Trends in Colony Sizes for Five Colonial Waterbird Species in the Atlantic Flyway

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Abstract

Robust estimates of colonial waterbird (CWB) breeding population trends are deficient owing to a lack of range wide, standardized survey efforts. Evaluating conservation priorities and effectiveness of management requires reliable trend estimates across multiple spatial scales. One potential data source for CWB trend estimation is the Colonial Waterbird Database, created in 2003 by U.S. Geological Survey and the U.S. Fish and Wildlife Service and intermittently updated since then. The database combines state or provincial survey data, particularly from the United States Atlantic Flyway, with historical colony counts obtained from publications. We combined recently collected survey data from Atlantic Flyway states and provinces with data archived in the database to generate population size trend estimates for five species: Double-crested Cormorant (*Phalacrocorax auritus*), Laughing Gull (*Leucophaeus atricilla*), Least Tern

(*Sternula antillarum*), Common Tern (*Sterna hirundo*), and Black Skimmer (*Rynchops niger*). These species represent two actively managed conflict species and three species of conservation concern, respectively. We used mixed effects models to fit an exponential growth model to determine yearly trends in populations at Atlantic Flyway- and state-scales with survey data collected between 1964 and 2019. Direction of within-state trend estimates varied. Trends for some species (Common Tern, Laughing Gull) were increasing in northern states and decreasing further south. At the Flyway scale, Double-crested Cormorant increased (2.08 ± 0.28 % year^{-1}) and Least Tern (-1.40 ± 0.36 % year^{-1}) and Black Skimmer (-1.13 ± 0.68 % year $^{-1}$) decreased, while Flyway-scale trends in Common Tern and Laughing Gull were not significant. Our analysis provides cross-state trend estimates to inform CWB management actions along the Atlantic Flyway.

Introduction

A defining characteristic of colonial waterbirds (CWB) is that they breed in colonies (two or more nesting pairs), typically in locations with few predators (Kushlan 1986). Threats to waterbirds were an important catalyst for bird conservation in North America. CWB populations declined steeply owing to pesticide contamination in the 1960s and 1970s, leading to an increased effort to inventory and understand CWB population trends to understand widespread effects of contamination (Kushlan 2012). Data to do so, however, were lacking. Traditional, coordinated avian count methods that cover broad geographic scales, such as the road-based Breeding Bird Survey (BBS), are not conducive for obtaining CWB trend estimates, because many species breed in remote habitats often surrounded by water and far from roads. CWB were singled out explicitly as poorly sampled by creators of the BBS (Robbins et al. 1986, Sauer et al.

2017). Broad, federally coordinated annual surveys similar to those for waterfowl, American Woodcock, and Sandhill Crane are not conducted for CWB in the Atlantic Flyway. Instead, estimates of CWB trends have been generated by: 1) conducting aperiodic broad-extent and large-effort surveys such as the aerial survey conducted in 1976–1977 across a large portion of the Atlantic Flyway (from south of Cape Elizabeth, Maine, to the Virginia-North Carolina state border), capturing a broad picture of CWB populations within a single time interval (Erwin 1979; Erwin and Korschgen 1979); 2) aggregating best available data from smaller and more intensively sampled portions of the Atlantic Flyway to generate a piecemeal description of trends within subsets of the Flyway (Kress et al. 1983); or, 3) using approaches other than census techniques, such as population genetics and metapopulation models (*e.g.,* Szczys et al. 2017).

In a broad sense, population level conservation of CWB is hindered by data deficiencies arising from diverse, uncoordinated data collection protocols that reflect different aims and conservation priorities among agencies and across jurisdictional boundaries (Kushlan 2012). Data are unbalanced, both temporally and geographically, and are often collected at inconsistent intervals. Labeling or naming conventions for colonies and sampling units (e.g., pairs, total individuals, adults, nests) vary; survey effort is typically unrecorded; and, geographic completeness of surveys differs temporally and across jurisdictions. CWB in eastern North America span conservation boundaries and jurisdictions of 19 states and provinces in the United States and maritime Canada. States design survey efforts based on within-state threats and conservation needs as identified by the State Wildlife Action Plan (SWAP) process (AFWA 2020; Riley et al. 2020) and with consideration of available resources and staff. The result is inconsistent data collection efforts with varied protocols across states, including incomplete state-level surveys and survey intervals between surveys that rarely are the same among states.

Therefore, any aggregation of data for generating Flyway estimates is likely to be unbalanced, both spatially and temporally.

There is an important need in CWB conservation and management to derive trends in populations despite the absence of an entity to coordinate data collection and management for these species at a regional or flyway scale. Trend information is important for assessing conservation status of at-risk species, and for evaluating the effectiveness of conservation and management actions. The U.S. Fish and Wildlife Service (USFWS) faces persistent challenges managing data deficient avian populations (Trapp et al. 1995). Quality estimates of population size and growth rates are essential for developing models to determine take limits for conflict species, such as Double-crested Cormorant (*Phalacrocorax auritus*) and gull species (Family Laridae; Runge et al. 2009), and for conserving priority species in accordance with federal laws such as the National Environmental Policy Act, Endangered Species Act, and Migratory Bird Treaty Act.

There have been efforts to bring together stakeholders interested in conserving waterbirds. The North American Waterbird Conservation Plan (Kushlan et al. 2002; NAWC Plan) was created under the Waterbird Conservation for the Americas Initiative by stakeholders interested in continent-wide waterbird conservation (Kushlan et al. 2012). The NAWC Plan emphasizes the importance of filling data gaps to increase the efficacy of conservation status assessments, evaluate population trends, and quantify effects of habitat changes across multiple spatial scales. Additionally, it recognizes the importance of standardized survey methods and survey data storage in a centralized location so they are readily available to inform and evaluate management decisions and actions. The Colonial Waterbird Database (CWBD; https://www.pwrc.usgs.gov/cwb/) was created by the USFWS, U.S. Geological Survey (USGS), and partners to provide a centralized location for housing waterbird data. The database includes data collected in surveys of terns and gulls (family Laridae), skimmers (*Rhynchops spp.*), pelicans (Order Pelecaniformes, cormorants (family Phalacrocoracidae), puffins, (family Alcidae), gannets (family Sulidae), petrels (family Procellariidae), shearwaters (Order Procelleriformes), herons and egrets (family Ardeidae), and ibis (family Threskiornithidae) conducted throughout North America. It is the most comprehensive repository of CWB survey data for the U.S. Atlantic and Gulf coastal states. The original CWBD was updated since 2003 to include data from coordinated breeding surveys conducted in 2008 and 2013 as part of the American Waterbird Conservation Plan's Mid-Atlantic/New England/Maritimes (MANEM Working Group 2006) plan, as well as state-led surveys conducted from Maine to Georgia from the mid-1990s to as recently as 2013. It also contains relevant information from the Cornell Waterbird Register (Fink et al. 2020) and results from CWB surveys carried out at locations around the Gulf of Mexico.

The purpose of our study was to develop estimates of trends in state and Atlantic Flyway scale population sizes for Least Tern (*Sternula antillarum*), Common Tern (*Sterna hirundo*), Black Skimmer (*Rynchops niger*), Laughing Gull (*Leucophaeus atricilla)*, and Double-crested Cormorant (Atlantic Coast, excluding inland) with colony survey data archived in the CWBD and other databases and publications. These species breed over a wide geographic range within the Flyway and are of particular conservation or management interest to the USFWS and Atlantic Flyway states (Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida). We used best available data from the CWBD, appended with additional data collected or discovered since 2013 (when the CWBD was last updated) to serve as proxies for population trends and a mixed models approach to account for unbalanced data, along with some simple assumptions. Analysis at the flyway scale can reveal if trends represent a range shift or changes in populations, as well as identify where data deficiencies for long-term monitoring can be addressed with standardized survey protocols. Our *a priori* expectations were that Double-crested Cormorant and Laughing Gull were increasing through much of this period and that the other species were declining, although the extent of these trends within and across the region were uncertain.

Methods

We combined breeding colony survey data recorded in the CWDB with data collected by state, federal, and NGO partners during recent (since 2013) Atlantic Flyway surveys initiated as part of the Atlantic Flyway Mid Atlantic New-England and Maritimes plan (MANEM Working Group 2006), the southeastern Seabird Atlas, North Carolina's PAWS database, and survey data collected under the purview of the Gulf of Maine Seabird Working Group (GOMSWG). We also solicited states for additional colonial waterbird data that were not included in these databases. Contact information for access to data sources used in this analysis is provided in the Acknowledgements and Appendix.

We built flyway-level and state-level models for the Least Tern, Common Tern, Black Skimmer, Laughing Gull, and Double-crested Cormorant to assess annual trends in colony sizes (i.e., number of breeding adults) within Atlantic Flyway states. The use of within-colony trends as indicators of population trends has precedence for CWB (*e.g.,* Jodice et al. 2007). We used a mixed model approach (Zuur et al. 2009) to analyze data for each species. We used exponential growth models, where changes in population per year are the classical continuous growth rate (Gotelli 2008) and included two random intercept and slope effects, one for state and one for colony. The data in the CWBD and other compiled sources are incomplete and imbalanced. All focal species were missing data from one or more states within their respective Atlantic coast ranges' because of differences in state-level survey priorities, a failure to enter available data into the CWBD, and because no coordinated Atlantic Flyway-wide surveys had been conducted. Random effects control for these inherent data deficiencies and imbalances by treating states as samples from a larger pool (i.e., the Atlantic Flyway). Random effects for colonies address imbalances in the number of years a colony was surveyed. We restricted the analysis to using data from colonies with more than one survey year. Colonies were identified by recorded geographic coordinates when consistent state-assigned colony labels were not available. We were unable to account for variation in precision among survey methods because of insufficient metadata (e.g., length of survey, number of observers), and we acknowledge this limitation. We generated separate state level models of annual trends for the subset of states with data from at least 50 surveys total (with each included colony surveyed at least twice). State models were the same as the global model for each species, except they lacked the random effect for state (i.e., the random effect value would be identical for within-state records). Year was treated as a numeric, fixed effect in all models. When multiple surveys were conducted within a colony within one year, we selected the largest count. Colony counts varied from regular, complete censuses on intensively studied islands to estimated data from infrequent aerial or boat-based surveys. The survey unit (typically nests, pairs, or individuals) varied among the states, species, and survey years. Therefore, we made the simple assumption that counts of "pairs" or "nests" could be treated interchangeably as two individuals. Data analyses were conducted in R (R Core Team 2019) using package lme4 (Bates et al. 2015).

Results

Counts of breeding adult Least Terns varied among years within Atlantic Flyway states, with standard errors exceeding the magnitude of trends for several states but with a declining trend across the Flyway overall (-1.40 ± 0.36% contraction per year, 95% CI = -2.12 – -0.71, $F_{1, 637.20}$ = -3.935, P < 0.001). For most states, the high degree of variability prevented detection of a within-state change. The notable exception was North Carolina, which showed a long-term decline during over 1977 through 2019 (Figure 1). States included in the Flyway estimate for Least Terns were Maine, Massachusetts, Connecticut, Rhode Island, New Jersey, Delaware, Maryland, North Carolina, South Carolina, Georgia, and Florida.

There was no change in counts of breeding adult Common Terns when evaluated across the flyway as a whole (0.003 ± 0.34% growth per year, 95% CI = -0.003 – 0.009, $F_{1, 1994}$ = 0.988, P = 0.323), however, state level assessment suggested a more complex pattern. There was a strong increasing trend in Maine (4.47 ± 0.63%, 95% CI = 3.24 – 5.7, $F_{1, 680.19}$ = 50.66, P <0.001) (Figure 2), however, other New England states with sufficient data for analysis showed no change (Massachusetts: -2.32 ± -1.41%, 95% CI = -5.1 – 0.55, $F_{1, 91.72}$ = 2.69, P = 0.104; Rhode Island: 0.32 ± 0.34%, 95% CI = -0.36 – 0.99, $F_{1, 636.91}$ = 0.86, P = 0.354). Two more southern states for which we had adequate data to evaluate changes showed strong decreases in counts of breeding adult Common terns (New Jersey: -4.64 ± 1.96%, 95% CI = -8.51– -0.79, $F_{1, 49.55}$ = 5.63, P = 0.022; North Carolina: -5.63 ± 0.77%, 95% CI = -7.16 – -4.09, $F_{1, 392.01}$ = 52.85, P < 0.001). States included in the Flyway estimate for Common Terns were Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, New Jersey, Delaware, Maryland, Virginia, North Carolina, and South Carolina.

There was a significant decrease in populations of adult breeding Black Skimmers at the Atlantic Flyway level (-1.13 ± 0.68% growth per year, 95% CI = -2.45 – 0.22%, $F_{1,303.9}$ = -1.168, P = 0.096; Figure 3), detectable in spite of limited data (e.g., 477 records for Black Skimmers compared to 1922 for Double-crested Cormorant). South Carolina showed a very strong decline (-6.32 ± 2.09%, 95% CI = -10.41– -2.05, $F_{1, 117.6}$ = 9.14, P = 0.003) in Black Skimmers, and North Carolina showed a decline (-1.26 ± 0.81%, 95% CI = -2.86 – 0.32, $F_{1, 254.07}$ = 2.43, P = 0.120), although the data were highly variable and the trend was not significant. States included in the Flyway estimate for Black Skimmers were Massachusetts, New Jersey, Maryland, North Carolina, South Carolina, Georgia, and Florida.

Laughing Gull numbers of breeding adults did not change significantly at the Atlantic Flyway scale, however, there was a rapid increase in Maine (6.34 ± -1.3%, 95% CI = 3.8-8.88, $F_{1, 132.57}$ = 23.85, P <0.001), no change in New Jersey (-2.67 ± 3.42%, 95% CI = -9.65 – 4.03, $F_{1, 42.65}$ = 0.61, P = 0.440), and a decreasing trend in North Carolina (-2.74 ± 1.16%, 95% CI = -5.02 – -0.47, $F_{1, 264.61}$ = 5.57, P = 0.019) (Figure 4). Northern growth and southern contraction mirrored the pattern observed in the Common Tern. States included in the Flyway estimate for Laughing Gulls were Maine, Massachusetts, New Jersey, Delaware, Maryland, North Carolina, South Carolina, Georgia, and Florida.

Double-crested Cormorants within the coastal Atlantic Flyway showed an increasing trend during 1964-2019 (2.08 ± 0.28 % increase per year, 95% CI = 1.55 – 2.65, t_{1851} = 7.43, P < 0.0010) (Figure 5). Populations of breeding adults in Maine (2.05 ± 0.32%, 95% CI = 1.43 – 2.67, $F_{1, 1482.91}$ = 41.85, P < 0.001) and Rhode Island (4.42 ± 0.76%, 95% CI = 2.92 – 5.90, $F_{1, 258.04}$ = 34.15, P < 0.001) increased, whereas, there was no change in Massachusetts (1.37 ± 1.08%, 95% CI = -0.88 – 3.57, $F_{1, 105.09}$ = 1.61, P = 0.207), the only other state with sufficient data for intrastate estimation. States included in the Flyway estimate for Double-Crested Cormorants were Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, Virginia, and North Carolina.

Discussion

Species trends

At the Atlantic Flyway scale, the trends in populations of breeding adults met our *a priori* expectations of general declines in conservation priority species (Least Tern, Black Skimmer) and increases in one human-conflict associated species (Double-crested Cormorant). Laughing Gulls and Common Tern, a conservation priority species, presented a more complex picture. In a comprehensive study of regional breeding tern populations in the northeastern United States compiled in the early 1980s, Kress et al. (1983) found long-term decreases in Common Tern numbers concomitant with increases in gulls after cessation of the millinery trade in the late 19th century. Since that time, outside of northeastern North America, others have concluded that breeding Common Tern populations have decreased sharply in the Great Lakes region of the United States and Canada (Morris et al. 2010, 2012), and roughly by two-thirds in Manitoba, Canada, since the 1990s (Wilson et al. 2014). There has been a rapid 10-fold increase in dispersal from inland sites to coastal breeding locations since the 1960s, with evidence from genetic analysis (Szczys et al. 2017) suggesting this directional movement that is concurrent with Great Lakes declines (Cuthbert et al. 2003).

Management actions intended to benefit Common, Roseate (*Sterna douglassi*), and Arctic Terns (*Sterna paradisaea*) include lethal and non-lethal control of predatory gulls within tern colonies, island closures to humans, and state and federal legislative protections (e.g., Maine

Natural Resource Protection Act, Endangered Species Act, Migratory Bird Treaty Act). More specifically, control measures for Herring Gulls (*Larus argentatus*) and Great Black-backed Gulls (*L. marinus*) were implemented in Maine as early as 1974 in response to CWB population declines (Kress 1983), which may have contributed to the increases in Common Tern populations in Maine. Together, these actions likely have buoyed Common Tern populations within the Atlantic Flyway (Donehower et al. 2007, USFWS 2012).

Other colonial waterbird species have shifted their distributions northward in the past, so a northward shift in Common Terns is not without precedent. For example, during the 20th century Sandwich Tern (*Sterna sandvicensis)* populations shifted their range northward into the Baltic Sea, from proportionally more disturbed sites in southern locations to more northerly island sites where gull control measures were implemented (Herrmann et al. 2008). Northern range shifts of birds also have been attributed to climate change, although typically on a much smaller spatial scale than observed at the extent of our study region (Thomas and Lennon 1999, Brommer et al. 2012). The mechanisms behind the changes we observed remain conjectural, as we did not identify causal relationships. However, evidence suggests fish species, especially those that are coastal and within foraging ranges of terns, are generally shifting poleward (Morley et al. 2018), which may be contributing to the observed changes in tern populations.

Within-colony trends for Least Terns reported here should be interpreted cautiously given the species' tendency to breed in small ephemeral colonies distributed over large areas, as well as on flat, pea-gravel covered rooftops (Fisk 1975; Burger 1984; Zambrano et al. 1997) that are not well-represented in surveys. Surveys reported in the CWBD generally focused on larger, more persistent colonies and not on rooftop colonies. Given the heterogeneity in within-colony counts, such as that observed for Least Terns, more data are needed to detect similar effect sizes in trends relative to other species. BBS trends suggest a long-term decline of 3.3% percent per year at the continental level, however, this is based on sparse data (the "data deficient" category), and the trend appears relatively flat beginning in the 1990s (Pardieck et al. 2019). Estimations of site and local trends have been attempted at various locales and intervals in the Atlantic Flyway over the last several decades with varied results. For example, population trends for Least Terns in South Carolina were approximately zero between 1988 and 2009 (Wilkinson 1997; Snipes and Sanders 2012), although overall numbers during this interval were less than historical numbers. Populations in the Florida panhandle were also apparently stable from the late 1970s through late 1990 (Gore 1991). Survey methods that are standardized and species-specific can help improve data quality and result in better population estimates developed from those surveys.

Black Skimmers have low inter-annual fidelity, are known to shift colony locations between salt marshes and beaches, and they often will not use the same colonies in successive years (Greene and Kale 1976). Locations with larger colonies are more consistently used for breeding (Burger and Gochfield 1990). Colony turnover rates as large as 50% have been documented for Black Skimmers and Least Terns (Visser and Peterson 1994), which complicates extrapolating population trends from within colony trends. For comparison, Laughing Gull site turnover is generally around 20% per year, and Common Tern site turnover may vary from 5% to 20% (McCrimmon and Parnell 1983, Visser and Peterson 1994). Black Skimmer populations in New Jersey declined by approximately 30% from 1976 to 1981 and then were relatively stable from 1981 through 1988 (Burger and Gochfield 1990). Longitudinal surveys of the Virginia barrier islands during 1975-1988 reported a decrease in Black Skimmers of unspecified magnitude (Williams et al. 1990), and by 2018 the population was estimated to be half of that in 1993 (Watts et al. 2019). Unlike the declines at breeding colonies in the Atlantic Flyway, analyses of wintering Christmas Bird Counts in Texas through Alabama (inclusive) during 1967-2008 found increases in wintering Black Skimmers of 2.02% per year (Sands and Brennan 2012). The contribution of Atlantic Flyway coastal birds to these winter numbers is not known, although Black Skimmers banded on the Atlantic coast have been documented wintering along the Gulf coast (Snipes and Sanders 2011).

Unlike other focal species in this analysis, Double-crested Cormorants have been comparatively well-studied, owing to efforts to better understand and mitigate increasing conflicts with human interests. Double-crested Cormorants are considered a "conflict species" owing to depredation of sport fish, negative effects on aquaculture production, fouling of waters and property, and adverse effects on other colonial nesting birds (Duffy 1995, Glahn et al. 2000, DeVault et al. 2012). Double-crested Cormorant populations were reduced in the mid-20th century by pesticide contamination and other pollutants, however, they rebounded strongly beginning in the late 1970s following the banning of DDT. This population increase also included breeding range expansion southward of the mid-Atlantic states (Wires and Cuthbert 2006). The historical southward expansion is in contrast to other species examined in this study, whose ranges are contracting towards more northerly states.

Because Double-crested Cormorants also breed at inland locations in relatively large numbers, their population trends are better captured by the Breeding Bird Survey than for other CWB. Between 1966 and 2015, BBS population estimates increased by 12.45% annually in the Atlantic Flyway. Much of that trend is attributed to the very rapid growth in the 1970s following the banning of DDT (Pardieck et al. 2019). When restricted to recent years (≥1999), the BBS growth rate is very similar to results herein (2.42% year^{-1}). It is important to note that the Double-crested Cormorant data used in our analysis were derived solely from coastal breeding sites and did not include data from any inland sites (e.g., inland lakes). Therefore, trends presented here apply only to Atlantic coastal breeding Double-crested Cormorants, even though both inland and coastal colonies in the flyway may constitute a single population (Kimble et al. 2020).

The trend we observed in Laughing Gulls, which suggests a northern expansion similar to that of the Common Tern, is supported by other research on gull populations. Although Parnell et al. (1997) reported a substantial increase in Laughing Gull numbers in North Carolina between 1977 and 1983, their numbers remained fairly consistent through the mid-1990s, and southern declines in our study occurred primarily after 2010. A pattern of exponential growth in the later part of the 20th century in northern states was also observed elsewhere, such as Jamaica Bay National Wildlife Refuge in New York, where populations expanded from no breeding birds in the mid-1970s to more than 7,000 nesting pairs in 1990 (Brown et al. 2001). Laughing Gulls in New Jersey also increased by nearly 2/3 between 1977 and 1979 from 30,730 to 52,914 breeding adults and slowly increased to over 58,000 by 1989 (Jenkins et al. 1990), while populations in Florida and along the Gulf of Mexico declined during this period (Belant and Dolbeer 1983). Laughing Gull trends in the southeastern United States may be related to the mass mortality from the Deepwater Horizon oil spill, which reduced numbers in the Gulf of Mexico and adjacent southern states by 32% (Haney et al. 2014). Sea level rise may also contribute to declining Laughing Gull populations (Watts et al., 2019). In Virginia, the Laughing Gull breeding population increased between 1977 and 1993, trailed by period of relative stability through 2003 (Watts et al., 2019). Between 2003 and 2013, however, the population declined by 47% (Watts and Paxton 2014) followed by a 31% decline in 2018. These dramatic decreases were attributed to repeated tidal flooding and abandonment of low elevation saltmarsh habitats where they historically nested in large numbers (Watts *et al.,* 2019).

A call for improved survey data collection, management and reporting

Our analysis was designed to extract population trends from incomplete, diverse, and disparate breeding survey datasets, and evaluate the datasets for trend estimates to increase our understanding of CWB populations. We also identified inconsistencies in survey protocols that could be reduced by standardizing data collection and reporting methods, which could increase reliability of future surveys for informing management decisions across multiple spatial scales. Within-colony counts provide information about how a species uses the local environment, however, these surveys are informative for detecting population trends only if they use consistent methods across surveys and are spatially complete. Additionally, increasing trends may be correlated with expansion to new colonies. These trends may be underestimated in areas that are not regularly surveyed. In the best-case scenario, even if surveys are conducted at new colonies immediately upon their formation, at least two years of survey data are needed to include the new locations in population estimates.

Employing standardized protocols for identifying colony location, data collection methods, and data management could improve data reliability and power in future monitoring and trend assessments. Improved consistency in colony and site naming and spatial location (e.g., X, Y coordinates, Datum) conventions, such as assigning unique colony identifiers or codes within state datasets, could facilitate tracking trends within and across colonies. Colony name alone is insufficient as a unique identifier; data recorders often use subtle naming differences that may not discriminate among unique colonies (e.g., Egg Rock, Eastern Egg Rock, Eastern Egg Rock Island, and Egg Rock Island may be four names for the same colony). Greater consistency in identifying the counted units for each survey is another critical part of dataset development and archiving. For example, we excluded records from analyses because it was impossible to identify the counted unit as nests, pairs or individuals. When trend estimation is the goal, all else being equal, repeated surveys at fewer colonies provides more useful information than surveying many colonies only once. Further, ensuring that zero counts are recorded, sampling effort is documented, and the estimated fraction of each colony that is sampled can provide flexibility in analyses, especially when colony use and composition is expected to vary over time.

Effective conservation of priority species and managed conflict species requires reliable waterbird population trend estimates developed from accurate and spatially representative counts, which are currently lacking for many species in the Atlantic and other North American Flyways. Obtaining such trends at regional and flyway scales requires extensive coordination across many organizations and agencies, some of which may have competing objectives and different priorities. In addition, adoption of uniform survey methodology, standardized data reporting, and cooperative data management are key to ensuring timely analyses with maximized statistical power and data consistency. The following areas could help to improve CWB survey information: a centralized repository of information detailing each organization's survey plans, universally accepted standardized survey methods and data collection protocols for colonial waterbird species, a centralized data archive (Steinkamp et al. 2003, Stenhouse and Goyette 2012a, 2012b), and a flyway-wide, pre-survey analysis plan for estimating species' population trends with the new and archived data. Cross-boundary partnerships of state, federal, and provincial wildlife agencies collaborating in periodic, coordinated surveys that are leveraged by agencies and management structures, such as the North American Flyway Councils, have the capacity to promote consistent and adequate survey coverage across administrative boundaries. These partnerships could facilitate addressing these improvements and result in datasets that could be used to better evaluate CWB trends and understand outcomes of CWB-focused management and conservation actions.

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List of Figures

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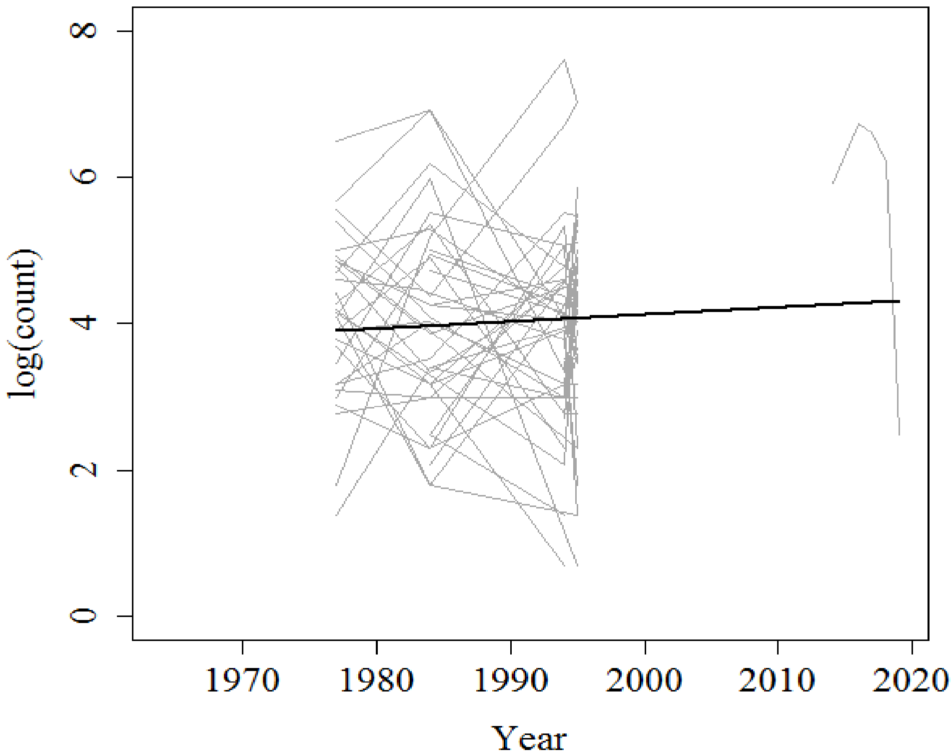
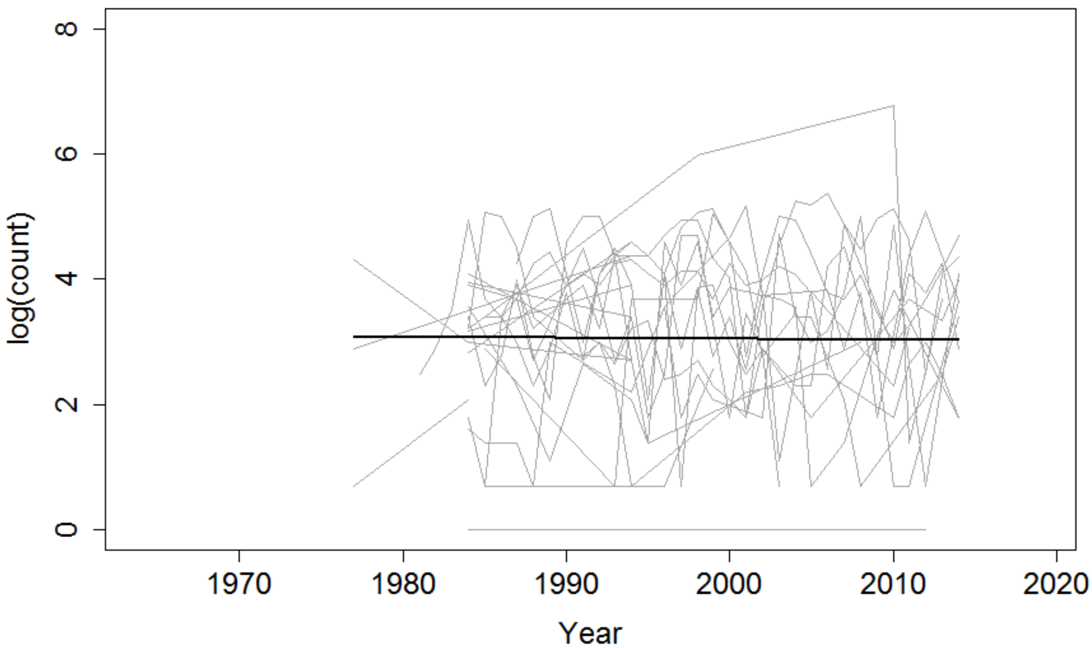
2. Common Tern (*Sterna hirundo*) intra-colony trends by state from data from the Colonial Waterbird Database for states with at least 50 surveys, Atlantic Flyway, United States, 1964–2019. Intervals and gaps in plots (light lines) indicate colony data availability. Significant state trends (dark line) are indicated with *.
3. Black Skimmer (*Rynchops niger*) intra-colony trends by state from data from the Colonial Waterbird Database for states with at least 50 surveys, Atlantic Flyway, United States, 1964–2019. Intervals and gaps in plots (light lines) indicate colony data availability. Significant state trends (dark lines) are indicated with *.
4. Laughing Gull (*Leucophaeus atricilla*) intra-colony trends by state from data from the Colonial Waterbird Database for states with at least 50 surveys, Atlantic Flyway, United States, 1964–2019. Intervals and gaps in plots (light lines) indicate colony data availability. Significant state trends (dark lines) are indicated with *.
5. Double-crested Cormorant (*Phalacrocorax auritus*) intra-colony trends by state from data from the Colonial Waterbird Database for states with at least 50 surveys, Atlantic Flyway, United States, 1964–2019. Intervals and gaps in plots (light lines) indicate colony data availability. Significant state trends (dark lines) are indicated with *.

Figure 1.

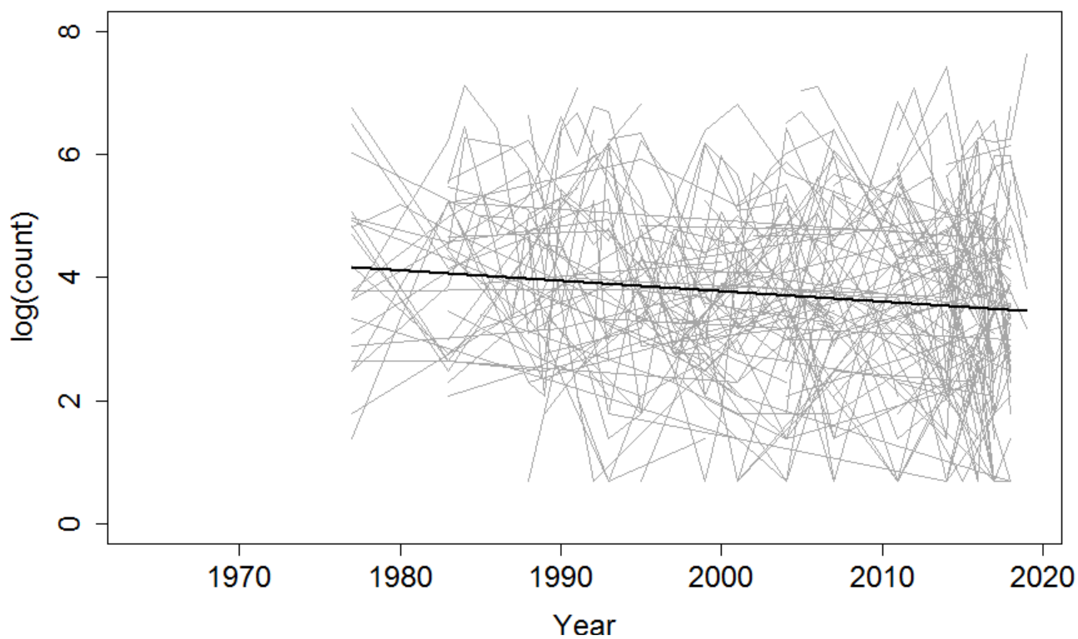
Least Tern (Massachusetts)



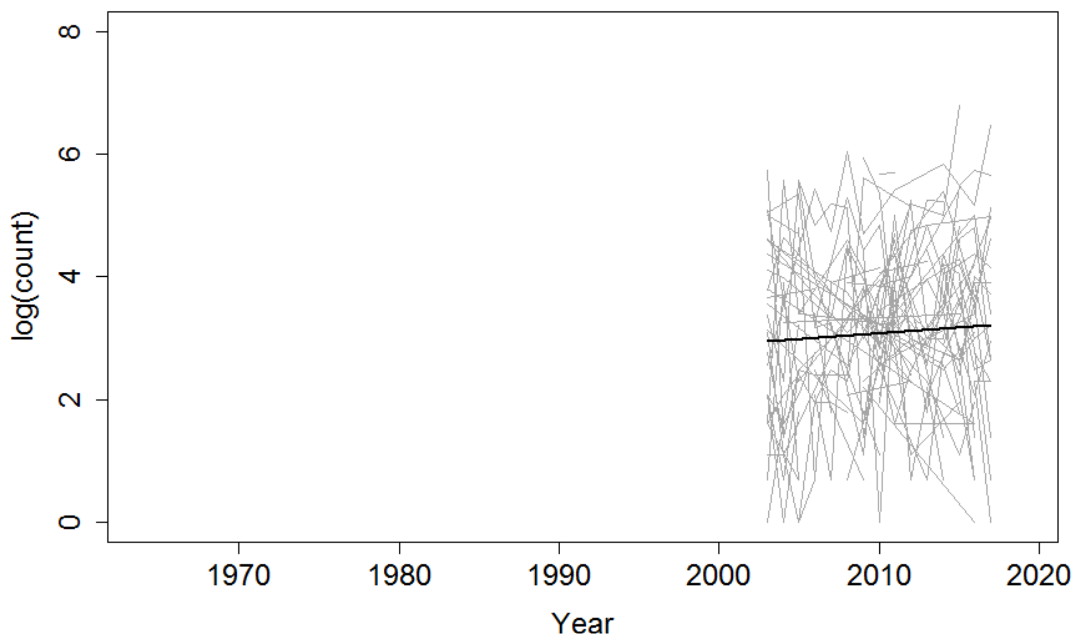
Least Tern (Rhode Island)



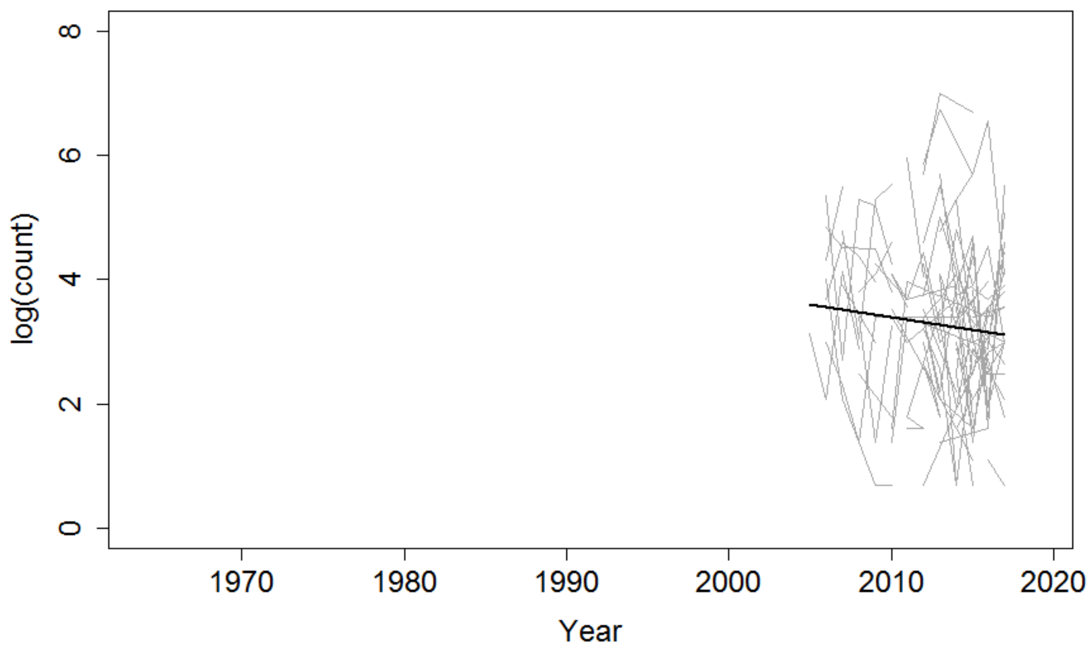
Least Tern (North Carolina*)



Least Tern (South Carolina)



Least Tern (Georgia)



Least Tern (Florida)

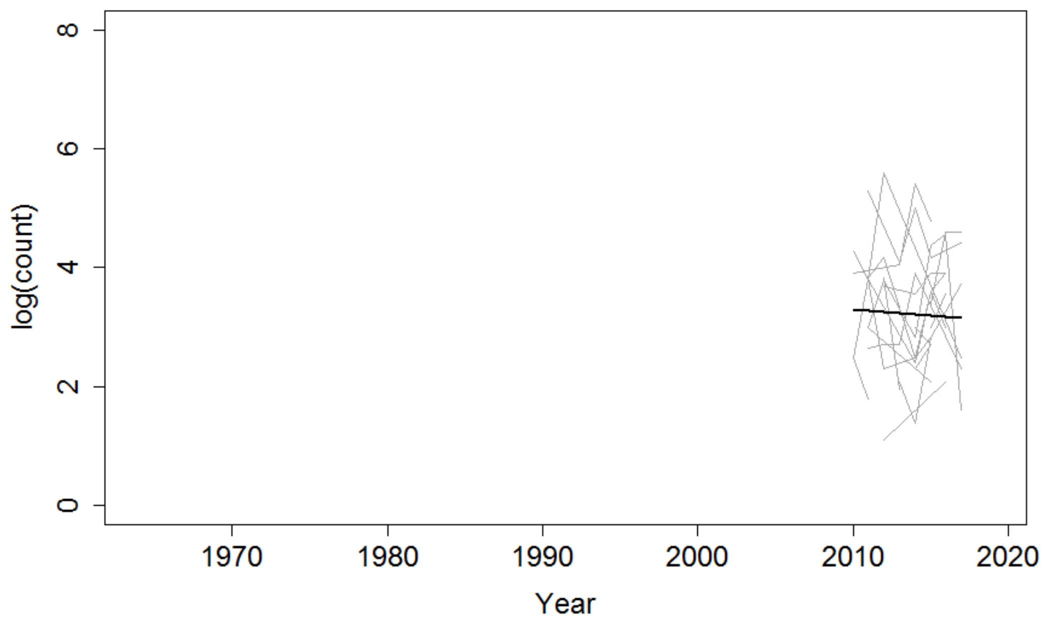
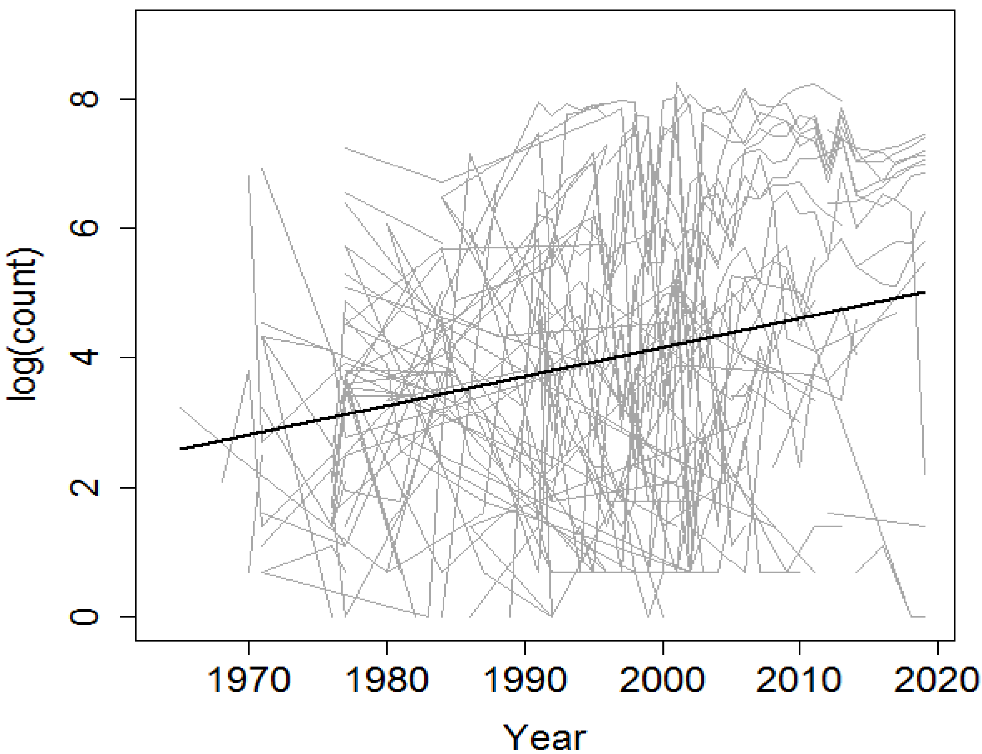
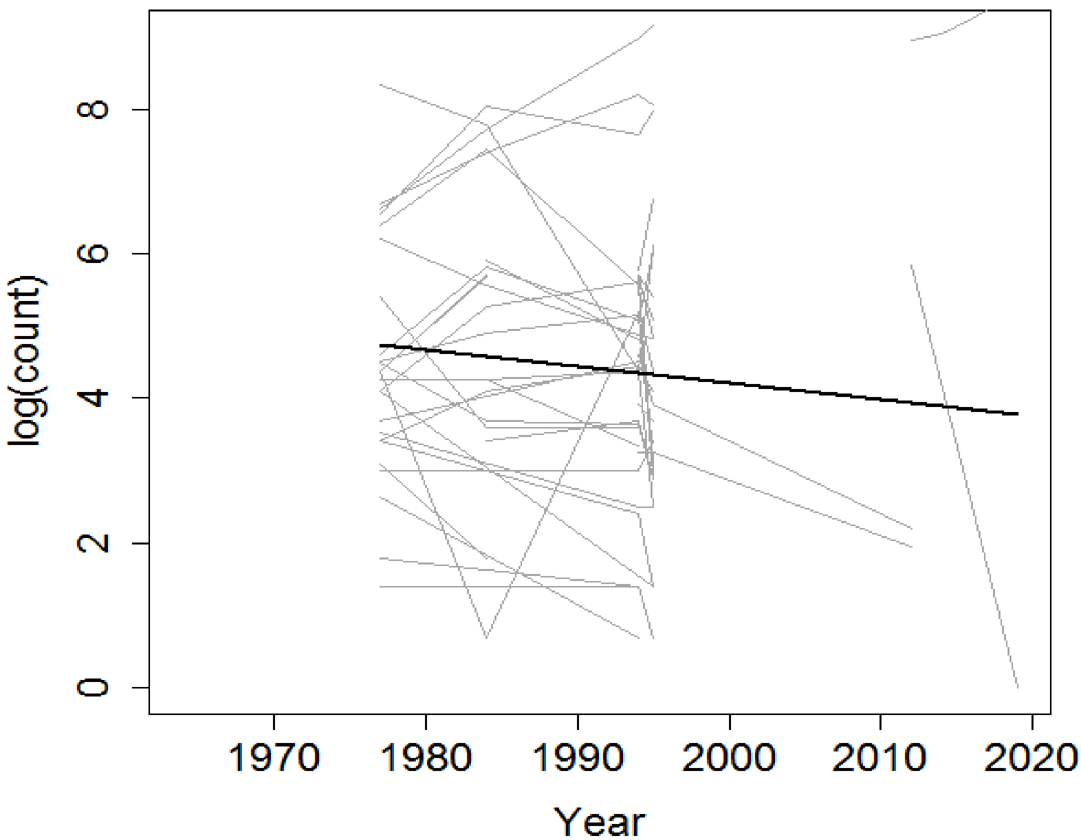


Figure 2.

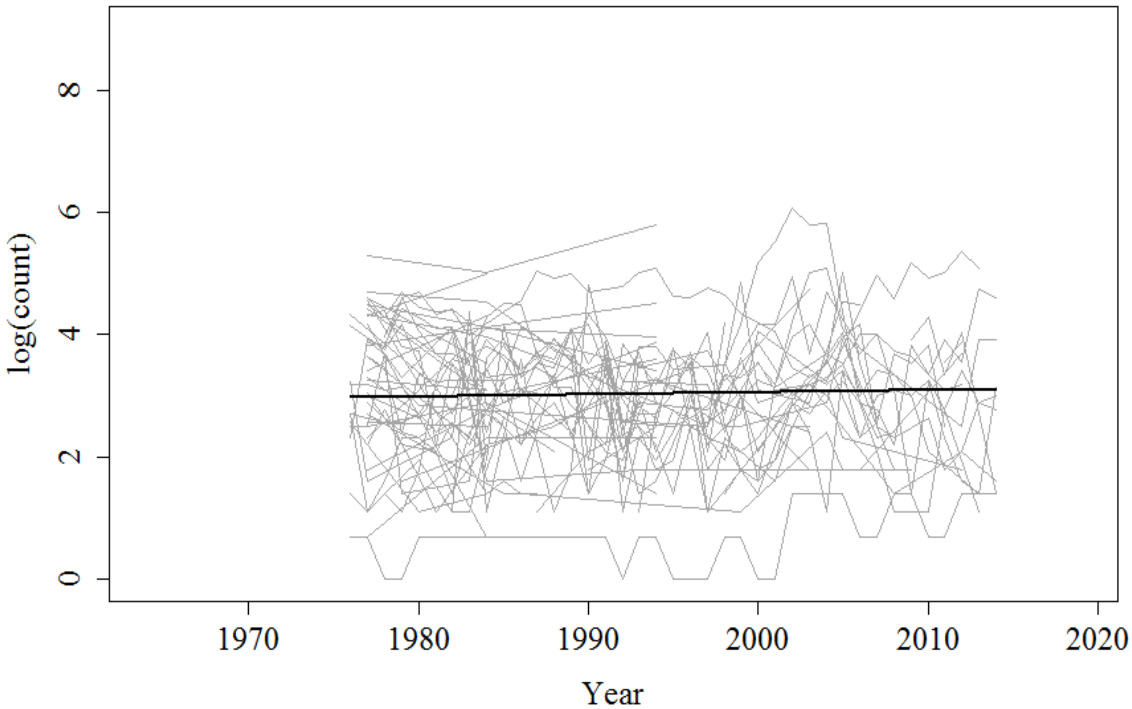
Common Tern (Maine*)



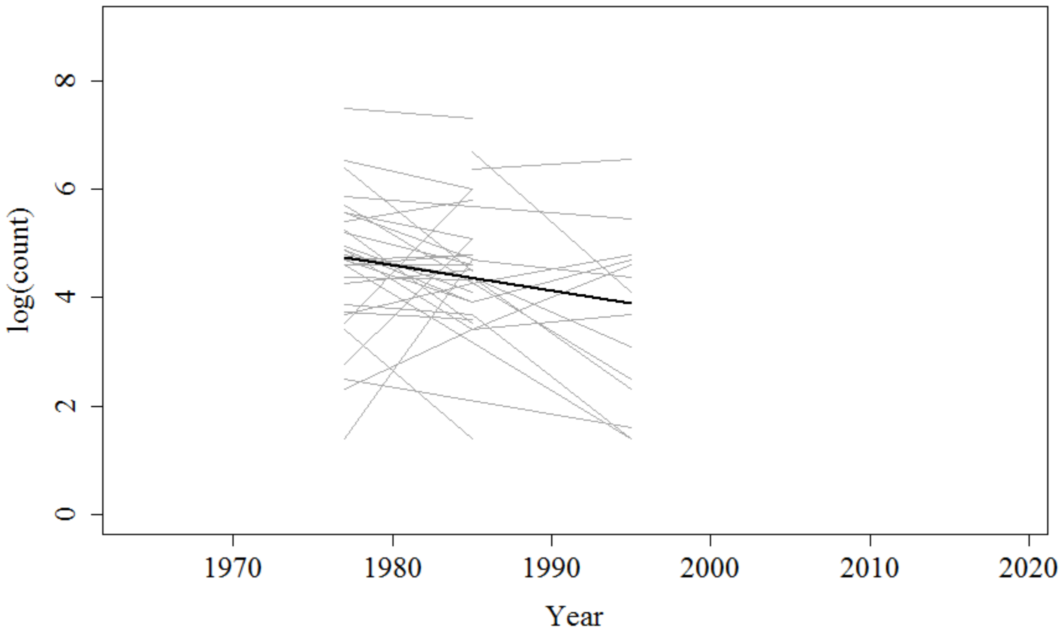
Common Tern (Massachusetts)



Common Tern (Rhode Island)



Common Tern (New Jersey)



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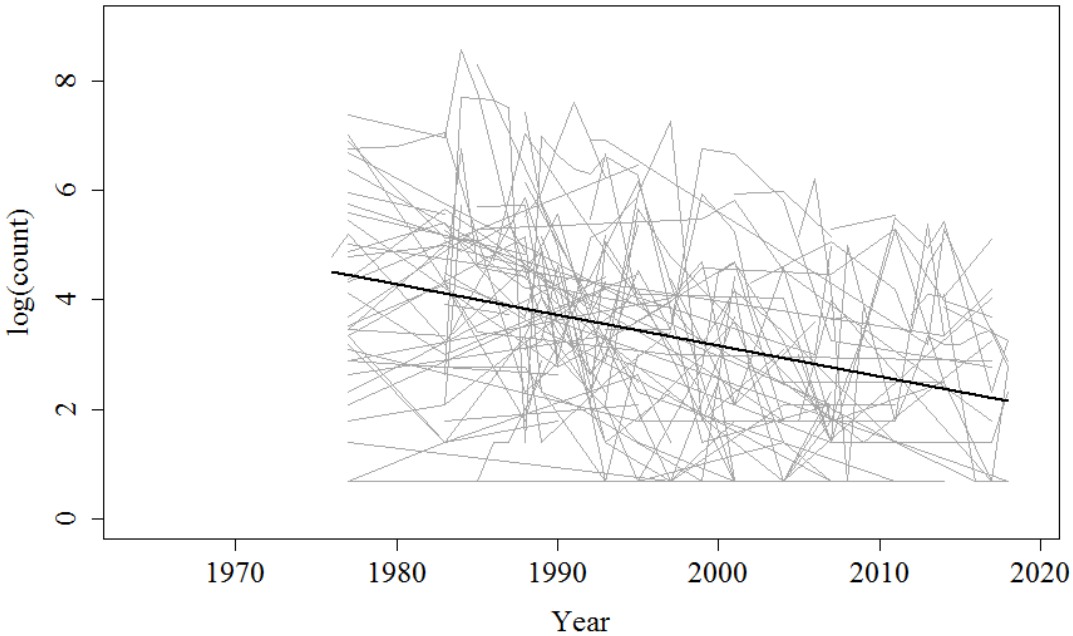
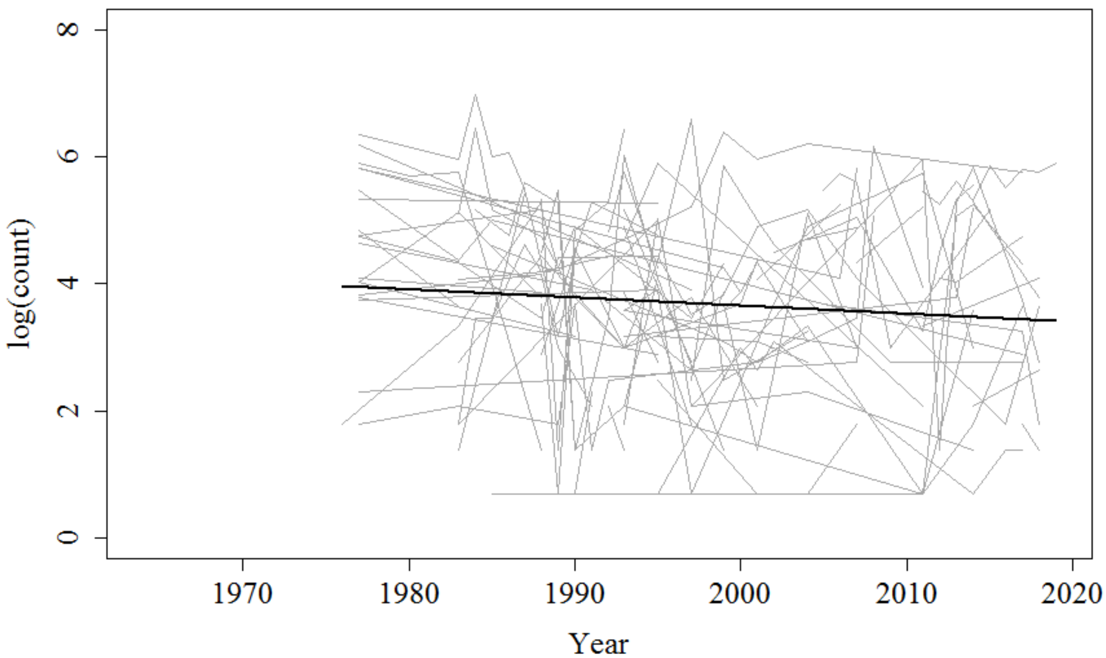


Figure 3.

Black Skimmer (North Carolina)



Black Skimmer (South Carolina*)

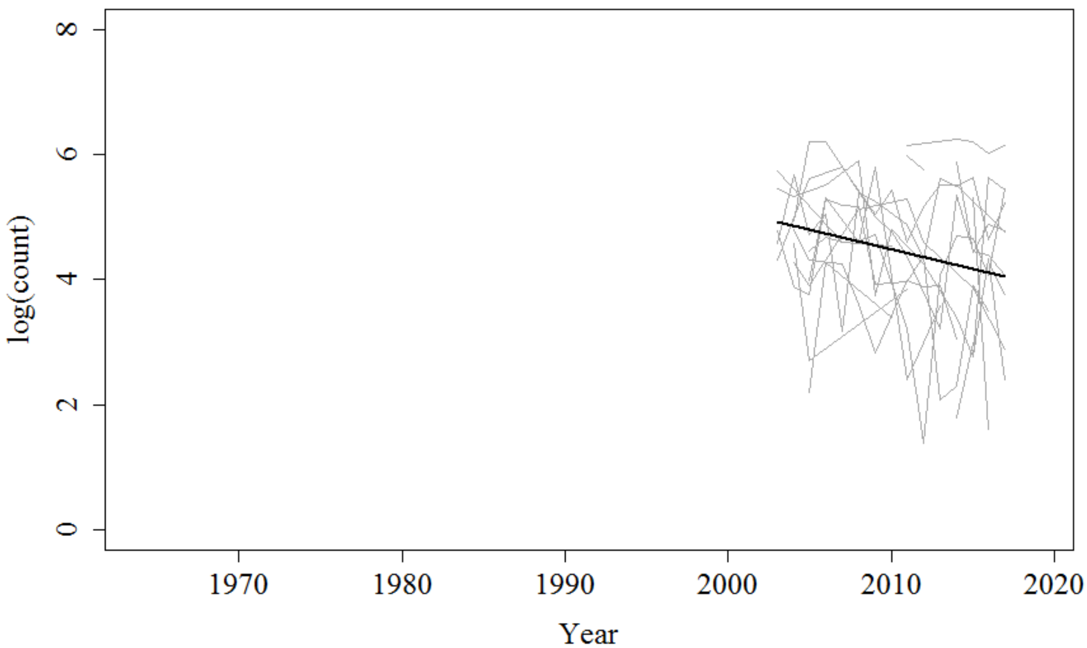
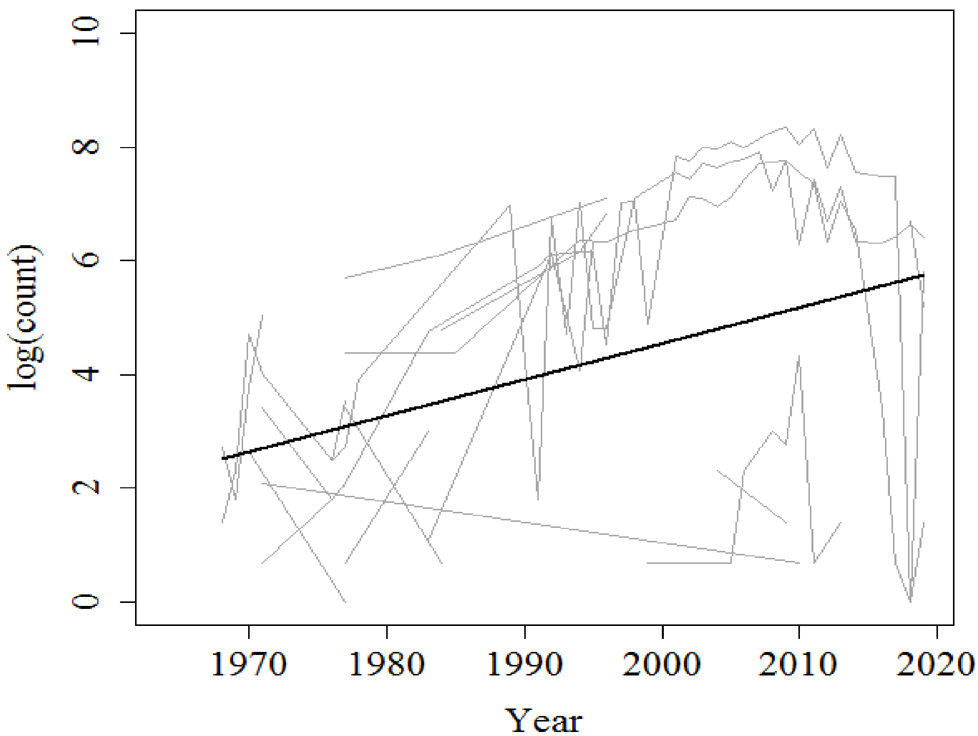
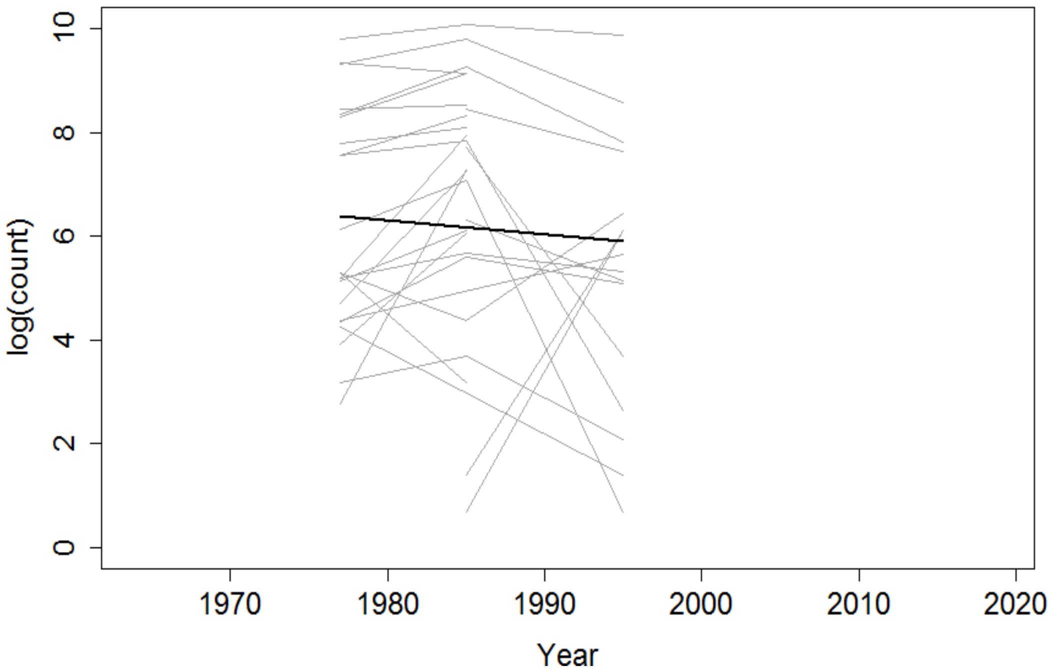


Figure 4.

Laughing Gull (Maine*)



Laughing Gull (New Jersey)



Laughing Gull (North Carolina*)

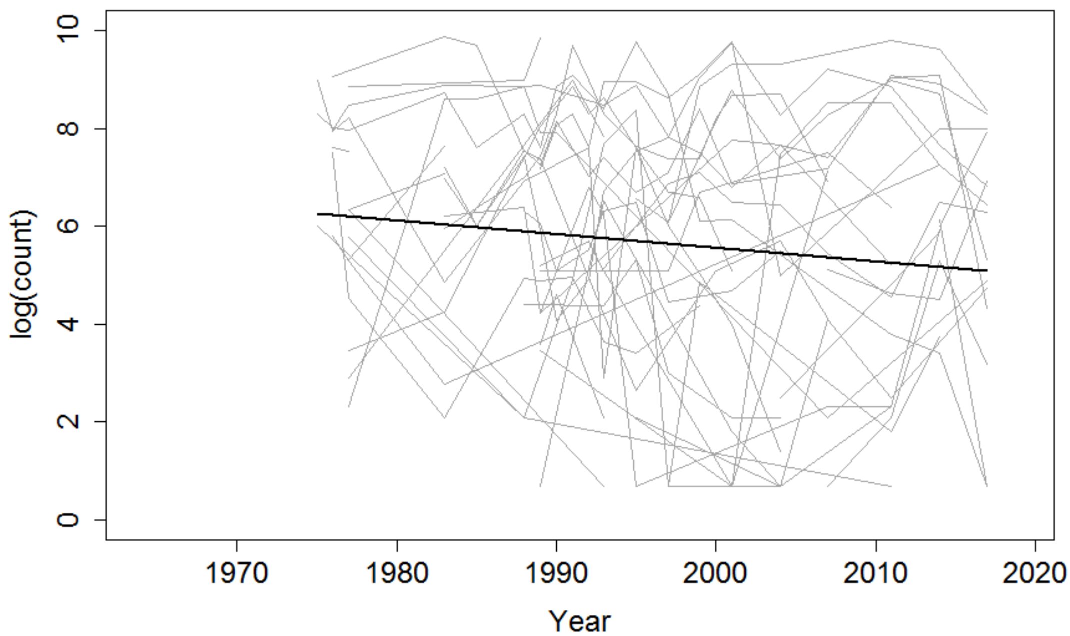
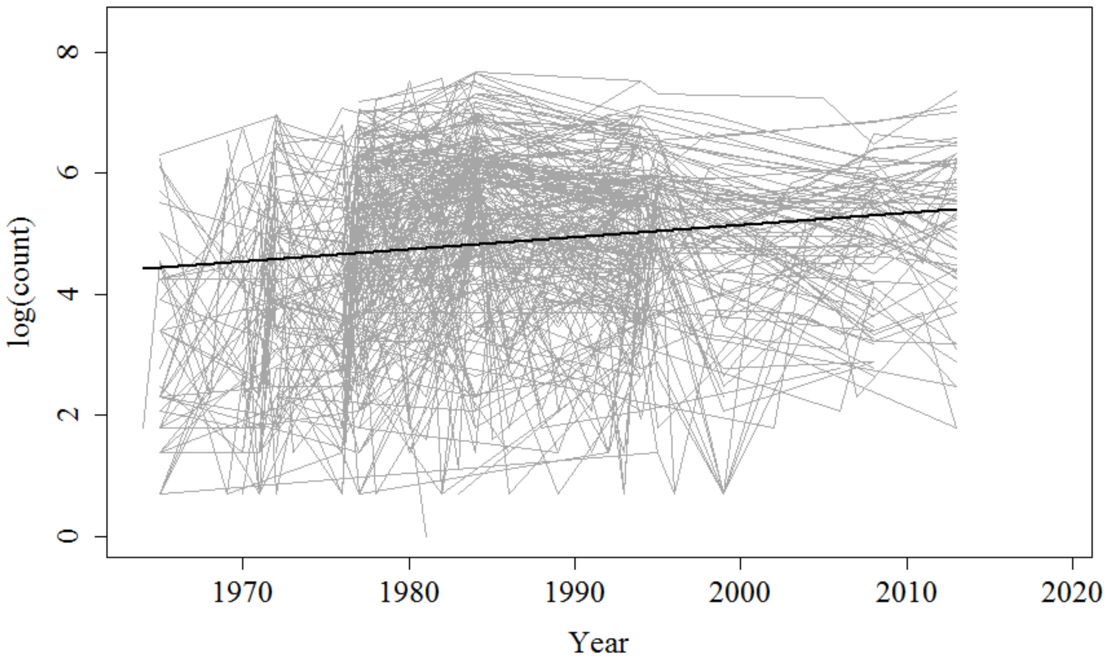
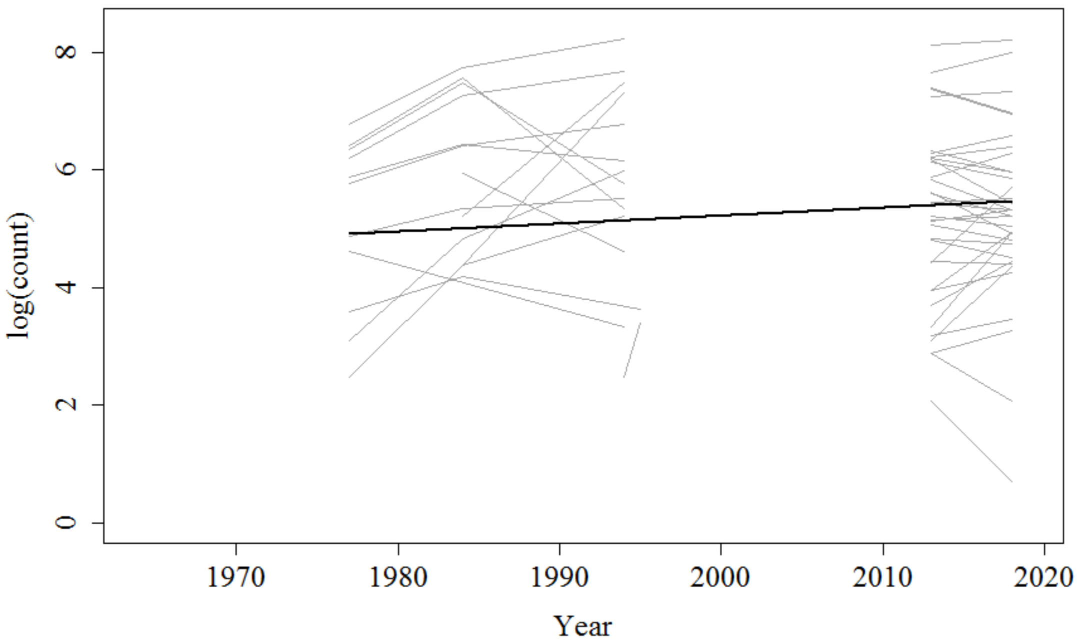


Figure 5.

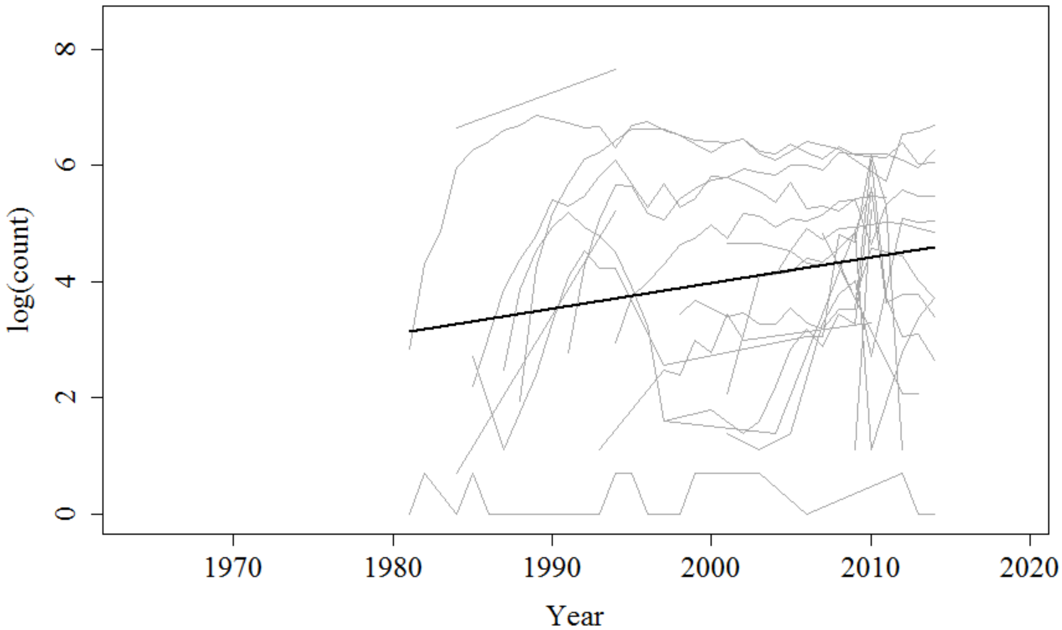
Double-crested Cormorant (Maine*)



Double-crested Cormorant (Massachusetts)



Double-crested Cormorant (Rhode Island*)



Appendix 1. List of sources providing data for the trend analysis. Data were collated from the Colonial Waterbird Database, publications, reports, and non-published surveys conducted of colonial waterbirds within the United States. Numbers in column headings refer to footnotes at the bottom of the table. Contact information for archived data sources accessed for the analysis are listed in the Acknowledgements of this report.

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Appendix Citation:

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