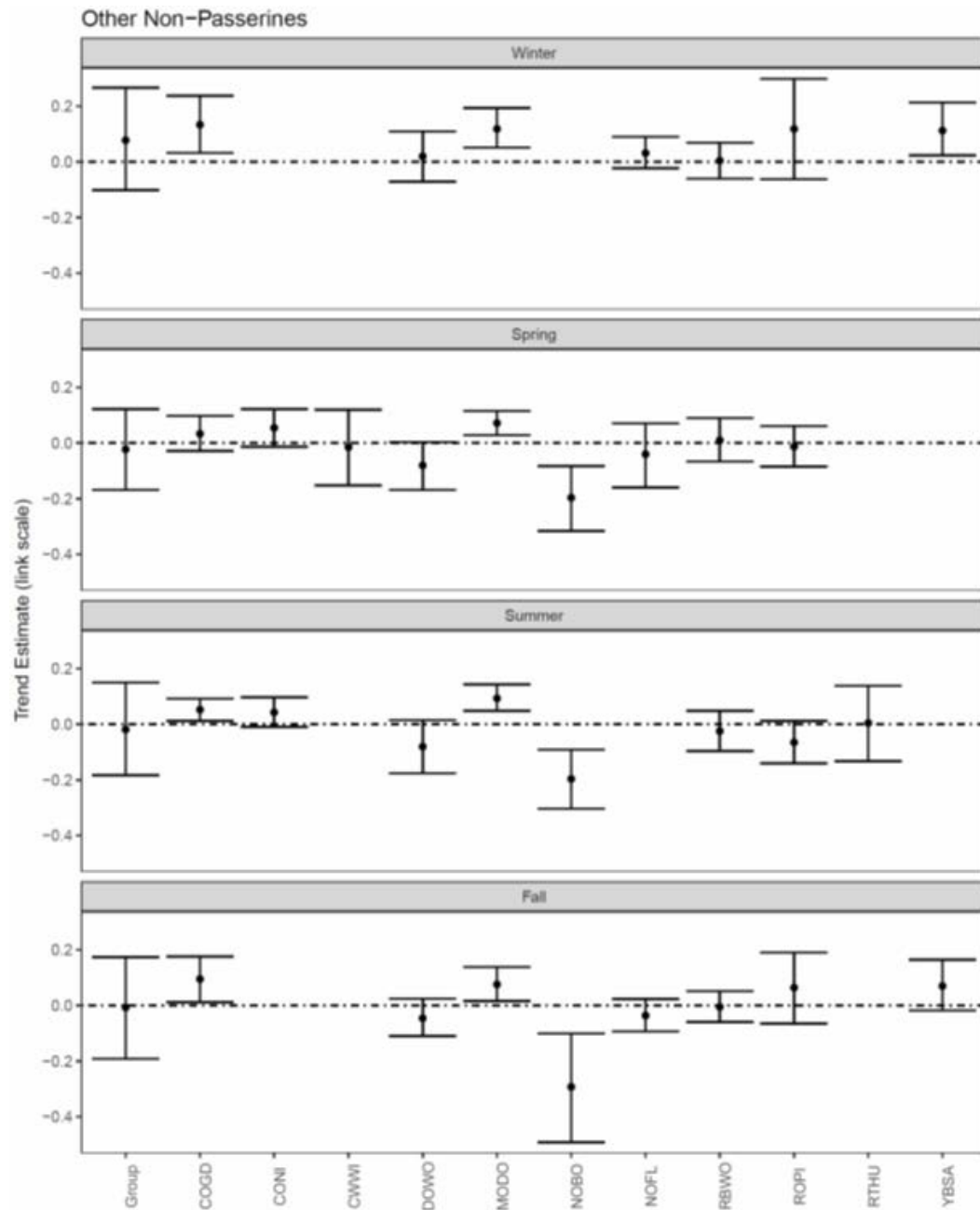


Figure D-6. Log-transformed means and 95% confidence intervals of seasonal Other Passerine species trends on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

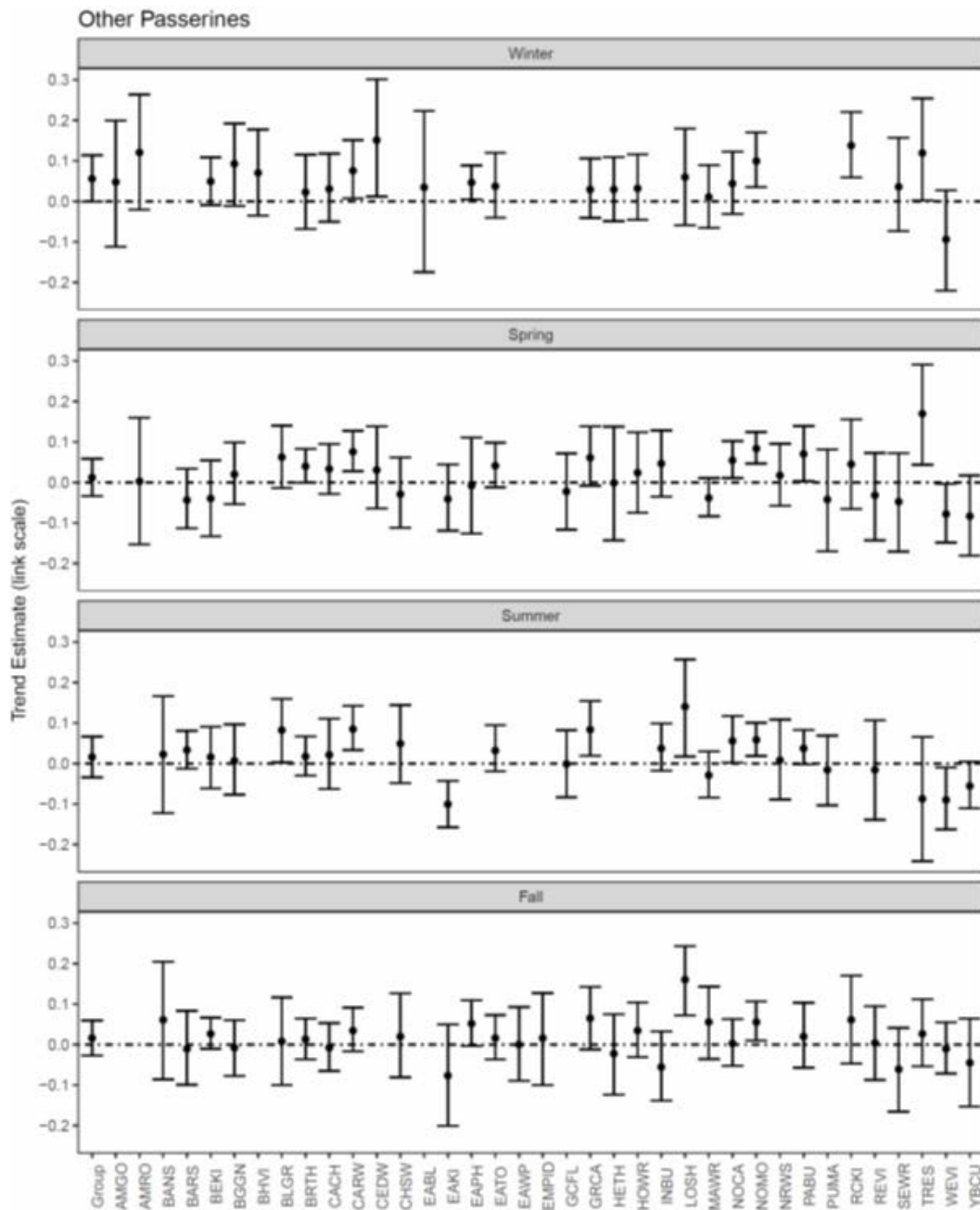


Figure D-7. Log-transformed means and 95% confidence intervals of seasonal Small Shorebird species trends on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

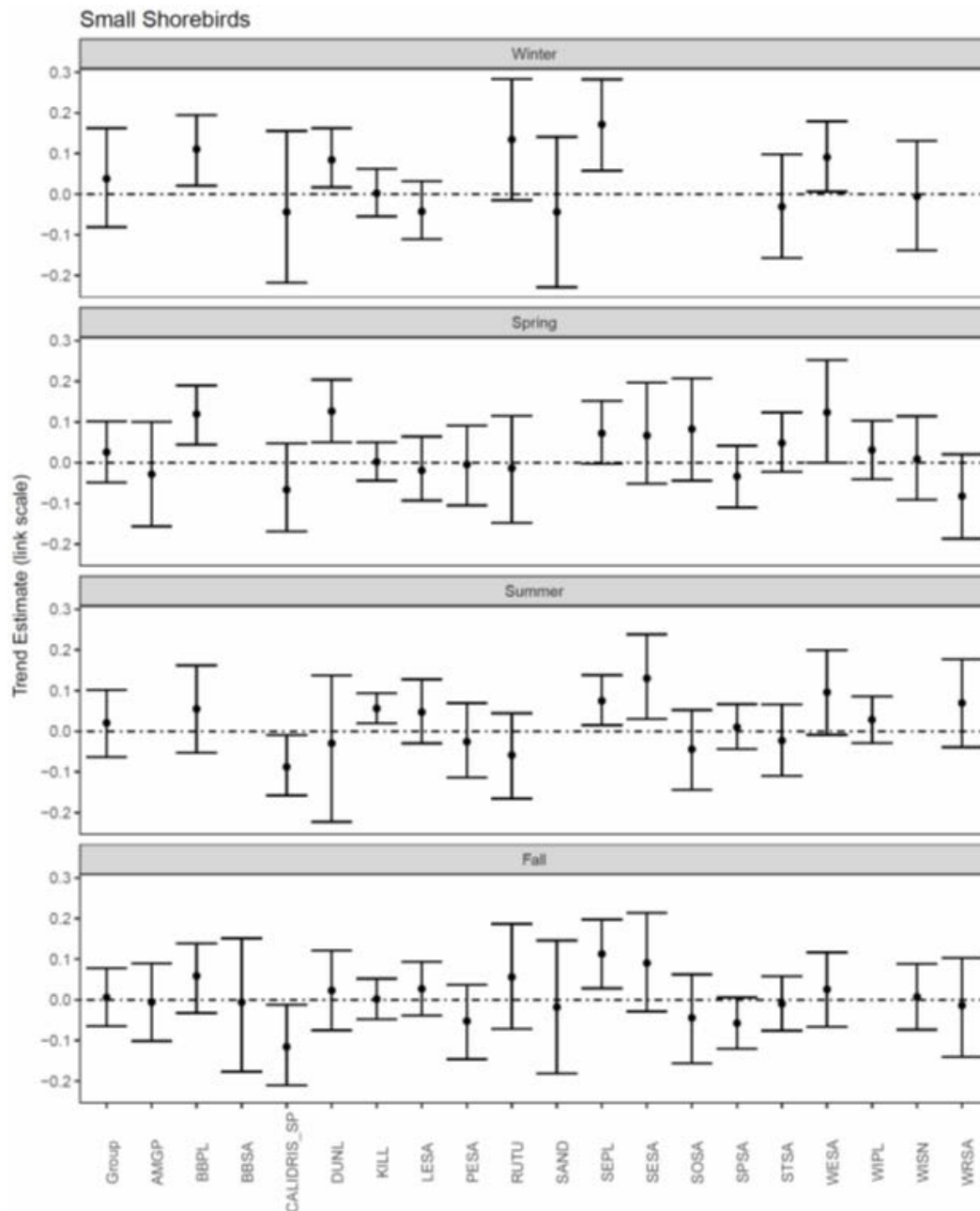


Figure D-8. Log-transformed means and 95% confidence intervals of seasonal Wading Bird species trends on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

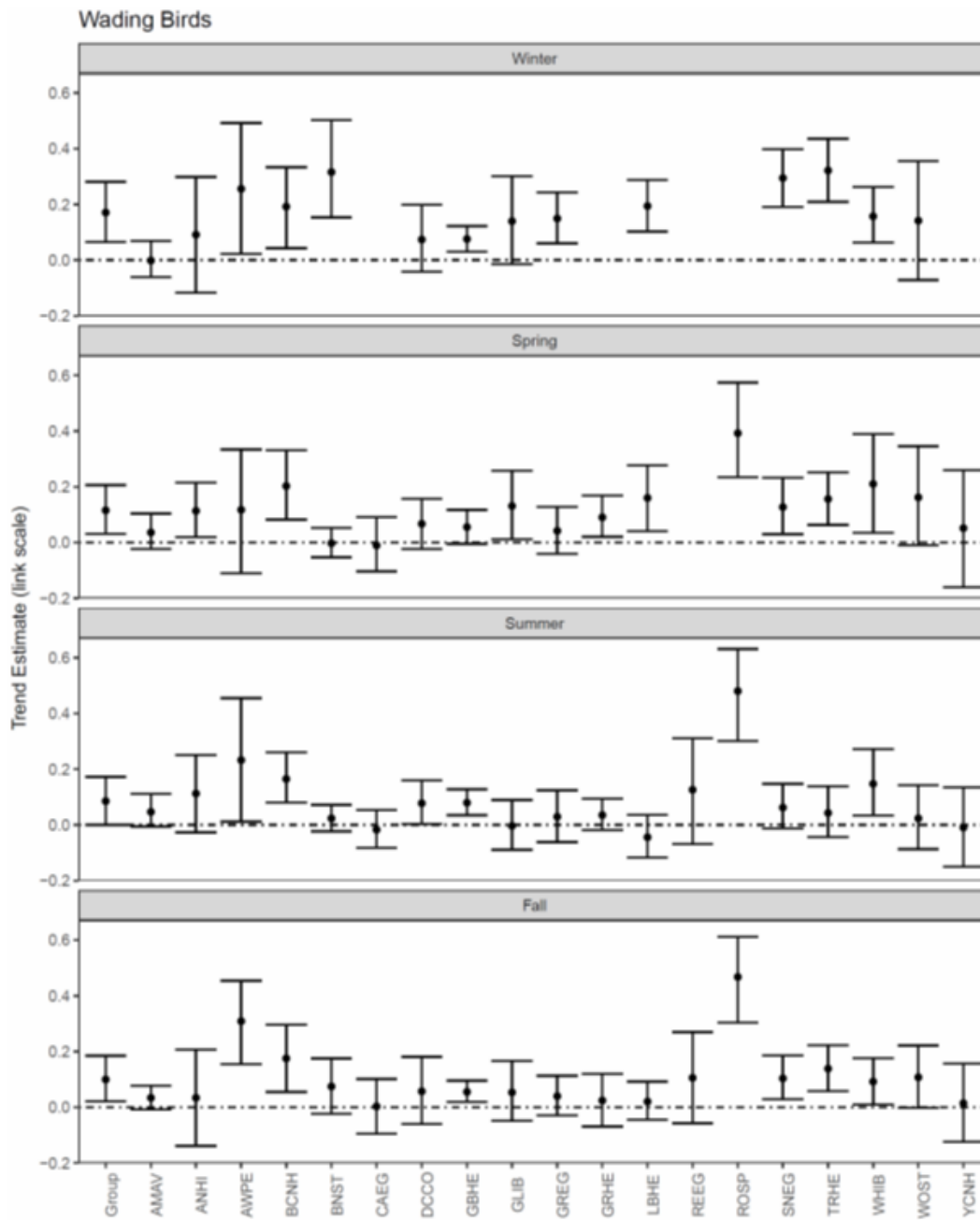


Figure D-9. Log-transformed means and 95% confidence intervals of seasonal Warbler species trends on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting.

Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

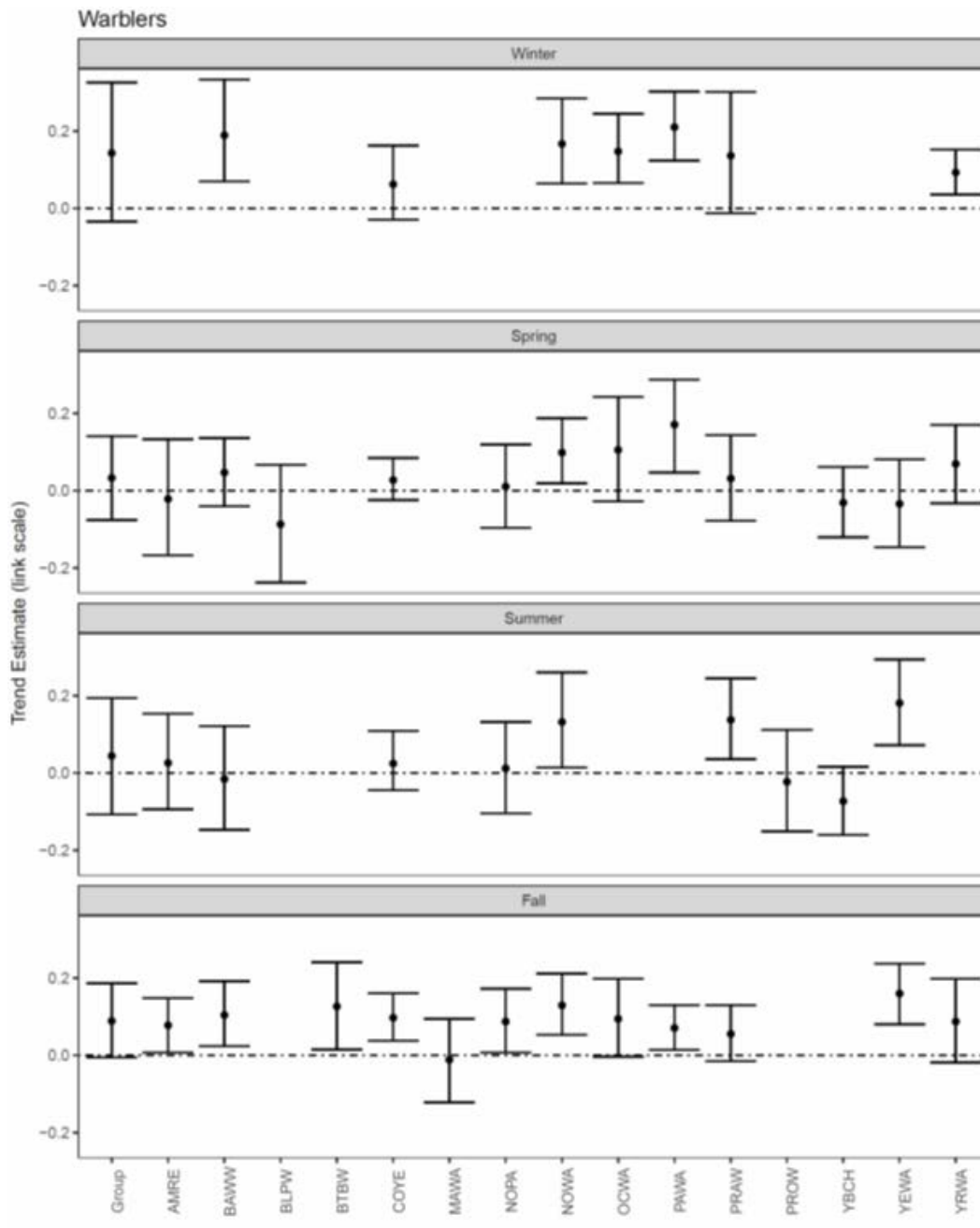
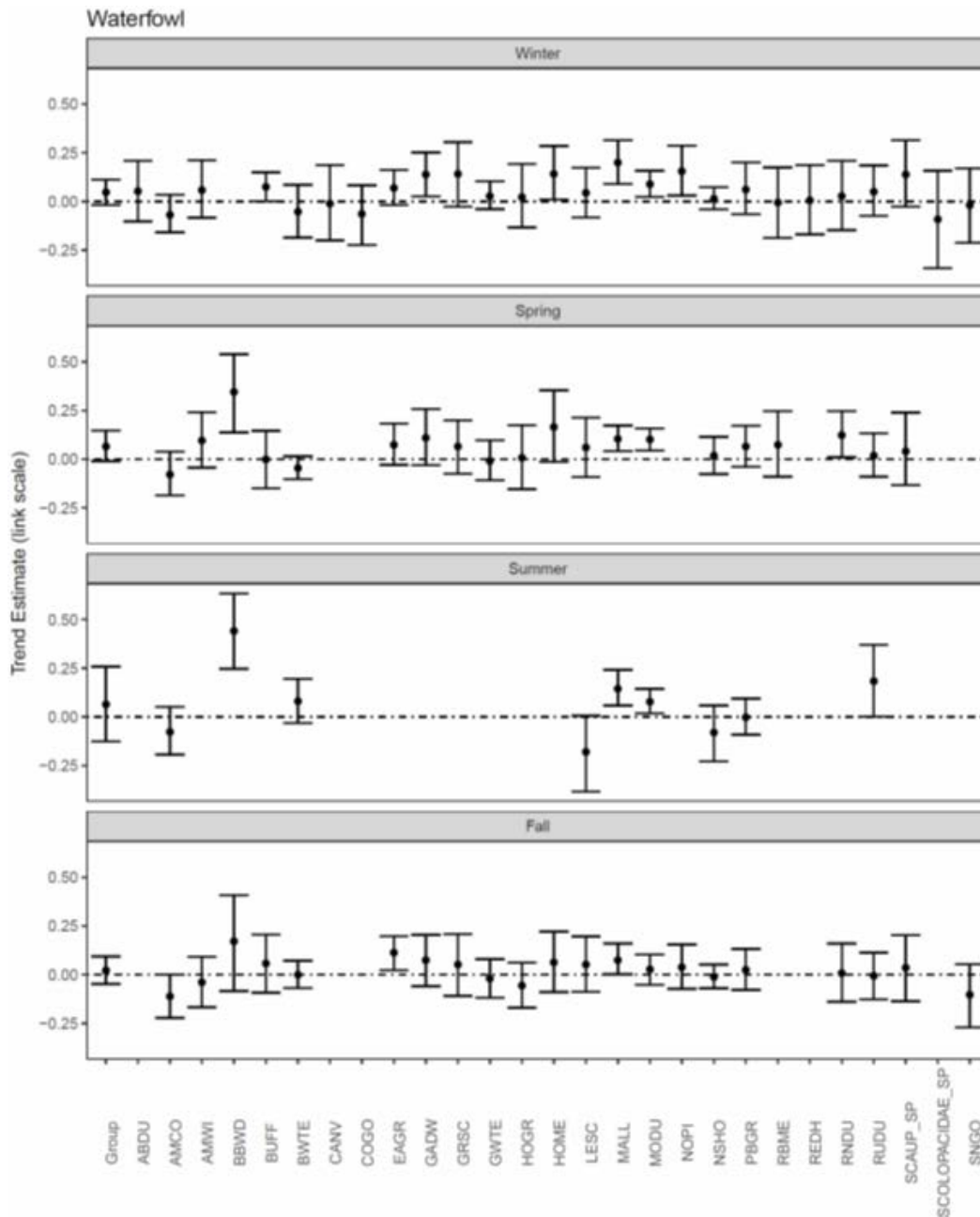


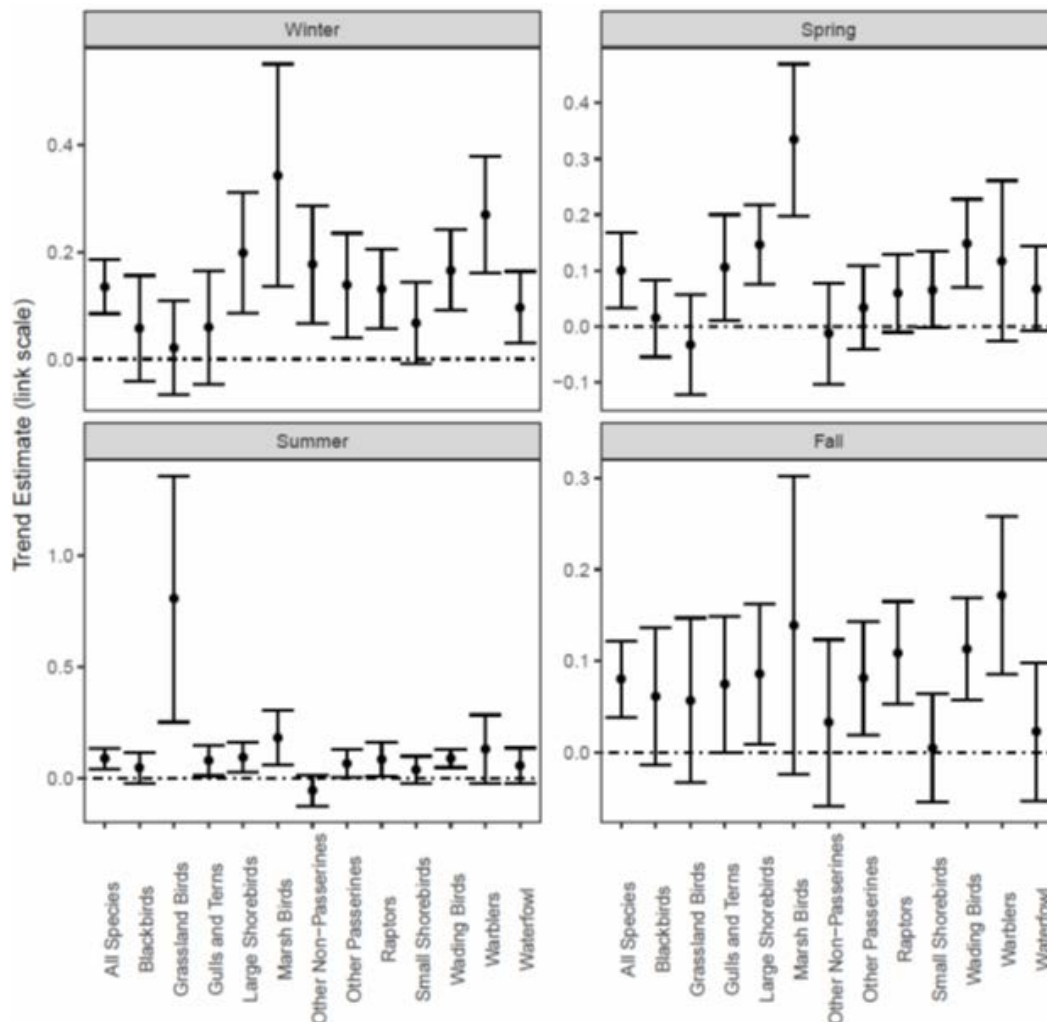
Figure D-10. Log-transformed means and 95% confidence intervals of seasonal Waterfowl species trends on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.



Appendix E: Mean Species Richness Trend

Analysis Results on the Savannah Harbor Navigation Project, Dredged Material Containment Areas, 1994-2012

Figure E-1. Log-transformed means and 95% confidence intervals of seasonal species richness trends for all species groups on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.



**Appendix F: Habitat Relationships of
Individual Species and Species Groups
Analysis Results on the Savannah Harbor
Navigation Project, Dredged Material
Containment Areas, 2001-2011**

Figure F-1. Log-transformed means and 95% confidence intervals of seasonal Blackbird species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

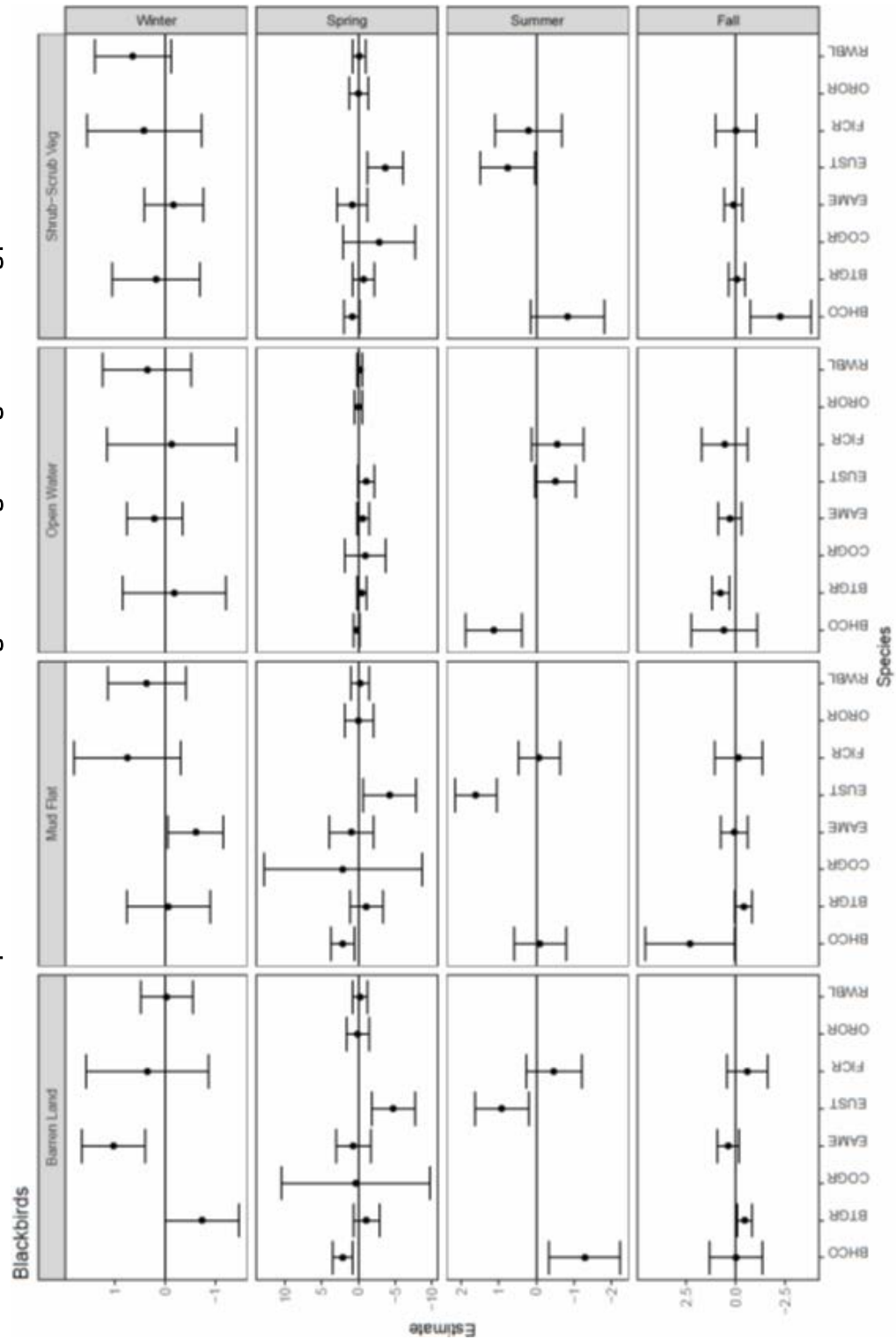


Figure F-2. Log-transformed means and 95% confidence intervals of seasonal Grassland Bird species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

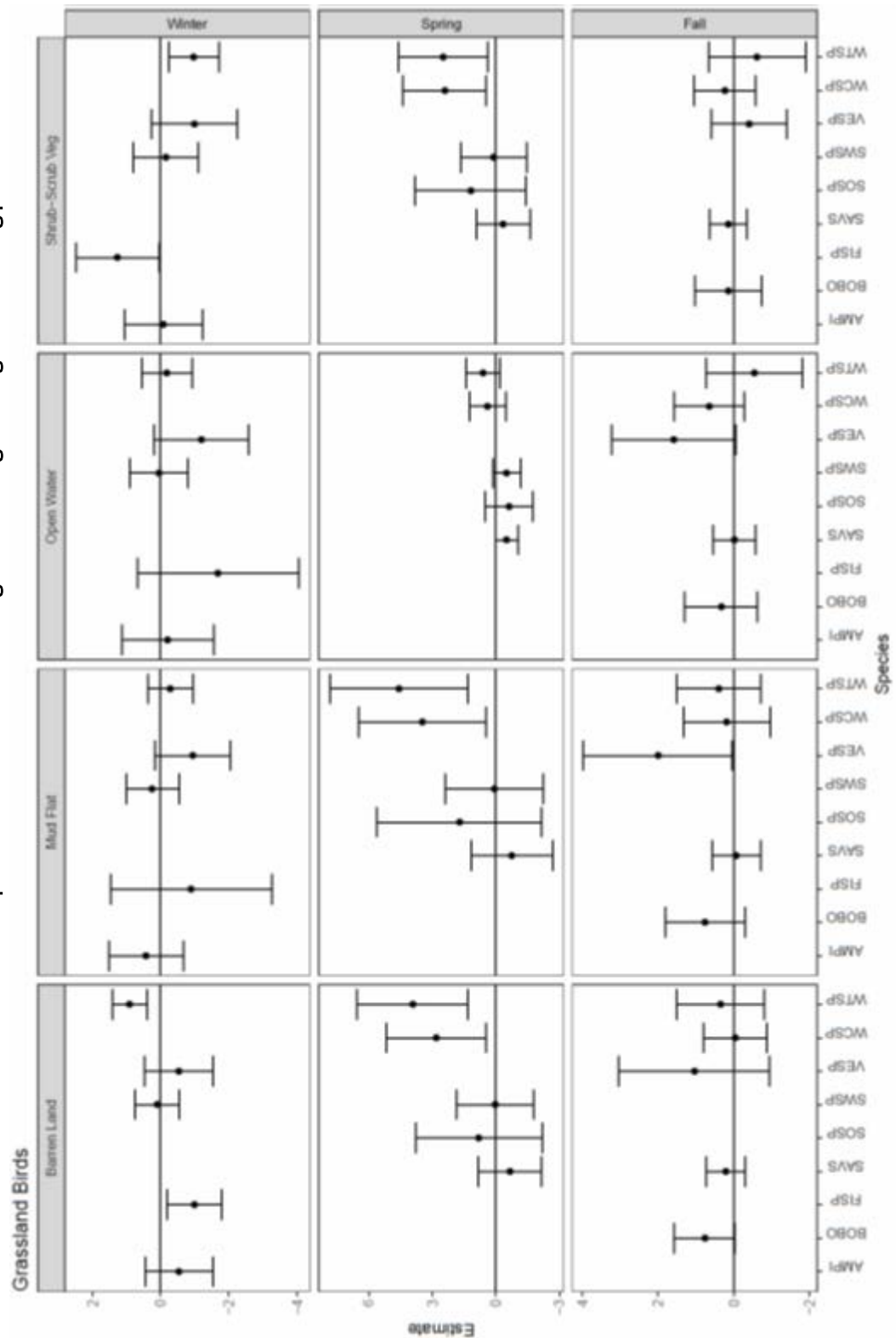


Figure F-3. Log-transformed means and 95% confidence intervals of seasonal Gull and Tern species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

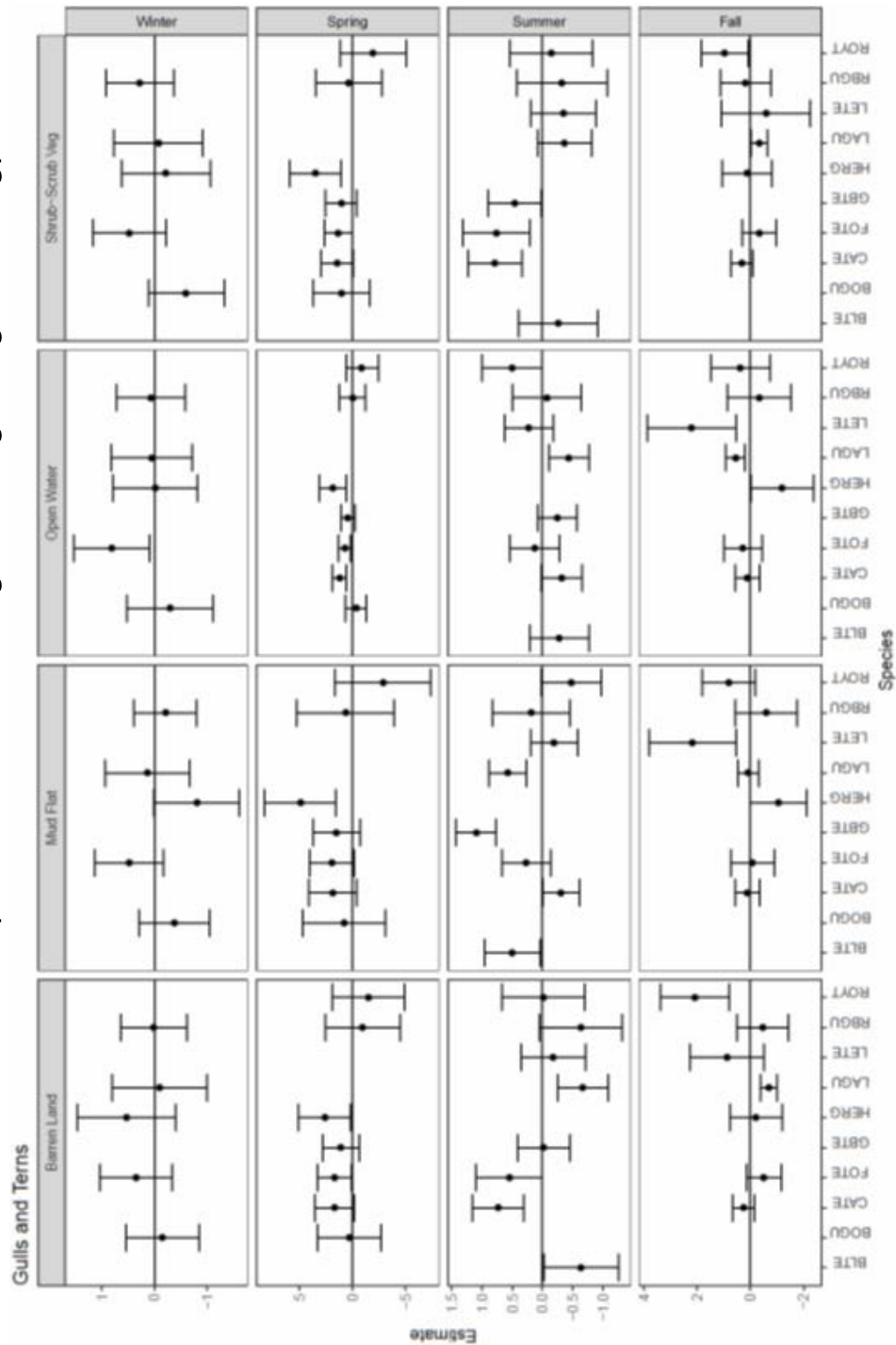


Figure F-4. Log-transformed means and 95% confidence intervals of seasonal Large Shorebird species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

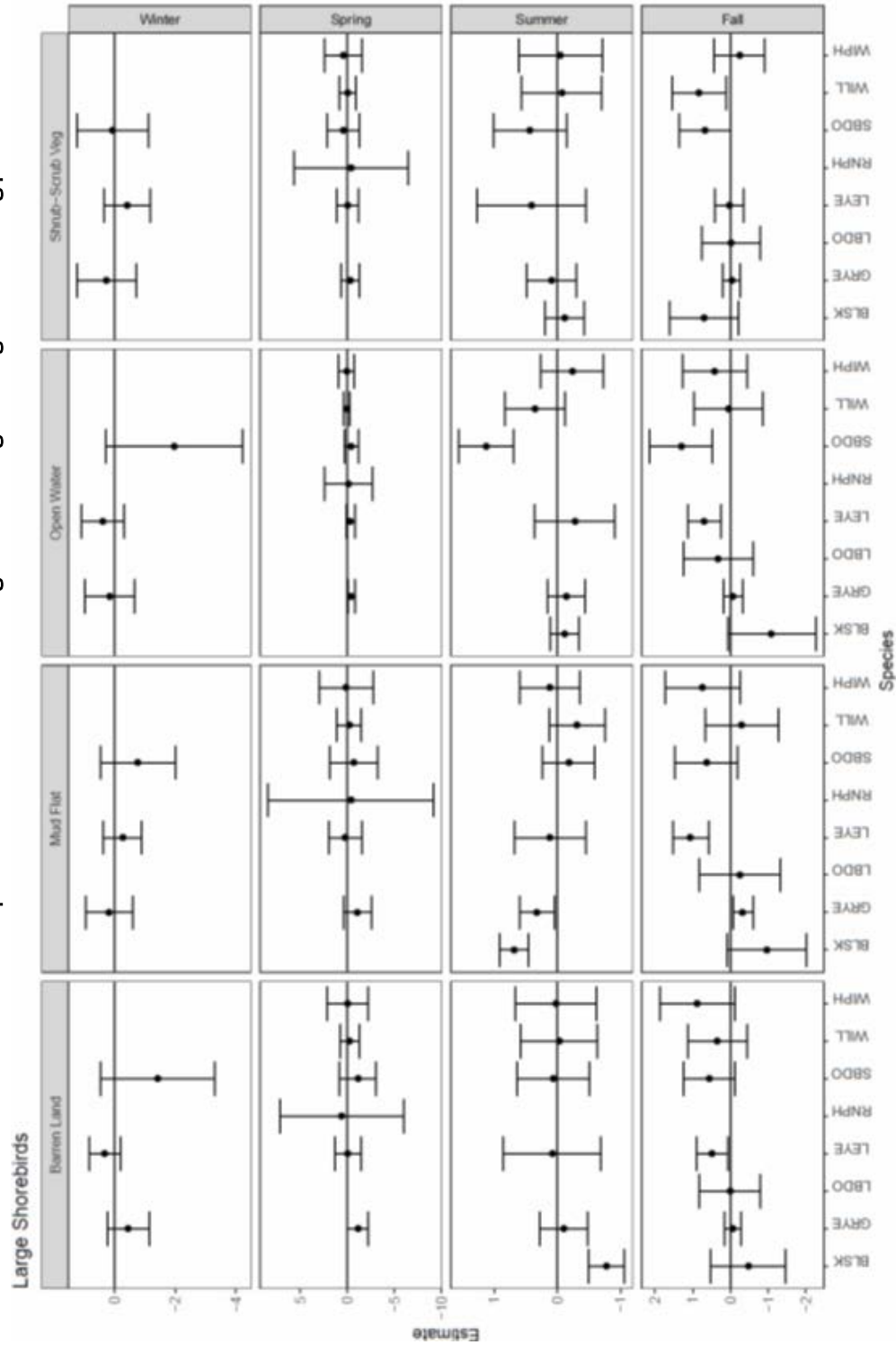


Figure F-5. Log-transformed means and 95% confidence intervals of seasonal Marshbird species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

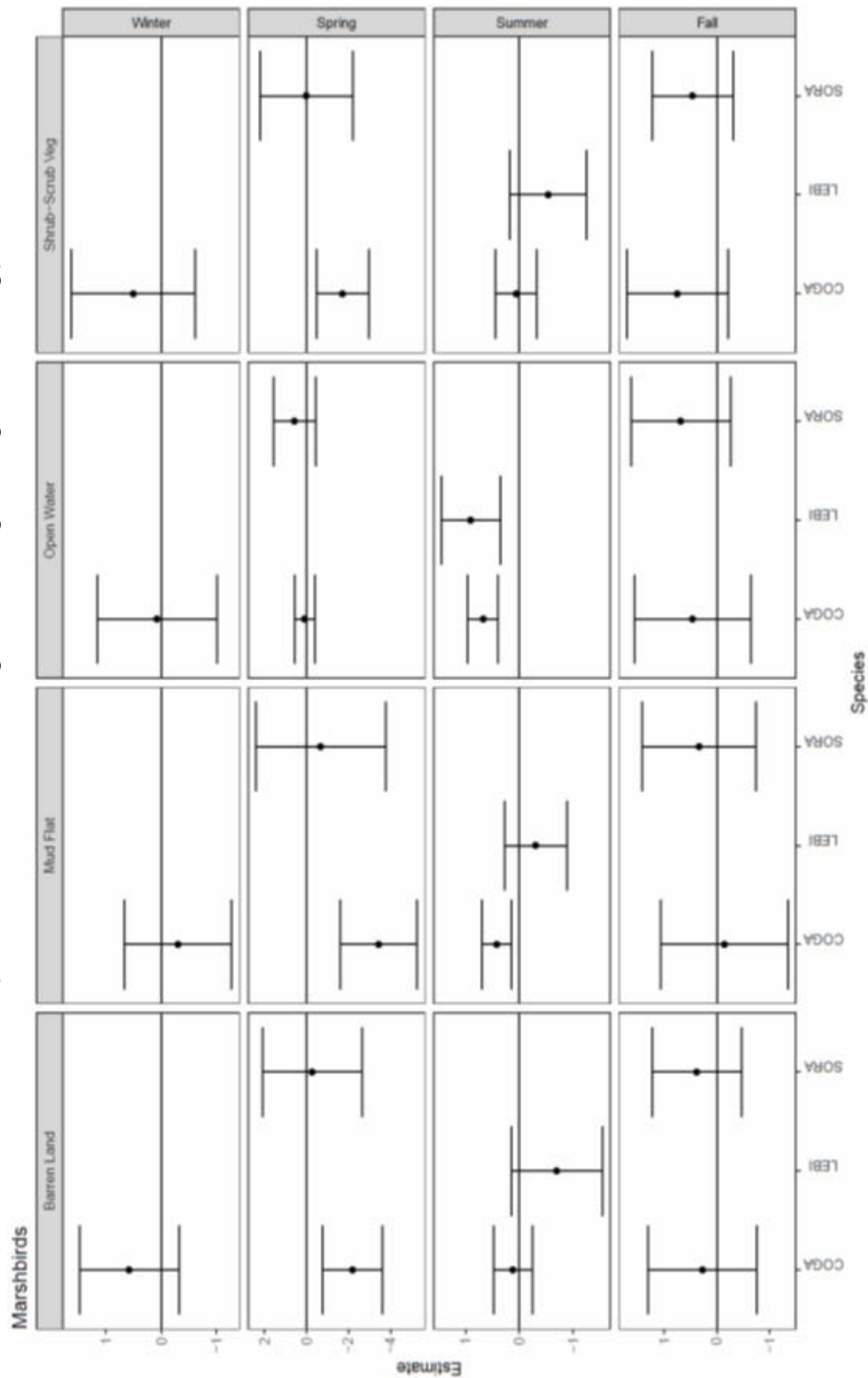


Figure F-6. Log-transformed means and 95% confidence intervals of seasonal Other Non-Passerine species trends and habitat covariates on the SHNP, DMCA's, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

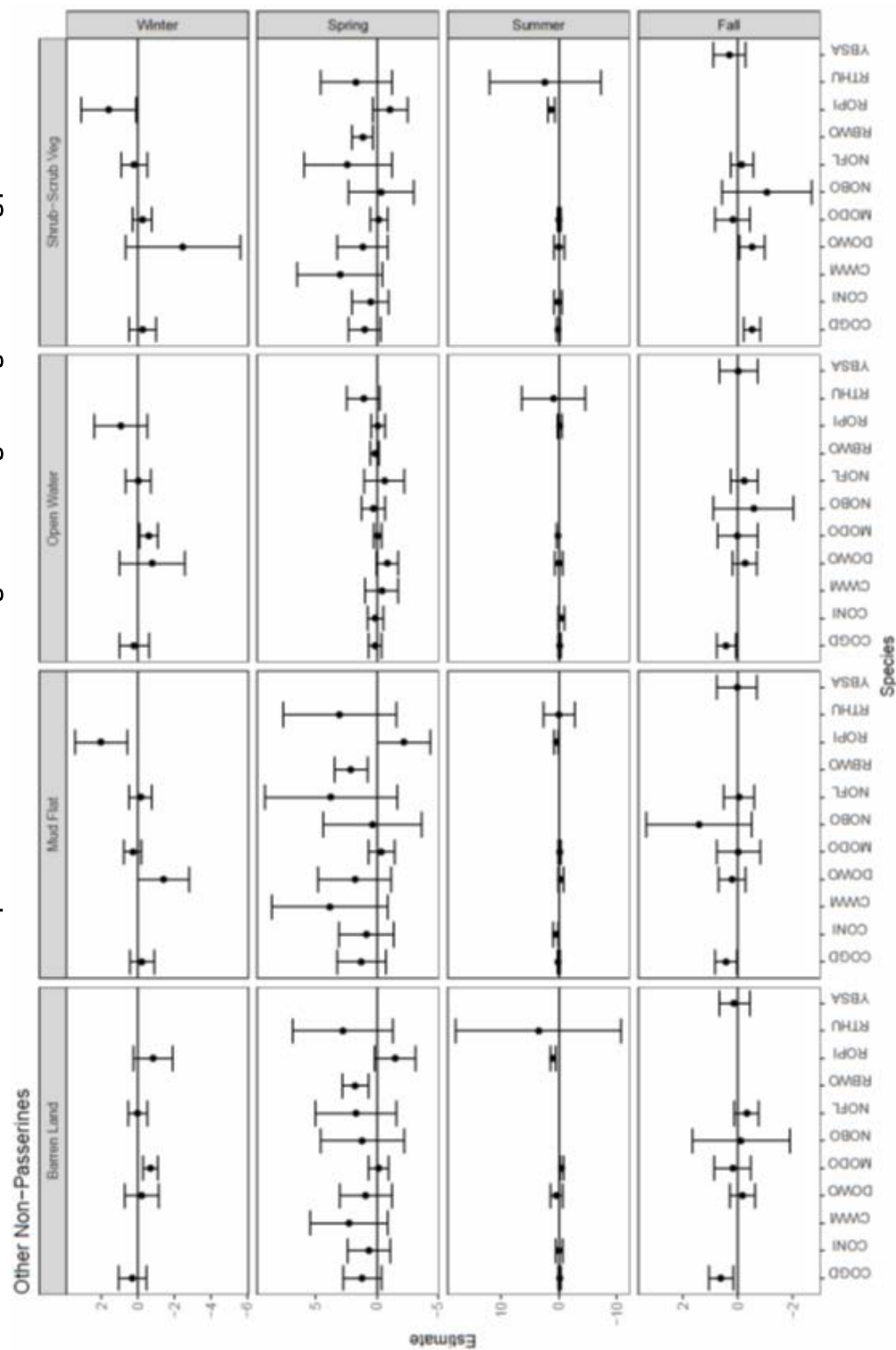


Figure F-7. Log-transformed means and 95% confidence intervals of seasonal Other Passerine species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

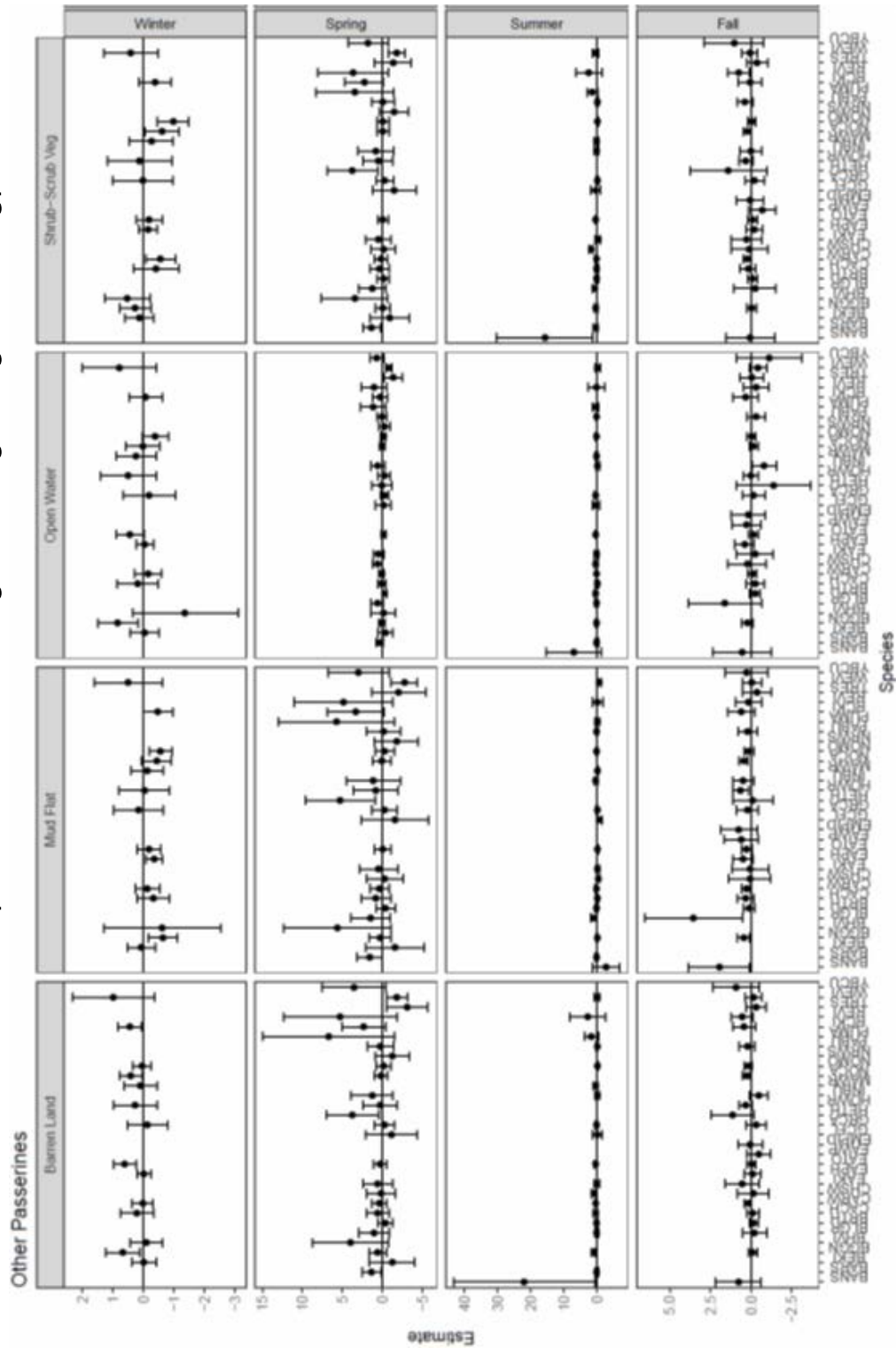


Figure F-8. Log-transformed means and 95% confidence intervals of seasonal Raptor species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

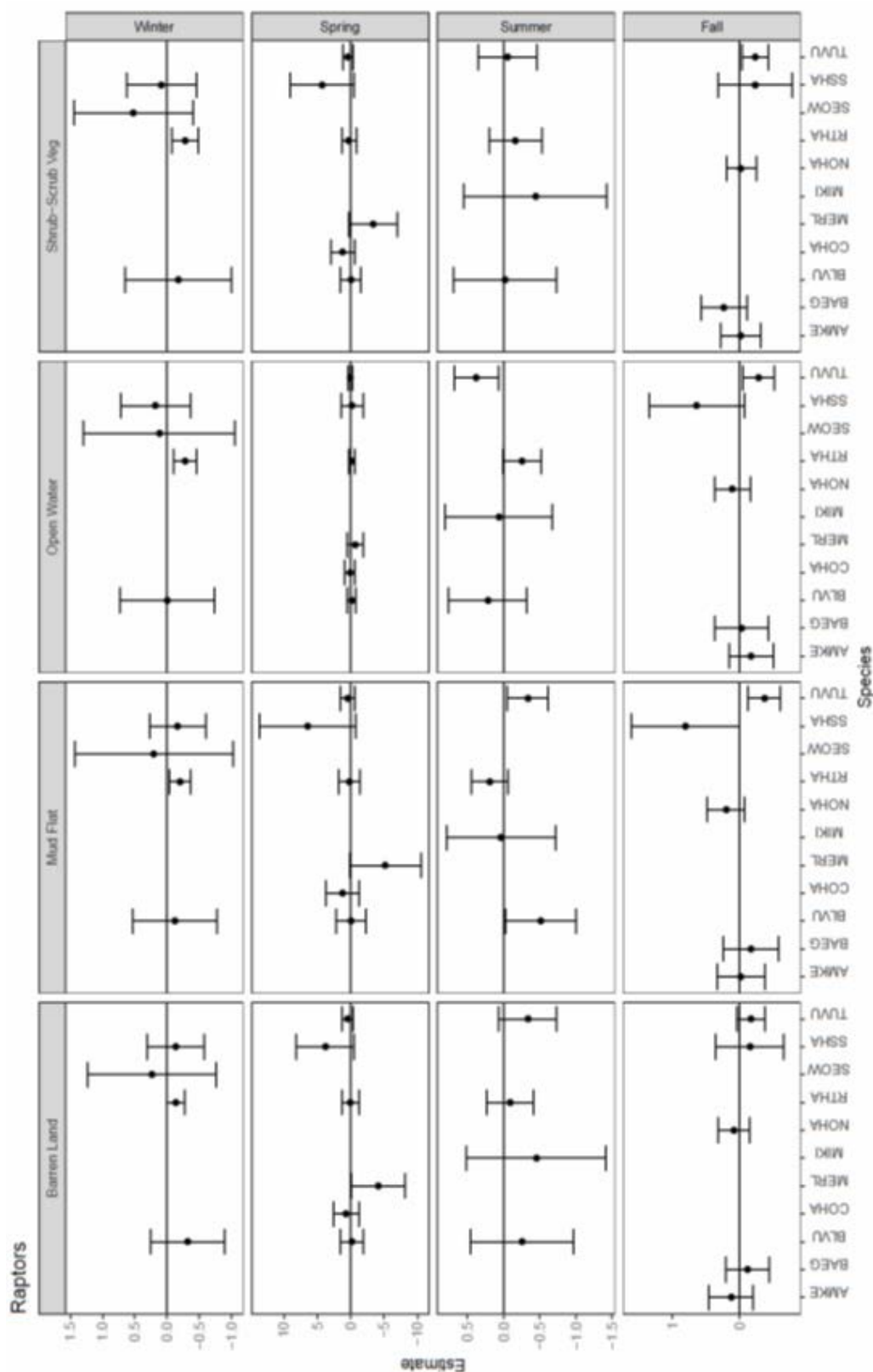


Figure F-9. Log-transformed means and 95% confidence intervals of seasonal Small Shorebird species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

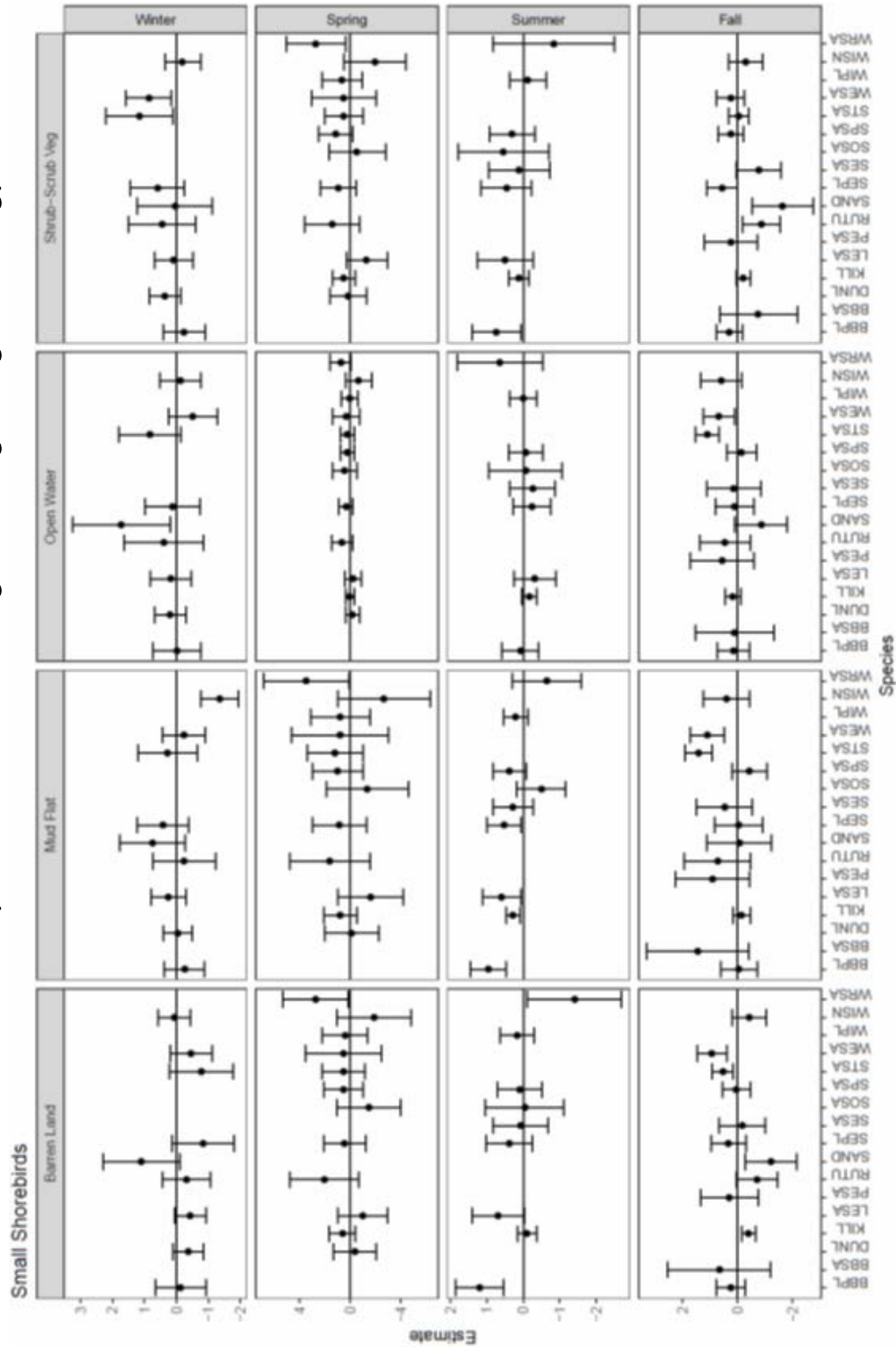


Figure F-10. Log-transformed means and 95% confidence intervals of seasonal Wading Bird species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

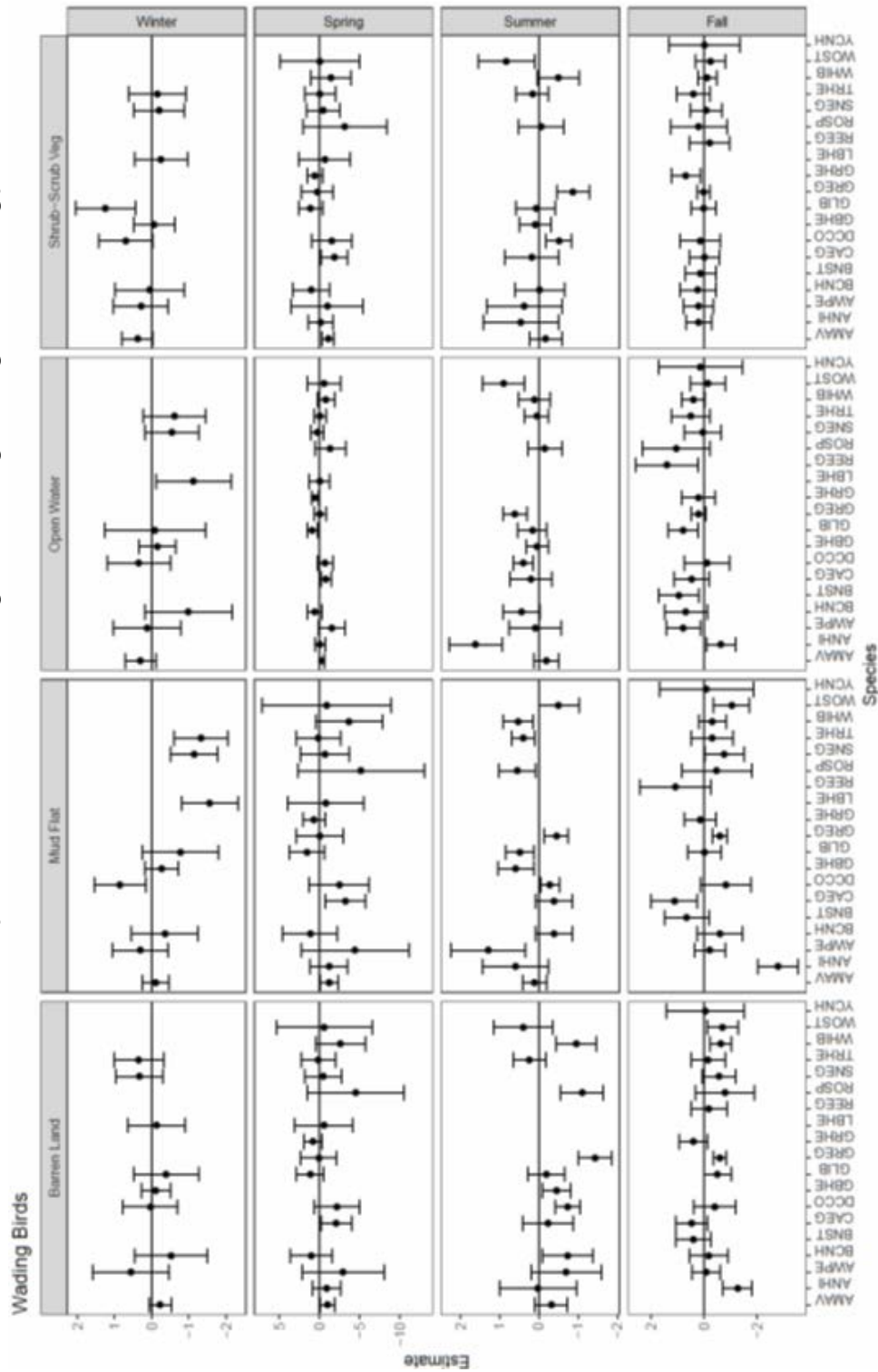


Figure F-11. Log-transformed means and 95% confidence intervals of seasonal Warbler species trends and habitat covariates on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.

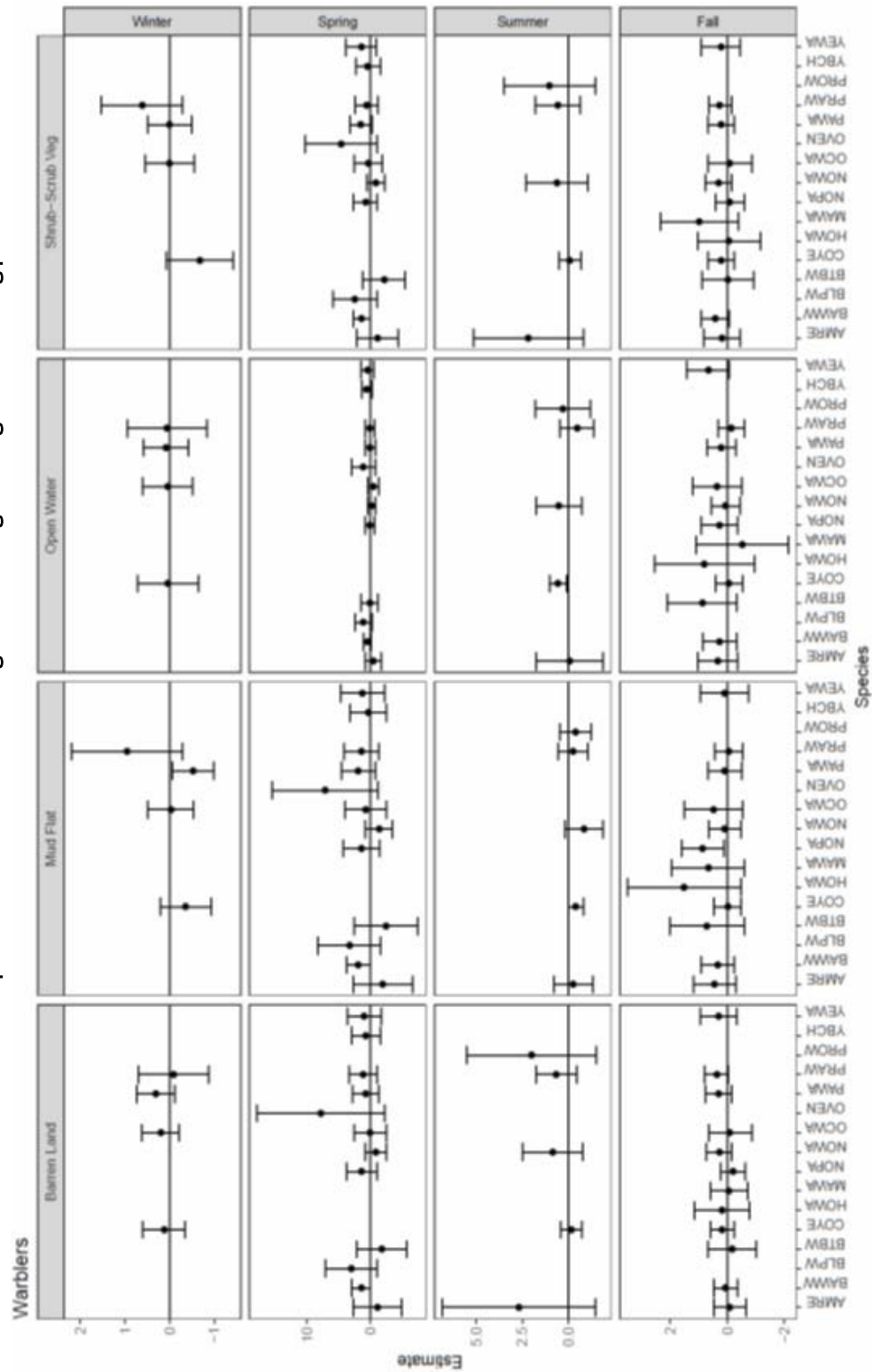
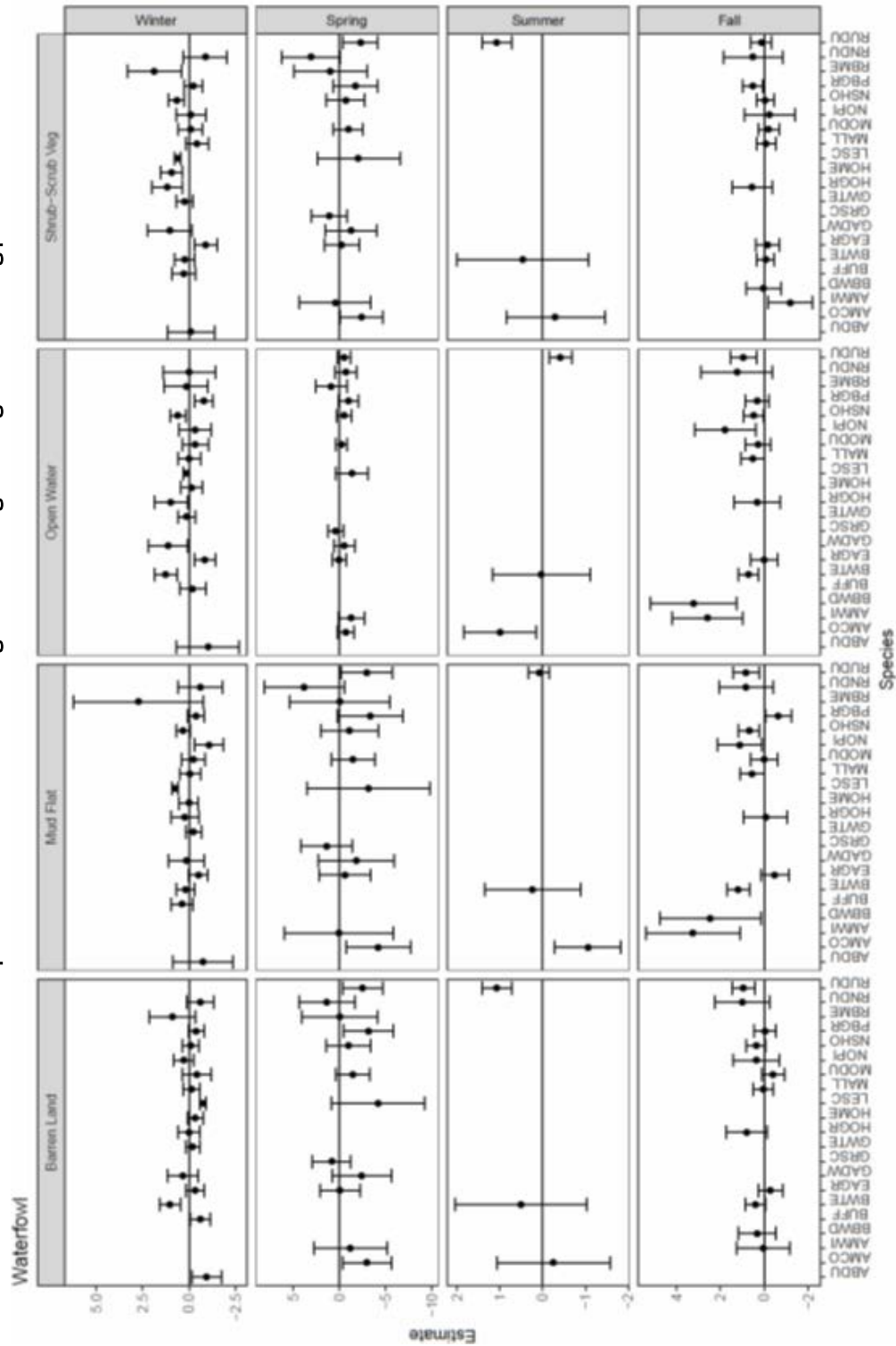


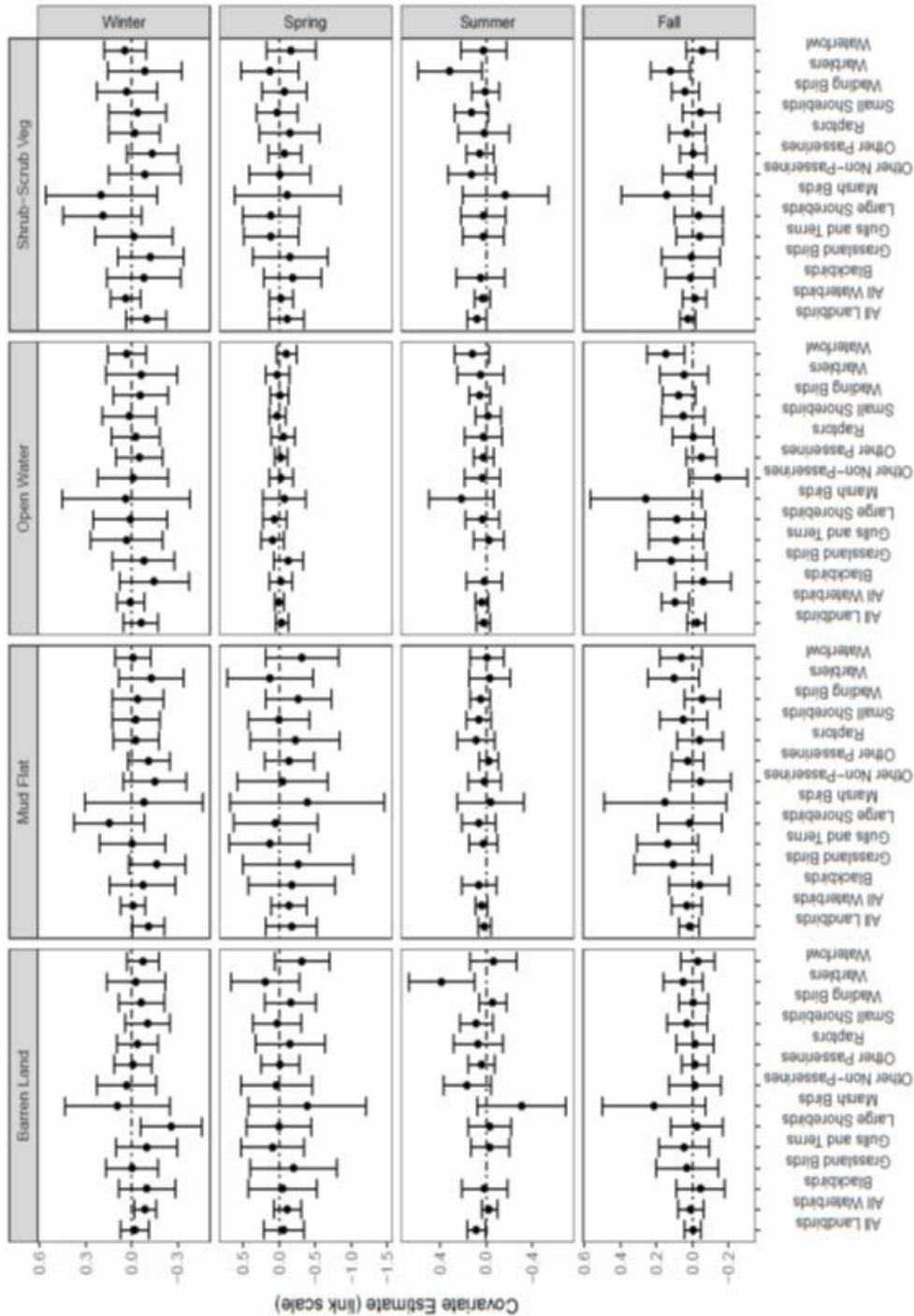
Figure F-12. Log-transformed means and 95% confidence intervals of seasonal Waterfowl species trends and habitat covariates on the SHNP, DMCA, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in abundance during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in abundance during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.



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**Appendix G: Habitat Relationships of
Mean Species Richness for Species
Groups Analysis Results on the Savannah
Harbor Navigation Project, Dredged
Material Containment Areas, 2001-2011**

Figure G-1. Log-transformed means and 95% confidence intervals of all seasonal species richness trends and habitat covariates for all species groups on the SHNP, DMCAs, Jasper County, South Carolina, 1994-2012. Year and habitat covariates were standardized to a mean of 0 and standard deviation of 1 before model fitting. Trends and 95% confidence intervals that lie above the dashed line indicate significant increase in species richness trends during the monitoring period; trends and 95% confidence intervals that lie below the dashed line indicate significant decrease in species richness during the monitoring period; trends and 95% confidence intervals that overlap the dashed line indicate no significant changes during the monitoring period.



**Appendix H: Notes on Nesting and
Reproductive Behavior for Select
Species, Savannah Harbor Navigation
Project, Dredged Material Containment
Areas, 1996-2012 (by J. Stevan Calver)**

Table H-1. Notes on nesting and reproduction behavior by common waterbirds on the SHNP DMCA's from 1996 to 2012.

Species	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
American Avocet**																	
Nests/Eggs/Young	-	-	-	-	-	-	1/-/-	2/-/-	2/-/-	2/-/-	-	-	-	-	-	-	-
Successful Pairs	-	-	-	-	-	-	1	2	2	2	-	-	-	-	-	-	-
DMCA's	-	-	-	-	-	-	12A	12A, 13B	12A, 13B	12A	-	-	-	-	-	-	-
Black-bellied Whistling Duck																	
Nests/Eggs/Young	-	-	-	-	-/-/2	-/-/14	2/-/7	-/-/6	1/-/8	-	-/-/11	-	-	-	-	-	-
Successful Pairs	-	-	-	-	1	1	2	2	1	-	1	-	-	-	-	-	-
DMCA's	-	-	-	-	14A	12A	12A, 13B	14A, 14B	13B	-	13A	-	-	-	-	-	-
Black-necked Stilt																	
Nests/Eggs/Young	86/23	-/-/99	-/-/2	55/-/-	33/-/-	17/-/-	-	-	-	81/-/-	61/-/100	82/-/209	121/-/172	131/-/130	51/-/160	218/-/260	109/-/46
Successful Pairs	9/-	63	95	55	33	17	-	-	-	81	35	82	100	72	115	145	109
DMCA's	12A, 12B, 13A, 13B, 14B	12A, 14A	12A, 14A	12A, 14A, 14B	13B, 14B	14B	-	-	-	12A	12A, 13B, 13A, 14A, 14B	12A, 13B, 14A, 14B	12A, 13B, 14A, 14B	12A, 12B, 13B, 14A, 14B	12A, 13A, 13B, 14A, 14B	12A, 13A, 13B, 14A, 14B	12A, 13B, 13A, 14A, 14B
Black Skimmer**																	
Nests/Eggs/Young	-	-	-	21/2/-	70/-/-	-	70/-/-	103/-/-	11/33/-	93/266/-	11/-/1	13/-/2	-/-/15	9/15/2	-/-/137	231/-/190	230/-/26
Successful Pairs	-	-	-	21	70	-	70	103	11	93	55	13	-	9	124	231	230
DMCA's	-	-	-	14B	14B	-	14B	-	12B	12A	12A	12A	13B	12A	12A	12A	13A
Gull-billed Tern**																	
Nests/Eggs/Young	-	-	-	22/-/-	164/-/34	-	-	160/-/-	77/204/-	164/203/-	122/-/16	109/-/2	-/-/2	39/-/17	116/-/3	123/-/85	172/64/14
Successful Pairs	-	-	-	22	164	-	-	160	77	164	122	109	-	10	116	123	172
DMCA's	-	-	-	22	164	-	-	160	77	164	122	109	-	10	116	123	172

Species	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	-	-	-	14B	14B	-		14B	12B	12A	12A	12A	14A	12A	12A	12A	13A
Killdeer																	
Nests/Eggs/Young Successful Pairs DMCA's	2/4 /3	1/-/-	-	-	-	11/- /6	2/4/13	1/3/2	1/-/4	-/-/2	-						
	1	1	1	-	-	11	7	2	2	1	-						
	13 A, 13 B, 14 B	14B	-	-	-	12A, 14A	12A, 14A, 14B	14A, 14B	13B, 14B	13B, 14B	-						
Least Tern**																	
Nests/Eggs/Young Successful Pairs DMCA's	12/ 14/ -	-	44/6/-	184/31/8	303/- /-	127/- /-	-	-	-	375/487/-	175/- /114	-/-/25	- /89/96	408/68/141	476/- /16	476/- /66	-/- /33
	12	-	44	184	303	127	-	-	-	375	167	149	256	259	225	225	39 2
	12 A, 12 B, 13 B	-	12A, 13B	14A, 14B	14B	14A, 14B	-	-	-	12A	12A, 14A	12A, 13B, 14A	12A, 13B, 14A	12A, 13B, 14A	12A, 13A, 13B, 14B	12A, 13A, 13B, 14A, 14B	12 B, 13 B, 14A , 14 B
Mottled Duck*																	
Nests/Eggs/Young Successful Pairs¹ DMCA's	-/- /6	1/4/50	-	-/-/14	3²/-/-	-	-	-	-	-	5/- /46	-/-/25	-/-/88	-/-/-	-/-/-	-/- /158	-
	-	5	-	3	-	-	-	-	-	-	5	12	-	32	115	150	-
	12 A	12A,12B, 13B	-	12A, 13A, 13B	14B	-	-	-	-	-	12A, 14A	12A, 14B	12A, 13B, 14A, 14B	12A, 13B, 14A, 14B	12A, 13B	12A, 13B	-
Roseate Spoonbill																	
Nests/Eggs/Young Successful Pairs DMCA's	-	-	-	-	-	-	2/-/-	-	-	-	-						
	-	-	-	-	-	-	2	-	-	-	-						
	-	-	-	-	-	-	14A	-	-	-	-						
Ruddy Duck																	

Table H-2. Notes on nesting and reproductive behavior observed by colonial waterbirds on the SHNP DMCAs from 1996 to 2012.

Species	1996	1997	1999	2005	2006	2007	2008	2012
Anhinga								
Nests/Eggs/Young	-	1/-/2	-	2/-/-	50/-/150	2/-/1	5/9/	7/-/-
Successful Pairs	-	1	-	2	50	1	5	7
DMCAs	-	14A	-	14A	-	14A, 14B	14A	13A
Great Egret*								
Nests/Eggs/Young	-	-	-	2/-/-	-	-	8/-/-	-
Successful Pairs	-	-	-	2	-	-	8	-
DMCAs	-	-	-	14A	-	-	14A	-
Snowy Egret**								
Nests/Eggs/Young	4/-/-	48/-/191	85/-/173	92/-/-	-	10/-/-	72/-/-	12/-/-
Successful Pairs	1	40	85	92	-	10	72	12
DMCAs	12A	14A	12A	14A	-	14A	12A, 14A	13A
Little Blue Heron**								
Nests/Eggs/Young	1/-/-	3/-/2	1/-/4	3/-/-	-	2/-/-	1/-/-	3/-/-
Successful Pairs	1	3	1	3	-	2	1	3
DMCAs	12A	14A	12A	14A	-	14A	14A	13A
Tricolored Heron**								
Nests/Eggs/Young	1/-/-	3/-/72	15/-/8	38/-/-	-	5/-/-	23/-/2	3/-/-
Successful Pairs	1	3	15	38	-	5	23	3
DMCAs	12A	14A	12A, 13B	14A	-	14A	12A, 14A	13A
Cattle Egret								
Nests/Eggs/Young	13/-/-	-	17/-/12	1/-/-	-	1/-/-	1/-/-	-
Successful Pairs	2	-	17	1	-	1	1	-
DMCAs	12A	-	12A	14A	-	14A	-	-
Green Heron								
Nests/Eggs/Young	-	-	1/-/3	2/-/-	-/-/2	1/-/-	-	-
Successful Pairs	-	-	2	2	-	1	-	-
DMCAs	-	-	12A, 13B	14A	-	14A	-	-
Black-crowned Night Heron**								
Nests/Eggs/Young	-	-	-	5/-/-	-	2/-/-	6/-/-	1/-/-

Species	1996	1997	1999	2005	2006	2007	2008	2012
Successful Pairs	-	-	-	5	-	2	6	1
DMCAs	-	-	-	14A	-	14A	14A	13A
White Ibis**								
Nests/Eggs/Young	-	-	-	30/-/-	-	100/-/-	-	-
Successful Pairs	-	-	-	30	-	100	-	-
DMCAs	-	-	-	14A	-	14A	-	-
Glossy Ibis**								
Nests/Eggs/Young	-	-	-/-/2	18/-/-	-	-	1/-/-	-
Successful Pairs	-	-	1	18	-	-	-	-
DMCAs	-	-	14B	14A	-	-	-	-

¹Successful pairs indicate number of pairs thought to produce young; however, if estimate of successful pairs not noted, then maximum number of pairs observed is provided.

²Number of nests usually is the maximum of actual number of nests counted and/or the number of incubating birds observed; often the number of nests equals the number of pairs, although it was not uncommon to observe paired individuals that did not have a confirmed nest in the area.

Priority bird rankings from the SAMBI plan (Watson and Malloy 2008):

*** Highest Priority Species

** High Priority Species

* Moderate Priority Species

Table H-3. Notes on nesting and reproductive behavior on miscellaneous bird species observed on the SHNP DMCAs 1996 – 2012.

Species	1996	1999	2001	2005	2006	2007	2008	2009	2010	2011	2012
Turkey Vulture											
Nests/Eggs/Young	-	-	-	-	-	1/2/2	1/1/2	1/4/-	-	-	-
Successful Pairs	-	-	-	-	-	1	1	2	-	-	-
DMCAs	-	-	-	-	-	14B	14B	14B, 13B	-	-	-
Red-tailed Hawk*											
Nests/Eggs/Young	-	1/-/2	-	-	-	-	-	-	-	-	-
Successful Pairs	-	1	-	-	-	-	-	-	-	-	-
DMCAs	-	14B	-	-	-	-	-	-	-	-	-
Common Moorhen**											
Nests/Eggs/Young	-	-	-	-	-	-	-	-/-/2	-/-/2	-/-/2	-
Successful Pairs	-	-	-	-	-	-	-	-	-	-	-
DMCAs	-	-	-	-	-	-	-	12A, 13B, 14A, 14B	12A, 13B	12A, 13B, 14A	-

Species	1996	1999	2001	2005	2006	2007	2008	2009	2010	2011	2012
Mourning Dove											
Nests/Eggs/Young	-	1/-/-	-	-	-	-	-	-	-	-	-
Successful Pairs	-	1	-	-	-	-	-	-	-	-	-
DMCAs	-	14B	-	-	-	-	-	-	-	-	-
Common Nighthawk											
Nests/Eggs/Young	-/-/2	-	-	-	-	1/2/-	1/2/2	7/4/6	3/4/2	-	-
Successful Pairs	1	-	-	-	-	1	1	7	3	-	-
DMCAs	12B	-	-	-	-	12A	12A	12A	12A, 14B	-	-
Red-bellied Woodpecker											
Nests/Eggs/Young	-	1/-/1	-	-	-	-	-	-	-	-	-
Successful Pairs	-	1	-	-	-	-	-	-	-	-	-
DMCAs	-	-	-	-	-	-	-	-	-	-	-
Northern Cardinal											
Nests/Eggs/Young	-	1/-/3	-	-	-	-	-	-	-	-	-
Successful Pairs	-	2	-	-	-	-	-	-	-	-	-
DMCAs	-	14B	-	-	-	-	-	-	-	-	-
Eastern Towhee**											
Nests/Eggs/Young	-	-/-/2	-	-	-	-	-	-	-	-	-
Successful Pairs	-	1	-	-	-	-	-	-	-	-	-
DMCAs	-	14B	-	-	-	-	-	-	-	-	-
Boat-tailed Grackle											
Nests/Eggs/Young	-	2/-/1	-	-	-	-	-	-	-	-	-
Successful Pairs	-	3	-	-	-	-	-	-	-	-	-
DMCAs	-	12A, 13B	-	-	-	-	-	-	-	-	-

¹Successful pairs indicate number of pairs thought to produce young; however, if estimate of successful pairs not noted, then maximum number of pairs observed is provided.

²Number of nests usually is the maximum of actual number of nests counted and/or the number of incubating birds observed; often the number of nests equals the number of pairs, although it was not uncommon to observe paired individuals that did not have a confirmed nest in the area.

Priority bird rankings from the SAMBI plan (Watson and Malloy 2008):

*** Highest Priority Species

** High Priority Species

* Moderate Priority Species

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14. ABSTRACT This report presents the results of a long-term habitat and trend analyses of bird community data from a monitoring effort conducted on five Dredged Material Containment Areas (DMCAs) from 1994 to 2012. The USACE Savannah District developed and implemented a Long-Term Management Strategy (LTMS) for the DMCAs in 1996 to mitigate lost wetland habitat due to maintenance operations in the Savannah Harbor, and to provide habitat for the floral and faunal communities that otherwise would be available if not for the urban and economic development of the area. Bimonthly surveys were conducted from 1994 to 2012 to assess the effectiveness of the LTMS to provide seasonal habitat for the bird community. Archived quarterly satellite imagery was collected and analyzed from 2001 to 2011 to assess year-round seasonal habitat availability. All bird community data collected were fitted to a negative binomial (mean abundance) or Poisson distribution (mean species richness) and used to assess trends for 180 individual species and 12 species groups for spring, summer, fall, and winter seasons from 1994 to 2012. Results indicate that the Savannah DMCAs support stable to increasing populations of most species and species groups during each season, including many species ranked as regional priority species.					
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