IV. STATUS AND TRENDS OF SELECTED VERTEBRATE RESOURCES IN THE GALVESTON ESTUARY: BIRDS AND ALLIGATORS

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The objectives of this study were to: (1) evaluate the validity of available data sets for use in the characterization of living resources of the Galveston Estuary, (2) conduct analyses of the status and trends of selected avian populations and assemblages, and alligator populations.

METHODS

Existing data sets for selected vertebrate resources in the Galveston Estuary were identified. All data sets were evaluated for appropriateness of spatial and temporal coverage. Only data sets with greater than five continuous years of coverage, similar sampling schemes and sampling periods, and geographic relevance (Figure IV.1) to the Galveston Estuary were used in subsequent trend analyses.

Available Data Sets

Texas Colonial Waterbird Survey (TCWS)

The Texas Colonial Waterbird Society and the TPWD have compiled and published the results of colonial waterbird surveys of the Galveston Estuary from 1973 to the present (Slack 1978, Texas Colonial Waterbird Society 1982, Martin 1989). Surveys were conducted annually during a two-week period beginning the last week of May, corresponding to the incubation period of most colonial nesting waterbirds. Most surveys of the Galveston Estuary were conducted from the ground; however, counts from several aerial surveys were also reported. Ground counts were conducted by two to four people viewing the colony from a boat or on foot. Counts of individual birds were found to correspond directly to the number of nests and therefore the number of nesting pairs found in colonies (Texas Colonial Waterbird Society 1982). The Texas Colonial Waterbird Society (1982) reported 22 species of colonial waterbirds nesting in 70 colonies in the Galveston Estuary. Species selected for study as identified by the Galveston Bay National Estuary Program include the black-crowned night-heron (Nycticorax nycticorax), tricolored heron (Egretta tricolor), snowy egret (Egretta thula), great egret (Casmerodius albus), roseate spoonbill (Ajaia ajaja), Forster's tern (Sterna forsteri), black skimmer (Rynchops niger), and olivaceous cormorant (Phalacrocorax olivaceus).

North American Breeding Bird Survey

The U.S. Fish and Wildlife Service coordinated breeding bird surveys along two 80-km roadside routes within the Galveston Estuary area (counts #20, #21). Each route consisted of approximately 50 3-minute counting locations 0.8 km apart. Observers started their routes one-half hour before sunrise and continued for approximately 4 hours.

Data Set Coverages

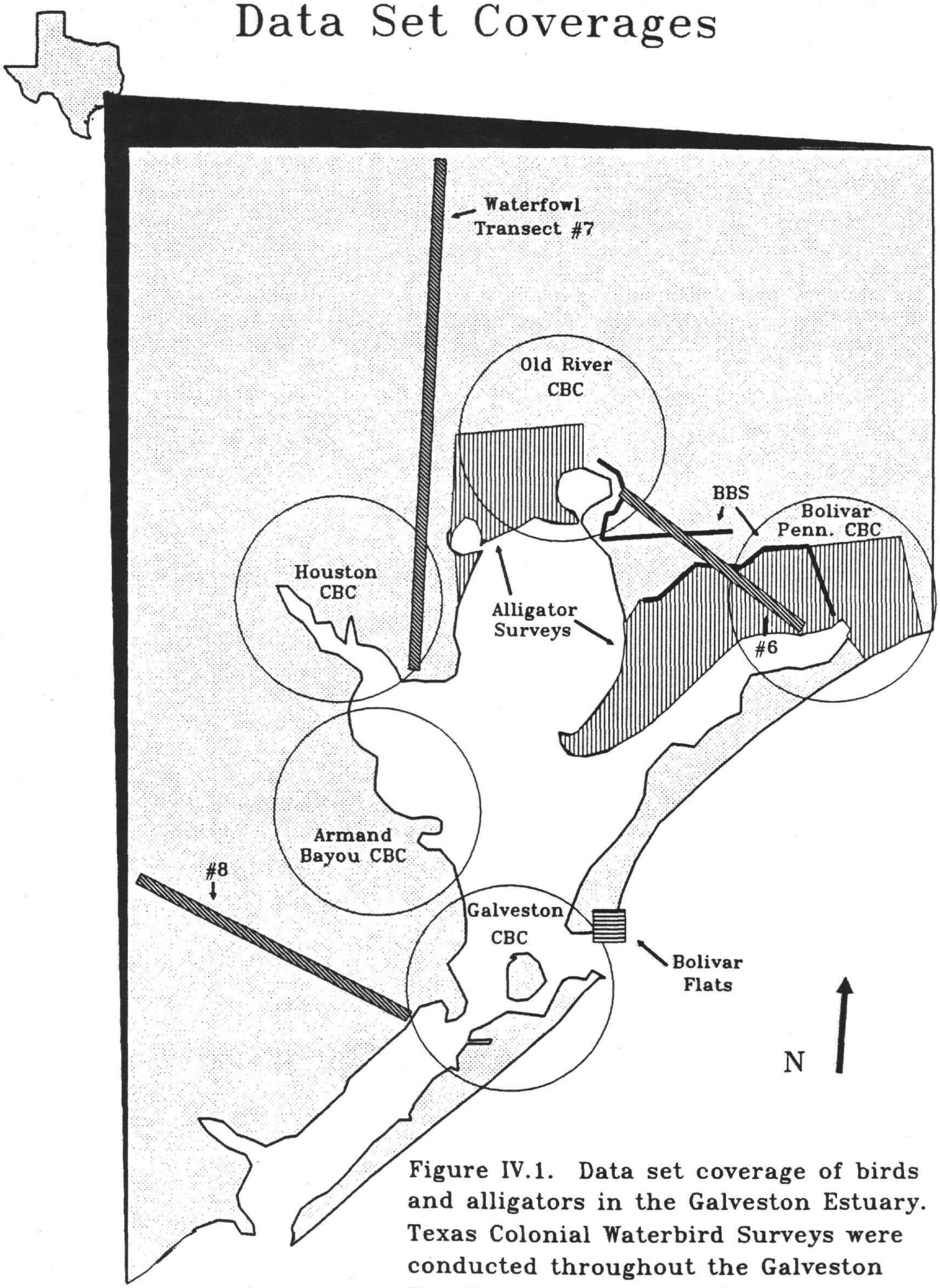


Figure IV.1. Data set coverage of birds and alligators in the Galveston Estuary. Texas Colonial Waterbird Surveys were conducted throughout the Galveston Bay System. 1 cm = 8 km.

Only birds seen or heard within the 3-minute stops were included (Bystrak 1981). Continuous data sets from both survey routes were available for the years 1986-1990 with intermittent coverage dating back to 1968. Five species associated with marine systems were observed on the selected survey routes; however, only 3 species were observed frequently enough to allow detailed analyses. These species include the red-winged blackbird (Agelaius phoeniceus), boat-tailed grackle (Quiscalus major), and great-tailed grackle (Quiscalus mexicanus).

Mid-winter Waterfowl Survey

The Texas Parks and Wildlife Department, in cooperation with the U.S. Fish and Wildlife Service, has conducted an annual mid-winter waterfowl survey of the Texas coast and prairies since 1973 (Haskins 1990); however, data were only available from 1986 to 1991. The survey consisted of one systematic scheme of sampling along transects and another less systematic sampling scheme of counting birds in general locations. The Mid-winter Waterfowl Transects (MWT) required two observers and a pilot to make aerial counts at an altitude of 61 m along predefined transects. Transects were 0.4 km wide and varied in length (D. Lobpries, TPWD, personal communication). Only waterfowl sighted within the transects were recorded. Three aerial transects (#6, #7, and #8) included portions of the Galveston Bay System. The second sampling scheme, the Mid-winter Waterfowl Cruise Count (MWCC), represented an aerial count of waterfowl in many of the open water areas of the Galveston Bay System. Spatial coverage varied both within and among years (D. Lobpries, TPWD, personal communication). Although Sheridan et al. (1988) have reported 32 species of waterfowl for the Galveston Bay System, the Mid-winter Waterfowl Survey included sightings of only 17 species: cormorant spp. (Phalacrocorax spp.), green-winged teal (Anas crecca), blue-winged teal (Anas discors), mottled duck (Anas fulvigula), mallard (Anas platyrhynchos), ruddy duck (Oxyura jamaicensis), ring-necked duck (Aythya collaris), bufflehead (Bucephala albeola), northern pintail (Anas acuta), northern shoveler (Anas clypeata), gadwall (Anas strepera), American wigeon (Anas americana), canvasback (Aythya valisineria), redhead (Aythya americana), scaup spp. (Aythya spp.), merganser spp. (Mergus spp.), and American coot (Fulica americana). These data provided information on abundance of waterfowl by species and by transect, or by general location within the surrounding waters of the Galveston Bay System.

Christmas Bird Counts (CBC)

The annual CBC sponsored by the National Audubon Society were day-long tallies of birds seen within selected 24-km diameter areas. The number of participants and temporal coverage was recorded for each count-area and varied both among years and counts. Each count-area was traversed by observers with some combination of automobile, boat, walking, or by monitoring backyard bird feeders (Butcher 1990). Five count-areas included portions of the Galveston Estuary. Four count-areas were used in the analyses (Bolivar Peninsula, Galveston, Houston, and Old River) and provide nearly continuous coverage back to 1965. The fifth count-area, Armand Bayou, was initiated in 1982 and was excluded from analyses because of significant differences in sampling periods in comparison to the other four routes. Thirty-two species associated with the marine system were chosen for analysis.

Shorebird Surveys of Bolivar Flats

Thirty-five species of shorebirds have been reported for the Galveston Estuary, prompting the estuary's designation as a regional reserve site in the Western Hemisphere Shorebird Reserve Network. The 6 most common shorebird species occurring in the Galveston Estuary are: black-bellied plover (Pluvialis squatarola), American avocet (Recurvirostra americana), willet (Catoptrophorus semipalmatus), sanderling (Calidris alba), western sandpiper (Calidris mauri), and dunlin (Calidris alpina; Sheridan et al. 1988). The U.S. Fish and Wildlife Service, Clear Lake Office, has conducted irregular monthly surveys of the Bolivar Flat system continuously since 1980. Surveys were conducted from 0900 to about 1130 usually by one observer, while walking through beach and marsh habitats. Spotting scopes were used to identify all species of birds (D. Peterson, U.S. Fish and Wildlife Service, personal communication).

Alligator Survey

The Texas Parks and Wildlife Department has conducted annual helicopter surveys of American alligator (Alligator mississippiensis) nests along established transects in the marshes adjacent to East Bay and Trinity Bay from 1980 through 1984. From 1985 to the present each transect was surveyed approximately once every three years. Transects were 91 m wide, varied in length, and occurred at 1.6 km or 4.8 km intervals. Transects were flown at an altitude of 91 m and all observed nests were plotted on maps (Potter 1981). In addition to nest counts, the TPWD conducted alligator night-count surveys on 3 selected navigable waterways (routes) within the Galveston Bay System. Night-count surveys were conducted from a boat with 2 observers using spot-lights to detect animals. Most surveys were conducted in May to reduce the negative effects of increased vegetative growth on visibility. An effort was made to standardize lighting equipment and boats.

Data Analysis and Presentation

The general approach to all data analyses was to develop models for each species that described the relationship between counts and years while accounting for as much unwanted variation as possible (e.g., biases due to observer effort, location, and season). Including these sources of variation in models improved their performance and increased the statistical power of the tests (Ott 1988). Sources of extraneous variation represented by continuous variables were treated as covariates (e.g. observer effort) and discrete class variables were treated as blocks (e.g. transects). If the effect of a covariate was not a significant factor in a model it was removed (Butcher and McCulloch 1990). Models that included class variables produced one parallel regression line for each class, however, only the "average" regression line for all classes was depicted in figures. Interactions between the year terms and the class variables were also examined. A significant interaction indicated that effects due to the year term were not consistent among all classes and therefore the slopes of the lines in each class were not the same

(Ott 1988). The presence of significant interaction terms was identified by species to provide further information on the temporal and spatial relationships. After testing for a significant interaction, the interaction terms were removed from all final models. When analyses on raw counts resulted in proportional variance-to-mean ratios, data were transformed using natural logs (Ott 1988). A constant of 0.5 was added to all 0 counts used in log models (Butcher and McCulloch 1990). The critical level for all tests was P = 0.05. Analyses were conducted using the SAS General Linear Models Procedure (SAS 1985). The General Linear Model procedure allowed for the development of a wide range of models, including polynomial models, and it is recommended for unbalanced data where each x is not associated with a corresponding y (i.e., surveys not conducted in some years; Freund et al. 1986).

The performance of the final models determined the format in which the data were displayed for each species. Plots containing a regression line through the individual counts were constructed for all models indicating that a species' numbers were changing significantly. If final models were based on log-transformed values, plots of the raw untransformed counts and a plot with the regression line through the transformed values were generated. Raw counts and a line of annual mean values were plotted for all models that did not indicate a significant trend. Plots containing a distribution of counts as well as a regression line allowed for a qualitative assessment of the fit of the line and a visual measure of variance. Analysis of variance tables were included for all significant models. Figures with multiple plots were grouped by data sets and therefore were not referenced in sequence.

Texas Colonial Waterbird Survey

Three separate analyses were conducted on each species to detect changes in (1) the total number of individuals, (2) number of active colonies containing those individuals, and (3) the mean number of individuals per colony. The response variable used to detect a change in the total number of individuals was calculated by summing the counts of all birds seen in a given year. Similarly, the response variable used to detect a change in number of active colonies was calculated as the frequency of colonies containing a species in a given year. The response variable for determining a change in the mean number of birds per colony was simply the reported number of birds per colony.

Quantitative studies of waterbird communities are well suited to a multivariate approach to data analysis because of the potential complexity of relationships both within and among communities. In order to better identify the spatial and temporal relationships of waterbird communities, researchers have applied a variety of multivariate analysis techniques, including factor analysis and canonical correlation (Beaver et al. 1980), correspondence analysis (Abrams and Underhill 1986, Spendelow et al. 1989), and detrended correspondence analysis (DCA; Spendelow et al. 1989). Detrended correspondence analysis (Hill 1979) was chosen in this study because it is currently one of the most powerful techniques available to identify community patterns, and makes no rigorous assumption of linearity of data (Gauch et al. 1981, Peet et al. 1988). Each sample used in the analysis consisted of a set of annual abundance values for all species seen on the TCWS from 1973 to 1990. Ordination of these data should illustrate changes in the distribution patterns and structure of the colonial waterbird community over time. Years that have similar distributions of colonial waterbirds should cluster more closely than years with more dissimilar distributions. Therefore, if the structure of the colonial waterbird community has not changed over time, plots of the ordination scores of years will show little separation. Likewise, plots of species scores should separate species with more dissimilar distribution patterns.

North American Breeding Bird Survey

Although annual surveys were conducted along the same routes, the number of 3-minute counting locations (stops) varied among routes and among years. Therefore, to standardize annual surveys the number of birds seen per route was divided by the number of stops per route. This standardized value was used as the response variable and routes were treated as blocks.

Mid-winter Waterfowl Transects

Sampling design allowed for constant effort per transect among years; therefore, no measure of effort was included in final models. Transects were treated as blocks and the number of individuals per year was used as the response variable.

Mid-winter Waterfowl Cruise Count

Sampling effort varied among locations and years, with no measure of sampling effort recorded by observers. Therefore they were necessarily excluded from subsequent analyses, and models simply consisted of a response variable and a year term. The response variable was calculated as the sum of all birds seen in the Galveston Estuary area in a given year.

Christmas Bird Count

The effects of sampling effort are known to vary with species, and several measures of effort are recorded for each count-area. "Party-miles" was selected as the best measure of observer effort based on the criteria outlined in Butcher and McCulloch (1990); however, if this term was not significant it was not included in final models. Count-areas were included in all final models and were treated as blocks.

Shorebird Survey of Bolivar Flats

Observers made an effort to keep spatial coverage and observer effort constant; however, surveys were conducted at irregular intervals throughout the year resulting in temporal biases. In order to account for these biases, seasons were treated as blocks and the number of individuals per survey was used as the response variable.

Alligator Nest Counts

Nest counts were conducted along established transects; however, the location and number of transects varied among years, so that transects could not be treated as blocks. The response variable was calculated by summing all nests observed in a given year and dividing by the number of transects surveyed.

Alligator Night-count Surveys

Night-count surveys were conducted along the same route each year with approximately the same level of observer effort, therefore routes were treated as blocks and the number of alligators seen was used as the response variable. Beginning in 1985, routes were surveyed every three years rather than annually. Therefore only those surveys conducted prior to 1985 were included in subsequent analyses.

RESULTS

Shorebirds

Numbers of black-bellied plovers (Figures IV.2, IV.3; Table IV.1), willets (Figures IV.4, IV.5, Table IV.2), sanderlings (Figures IV.6, IV.7; Table IV.3) and western sandpipers (Figures IV.8, IV.9; Table IV.4) increased significantly based on both the Shorebird Survey of Bolivar Flats and the CBC. The interaction between year and count-area was significant for western sandpipers seen on the CBC. American avocets (Figures IV.10, IV.11; Table IV.5) and dunlins (Figures IV.10, IV.12; Table IV.6) showed no change in numbers based on the Shorebird Survey of Bolivar Flats; however, both species increased based on the CBC.

Colonial Waterbirds

Tricolored herons showed a decrease in the total number of birds observed per year, an increase in the number of colonies containing these birds, and a curvilinear trend in the average number of birds per colony (Figure IV.13, Table IV.7) based on the TCWS. Tricolored herons showed no change in numbers based on the CBC (Figure IV.14, Table IV.7); however, the interaction between year and count-area was significant.

Based on the TCWS, snowy egrets (Figure IV.15, Table IV.8), roseate spoonbills (Figure IV.17, Table IV.9), and black skimmers (Figure IV.19, Table IV.10) showed a decrease in both the total number of birds and in the average number of birds per colony. Black skimmers showed a curvilinear decrease in the average number of birds per colony. Models describing the trend in the number of colonies containing these species were not significant, indicating no change over time. Snowy egrets (Figure IV.16, Table IV.8) and roseate spoonbills (Figure IV.18, Table IV.9) increased in numbers based on the CBC, however the interaction between year and count-area was significant for both species. Numbers of black skimmers did not change based on the CBC (Figure IV.20, Table IV.10).

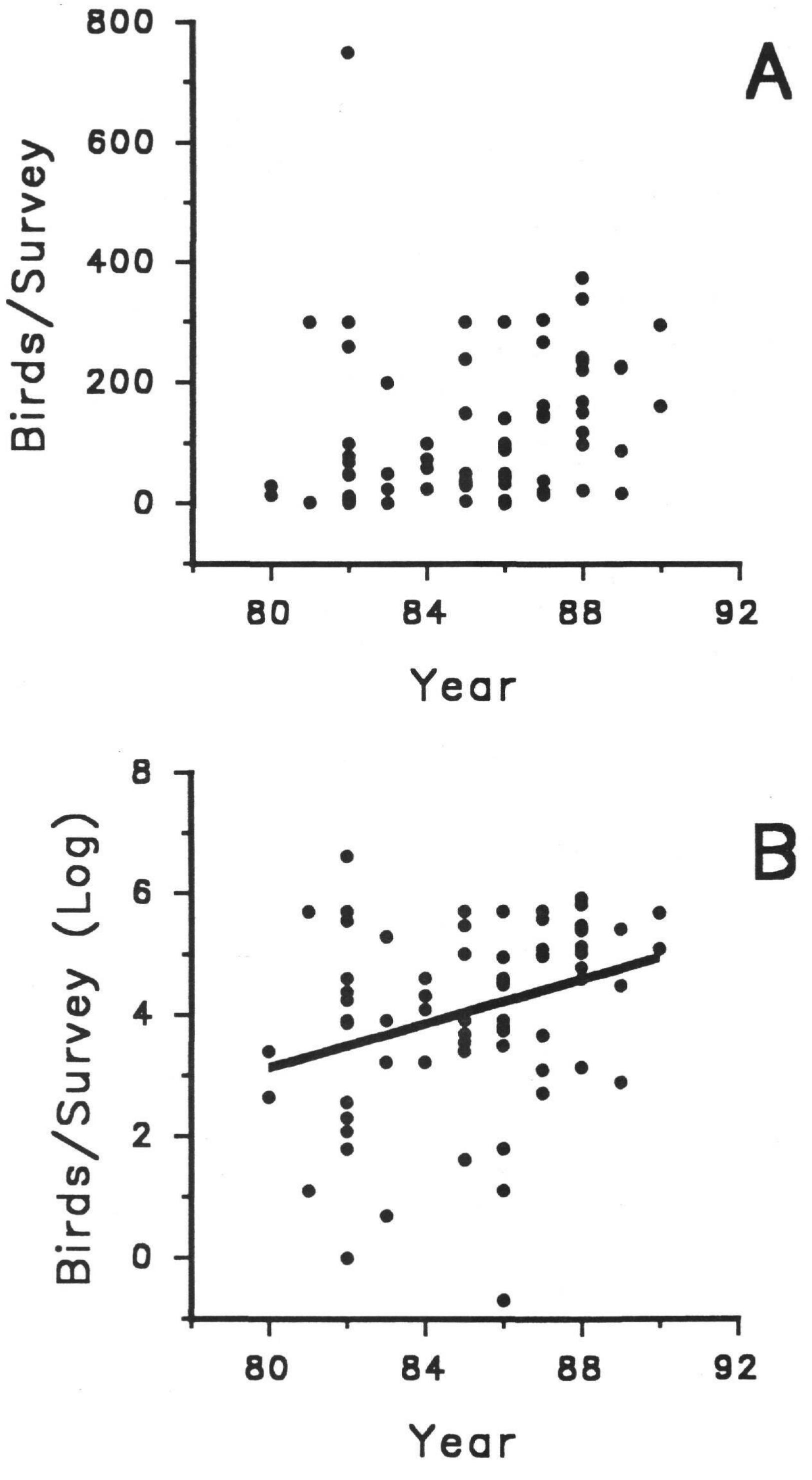


Figure IV.2. A. Number of black-bellied plovers per survey (N=92) from 1980 to 1990 during Shorebird Surveys of Bolivar Flats. B. Trend in black-bellied plovers from 1980 to 1990 during Shorebird Surveys of Bolivar Flats.

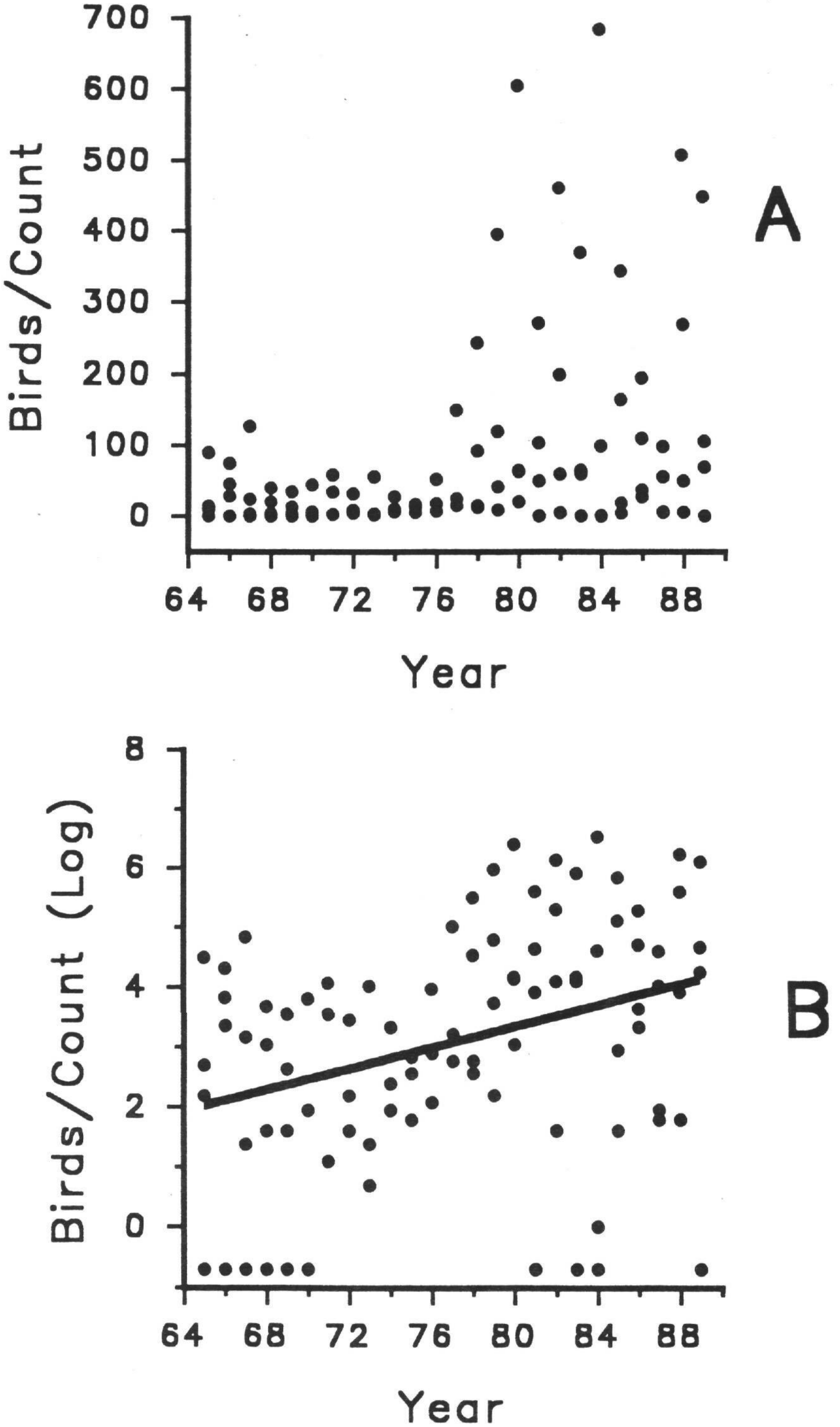


Figure IV.3. A. The number of black-bellied plovers per count (N=92) from 1965 to 1989 during Christmas Bird Counts.
B. Trend in black-bellied plovers from 1965 to 1989 during Christmas Bird Counts.

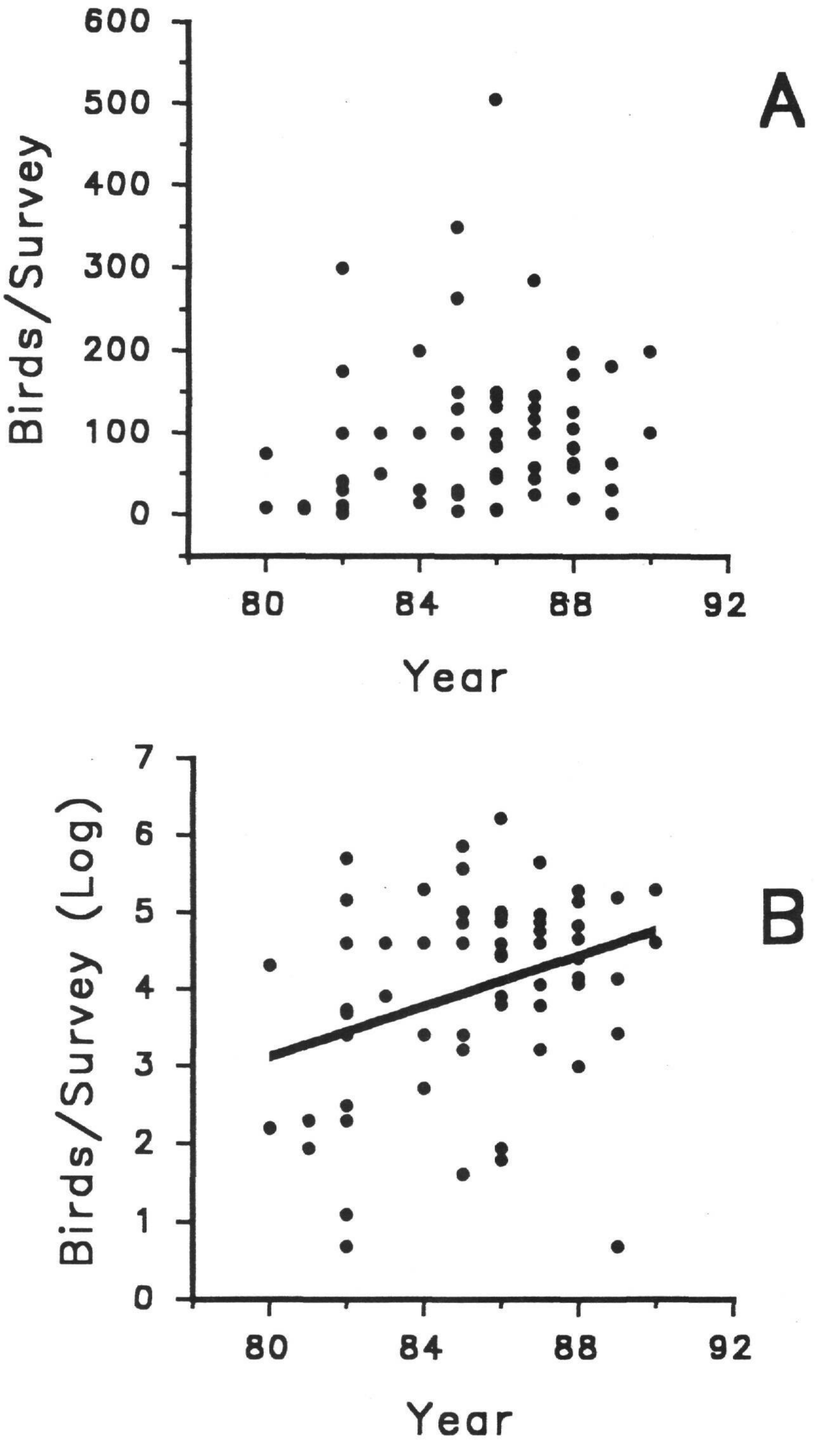


Figure IV.4. A. Number of willets per survey (N=72) from 1980 to 1990 during Shorebird Surveys of Bolivar Flats. B. Trend in willets from 1980 to 1990 during Shorebird Surveys of Bolivar Flats.

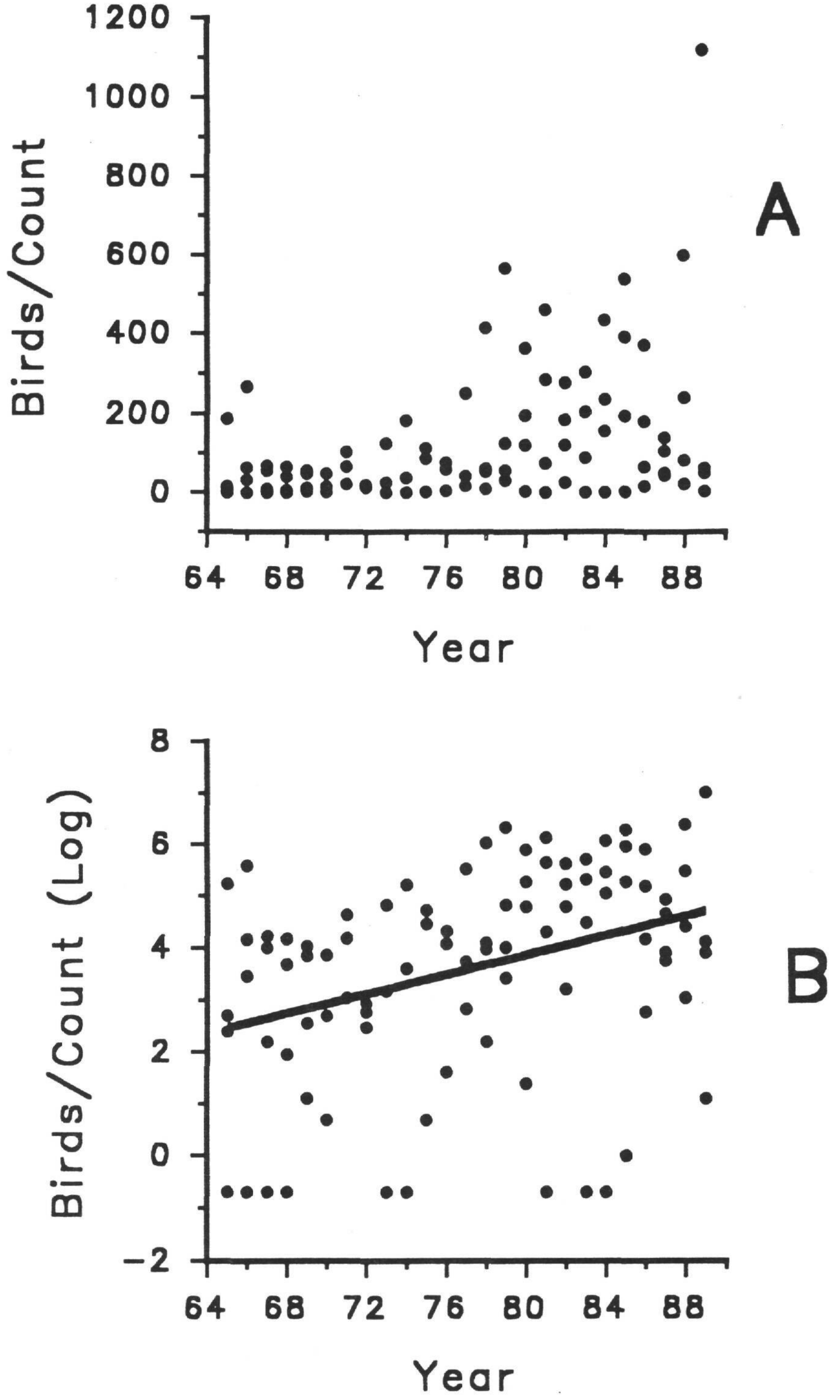


Figure IV.5. A. The number of willets per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in willets from 1965 to 1989 during Christmas Bird Counts.

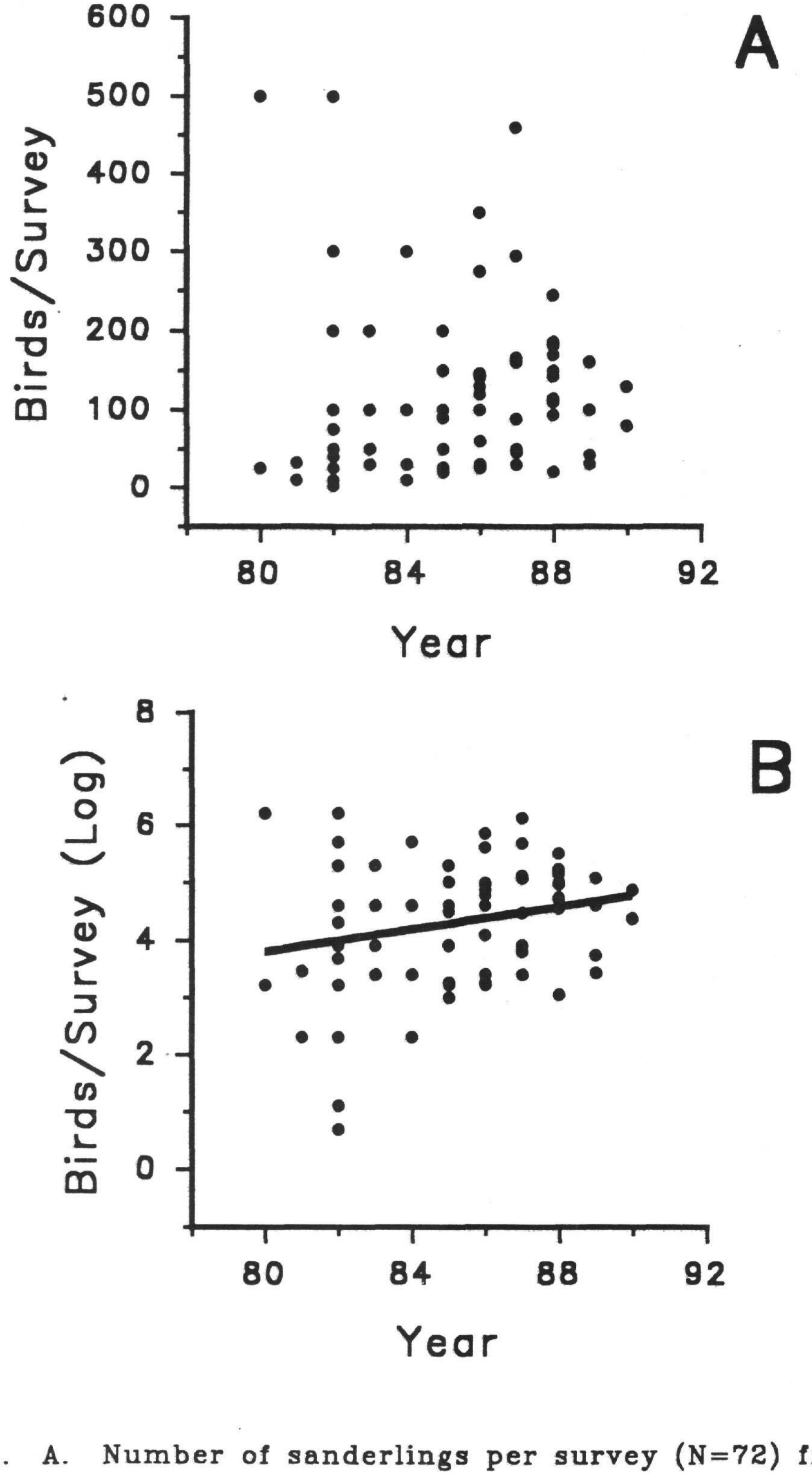


Figure IV.6. A. Number of sanderlings per survey (N=72) from 1980 to 1990 during Shorebird Surveys of Bolivar Flats. B. Trend in sanderlings from 1980 to 1990 during Shorebird Survey of Bolivar Flats.

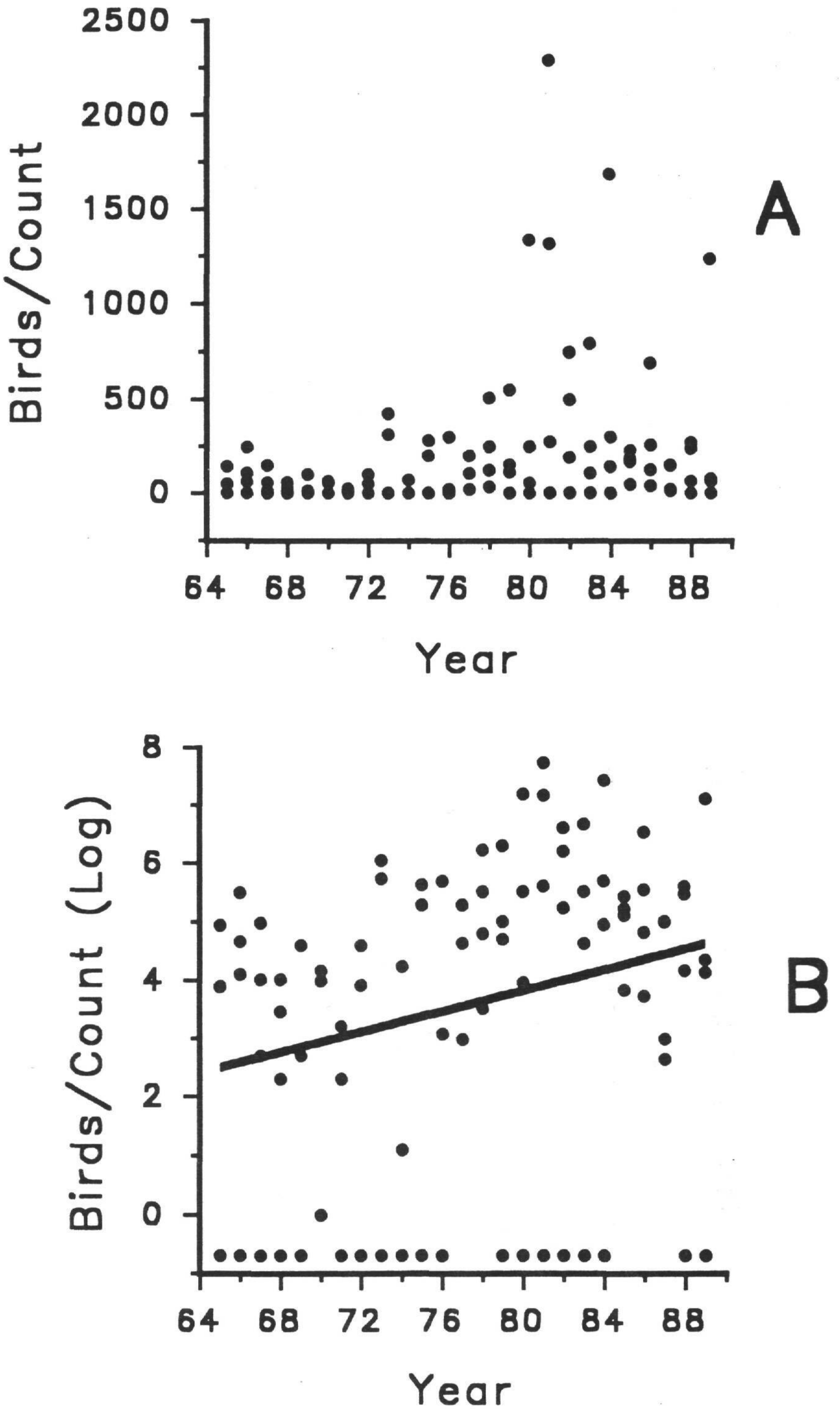


Figure IV.7. A. The number of sanderlings per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in sanderlings from 1965 to 1989 during Christmas Bird Counts.

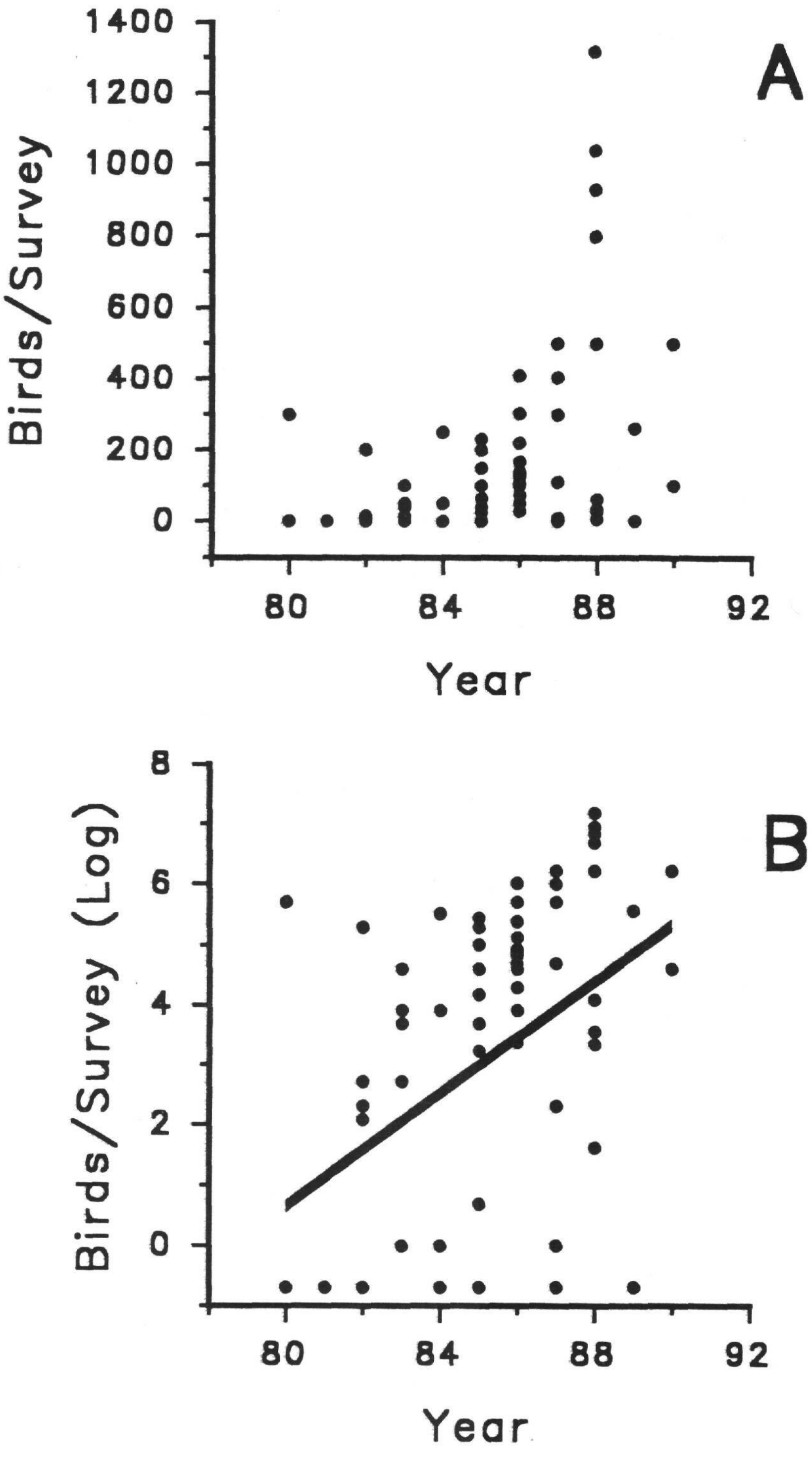


Figure IV.8. A. Number of western sandpipers per survey (N=72) from 1980 to 1990 during Shorebird Surveys of Bolivar Flats. B. Trend of western sandpipers from 1980 to 1990 during Shorebird Surveys of Bolivar Flats.

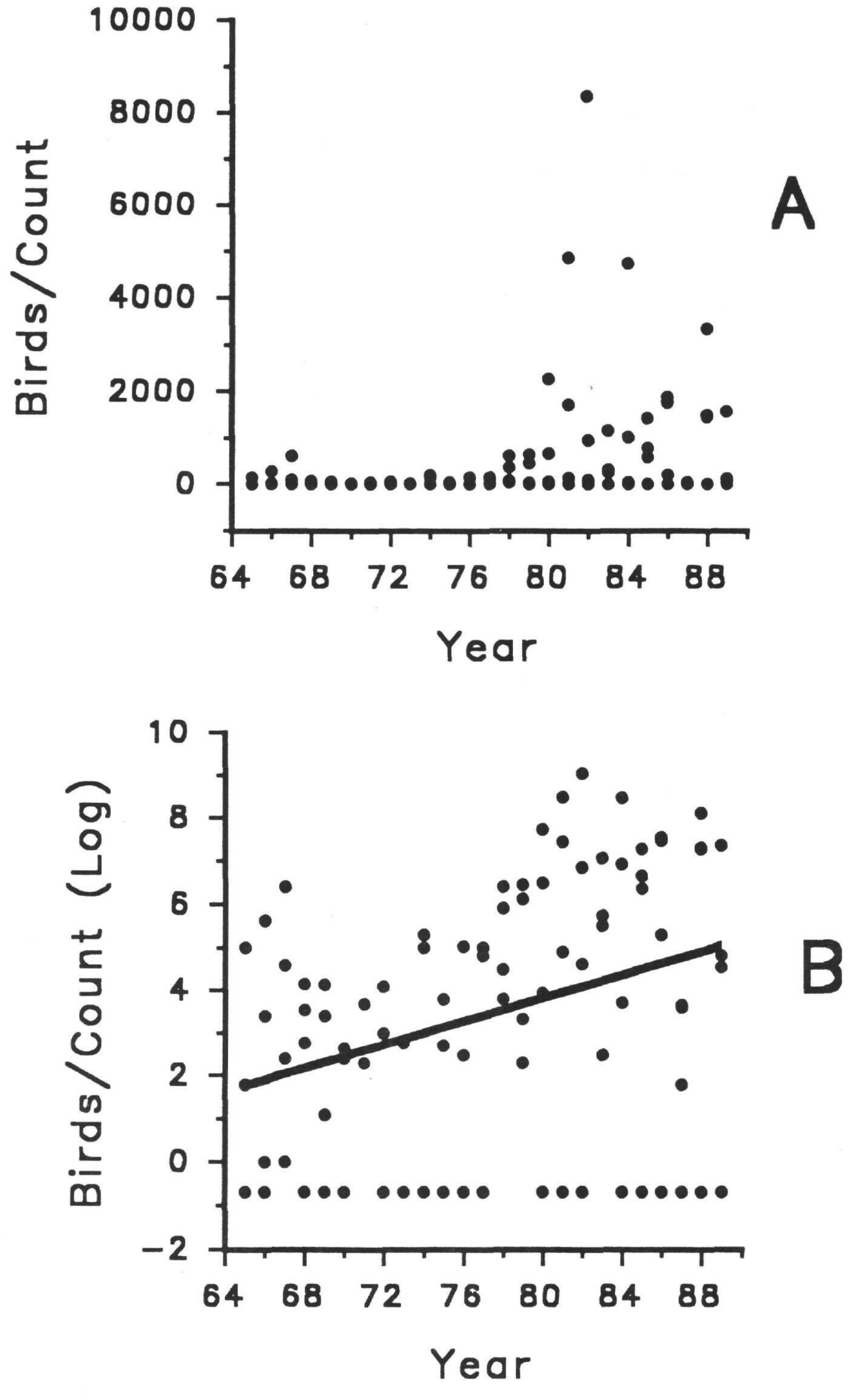
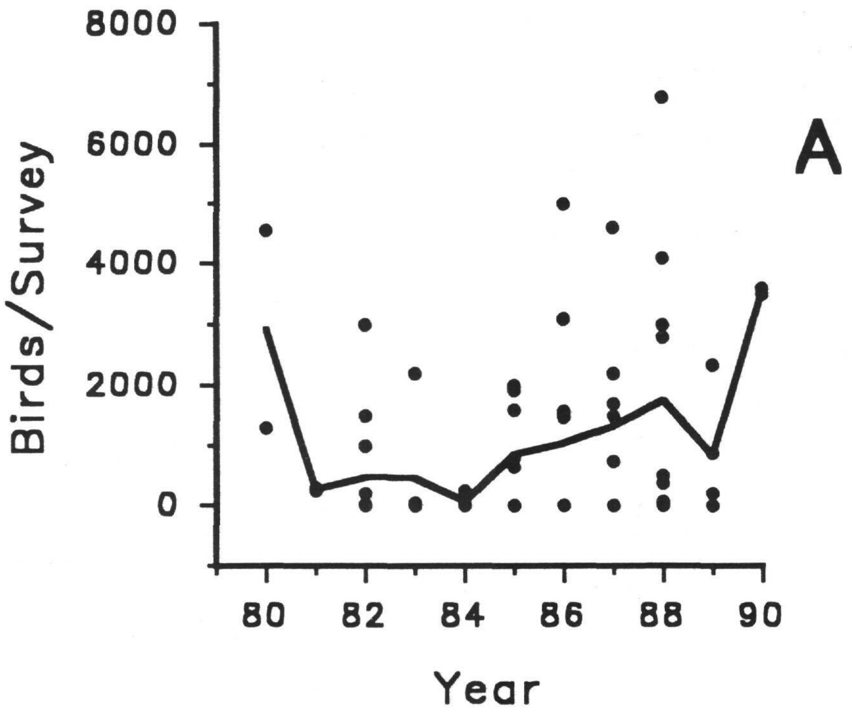


Figure IV.9. A. The number of western sandpipers per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in western sandpipers from 1965 to 1989 during Christmas Bird Counts.



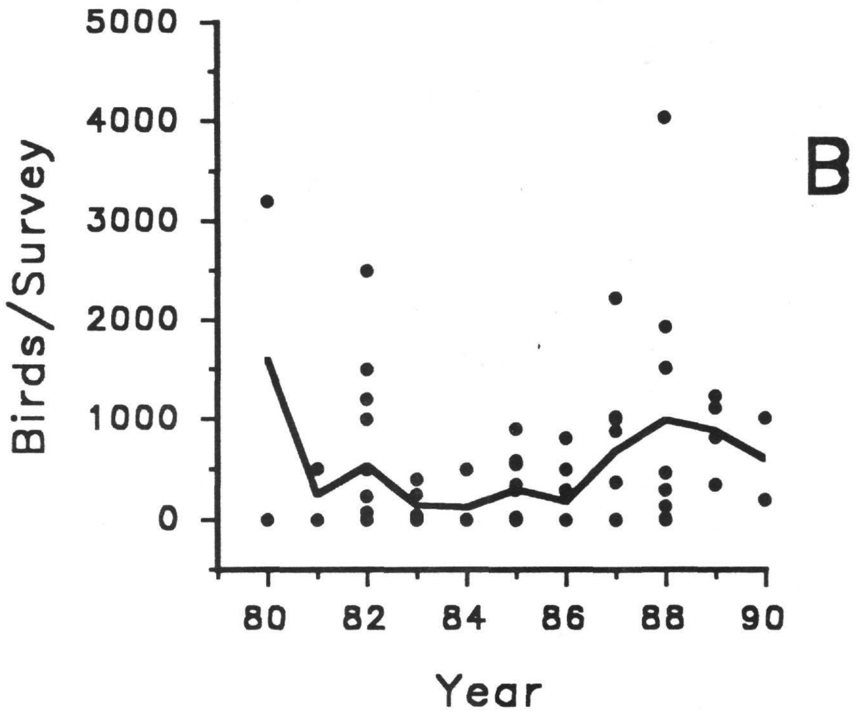


Figure IV.10. A. Individual counts and mean number of American avocets per survey from 1980 to 1990 during Shorebird Surveys of Bolivar Flats. B. Individual counts and mean number of dunlins per survey from 1980 to 1990 during Shorebird Surveys of Bolivar Flats.

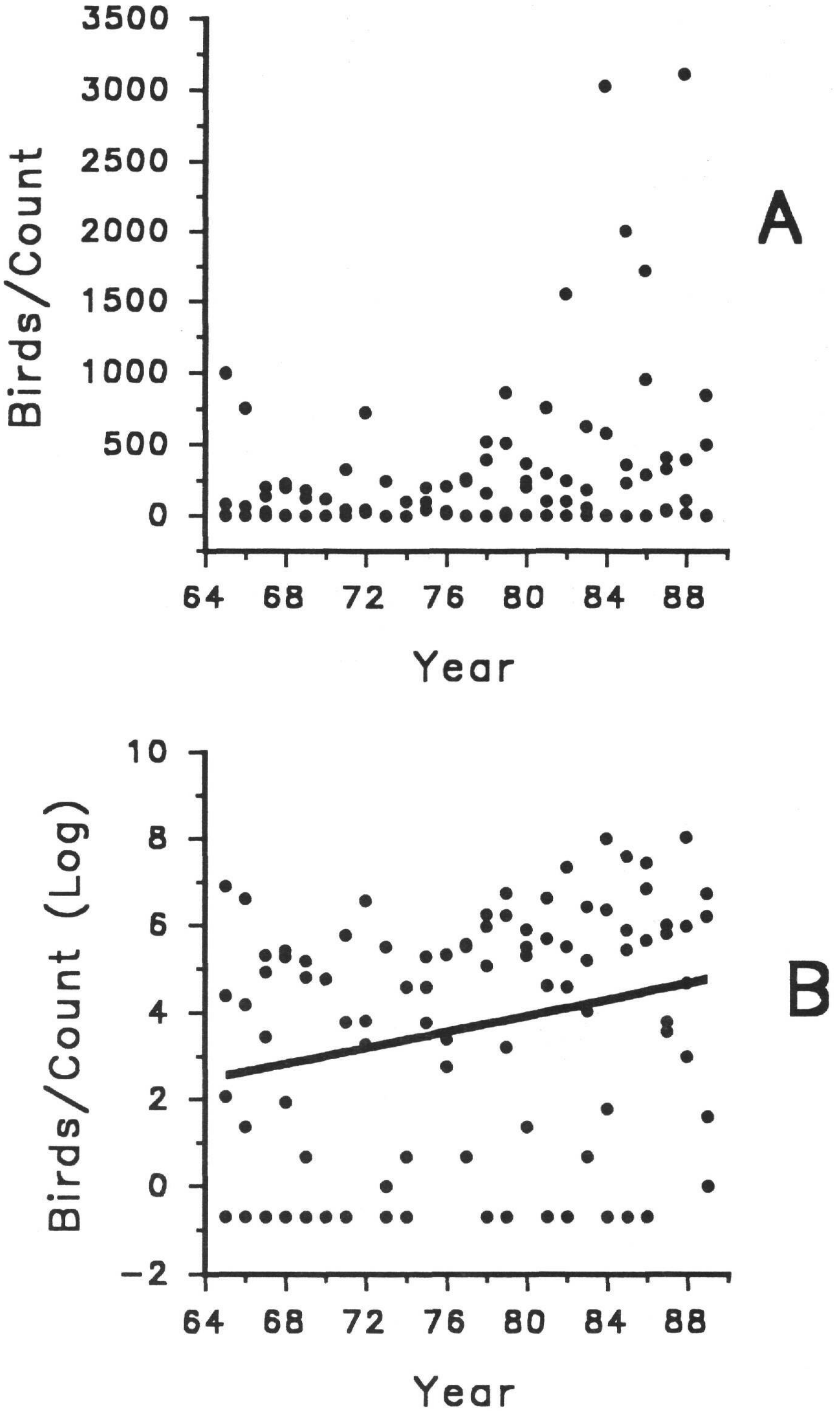


Figure IV.11. A. The number of American avocets per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in American avocets from 1965 to 1989 during Christmas Bird Counts.

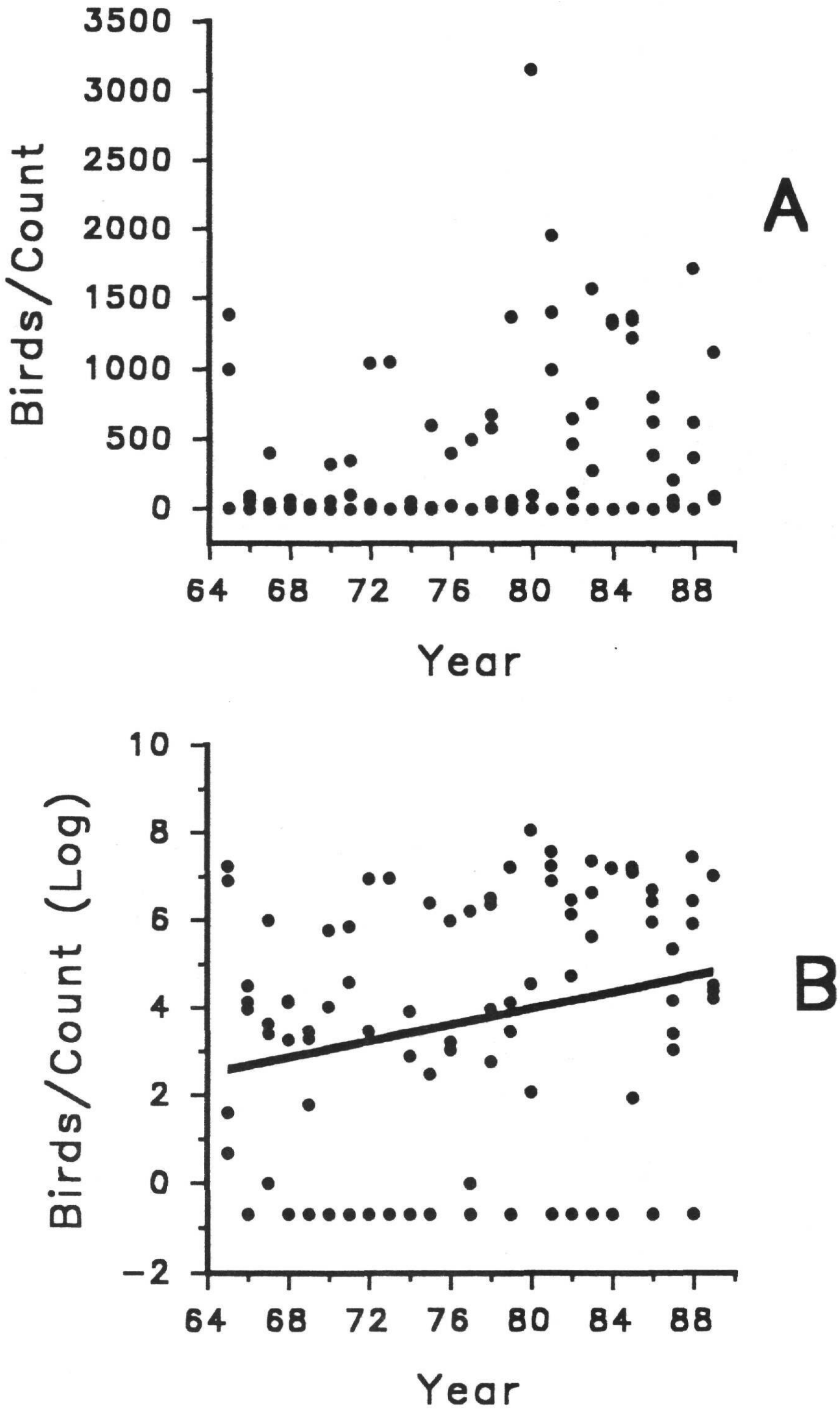


Figure IV.12. A. The number of dunlins per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in dunlins from 1965 to 1989 during Christmas Bird Counts.

Table IV.1. Analysis of variance table for black-bellied plovers.

	r^2	df	F	P	Parameter Estimate
Bolivar Flats Shorebird Surveys					
Model (log)	0.25	4	5.71	<0.001	
Season		3	4.68	0.005	
Year		1	7.26	0.009	0.17
Year*Season		3	1.27	0.292	
Christmas Bird Counts					
Model (log)	0.72	5	44.28	<0.001	
Route		3	62.04	<0.001	
Miles		1	13.45	<0.001	
Year		1	23.12	<0.001	0.07
Year*Route		3	0.31	0.821	

Table IV.2. Analysis of variance table for willets.

	r^2	df	F	P	Parameter Estimate
Bolivar Flats Shorebird Surveys					
Model (log)	0.15	4	2.85	0.030	
Season		3	0.90	0.444	
Year		1	8.00	0.006	0.16
Year*Season		3	1.92	0.135	
Christmas Bird Counts					
Model (log)	0.78	5	62.75	<0.001	
Route		3	88.17	<0.001	
Miles		1	10.41	0.002	
Year		1	34.00	<0.001	0.08
Year*Route		3	0.49	0.688	

Table IV.3. Analysis of variance table for sanderlings.

	r^2	df	F	P	Parameter Estimate
Bolivar Flats Shorebird Surveys					
Model (log)	0.25	4	5.56	<0.001	
Season		3	5.89	0.001	
Year		1	4.94	0.030	0.10
Year*Season		3	0.97	0.413	
Christmas Bird Counts					
Model (log)	0.79	5	65.11	<0.001	
Route		3	96.97	<0.001	
Miles		1	6.16	0.015	
Year		1	18.90	<0.001	0.07
Year*Route		3	0.37	0.777	

Table IV.4. Analysis of variance table for western sandpipers.

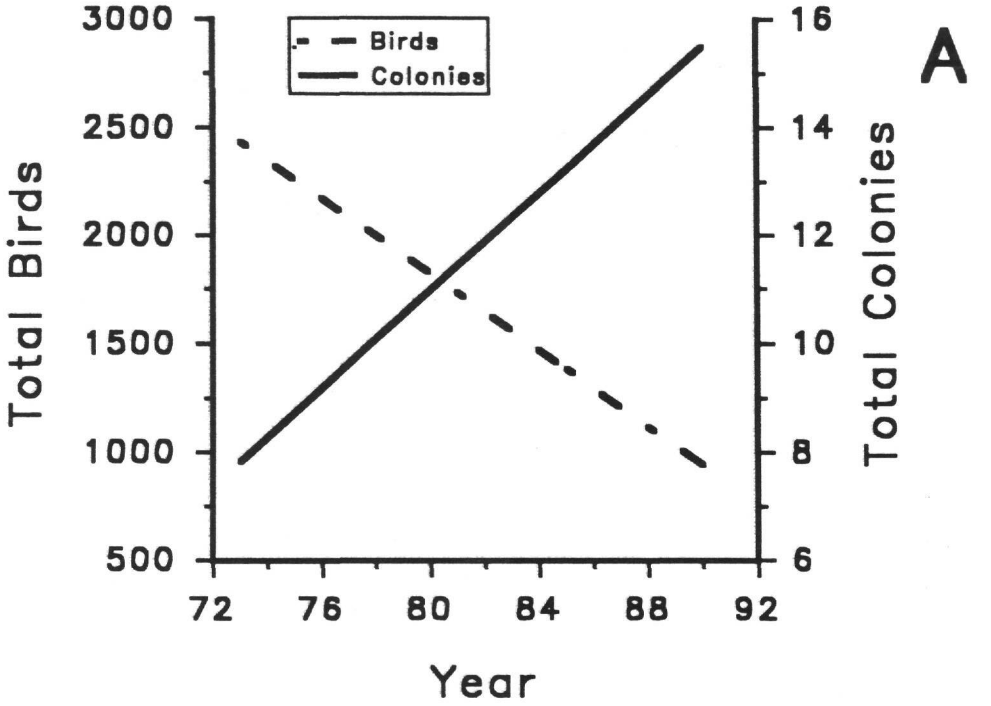
	r^2	df	F	P	Parameter Estimate
Bolivar Flats Shorebird Surveys					
Model (log)	0.32	4	7.84	<0.001	
Season		3	3.64	0.017	
Year		1	19.82	<0.001	0.47
Year*Season		3	0.87	0.462	
Christmas Bird Counts					
Model (log)	0.65	5	31.79	<0.001	
Route		3	34.90	<0.001	
Miles		1	8.82	0.004	
Year		1	21.92	<0.001	0.12
Year*Route		3	7.38	<0.001	

Table IV.5. Analysis of variance table for American avocets.

	r^2	df	F	P	Parameter Estimate
Bolivar Flats Shorebird Surveys					
Model (log)	0.58	4	23.02	<0.001	
Season		3	29.04	<0.001	
Year		1	1.84	0.180	0.16
Year*Season		3	0.89	0.449	
Christmas Bird Counts					
Model (log)	0.71	4	53.74	<0.001	
Route		3	65.42	<0.001	
Year		1	13.36	<0.001	0.08
Year*Route		3	0.42	0.739	

Table IV.6. Analysis of variance table for dunlins.

	r^2	df	F	P	Parameter Estimate
Bolivar Flats Shorebird Surveys					
Model (log)	0.62	4	27.76	<0.001	
Season		3	34.69	<0.001	
Year		1	3.02	0.087	0.17
Year*Season		3	1.02	0.391	
Christmas Bird Counts					
Model (log)	0.54	4	25.75	<0.001	
Route		3	30.64	<0.001	
Year		1	8.01	0.006	0.08
Year*Route		3	0.06	0.980	



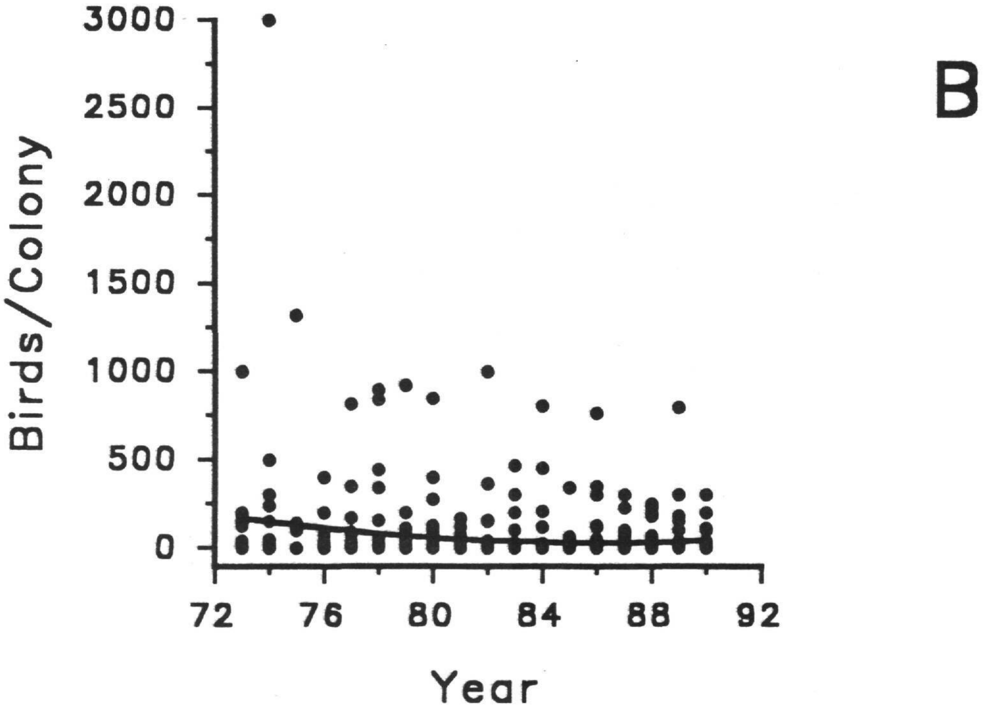


Figure IV.13. A. Trend in tricolored herons per year (N=18) and the trend in numbers of colonies containing tricolored herons from 1973 to 1990 during Texas Colonial Waterbird Surveys. B. Individual colony counts and trend in tricolored herons per colony from 1973 to 1990 (N=516) during Texas Colonial Waterbird Surveys.

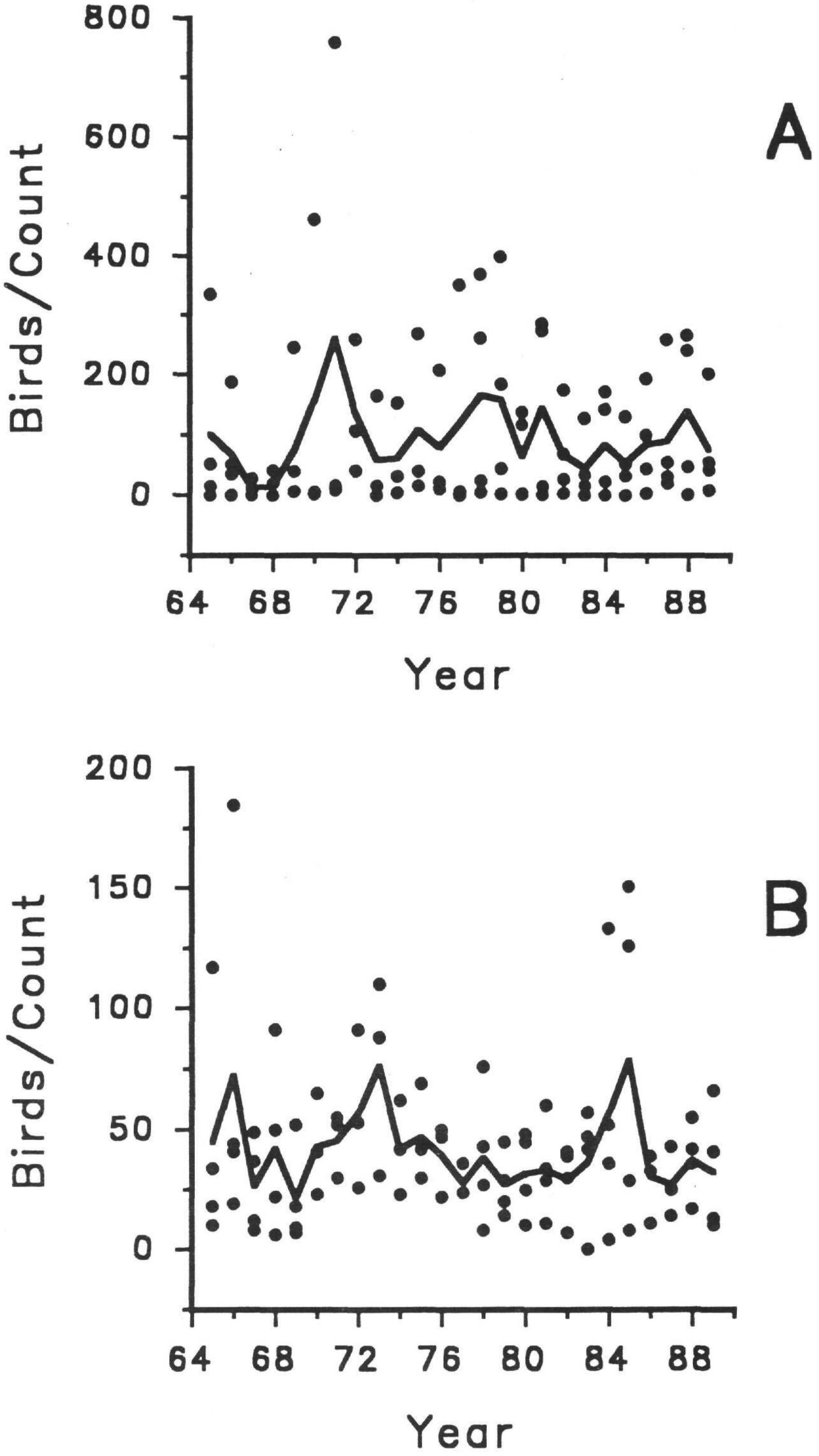


Figure IV.14. A. Individual counts and mean number of black-crowned night herons per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Individual counts and mean number of tricolored herons per count (N=92) from 1965 to 1989 during Christmas Bird Counts.

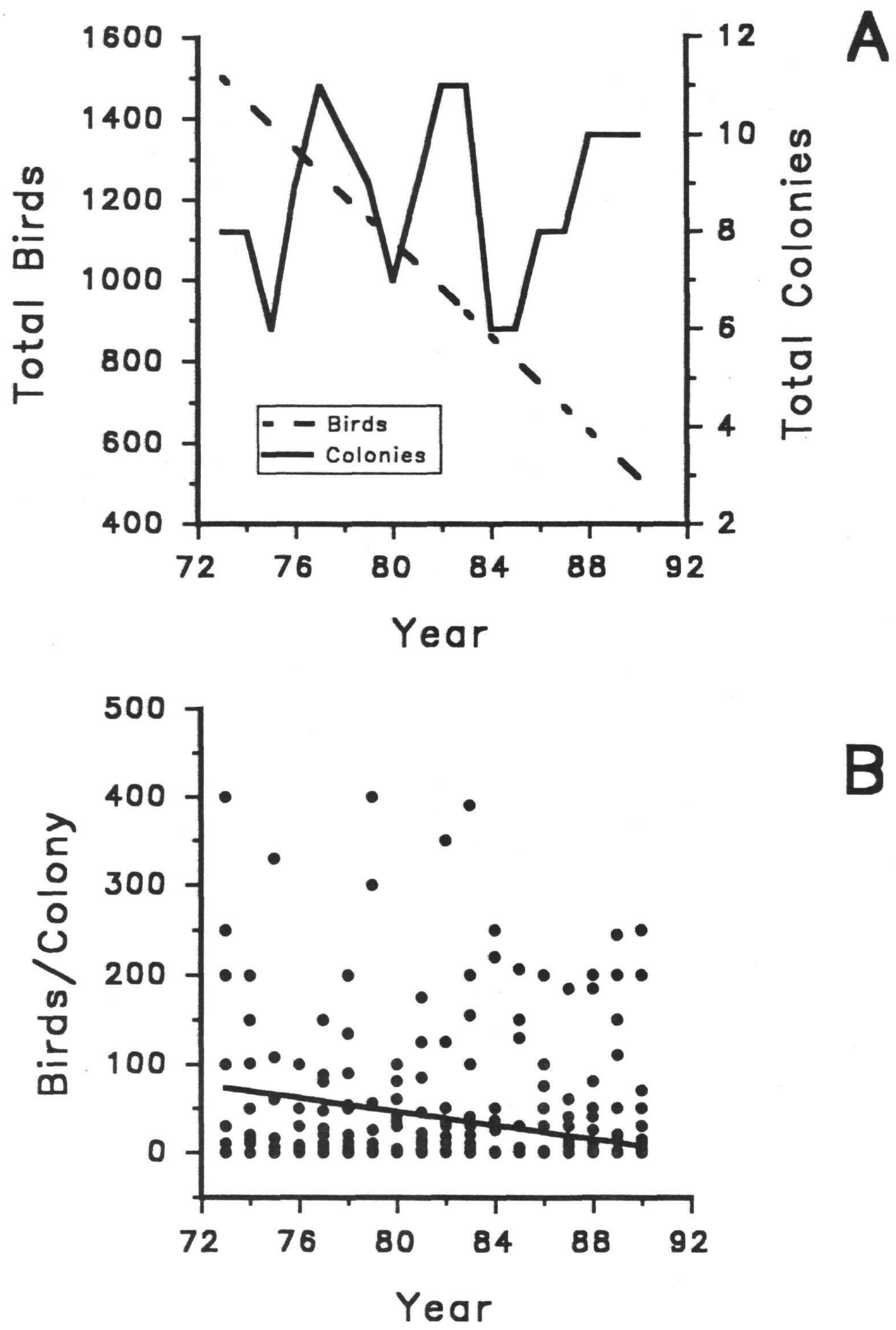


Figure IV.15. A. Trend in snowy egrets per year (N=18) and the number of colonies containing snowy egrets from 1973 to 1990 during Texas Colonial Waterbird Surveys. B. Individual colony counts and trend in snowy egrets per colony from 1973 to 1990 (N=516) during Texas Colonial Waterbird Surveys.

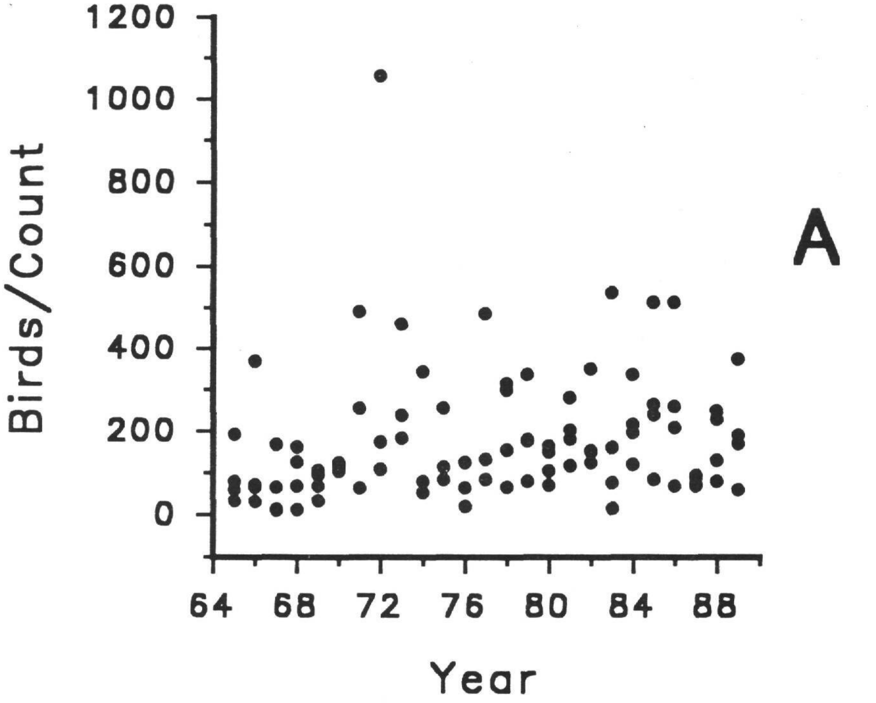


Figure IV.16. A. The number of snowy egrets per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in snowy egrets from 1965 to 1989 during Christmas Bird Counts.

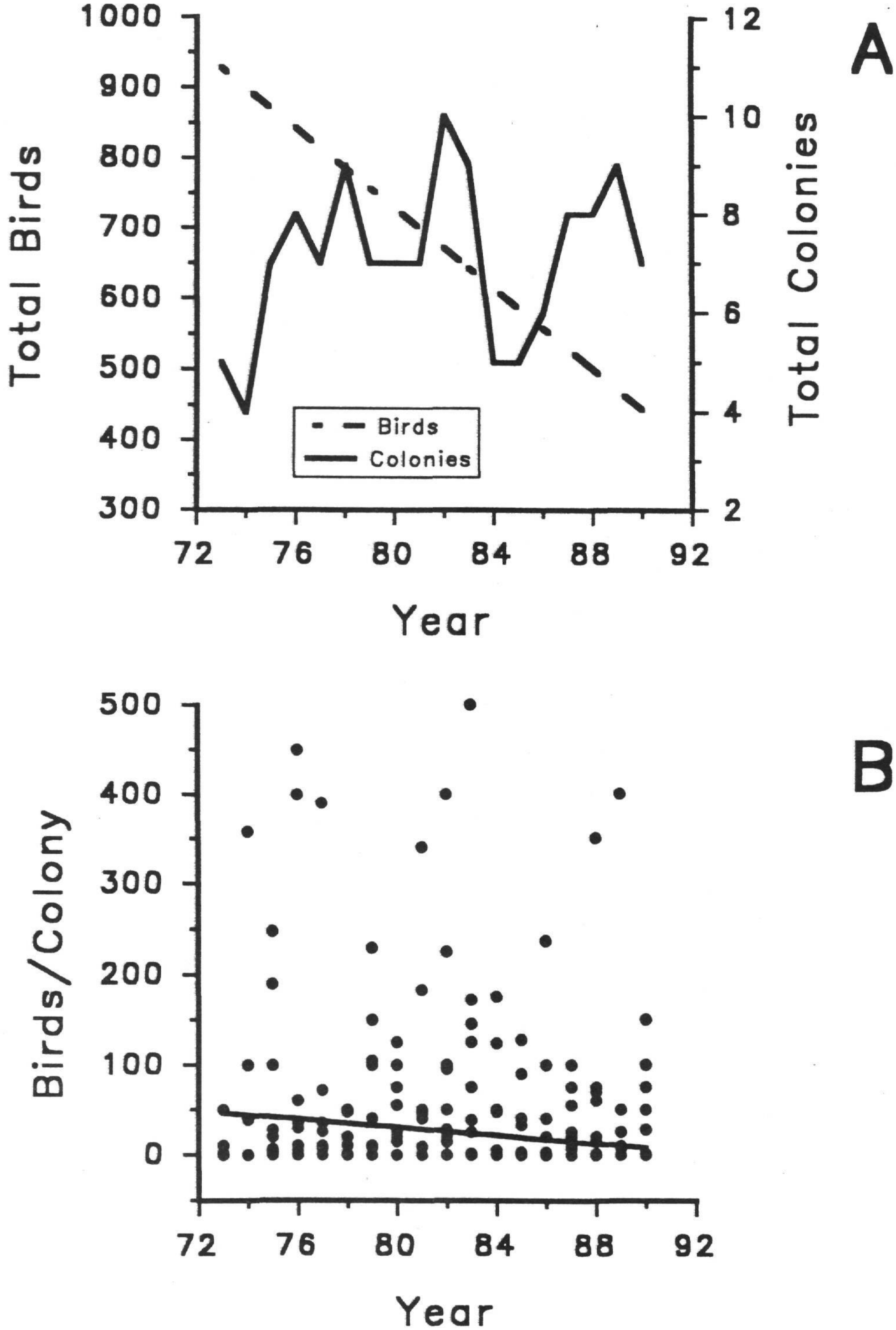


Figure IV.17. A. Total number of roseate spoonbills per year (N=18) and the number of colonies containing roseate spoonbills from 1973 to 1990 during Texas Colonial Waterbird Surveys. B. Individual colony counts and trend in roseate spoonbills per colony from 1973 to 1990 (N=516) during Texas Colonial Waterbird Surveys.

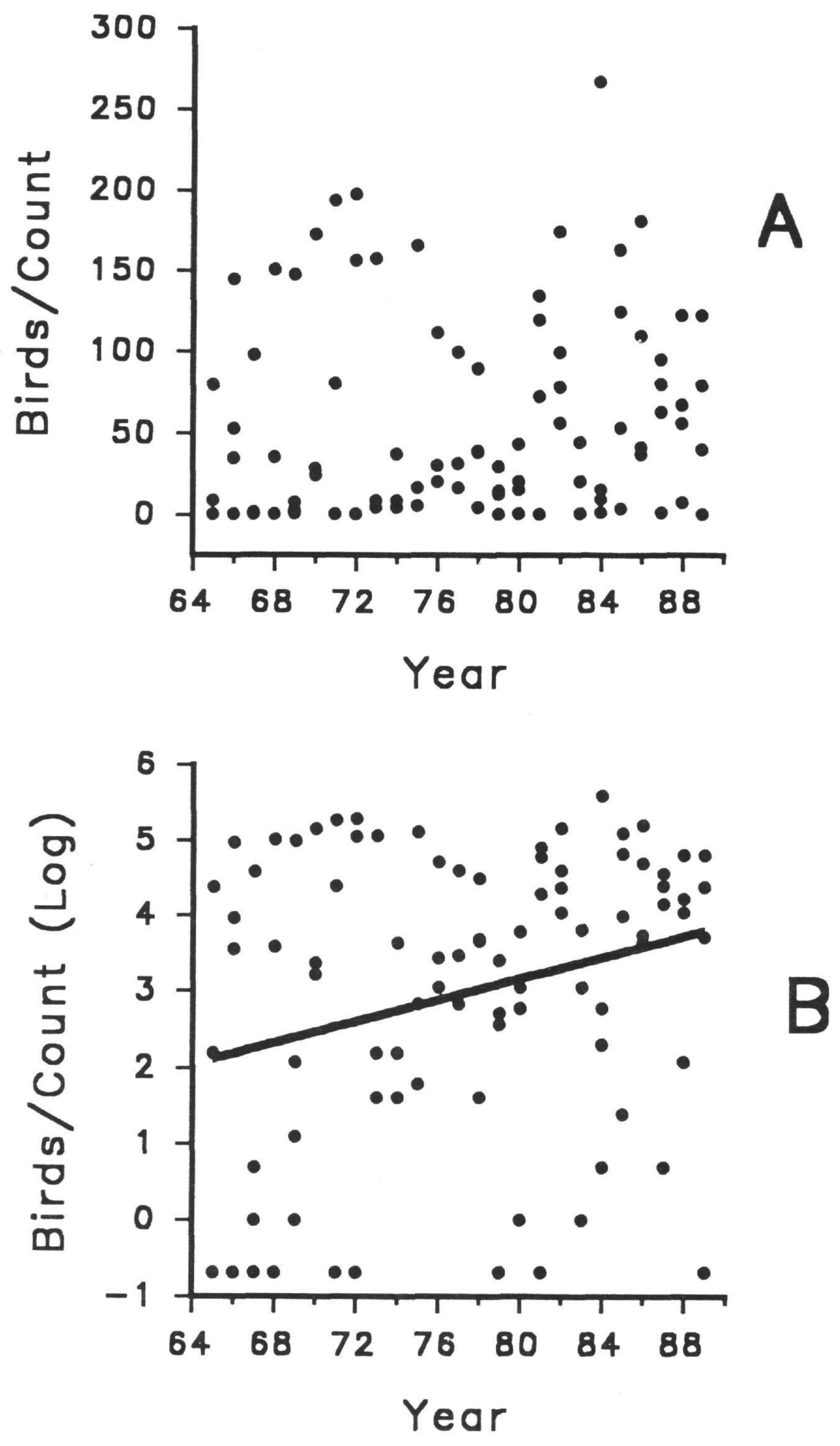


Figure IV.18. A. The number of roseate spoonbills per count (N=92) from 1965 to 1989 during Christmas Bird Counts.
B. Trend in roseate spoonbills from 1965 to 1989 during Christmas Bird Counts.

Table IV.7. Analysis of variance table for tricolored herons.

	r^2	df	F	P	Parameter Estimate
TCWS - Total Birds					
Model	0.27	1	5.83	0.028	
Year		1	5.83	0.028	-87.81
TCWS - Number of Colonies					
Model	0.44	1	12.46	0.003	
Year		1	12.46	0.003	0.45
TCWS - Birds/Colony					
Model	0.03	2	8.53	<0.001	
Year		1	5.08	0.025	-143.13
$Year^2$		1	4.65	0.031	0.83
Christmas Bird Counts					
Model	0.15	4	3.93	0.006	
Route		3	5.01	0.003	
Year		1	0.87	0.354	-0.41
Year*Route		3	10.30	<0.001	

Table IV.8. Analysis of variance table for snowy egrets.

	r^2	df	F	P	Parameter Estimate
TCWS - Total Birds					
Model	0.28	1	6.33	0.023	
Year		1	6.33	0.023	-57.91
TCWS - Birds/Colony					
Model	0.02	1	11.83	<0.001	
Year		1	11.83	<0.001	-3.91
Christmas Bird Counts					
Model (log)	0.26	5	6.11	<0.001	
Route		3	1.95	0.128	
Miles		1	4.14	0.045	
Year		1	9.46	0.003	0.03
Year*Route		3	2.85	0.043	

Table IV.9. Analysis of variance table for roseate spoonbills.

	r^2	df	F	P	Parameter Estimate
TCWS - Total Birds					
Model	0.30	1	6.77	0.019	
Year		1	6.77	0.019	-28.51
TCWS - Birds/Colony					
Model	0.02	1	9.51	0.002	
Year		1	9.51	0.002	-2.25
Christmas Bird Counts					
Model (log)	0.15	4	3.70	0.008	
Route		3	2.50	0.065	
Year		1	7.28	0.008	0.07
Year*Route		3	4.08	0.009	

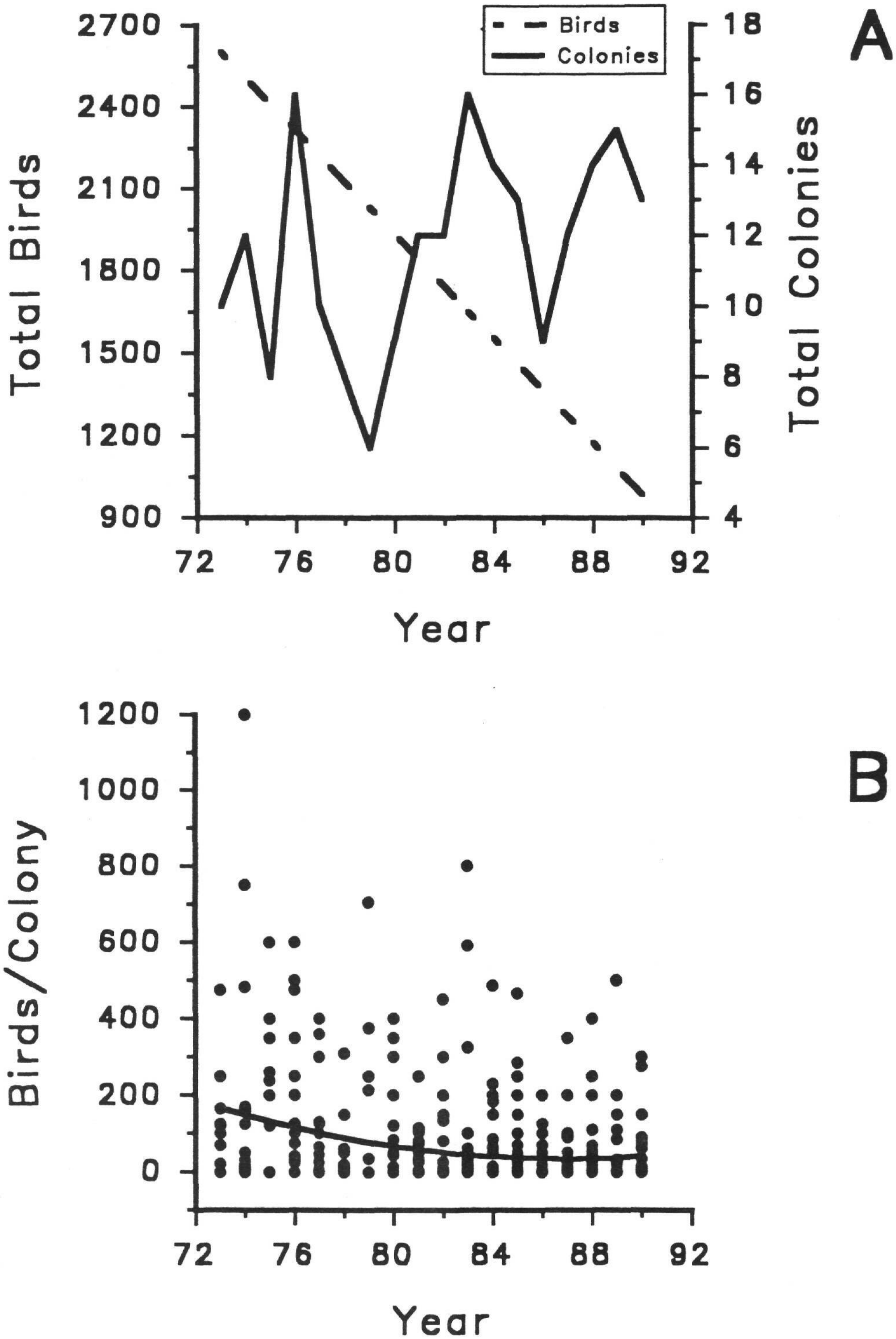
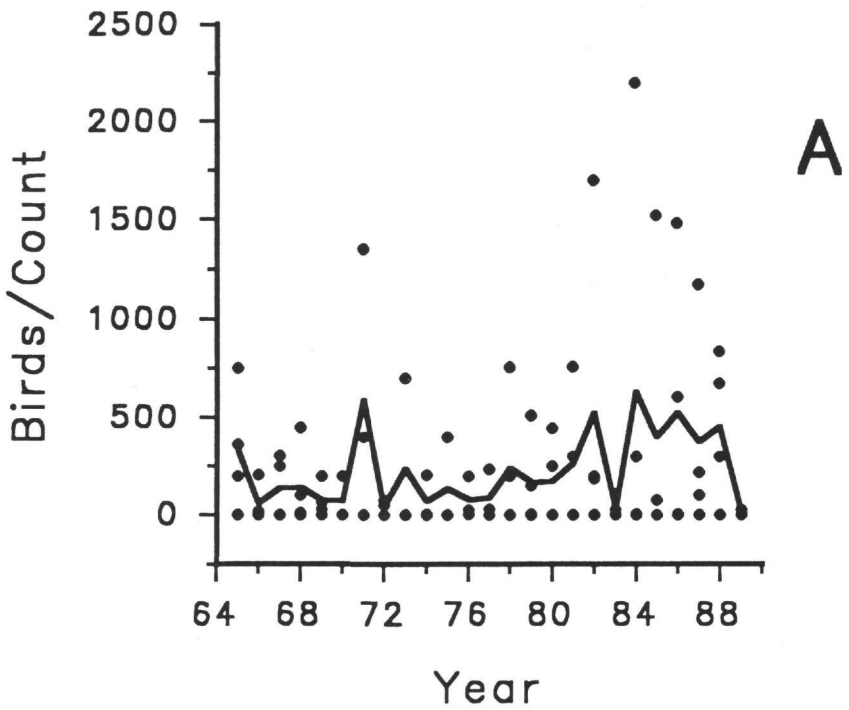


Figure IV.19. A. Trend in numbers of black skimmers per year (N=18) and the number of colonies containing black skimmers from 1973 to 1990 during Texas Colonial Waterbird Surveys. B. Individual colony counts and trend in numbers of black skimmers per colony from 1973 to 1990 (N=516) during Texas Colonial Waterbird Surveys.



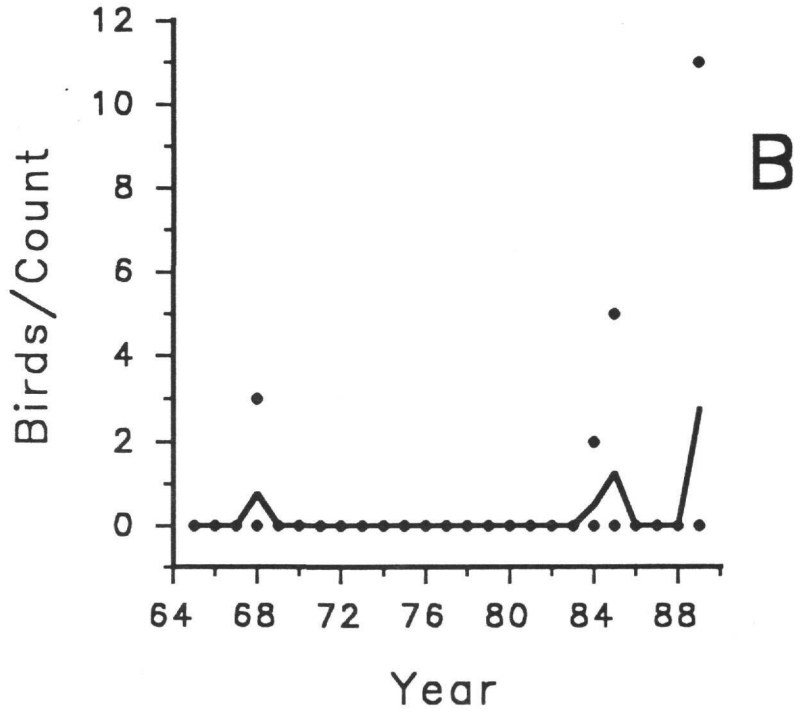


Figure IV.20. A. Individual counts and mean number of black skimmers per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Individual counts and mean number of fulvous whistling ducks per count (N=92) from 1965 to 1989 during Christmas Bird Counts.

Table IV.10. Analysis of variance table for black skimmers.

	r^2	df	F	P	Parameter Estimate
TCWS - Total Birds					
Model	0.27	1	5.98	0.026	
Year		1	5.98	0.026	-95.08
TCWS - Birds/Colony					
Model	0.07	1	18.77	<0.001	
Year		1	7.78	0.006	-120.90
$Year^2$		1	6.95	0.009	0.70
Christmas Bird Counts					
Model (log)	0.62	4	35.70	<0.001	
Route		3	47.56	<0.001	
Year		1	0.10	0.758	-0.01
Year*Route		3	0.37	0.772	

Olivaceous cormorants increased in total numbers and in number of colonies (Figure IV.21, Table IV.11), based on the TCWS. Models describing the mean number of birds per colony were not significant. Numbers of birds seen on the CBC increased significantly (Figure IV.22, Table IV.11); however, the interaction between year and count-area was significant.

Black-crowned night-herons and Forster's terns (Figures IV.23, IV.24; Tables IV.12, IV.13) increased in number of colonies; however, no significant models were found to describe changes in total birds or mean colony sizes based on the TCWS. Numbers of both species increased based on the CBC (Figures IV.14, IV.25; Tables IV.12, IV.13), and the interaction term was significant for black-crowned night-herons.

The number of colonies containing great egrets showed a curvilinear trend and the mean number of birds per colony decreased based on the TCWS (Figure IV.26, Table IV.14). Models showing changes in total number of individuals were not significant for the TCWS; however, they showed an increase based on the CBC (Figure IV.27, Table IV.14).

Table IV.11. Analysis of variance table for olivaceous cormorants.

	r^2	df	F	P	Parameter Estimate
TCWS - Total Birds					
Model	0.27	1	5.87	0.028	
Year		1	5.87	0.028	40.24
TCWS - Number of Colonies					
Model	0.59	1	23.39	<0.001	
Year		1	23.39	<0.001	0.37
Christmas Bird Counts					
Model (log)	0.75	4	66.13	<0.001	
Route		3	23.61	<0.001	
Year		1	187.60	<0.001	0.21
Year*Route		3	7.98	<0.001	

Table IV.12. Analysis of variance table for black-crowned night-herons.

	r^2	df	F	P	Parameter Estimate
TCWS - Number of Colonies					
Model	0.29	1	6.57	0.021	
Year		1	6.57	0.021	0.17
Christmas Bird Counts					
Model (log)	0.51	4	22.26	<0.001	
Route		3	28.31	<0.001	
Year		1	3.46	0.066	0.04
Year*Route		3	5.11	0.003	

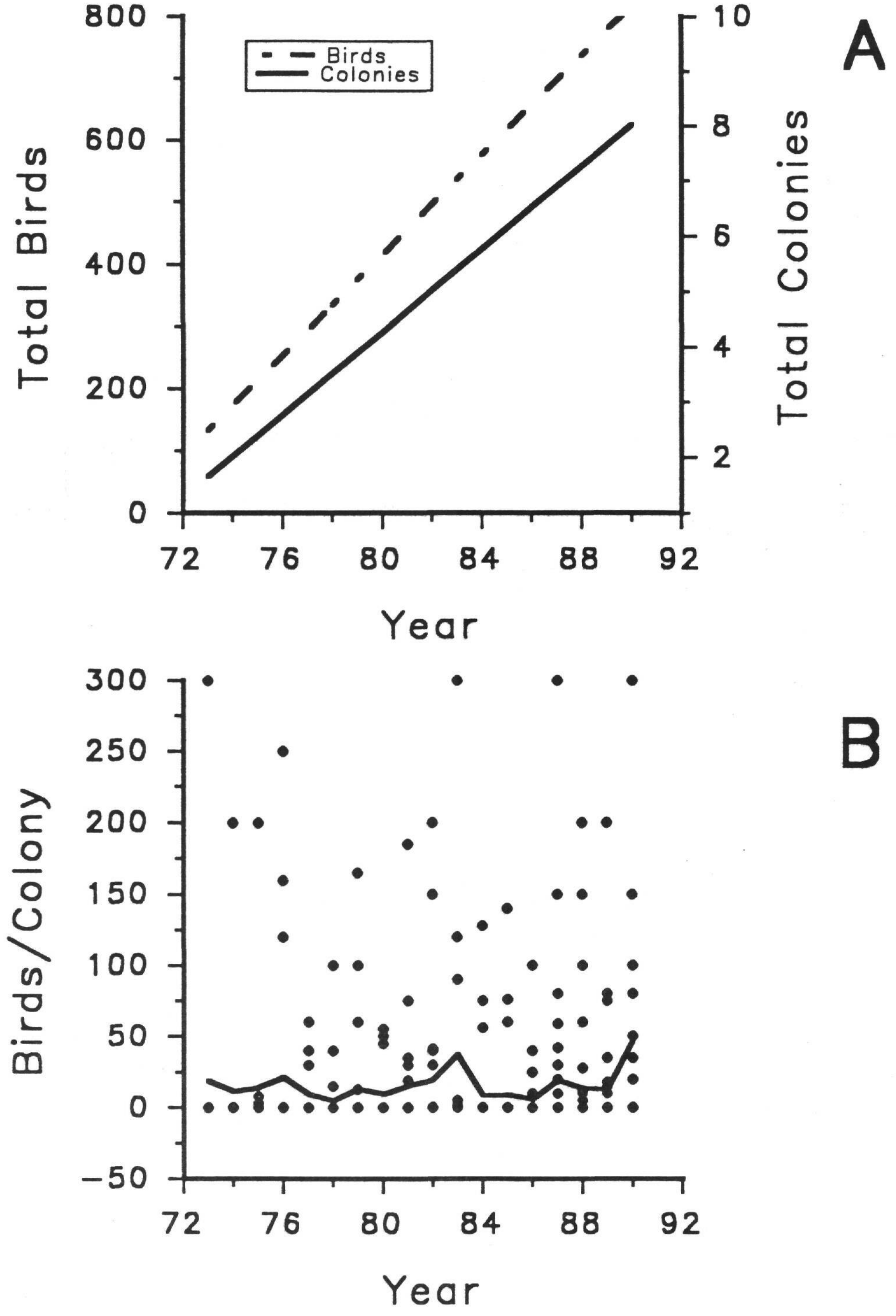


Figure IV.21. A. Trend in olivaceous cormorants per year (N=18) and the trend in number of colonies containing olivaceous cormorants from 1973 to 1990 during Texas Colonial Waterbird Surveys. B. Individual colony counts and mean number of olivaceous cormorants per colony from 1973 to 1990 (N=516) during Texas Colonial Waterbird Surveys.

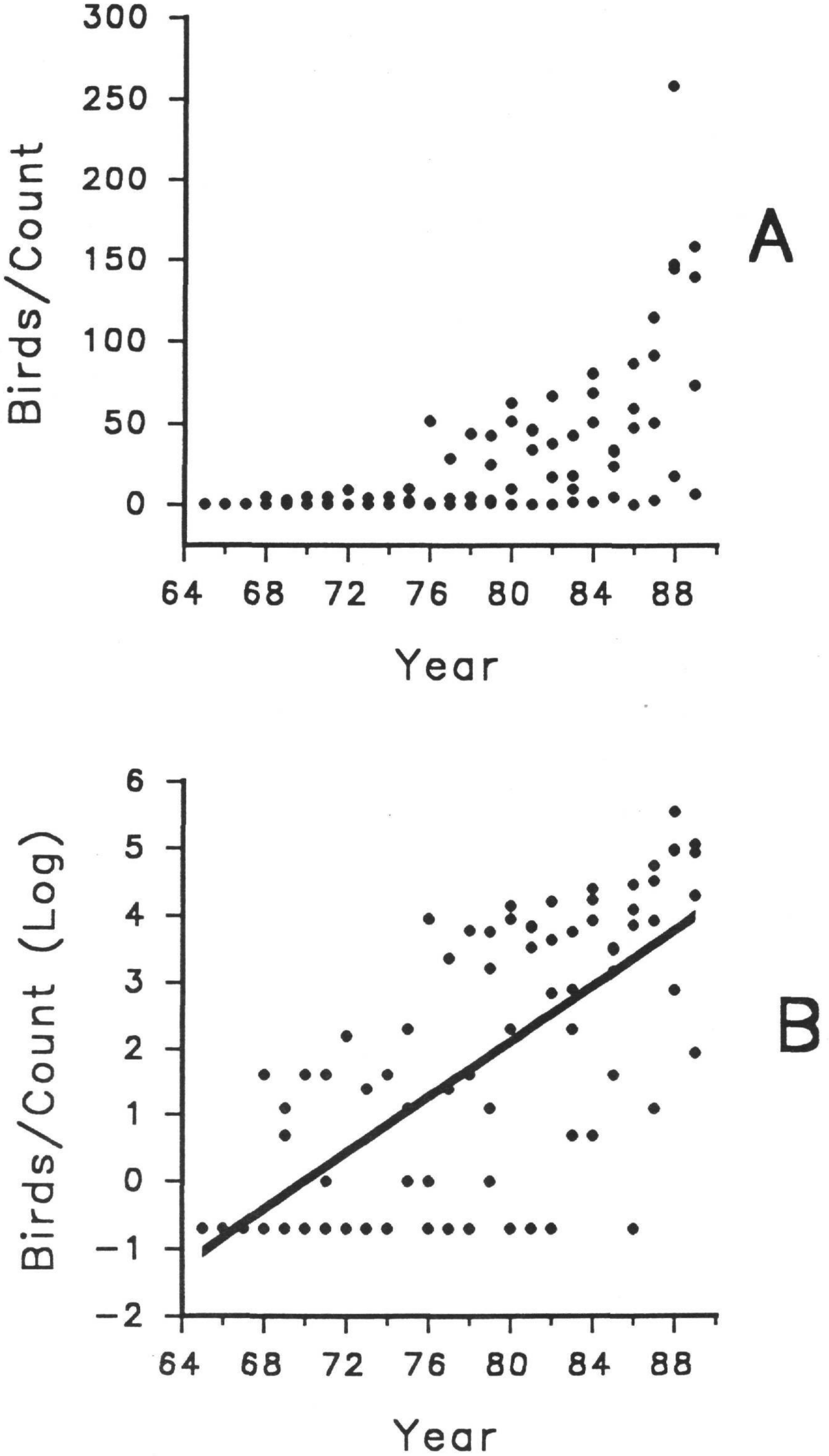


Figure IV.22. A. The number of olivaceous cormorants per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in olivaceous cormorants from 1965 to 1989 during Christmas Bird Counts.

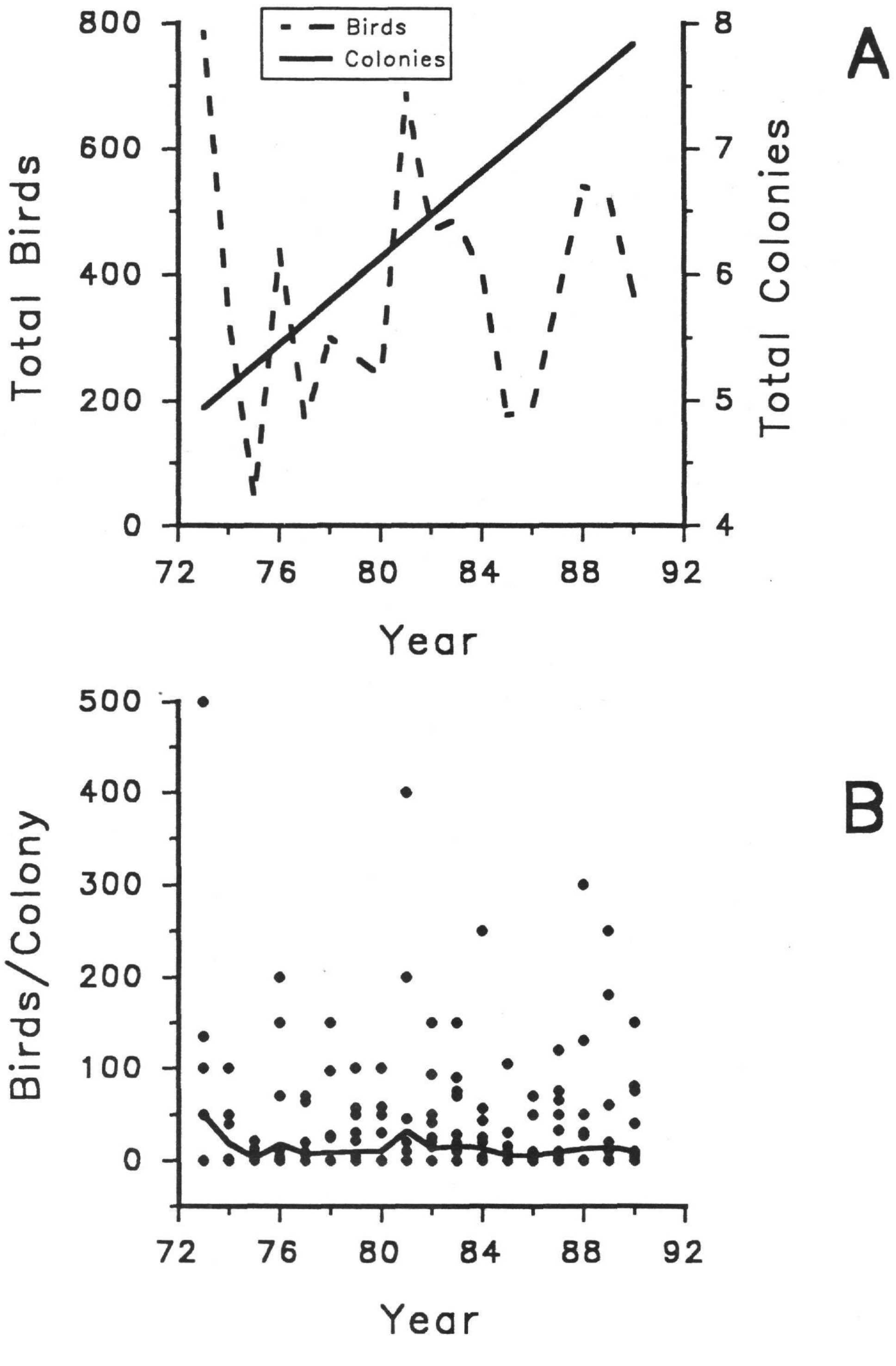


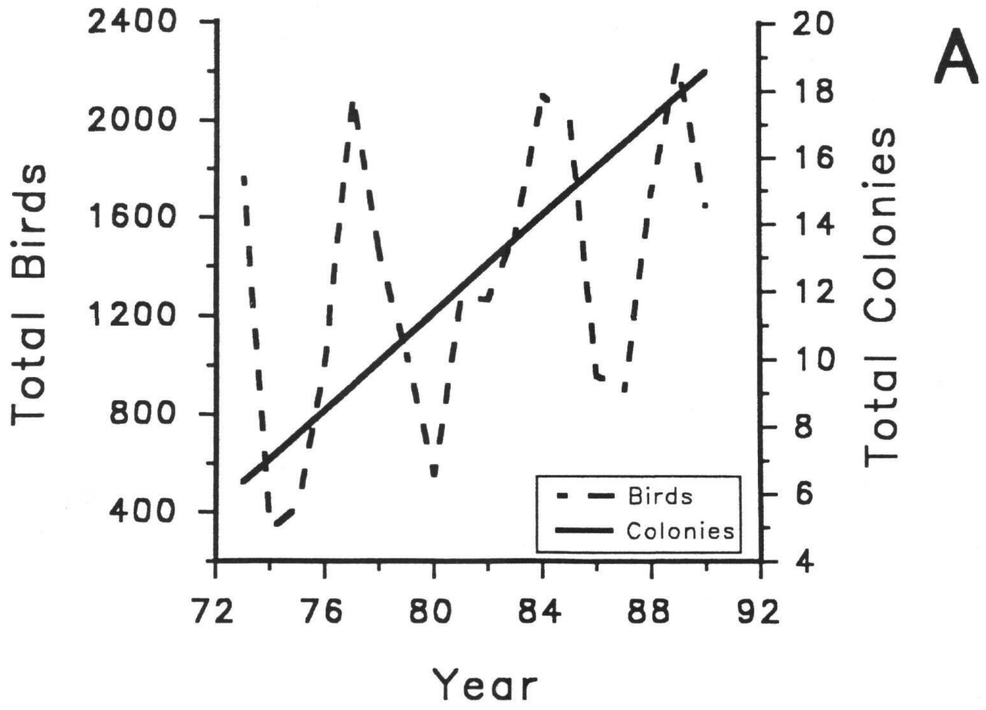
Figure IV.23. A. Total number of black-crowned night-herons per year (N=18) and the trend in number of colonies containing black-crowned night-herons from 1973 to 1990 during Texas Colonial Waterbird Surveys. B. Individual colony counts and mean number of black-crowned night-herons per colony from 1973 to 1990 (N=516) during Texas Colonial Waterbird Surveys.

Table IV.13. Analysis of variance table for Forster's terns.

	r^2	df	F	P	Parameter Estimate
TCWS - Number of Colonies					
Model	0.50	1	15.90	0.001	
Year		1	15.90	0.001	0.72
Christmas Bird Counts					
Model (log)	0.62	4	35.33	<0.001	
Route		3	37.24	<0.001	
Year		1	25.82	<0.001	0.07
Year*Route		3	1.56	0.205	

Table IV.14. Analysis of variance table for great egrets.

	r^2	df	F	P	Parameter Estimate
TCWS - Number of Colonies					
Model	0.44	3	3.65	0.039	
Year		1	6.47	0.023	190.18
$Year^2$		1	6.31	0.025	-2.31
$Year^3$		1	6.15	0.027	0.01
TCWS - Birds/Colony					
Model	0.01	1	4.23	0.040	
Year		1	4.23	0.040	-2.35
Christmas Bird Counts					
Model (log)		0.21	4	5.83	<0.001
Route		3	5.92	0.001	
Year		1	5.84	0.018	0.02
Year*Route		3	1.53	0.212	



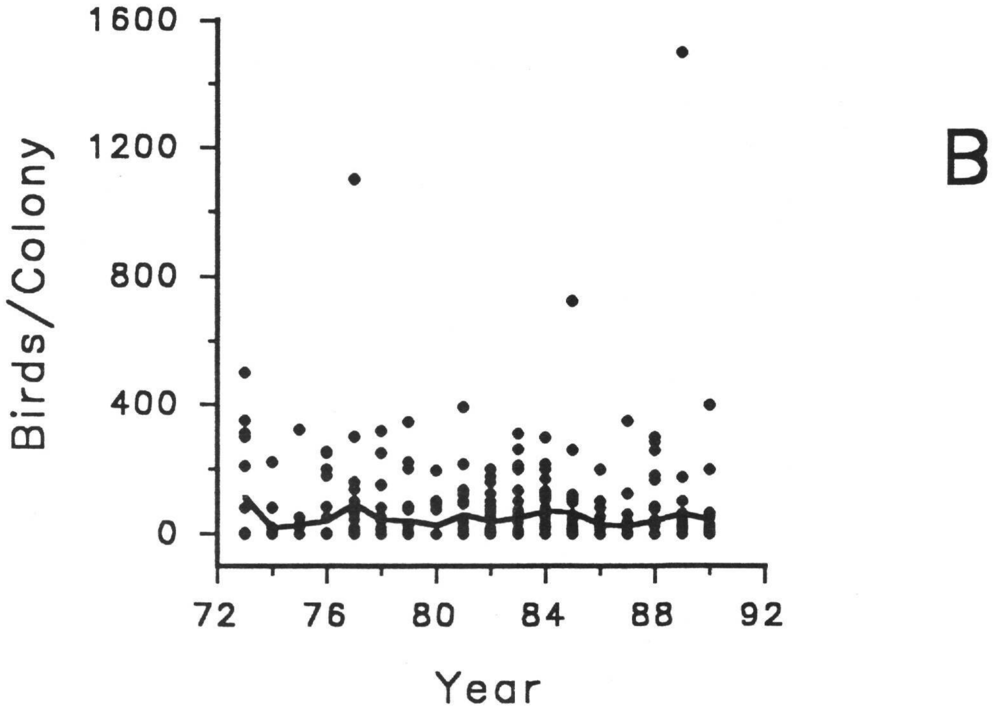


Figure IV.24. A. Total number of Forster's terns per year (N=18) and the trend in number of colonies containing Forster's terns from 1973 to 1990 during Texas Colonial Waterbird Surveys.
B. Individual colony counts and mean number of Forster's terns per colony from 1973 to 1990 (N=516) during Texas Colonial Waterbird Surveys.

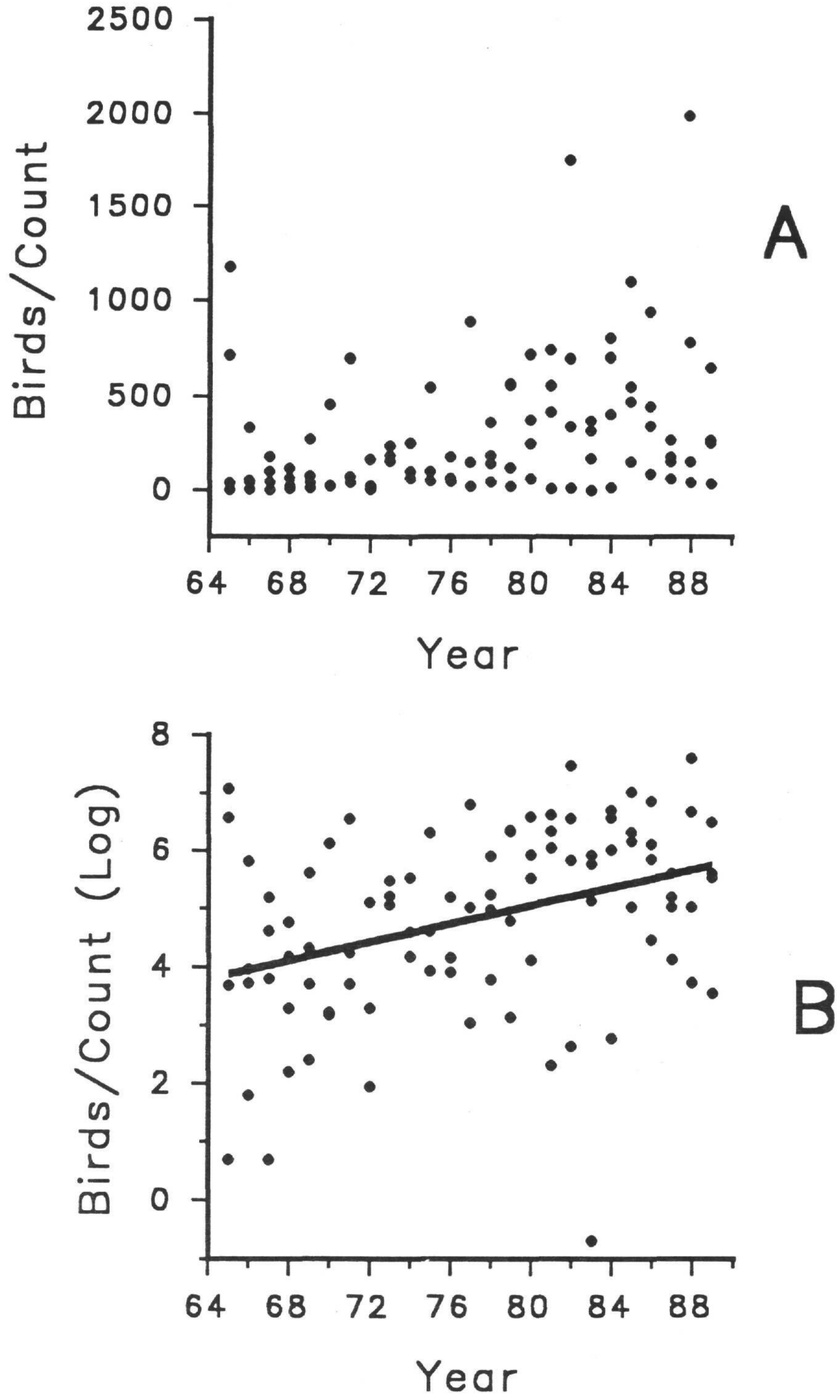


Figure IV.25. A. The number of Forster's terns per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in Forster's terns from 1965 to 1989 during Christmas Bird Counts.

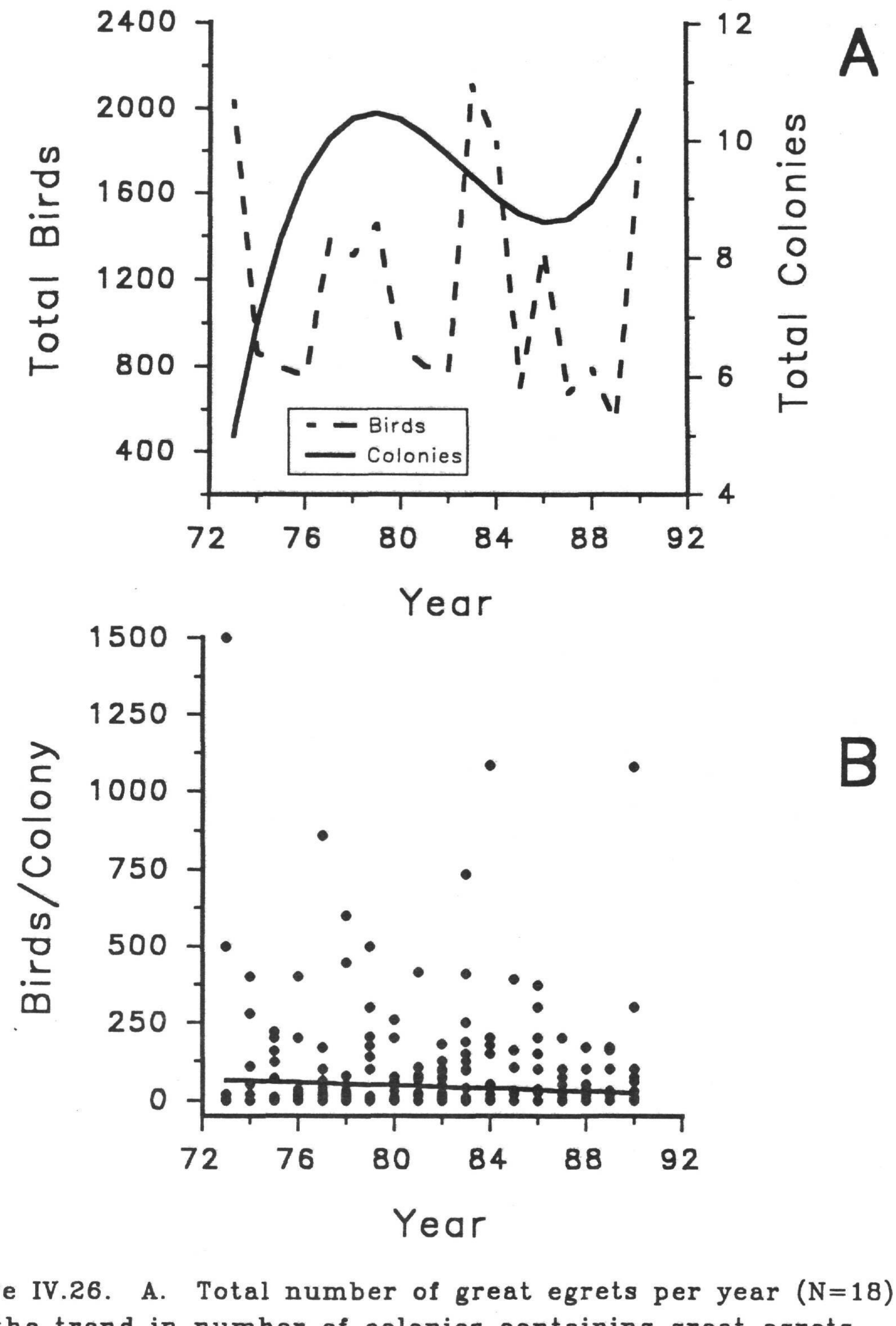


Figure IV.26. A. Total number of great egrets per year (N=18) and the trend in number of colonies containing great egrets from 1973 to 1990 during Texas Colonial Waterbird Surveys. B. Individual colony counts and mean number of great egrets per colony from 1973 to 1990 (N=516) during Texas Colonial Waterbird Surveys.

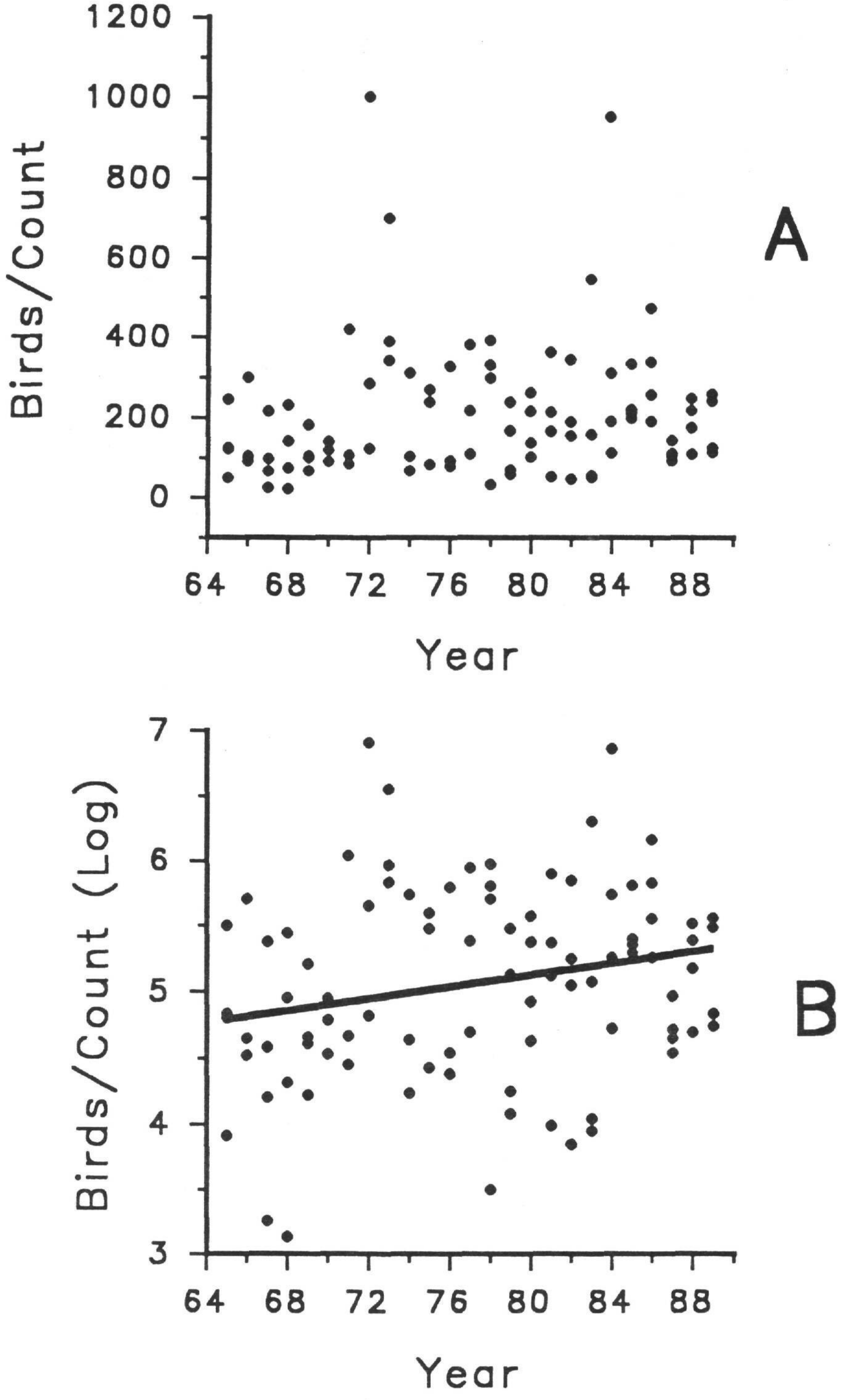


Figure IV.27. A. The number of great egrets per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in great egrets from 1965 to 1989 during Christmas Bird Counts.

Results from the detrended correspondence analysis of the 22 species included in the TCWS from 1973 to 1990 indicated that the structure of the colonial waterbird community has changed over the sample period. A plot of the ordination scores for sample years (Figure IV.28B) showed increasing separation of later years from early years. A plot of the species scores (Figure IV.28A) indicated that least terns (Sterna antillarum) and anhingas (Anhinga) had distinct distribution patterns relative to the other species. Further examination of their nesting habits indicate that these birds rarely co-occur with other colonial waterbird species. The remaining species showed little separation and could not be interpreted meaningfully.

Waterfowl

Merganser spp. (Figure IV.29, 30; Table IV.15) showed a significant decrease based on the MWCC and an increase based on the CBC.

The number of American coots did not change significantly based on the MWT (Figure IV.31, Table IV.16) and the CBC (Figure IV.32, Table IV.16); however, the interaction between year and count-area was significant based on the CBC. Adequate models of population trends could not be developed from the MWCC (Figure IV.53).

Numbers of green-winged teal, northern shovelers, and American wigeons have not changed significantly over the sampling period based on both the MWT and the CBC (Figures IV.31-IV.35, Tables IV.17-IV.19). The interaction between year and count-area was significant for northern shovelers based on the CBC, and the interaction between year and transect was significant for American wigeons based on the MWT.

Mallards and gadwalls showed no change in numbers based on the MWT (Figures IV.35, IV.36; Tables IV.20, IV.21). Models based on the CBC indicate that mallards are increasing linearly and gadwalls are increasing curvilinearly (Figures IV.33, IV.37; Tables IV.20, IV.21).

Numbers of mottled ducks and northern pintails decreased significantly based on the MWT (Figures IV.38, IV.40; Tables IV.22, IV.23); however, the interaction between year and transect was significant for both species. Alternately, numbers of mottled ducks increased linearly and numbers of northern pintails increased curvilinearly based on the CBC (Figures IV.39, IV.41; Tables IV.22, IV.23). The interaction between year and count-area was significant for mottled ducks.

Blue-winged teal showed a curvilinear decrease based on the MWT (Figures IV.42, Table IV.24). This species increased linearly based on the CBC (Figures IV.43, Table IV.24).

Scaup spp., ruddy ducks, bufflehead, and wood ducks (Aix sponsa) increased linearly and ring-necked ducks increased curvilinearly based on the CBC (Figures IV.44-IV.48, Tables IV.25-IV.29). The interaction between year and count-area was significant for bufflehead and wood ducks. Adequate models of these species could not be developed from MWCC (Figures IV.52, IV.53).

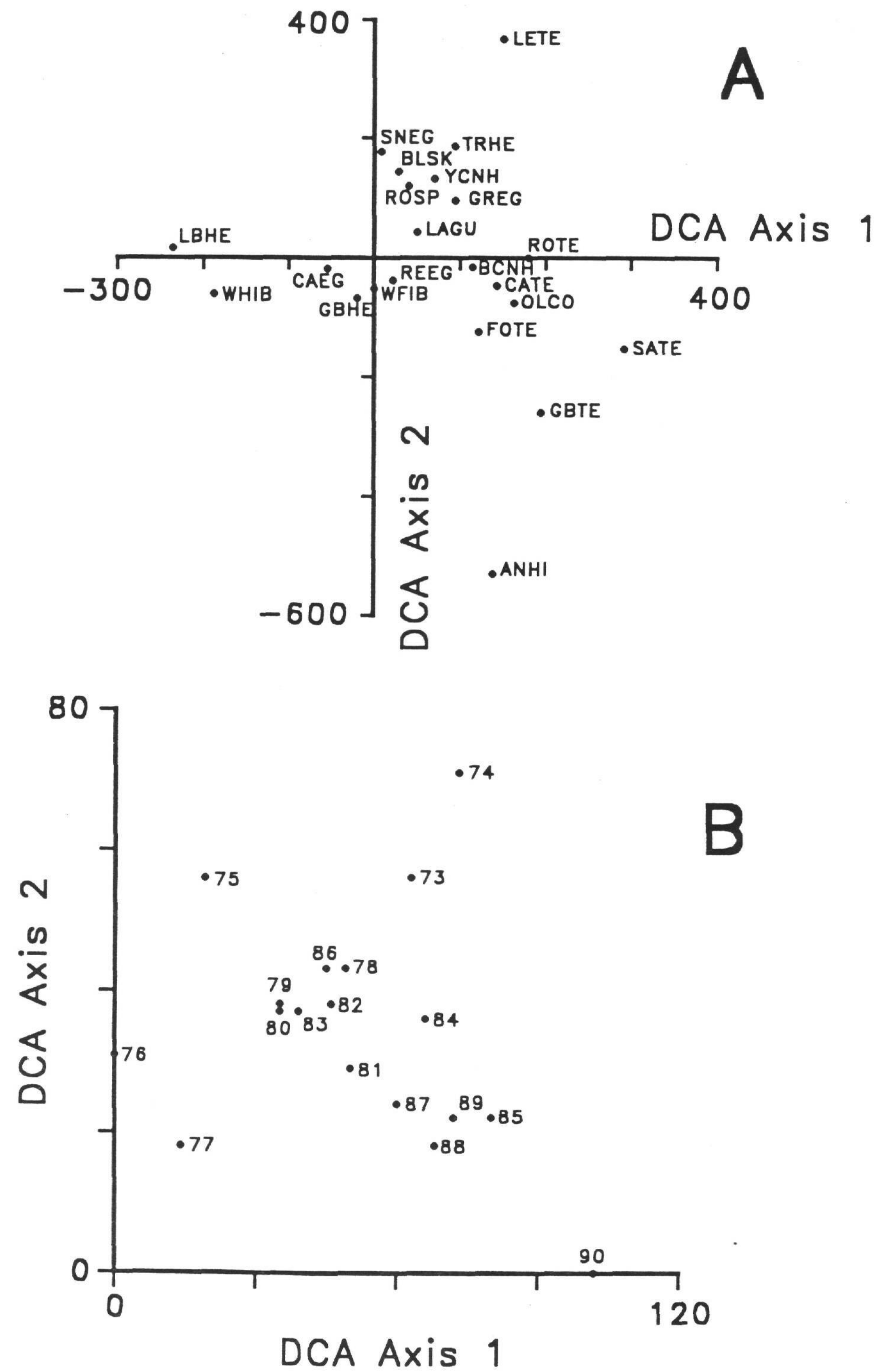


Figure IV.28. A. A plot of the ordination scores of colonial waterbird species surveyed from 1973 to 1990 (N=18).
B. A plot of the ordination scores of the sample years for Texas Waterbird Colonies from 1973 to 1990 (N=18).

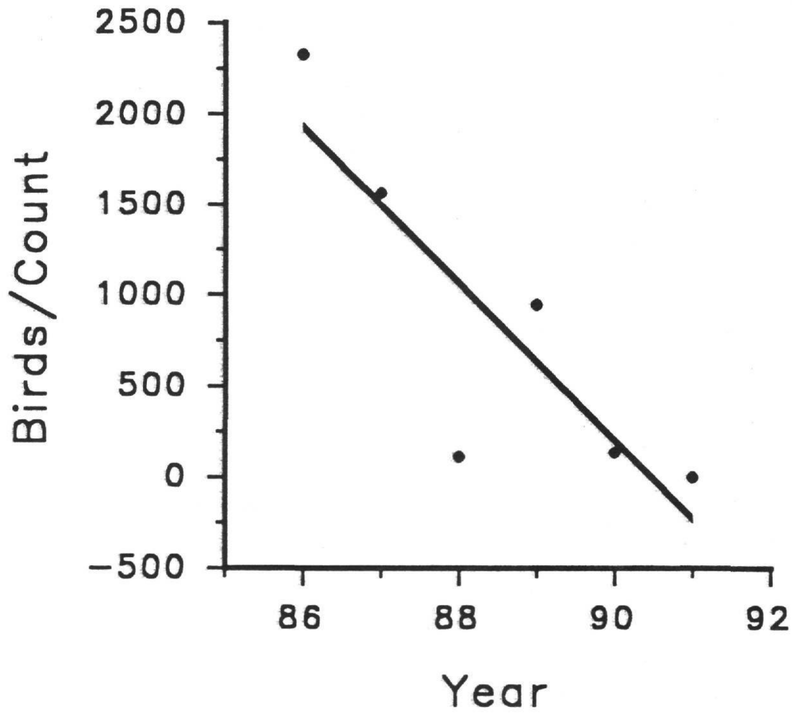


Figure IV.29 Individual counts and trend in merganser spp from. 1986 to 1991 (N=18) during Mid-winter Waterfowl Cruise Counts.

Table IV.15. Analysis of variance table for merganser spp.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Cruise Counts					
Model	0.73	1	10.59	0.031	
Year		1	10.59	0.031	-431.37
Christmas Bird Counts					
Model (log)	0.64	4	39.11	<0.001	
Route		3	28.80	<0.001	
Year		1	64.65	<0.001	0.16
Year*Route		3	1.95	0.128	

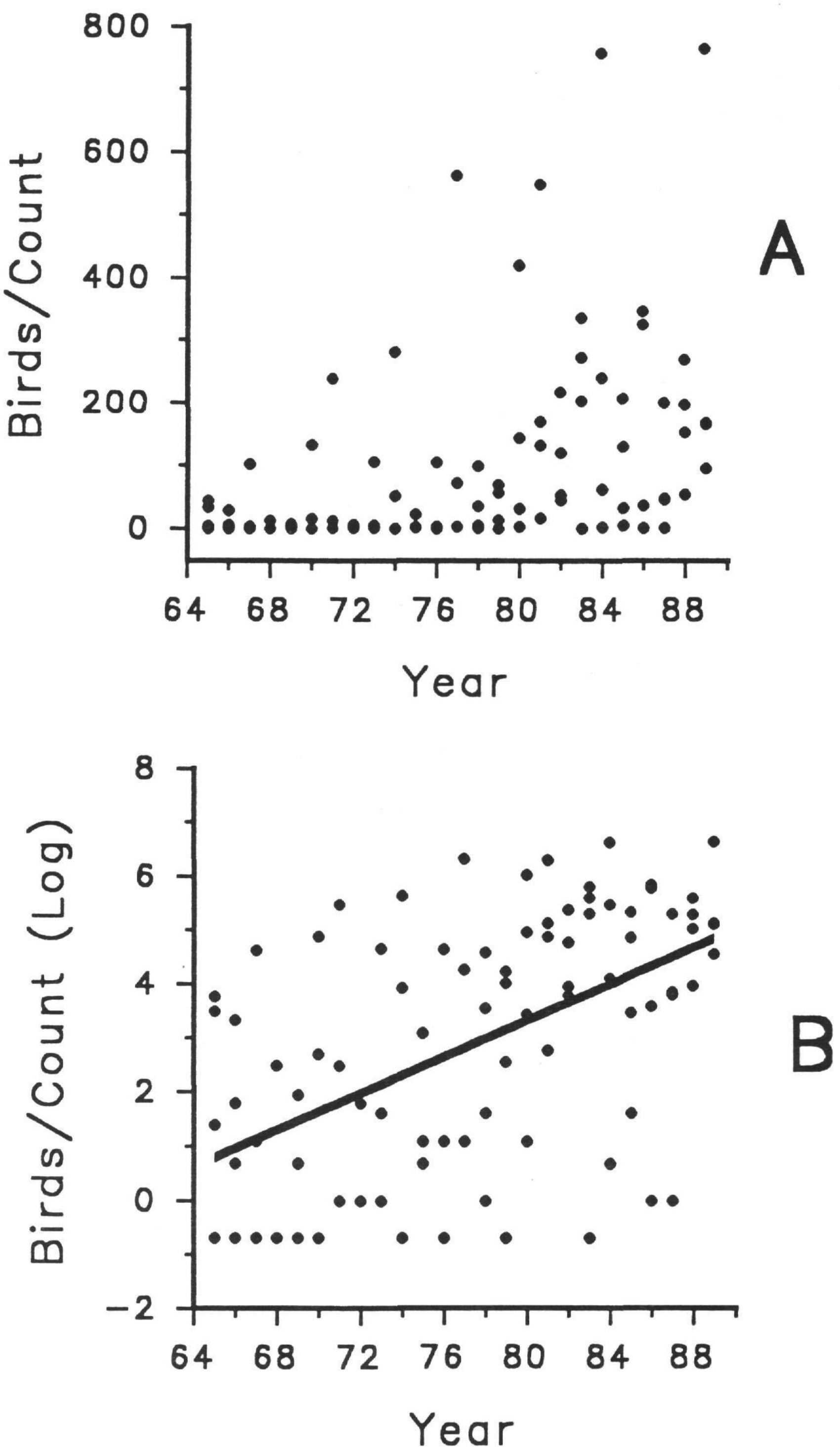


Figure IV.30. A. The number of mergansers spp. per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in mergansers from 1965 to 1989 during Christmas Bird Counts.

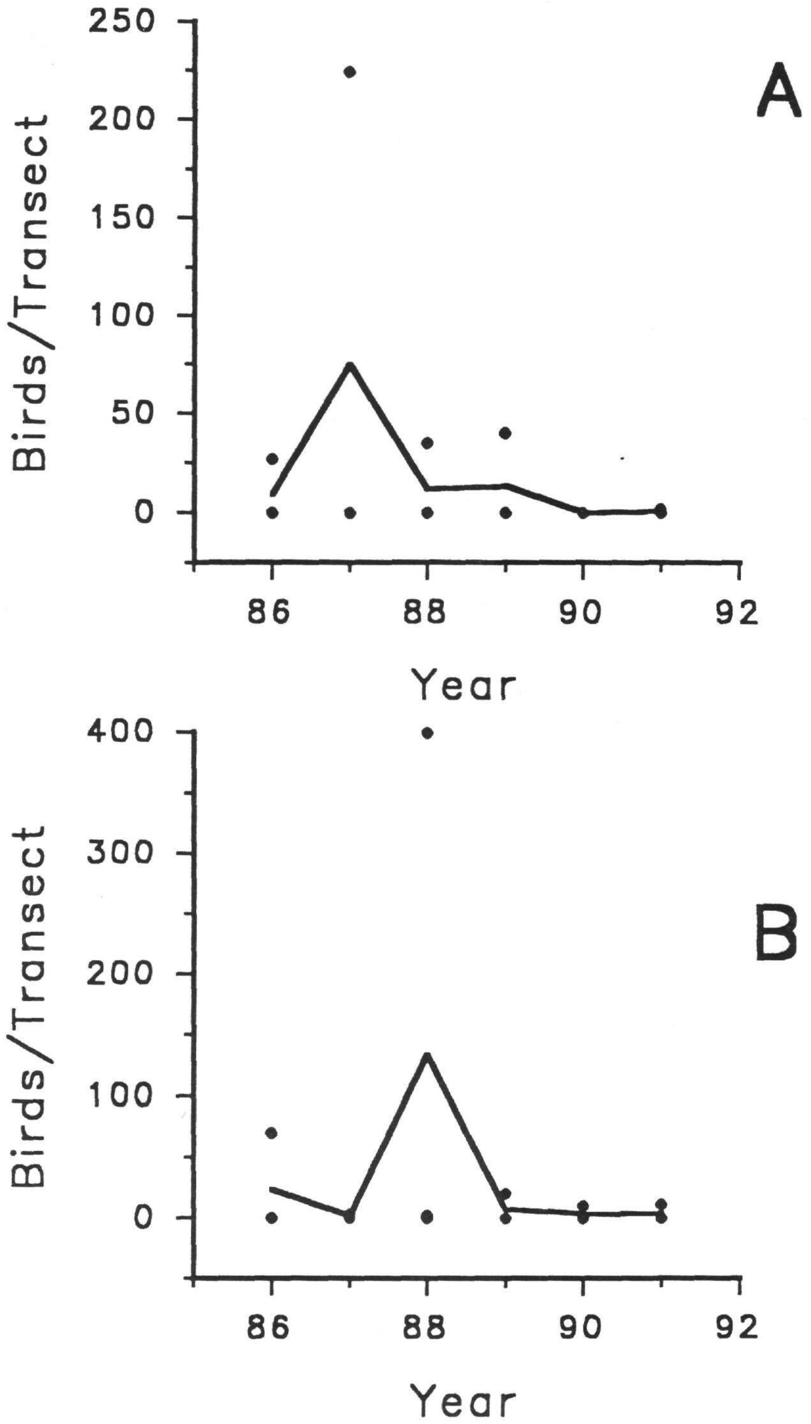


Figure IV.31. A. Individual counts and mean number of American wigeons per transect from 1986 to 1991 (N=18) during Mid-winter Waterfowl Transects. B. Individual counts and mean number of American coots per transect from 1986 to 1991 (N=18) during Mid-winter Waterfowl Transects.

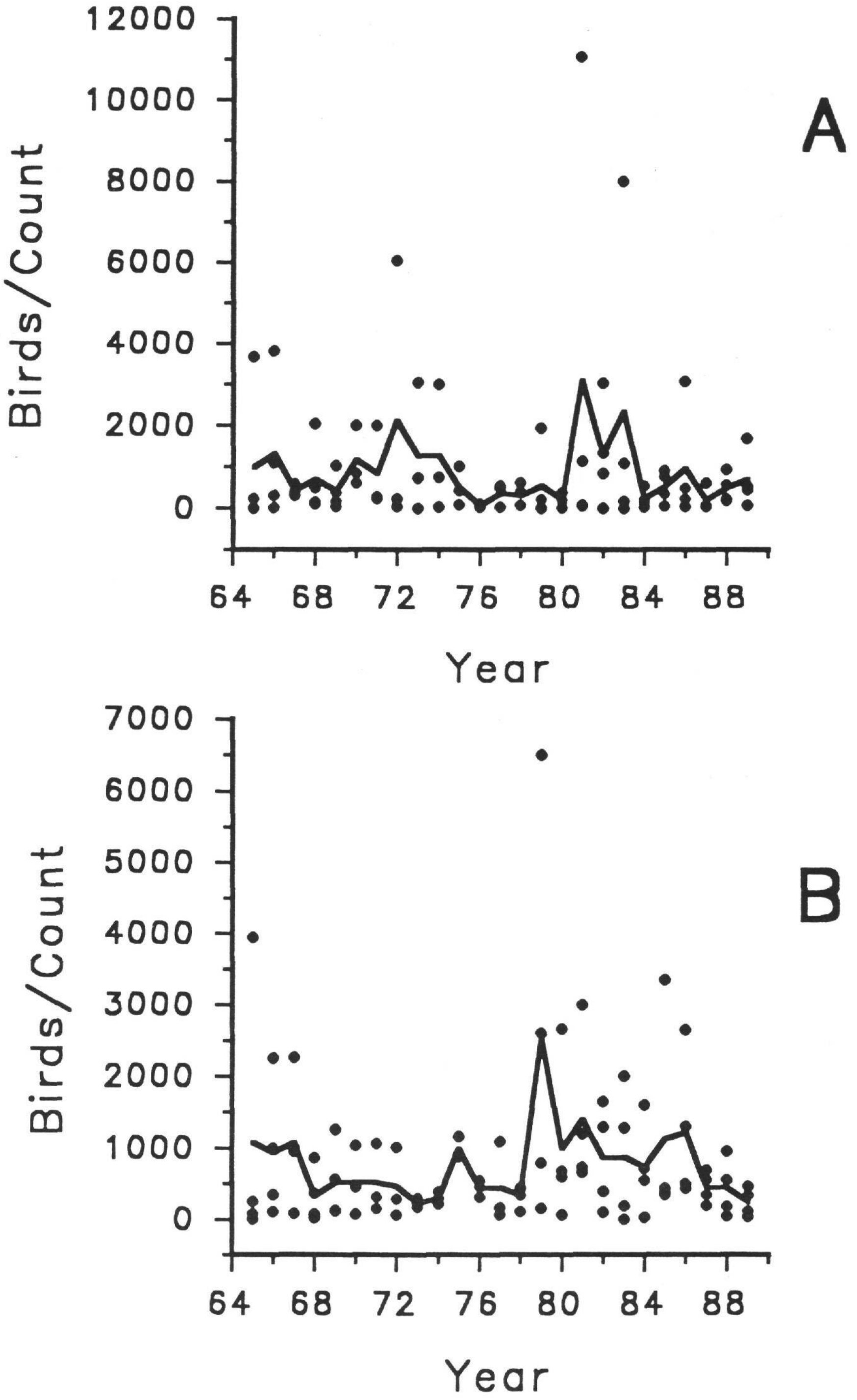


Figure IV.32. A. Individual counts and mean number of northern shovelers per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Individual counts and mean number of American coots per count (N=92) from 1965 to 1989 during Christmas Bird Counts.

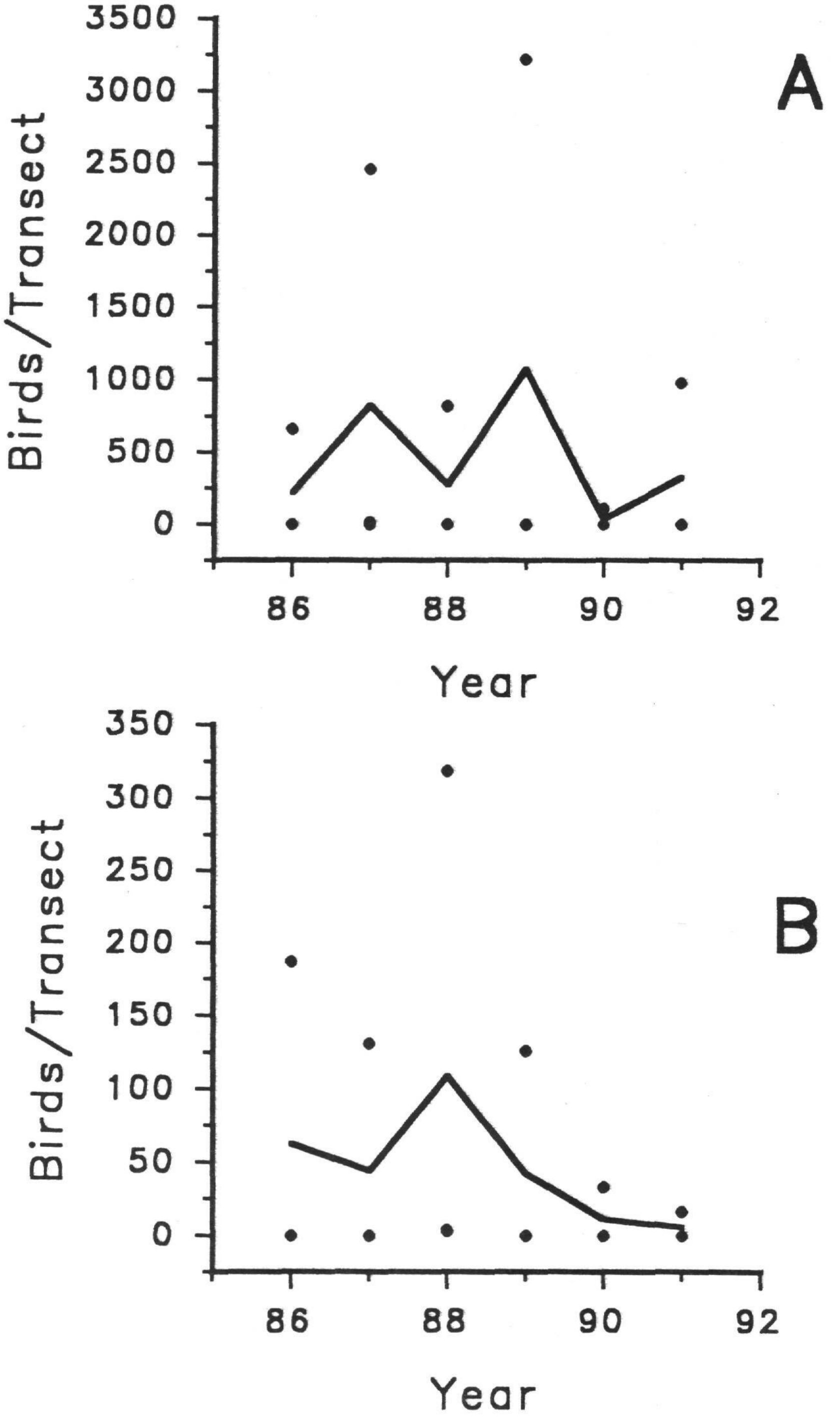
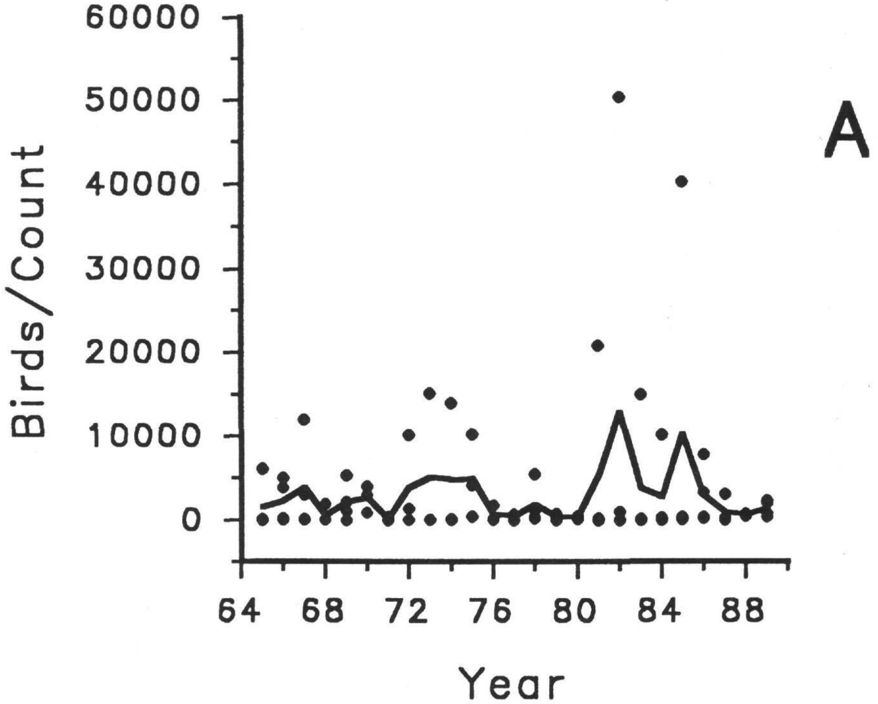


Figure IV.33. A. Individual counts and mean number of green-winged teal per transect from 1986 to 1991 (N=18) during Mid-winter Waterfowl Transects. B. Individual counts and mean number of mallards per transect from 1986 to 1991 (N=18) during Mid-winter Waterfowl Transects.



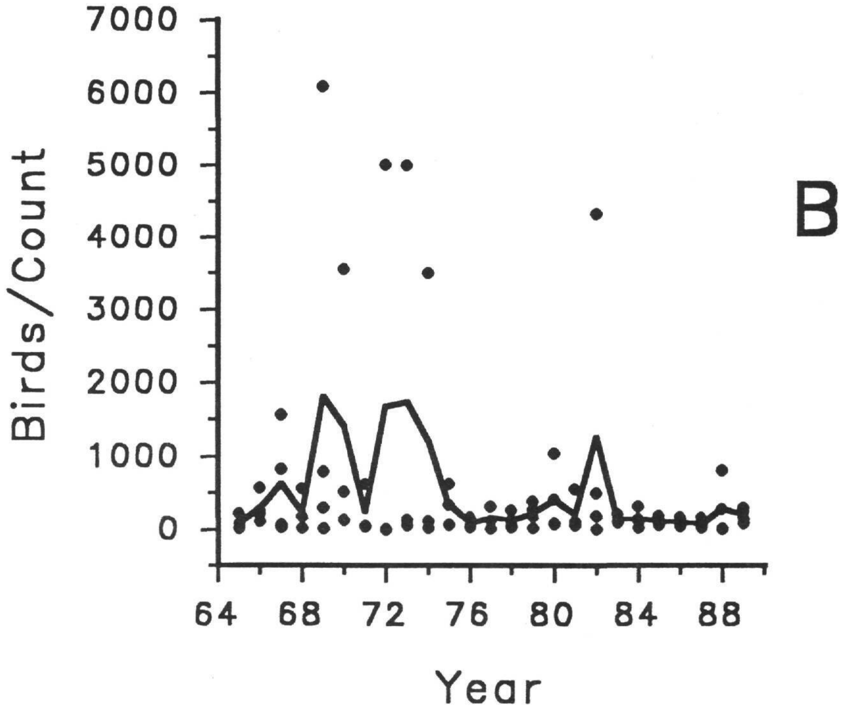


Figure IV.34. A. Individual counts and mean number of green–winged teal per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Individual counts and mean number of American wigeons per count (N=92) from 1965 to 1989 during Christmas Bird Counts.

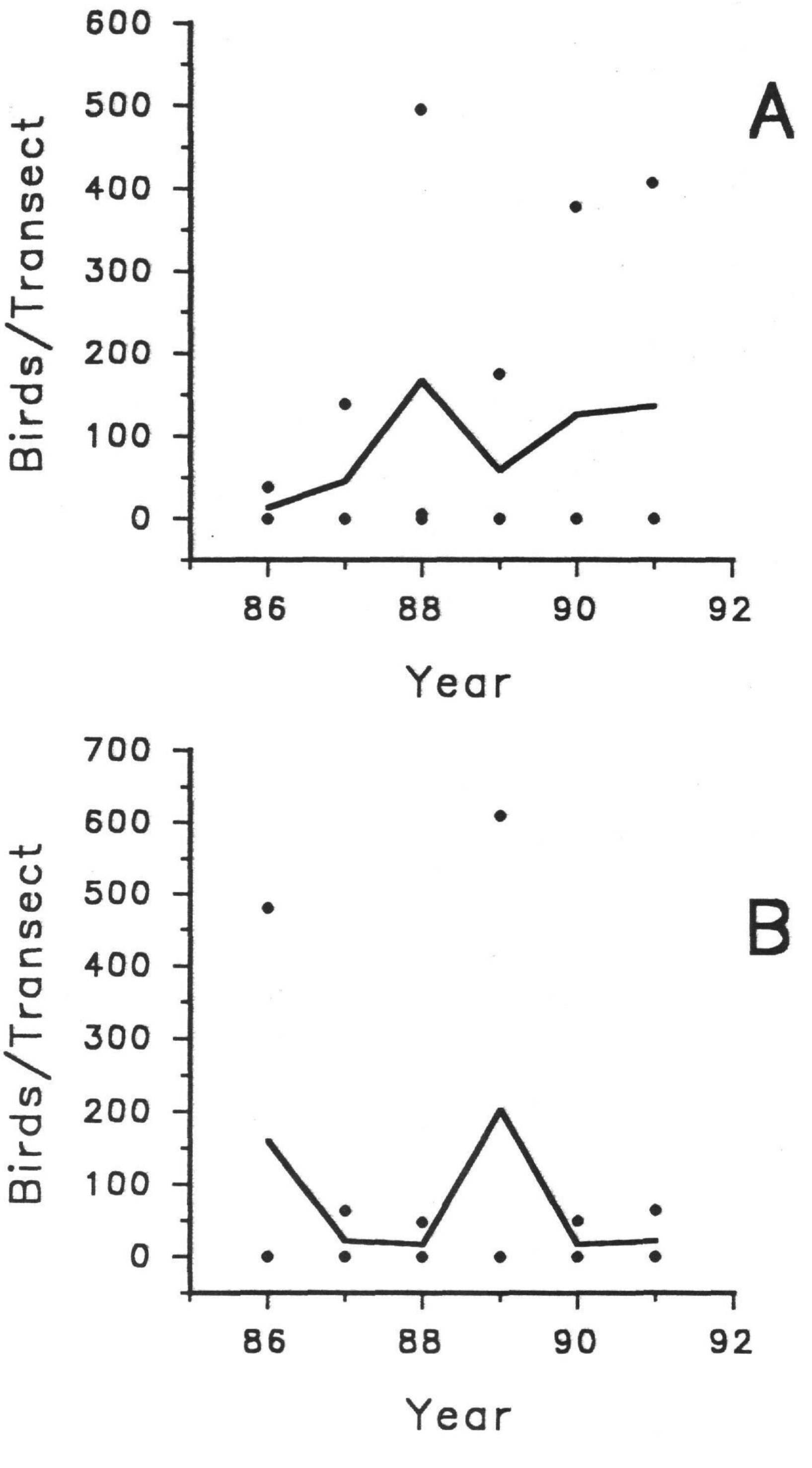


Figure IV.35. A. Individual counts and mean number of northern shovelers per transect from 1986 to 1991 (N=18) during Mid-winter Waterfowl Transects. B. Individual counts and mean number of gadwalls per transect from 1986 to 1991 (N=18) during Mid-winter Waterfowl Transects.

Table IV.16. Analysis of variance table for American coots.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Transects					
Model (log)	0.21	3	16.69	<0.001	
Transect		2	24.83	<0.001	
Year		1	0.42	0.527	-0.10
Year*Transect		2	0.24	0.790	
Christmas Bird Counts					
Model (log)	0.12	5	2.30	0.051	
Route		3	3.58	0.017	
Miles		1	6.80	0.011	
Year		1	0.47	0.497	0.01
Year*Route		3	5.74	0.001	

Table IV.17. Analysis of variance table for green-winged teal.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Transects					
Model (log)	0.93	3	62.69	<0.001	
Transect		2	93.47	<0.001	
Year		1	1.12	0.307	-0.15
Year*Transect		2	0.30	0.743	
Christmas Bird Counts					
Model (log)	0.30	4	9.36	<0.001	
Route		3	12.47	<0.001	
Year		1	0.15	<0.702	0.01
Year*Route		3	2.41	0.073	

Table IV.18. Analysis of variance table for northern shovelers.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Transects					
Model (log)	0.94	3	69.04	<0.001	
Transect		2	103.10	<0.001	
Year		1	0.93	0.350	0.11
Year*Transect		2	1.90	0.192	
Christmas Bird Counts					
Model (log)	0.36	4	12.49	<0.001	
Route		3	16.51	<0.001	
Year		1	0.35	0.554	-0.01
Year*Route		3	3.37	0.022	

Table IV.19. Analysis of variance table for American wigeons.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Transects					
Model (log)	0.71	3	11.39	<0.001	
Transect		2	15.48	<0.001	
Year		1	3.19	0.096	-0.30
Year*Transect		2	5.03	0.026	
Christmas Bird Counts					
Model (log)	0.13	5	2.65	0.028	
Route		3	3.71	0.014	
Miles		1	5.00	0.028	
Year		1	1.82	0.181	-0.03
Year*Route		3	1.07	0.366	

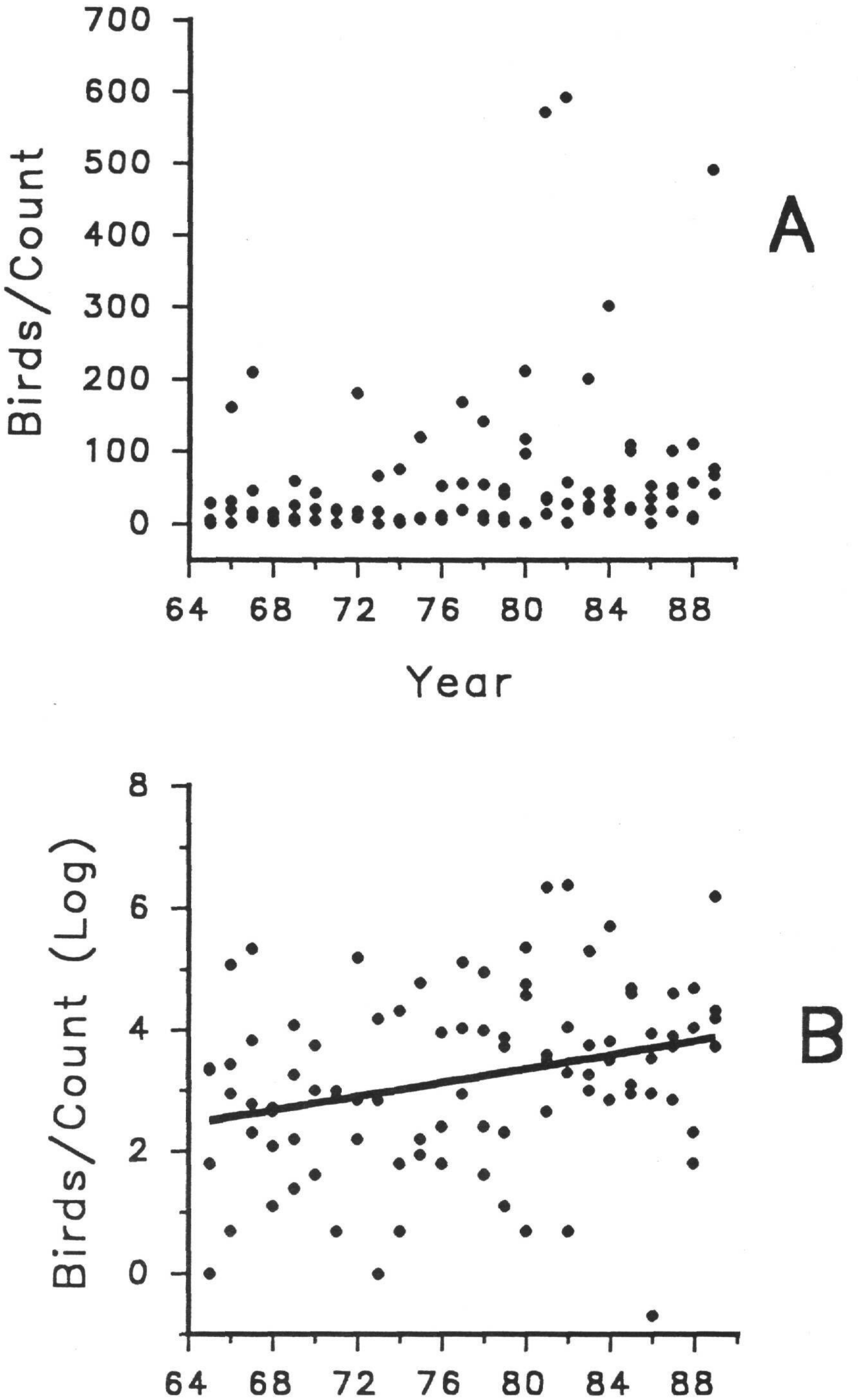


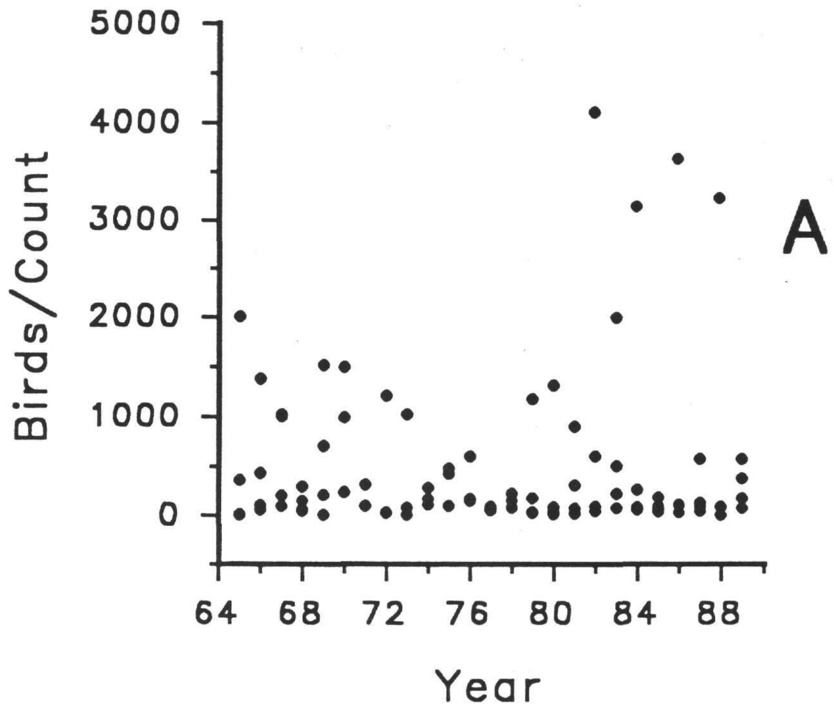
Figure IV.36. A. The number of mallards per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in mallards from 1965 to 1989 during Christmas Bird Counts.

Table IV.20. Analysis of variance table for mallards.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Transects					
Model (log)	0.90	3	43.01	<0.001	
Transect		2	63.09	<0.001	
Year		1	2.86	0.113	-0.20
Year*Transect		2	1.65	0.233	
Christmas Bird Counts					
Model (log)	0.30	4	9.42	<0.001	
Route		3	9.09	<0.001	
Year		1	12.60	<0.001	0.06
Year*Route		3	0.88	0.457	

Table IV.21. Analysis of variance table for gadwalls.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Transects					
Model (log)	0.95	3	84.78	<0.001	
Transect		2	126.83	<0.001	
Year		1	0.68	0.425	-0.08
Year*Transect		2	0.64	0.544	
Christmas Bird Counts					
Model (log)	0.30	6	5.95	<0.001	
Route		3	11.51	<0.001	
Miles		1	9.81	0.002	
Year		1	4.05	0.047	-0.95
$Year^2$		1	4.05	0.047	0.01
Year*Route		3	1.83	0.148	



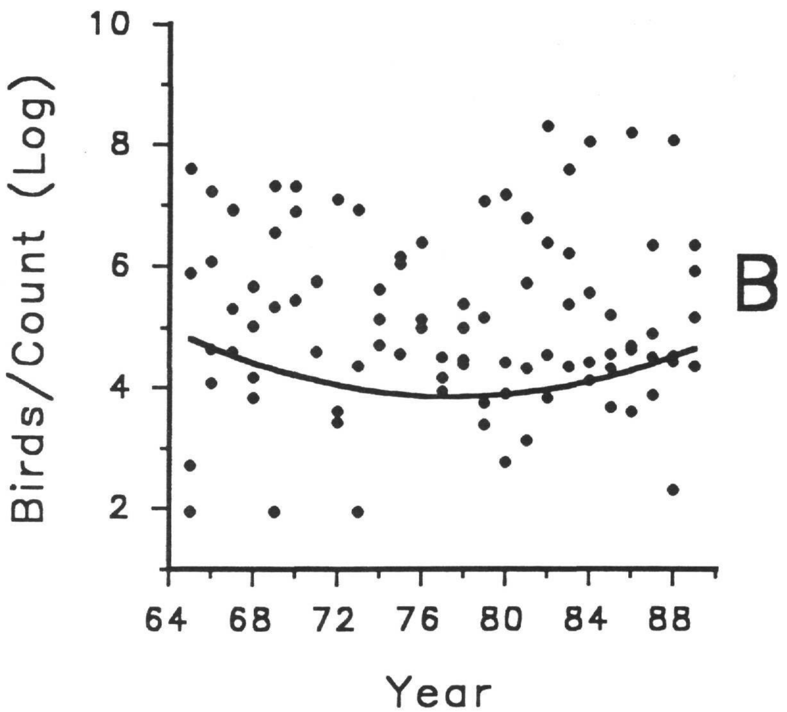


Figure IV.37. A. The number of gadwalls per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in gadwalls from 1965 to 1989 during Christmas Bird Counts.

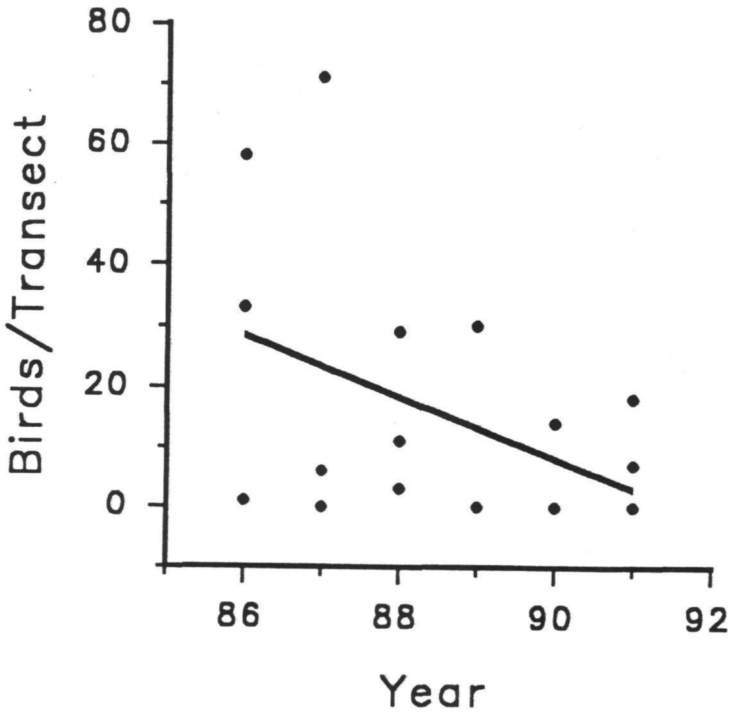
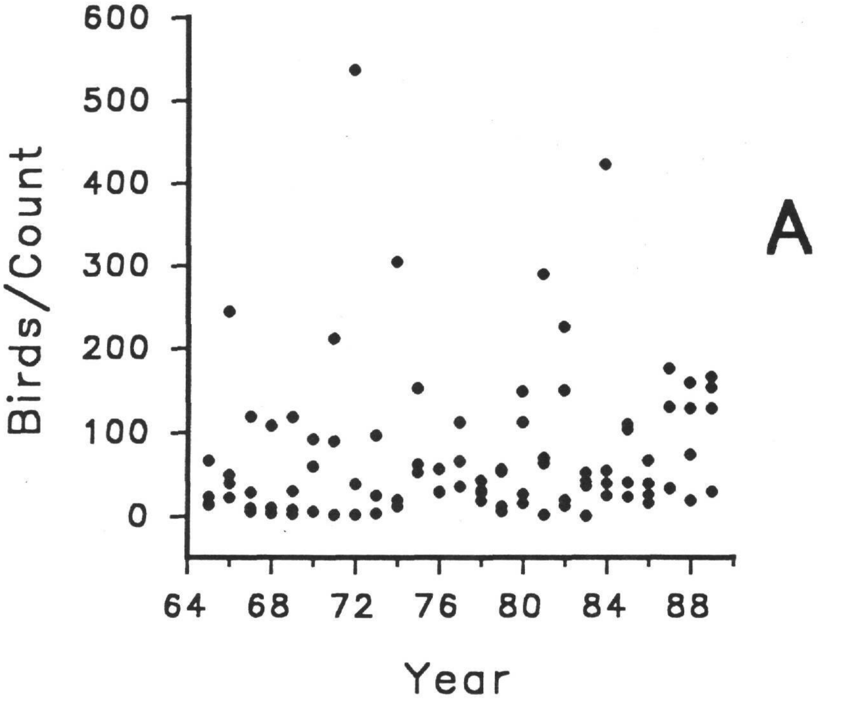


Figure IV.38. Individual counts and trend in mottled ducks from 1986 to 1991 (N=18) during Mid-winter Waterfowl Transects.

Table IV.22. Analysis of variance table for mottled ducks.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Transects					
Model	0.74	3	13.15	<0.001	
Transect		2	14.88	<0.001	
Year		1	9.68	0.008	-5.11
Year*Transect		2	5.44	0.021	
Christmas Bird Counts					
Model (log)	0.26	4	7.83	<0.001	
Route		3	8.30	<0.001	
Year		1	6.98	0.009	0.04
Year*Route		3	5.48	0.002	



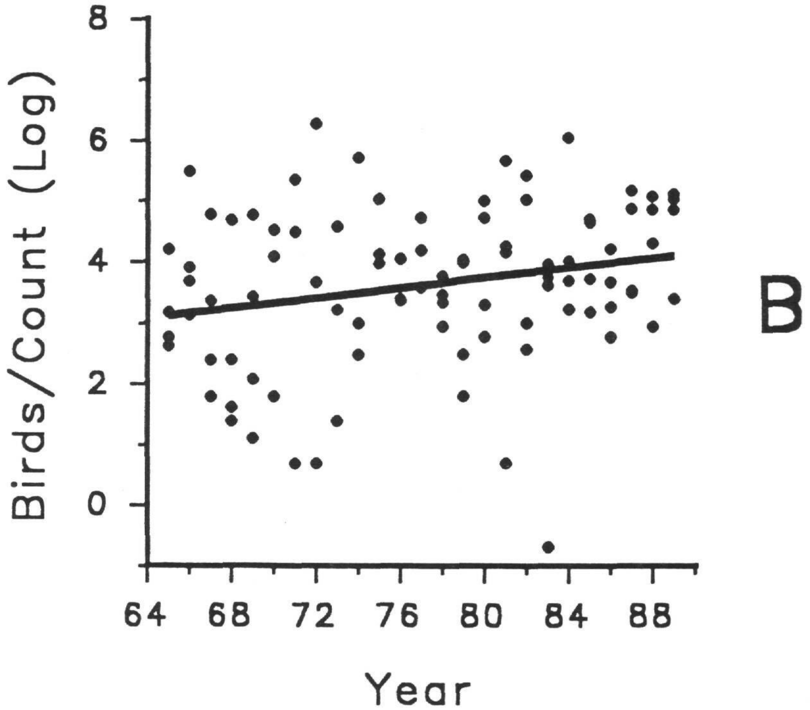


Figure IV.39. A. Number of mottled ducks per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in mottled ducks from 1965 to 1989 during Christmas Bird Counts.

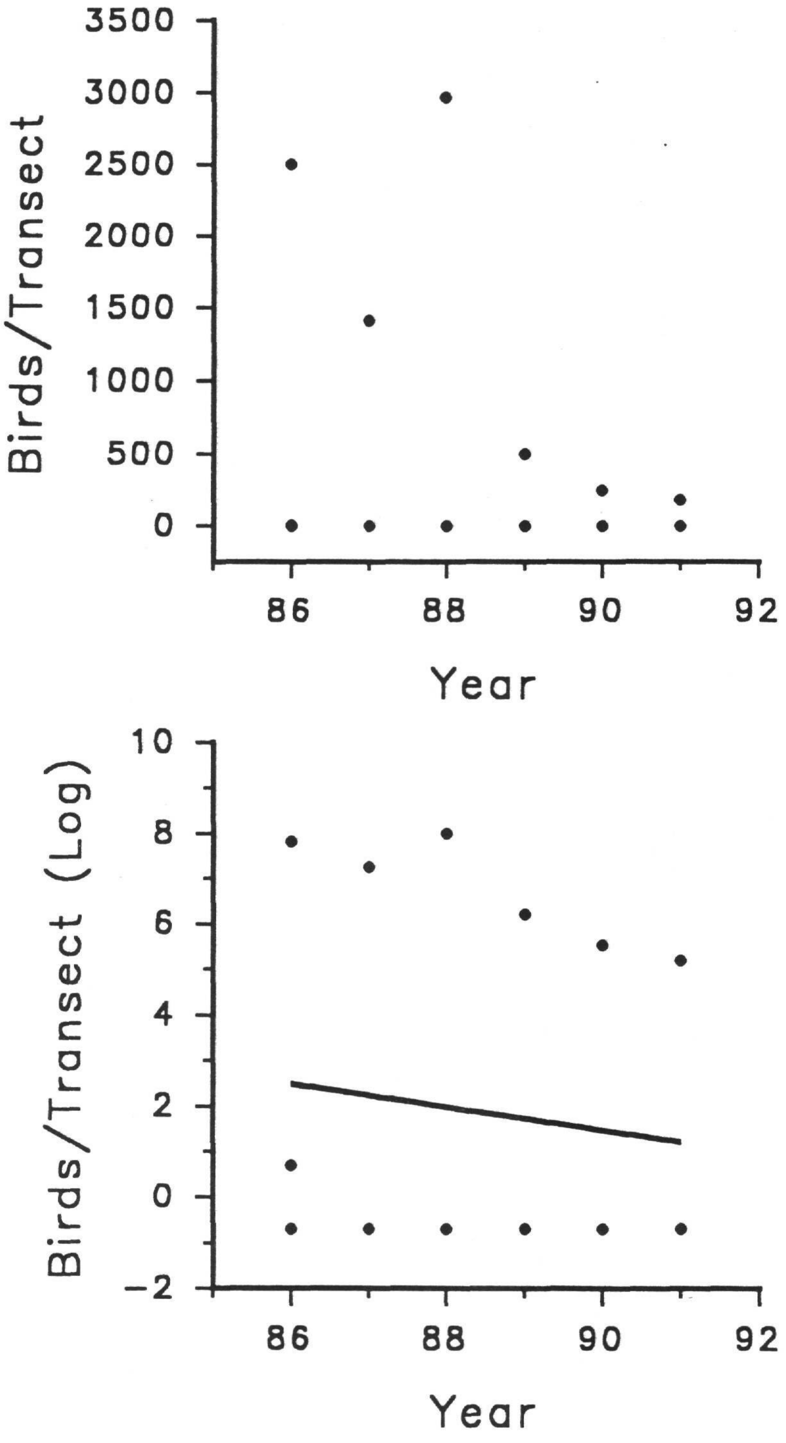


Figure IV.40. A. The numbers of northern pintails per transect from 1986 to 1991 (N=18) during Mid-winter Waterfowl Transects. B. Trend in northern pintails from 1986 to 1991 (N=18) during Mid-winter Waterfowl Transects.

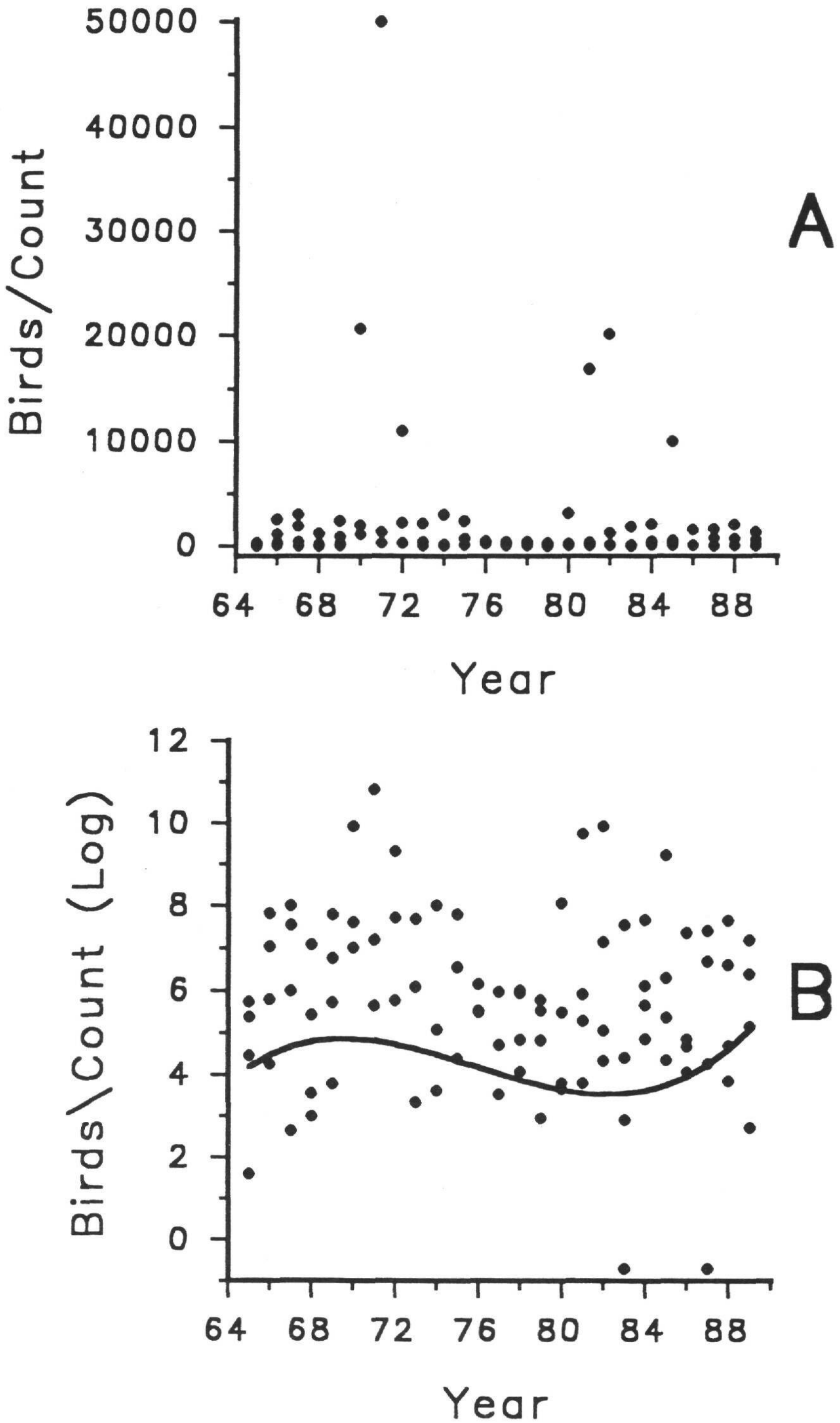


Figure IV.41. A. Number of northern pintails per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in northern pintails from 1965 to 1989 during Christmas Bird Counts.

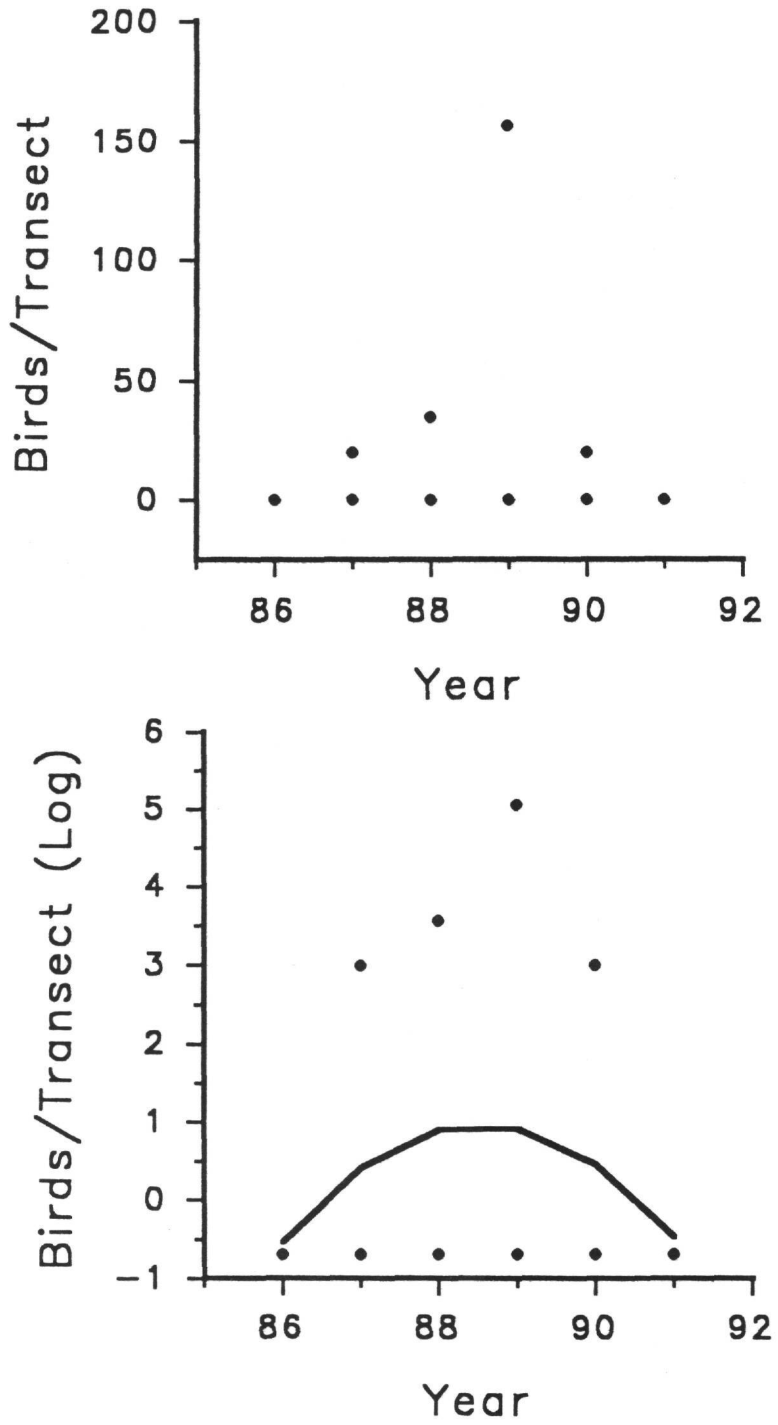


Figure IV.42. A. The numbers of blue−winged teal per transect from 1986 to 1991 (N=18) during Mid−winter Waterfowl Transects. B. Trend in blue−winged teal from 1986 to 1991 (N=18) during Mid−winter Waterfowl Transects.

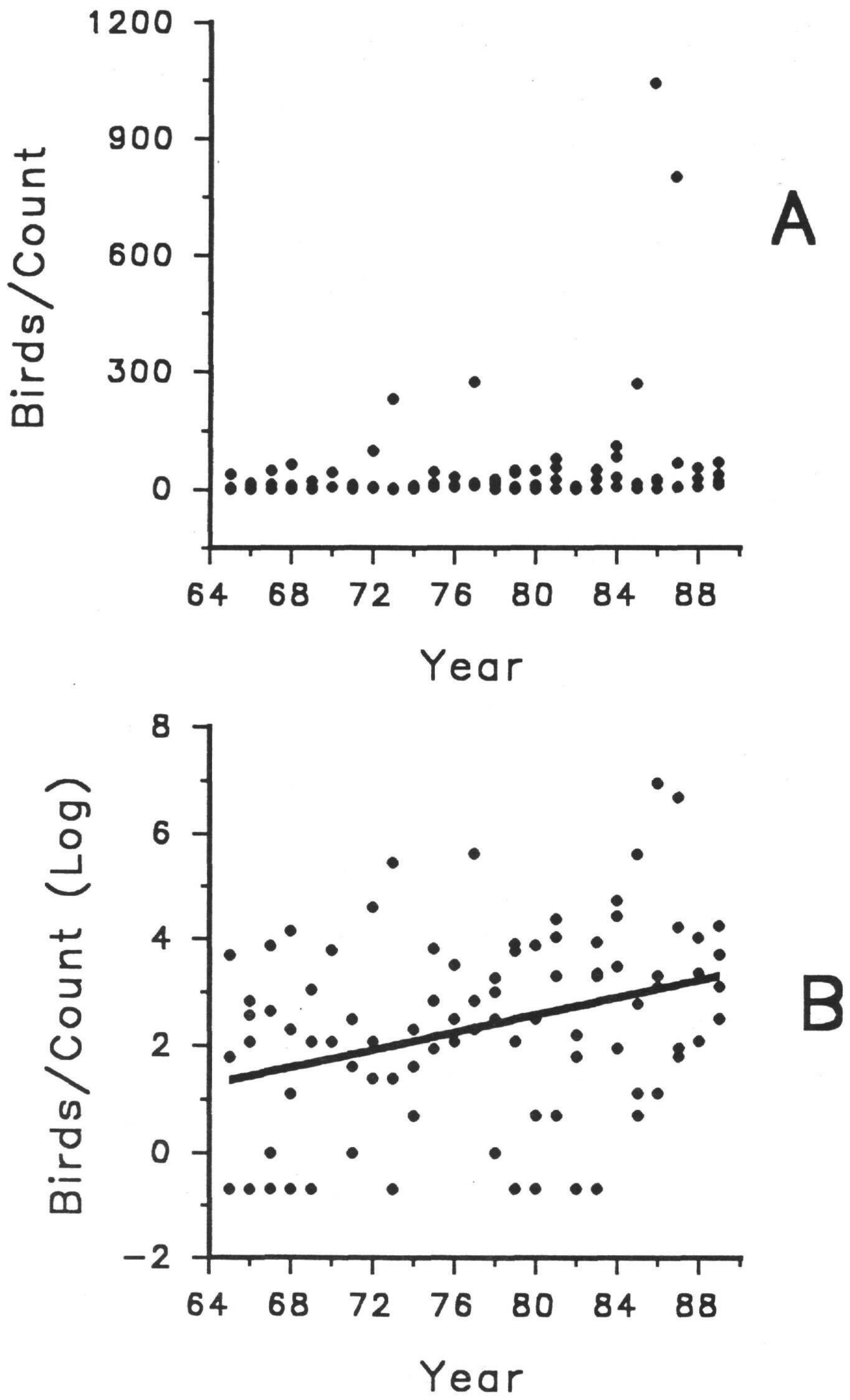


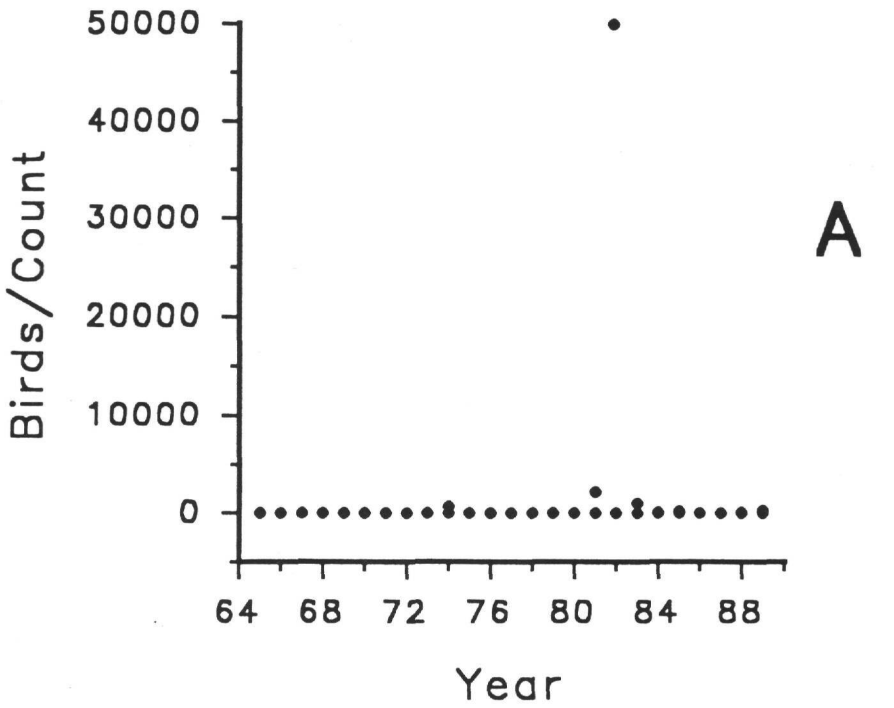
Figure IV.43. A. The number of blue−winged teal per count (N=92) from 1965 to 1989 during Christmas Bird Counts.
B. Trend in blue−winged teal from 1965 to 1989 during Christmas Bird Counts.

Table IV.23. Analysis of variance table for northern pintails.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Transects					
Model (log)	0.98	3	189.77	<0.001	
Transect		2	280.01	<0.001	
Year		1	9.30	0.008	-0.26
Year*Transect		2	7.93	0.006	
Christmas Bird Counts					
Model (log)	0.44	7	9.46	<0.001	
Route		3	19.32	<0.001	
Year		1	4.85	0.030	22.85
$Year^2$		1	5.02	0.028	-0.30
$Year^3$		1	5.16	0.026	0.00
Year*Route		3	1.26	0.293	

Table IV.24. Analysis of variance table for blue-winged teal.

	r^2	df	F	P	Parameter Estimate
Mid-winter Waterfowl Transects					
Model (log)	0.69	4	7.23	0.003	
Transect		2	11.43	0.001	
Year		1	6.07	0.029	49.89
$Year^2$		1	6.07	0.029	-0.28
Year*Transect		2	0.00	0.995	
Christmas Bird Counts					
Model (log)	0.37	4	12.74	<0.001	
Route		3	11.70	<0.001	
Year		1	14.72	<0.001	0.08
Year*Route		3	0.58	0.631	



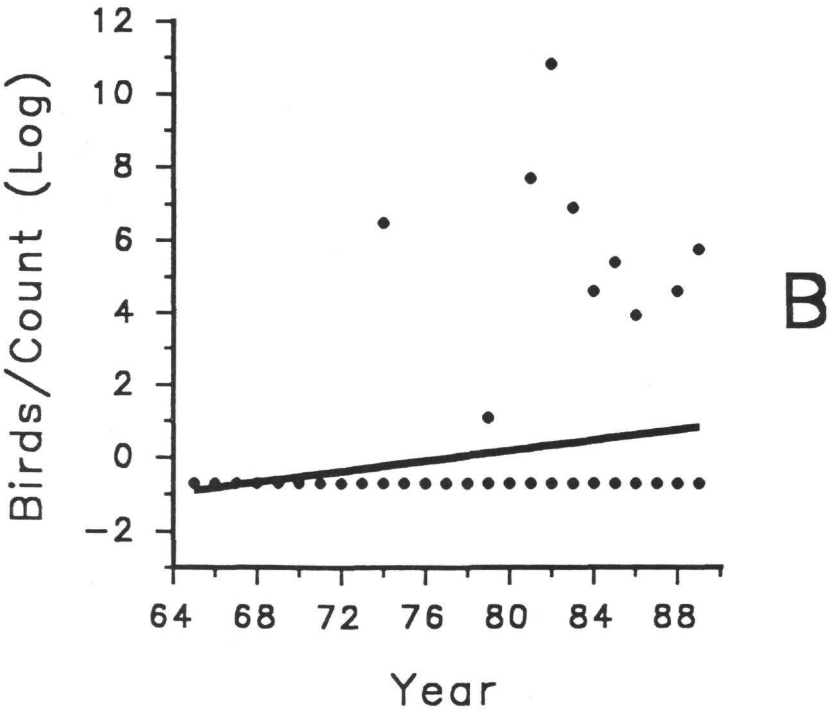


Figure IV.44. A. The number of scaup spp. per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in scaup spp. from 1965 to 1989 during Christmas Bird Counts.

Table IV.25. Analysis of variance table for scaup spp.

	r^2	df	F	P	Parameter Estimate
Christmas Bird Counts					
Model (log)	0.23	5	5.05	<0.001	
Route		3	2.22	0.092	
Miles		1	6.66	0.012	
Year		1	4.91	0.029	0.06
Year*Route		3	2.38	0.076	

Table IV.26. Analysis of variance table for ruddy ducks.

	r^2	df	F	P	Parameter Estimate
Christmas Bird Counts					
Model (log)	0.58	5	24.01	<0.001	
Route		3	12.45	<0.001	
Miles		1	3.85	0.054	
Year		1	3.79	0.055	0.05
Year*Route		3	1.41	0.246	

Table IV.27. Analysis of variance table for buffleheads.

	r^2	df	F	P	Parameter Estimate
Christmas Bird Counts					
Model (log)	0.65	5	32.55	<0.001	
Route		3	6.72	<0.001	
Miles		1	13.80	<0.001	
Year		1	33.69	<0.001	0.10
Year*Route		3	3.21	0.027	

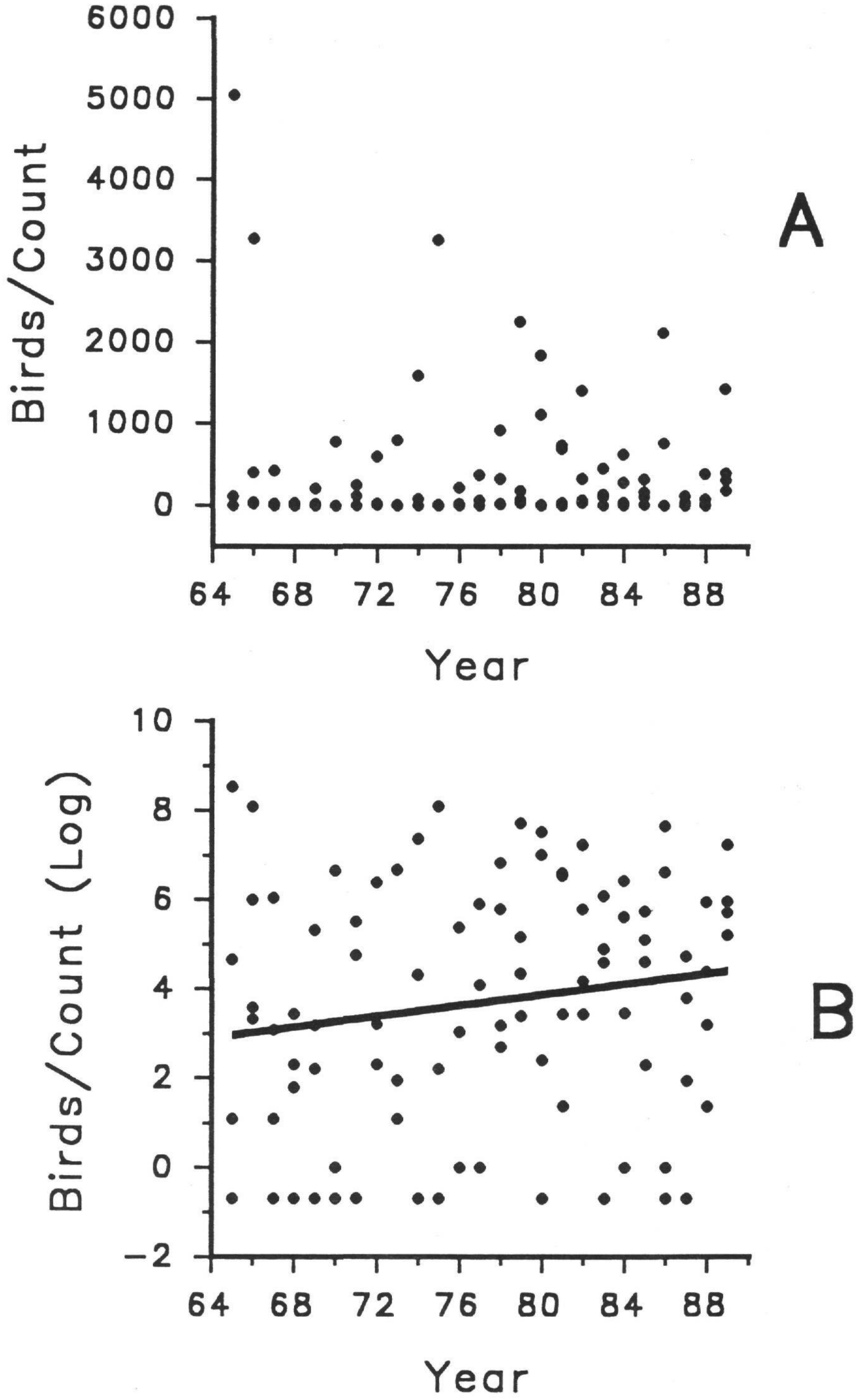


Figure IV.45. A. The number of ruddy ducks per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in ruddy ducks from 1965 to 1989 during Christmas Bird Counts.

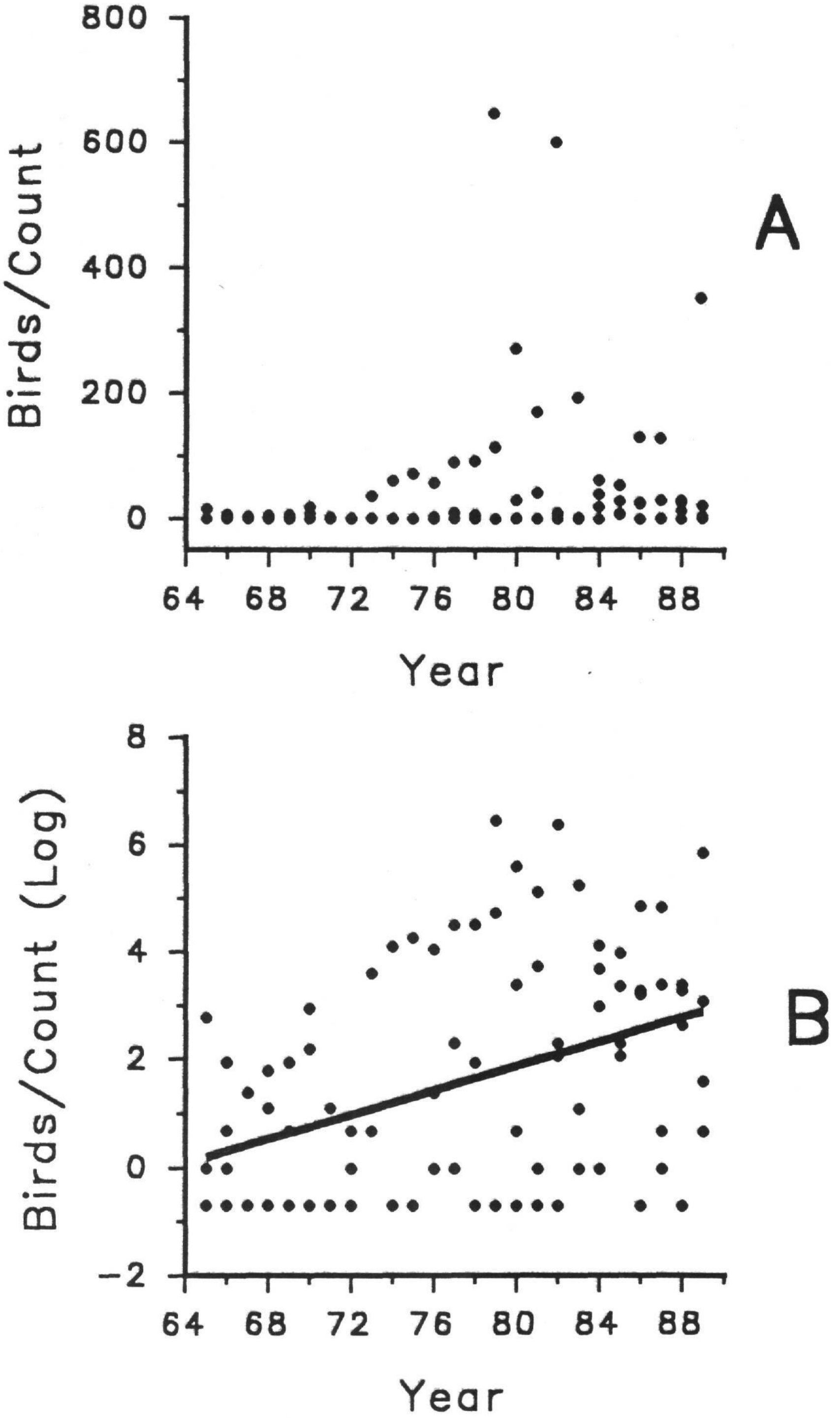


Figure IV.46. A. The number of buffleheads per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in buffleheads from 1965 to 1989 during Christmas Bird Counts.

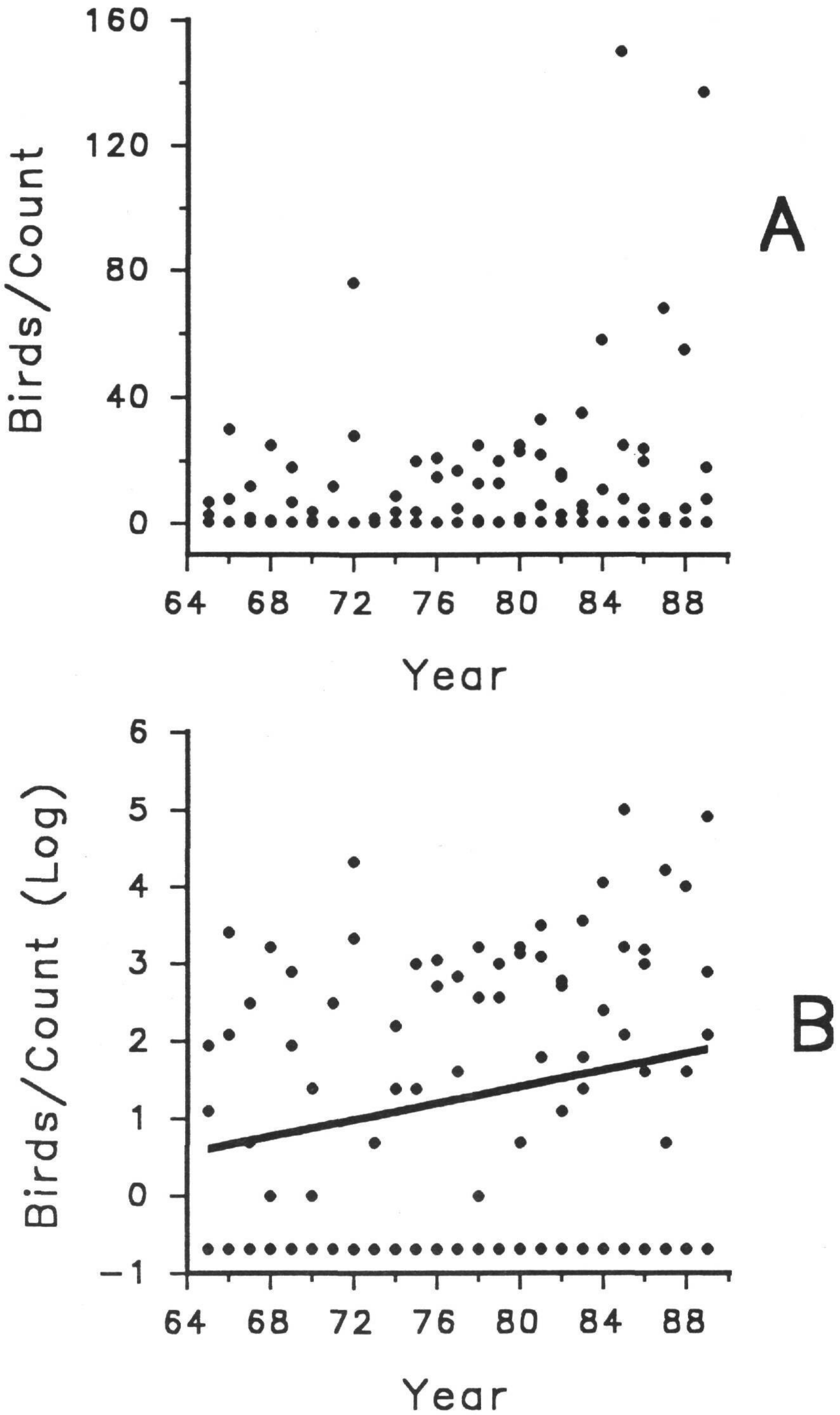


Figure IV.47. A. The number of wood ducks per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Trend in wood ducks from 1965 to 1989 during Christmas Bird Counts.

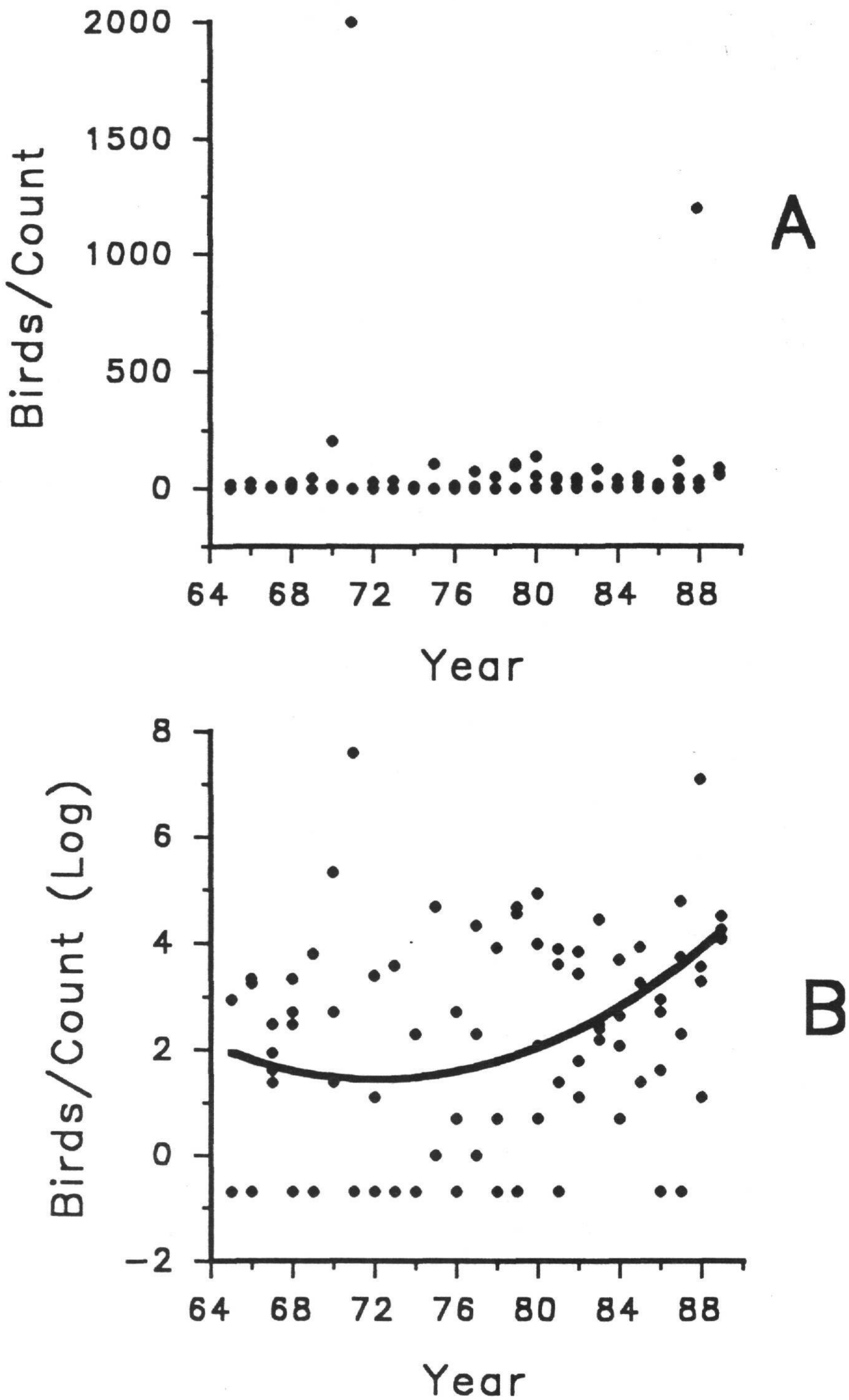


Figure IV.48. A. The number of ring-necked ducks per count (N=92) from 1965 to 1989 during Christmas Bird Counts.
B. Trend in ring-necked ducks from 1965 to 1989 during Christmas Bird Counts.

Table IV.28. Analysis of variance table for wood ducks.

	r^2	df	F	P	Parameter Estimate
Christmas Bird Counts					
Model (log)	0.73	5	49.69	<0.001	
Route		3	55.88	<0.001	
Miles		1	4.25	0.042	
Year		1	22.55	<0.001	0.06
Year*Route		3	9.93	<0.001	

Table IV.29. Analysis of variance table for ring-necked ducks.

	r^2	df	F	P	Parameter Estimate
Christmas Bird Counts					
Model (log)	0.33	6	7.07	<0.001	
Route		3	7.03	<0.001	
Miles		1	7.65	0.007	
Year		1	4.82	0.031	-1.42
$Year^2$		1	5.43	0.022	0.01
Year*Route		1	0.30	0.586	

Numbers of canvasbacks and fulvous whistling-ducks (Dendrocygna bicolor) did not vary significantly based on the CBC (Figures IV.49, IV.20; Tables IV.30, IV.31). Sightings of fulvous whistling-ducks were rare on the CBC and absent from the MWCC. The interaction between year and count-area was significant for canvasbacks based on the CBC. Satisfactory models of canvasback population trends could not be developed from the MWCC (Figure IV.52). Similarly, models could not be developed to adequately describe the variation in numbers of redheads from the MWCC or the CBC (Figure IV.49, IV.52).

Passerines

Numbers of red-winged blackbirds did not change significantly over the sampling period based on the North American Breeding Bird Survey; however, the interaction between year and routes was significant (Figure IV.50, Table IV.32).

Table IV.30. Analysis of variance table for canvasbacks.

	r^2	df	F	P	Parameter Estimate
Christmas Bird Counts					
Model (log)	0.24	5	5.31	<0.001	
Route		3	6.83	<0.001	
Miles		1	12.69	<0.001	
Year		1	1.41	0.238	-0.03
Year*Route		3	2.70	0.051	

Table IV.31. Analysis of variance table for fulvous whistling ducks.

	r^2	df	F	P	Parameter Estimate
Christmas Bird Counts					
Model (log)	0.14	4	3.44	0.012	
Route		3	3.84	0.012	
Year		1	2.52	0.116	0.01
Year*Route		3	2.53	0.063	

Table IV.32. Analysis of variance table for red-winged blackbirds.

	r^2	df	F	P	Parameter Estimate
North American Breeding Bird Survey					
Model	0.21	2	4.23	0.024	
Route		1	4.82	0.036	
Year		1	0.83	0.370	0.09
Year*Route		1	5.86	0.022	

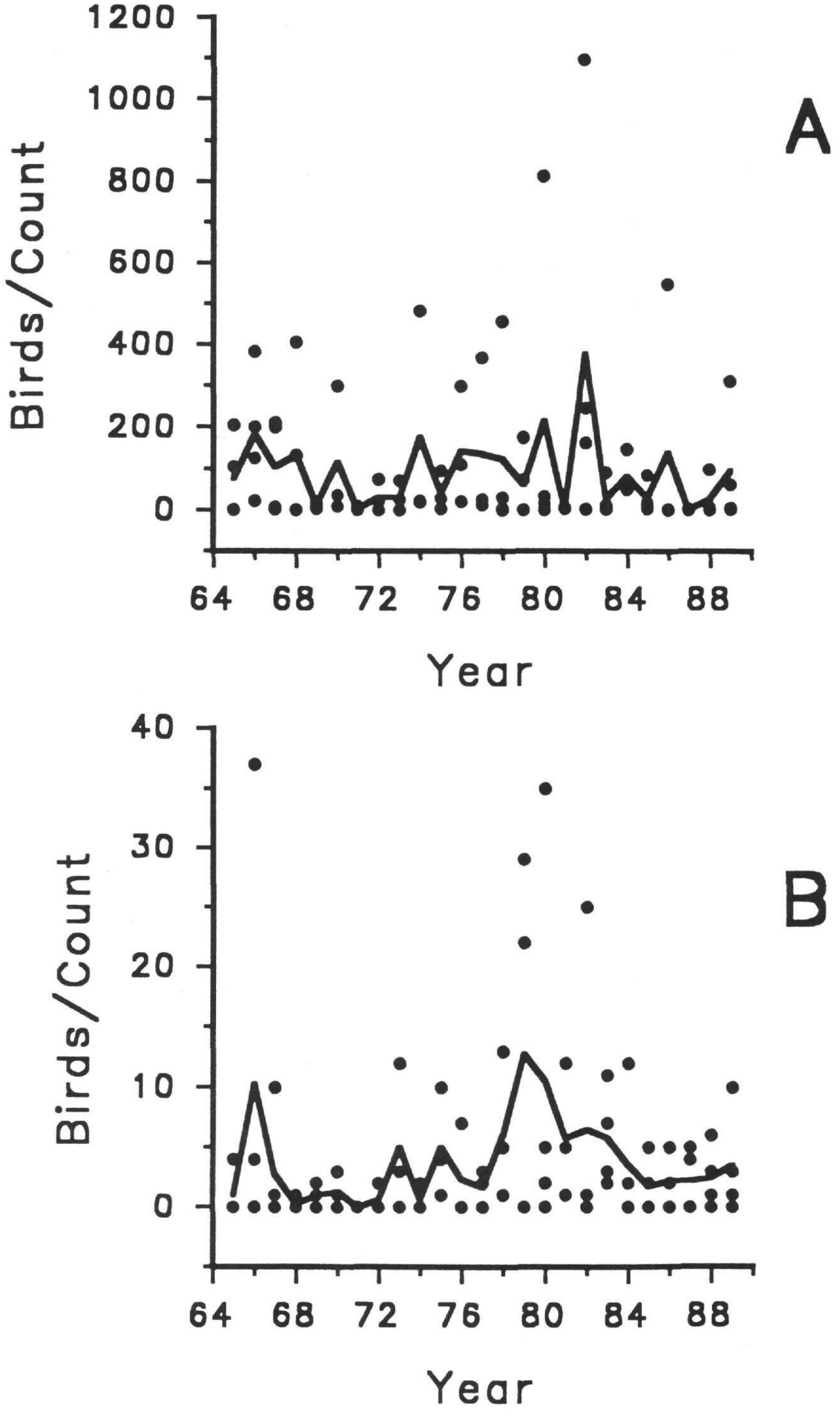
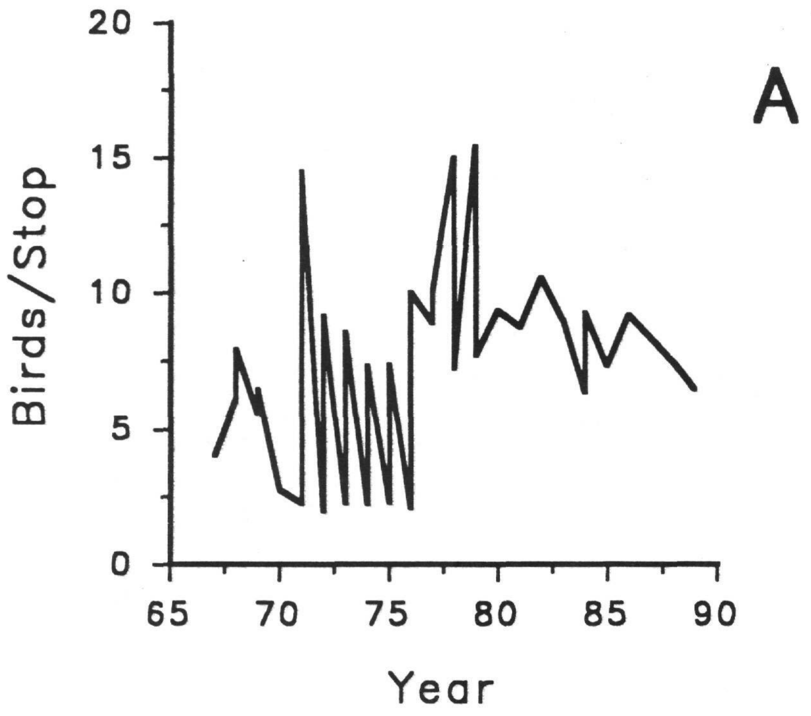


Figure IV.49. A. Individual counts and mean number of canvas-backs per count (N=92) from 1965 to 1989 during Christmas Bird Counts. B. Individual counts and mean number of redheads per count (N=92) from 1965 to 1989 during Christmas Bird Counts.



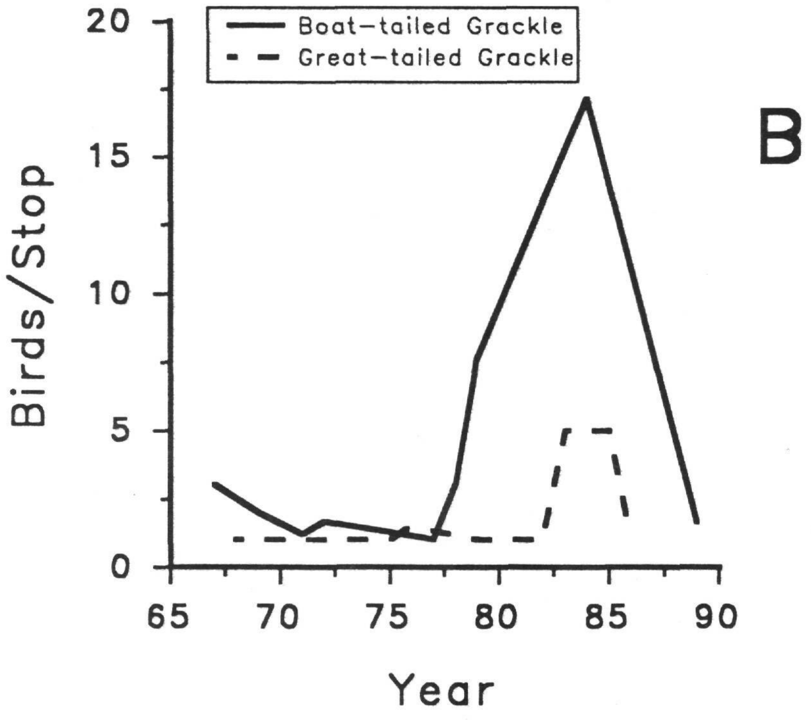


Figure IV.50. A. Mean numbers of red-winged blackbirds per stop (N=33) from 1967 to 1989 during North American Breeding Bird Surveys. B. Mean numbers of boat-tailed and great-tailed grackles per stop (N=9) from 1967 to 1989 during North American Breeding Bird Surveys.

No models were developed to adequately describe the variation in counts of great-tailed grackles and boat-tailed grackles among years based on the North American Breeding Bird Survey (Figure IV.50).

Alligators

Night-counts of alligators from 1971-1984 indicated a curvilinear increase in numbers with the lowest counts occurring in the late 1970s (Figure IV.51, Table IV.33). The interaction between year and location was significant. Satisfactory models could not be developed to explain the variation in numbers of nests from 1979-1983; however, night-counts of alligators over this same period indicated stable numbers (Figure IV.51, Table IV.33).

DISCUSSION

Data set validity

The usefulness of data sets for monitoring selected vertebrate resources in the Galveston Estuary area was dependent primarily on the sampling design, sampling consistency among years, temporal coverage, and spatial coverage.

Table IV.33. Analysis of variance table for American alligators.

	r^2	df	F	P	Parameter Estimate
Alligator Night Counts (1979-83)					
Model (log)	0.61	3	5.72	0.013	
Route		2	6.56	0.013	
Year		1	4.06	0.069	5.60
Year*Route		2	6.64	0.017	
Alligator Night Counts (1971-84)					
Model (log)	0.52	4	9.56	<0.001	
Route		2	13.78	<0.001	
Year		1	9.93	0.003	-87.41
$Year^2$		1	10.06	0.003	0.57
Year*Route		2	6.13	0.005	

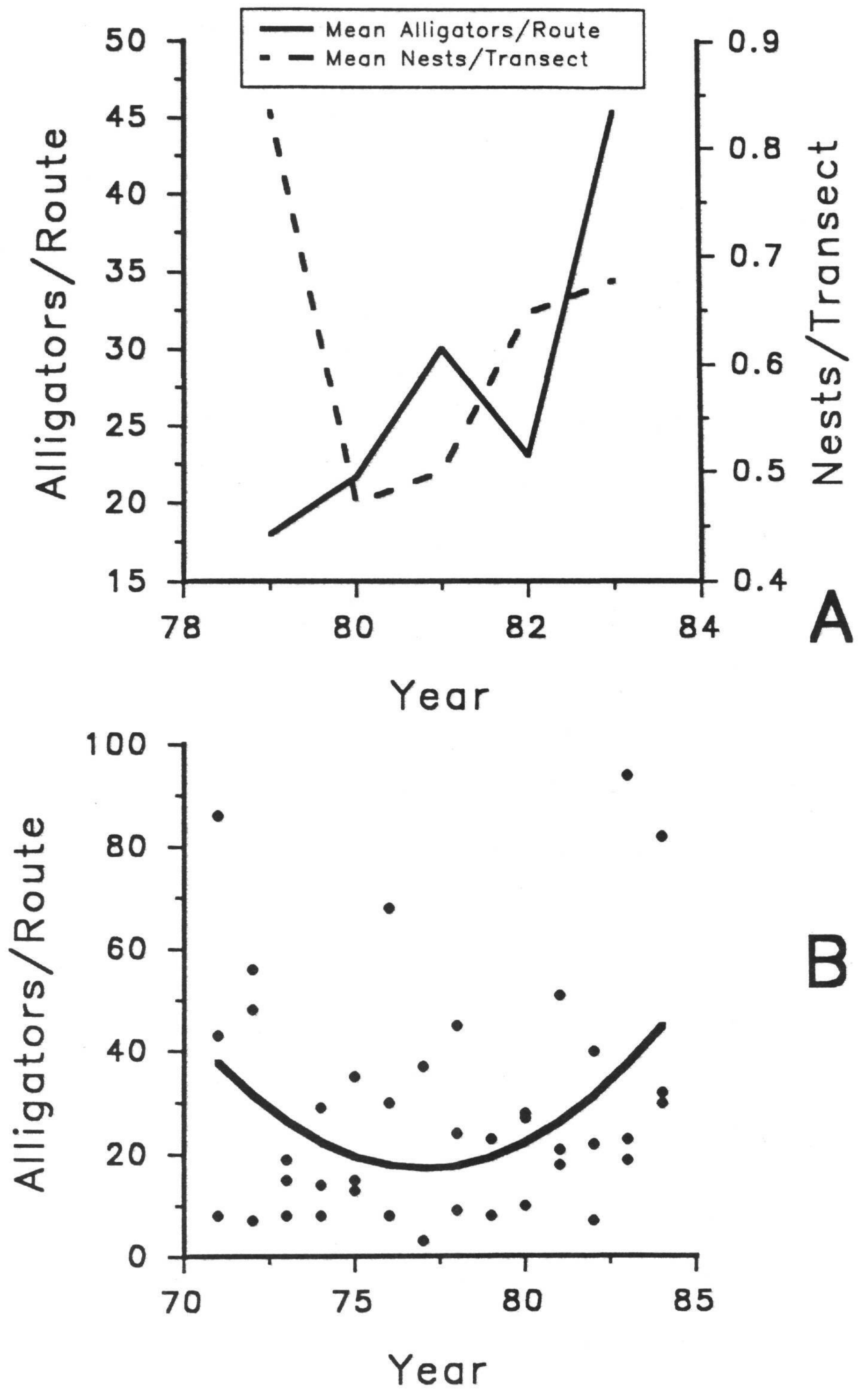


Figure IV.51. A. Number of alligators per route and alligator nests per transect from 1979 to 1983 during Alligator Surveys. B. Trend in alligators per route from 1971 to 1984 during Alligator Surveys.

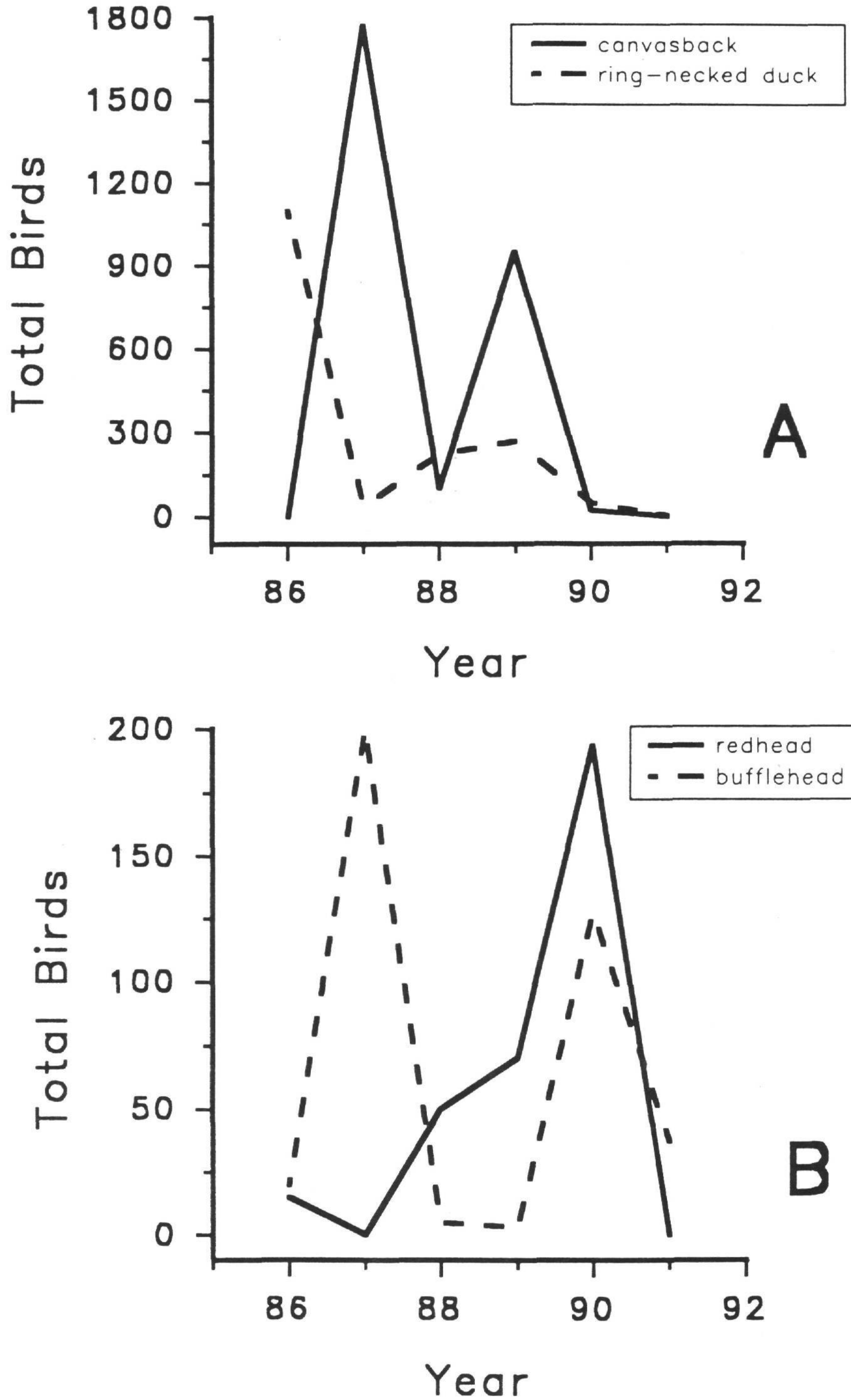


Figure IV.52. A. Total number of canvasbacks and ring-necked ducks from 1986 to 1991 (N=6) during Mid-winter Waterfowl Cruise Counts. B. Total number of redheads and buffleheads from 1986 to 1991 (N=6) during Mid-winter Waterfowl Cruise Counts.

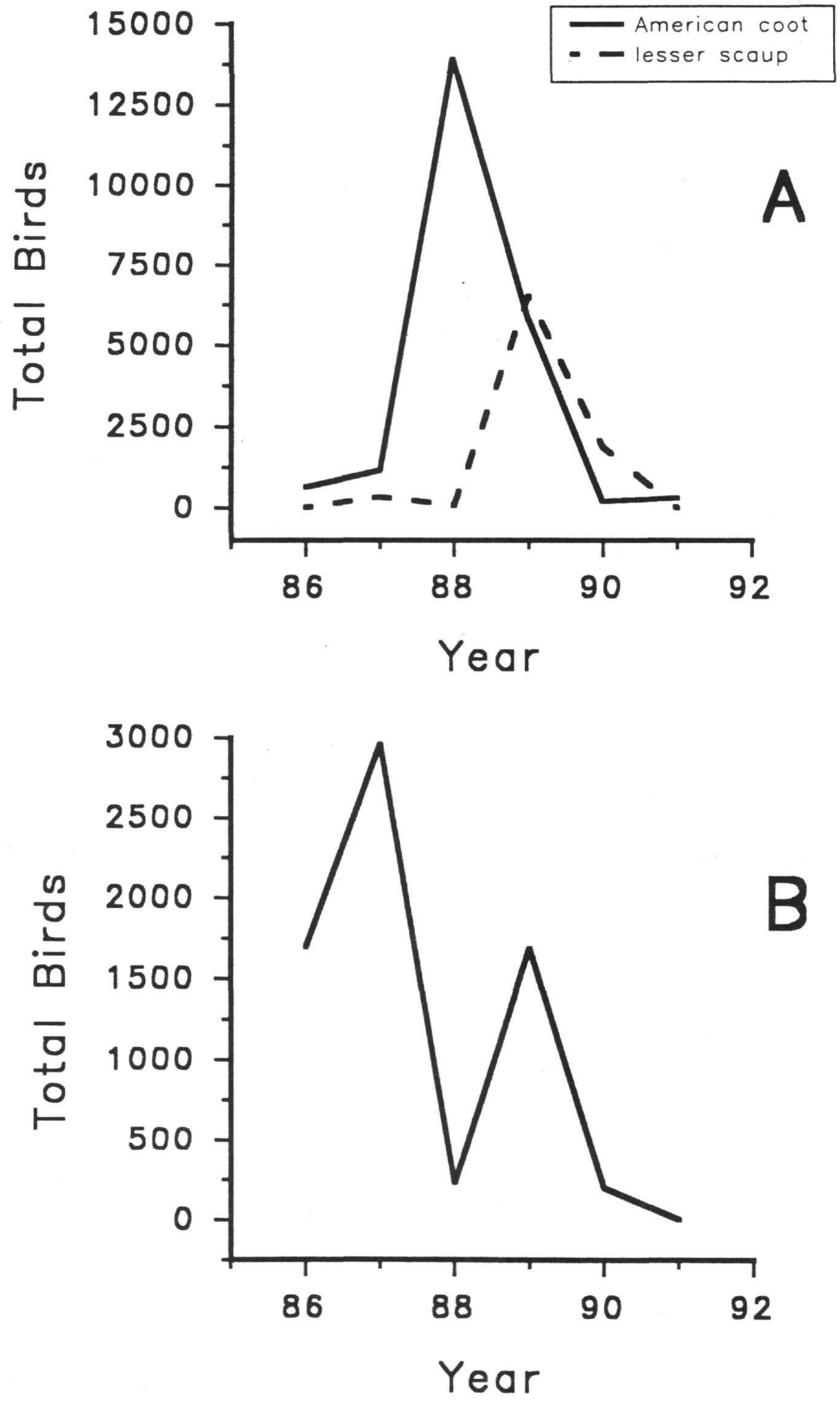


Figure IV.53. A. Total number of lesser scaups and American coots from 1986 to 1991 (N=6) during Mid-winter Waterfowl Cruise Counts. B. Total number of ruddy ducks from 1986 to 1991 (N=6) during Mid-winter Waterfowl Cruise Counts.

The sampling design of the TCWS is moderately systematic but does not include a measure of observer effort. Therefore variation due to observer effort cannot be accounted for with statistical models. However, if the variation in sampling effort is low among years, including it in analyses may do little to increase the models' antecedent performance. The TCWS was conducted by experienced participants in the same manner throughout the sampling period, and it provided adequate temporal and spatial coverage of all nesting colonial waterbirds. The ephemeral nature of colonies and the tendency of some colonies to shift within the Galveston Estuary did not allow the analyses conducted in this study to isolate and account for spatial distributions of colonial waterbirds. However, because the TCWS provided information on colonies as sampling units, analyses of colony attributes as well as bird numbers were possible. This added information on colony structure complemented observed changes in species populations and may be valuable for future monitoring.

Despite the highly systematic nature of the North American Breeding Bird Survey, consistency among years, and adequate temporal coverage, it was not appropriate for monitoring changes in bird populations of the Galveston Estuary. This was due to the limited contact between the survey routes and the marine system, thereby resulting in few sightings of birds associated with the Galveston Estuary.

The two sampling schemes included within the Mid-winter Waterfowl Survey differed in their usefulness as annual indices. The MWT was conducted in a consistent manner each year with qualified people surveying the same pre-established routes. This systematic sampling scheme resulted in data with little extraneous variation. Reducing unwanted variation through design and consistent sampling, rather than statistical force, produced more reliable models. The primary weakness of the MWT was that all data from this survey were difficult to obtain and data prior to 1986 were completely unavailable. If data were available for the years prior to 1986, the MWT would be a more valuable source for monitoring waterfowl of the Galveston Estuary. Conversely, the MWCC was difficult to analyze and provided little information about waterfowl in the open waters of the Estuary. Difficulties with the MWCC resulted from lack of a systematic sampling scheme and a defined measure of unit effort for given locations. As with the MWT, the data from the MWCC were not available for all years of the survey.

The long temporal coverage of the CBC provided a unique opportunity to evaluate long-term changes in bird populations. The CBC also included measures of observer effort for specific count-locations which could be accounted for in statistical models even though observer effort varied. Although it was possible to include variation due to count-area and observer effort in all models, other sources of variation could not be explained. All CBC participants are volunteers and most are amateur bird watchers rather than scientists. CBC participation nationwide is increasing (Butcher 1990). Likewise, participant bird-identification skills are improving because of better optical equipment, field guides, and identification tips (Butcher 1990). Although the CBC count-areas include approximately the same area each year, observers can vary coverage within an area by concentrating on better habitats. Similarly, as habitats are lost at an increasing rate, birds may become concentrated in the remaining habitats. As a result of these inherent biases, the CBC is probably most useful for examining trends over large areas with many count-areas (Bock and Root 1981). However, for the Galveston Estuary area, the CBC provided easily accessible data over a long time period, and it offered corroborative evidence of trends based on other data sets.

The Bolivar Flats Shorebird Surveys were readily available and were in a form conducive to data analysis. The multiple surveys conducted each year increased the reliability of annual population estimates, and because surveys were always conducted in the same area, there was no bias due to location. The most significant weakness of the survey was that it covered a small geographic area; therefore, it did not provide information on spatial distributions of birds of the Galveston Estuary. Hence, changes in populations of species cannot be tied to system-wide enhancements or deteriorations of habitat quality. Further, surveys were conducted at irregular intervals throughout the year which increased unwanted temporal sampling biases and reduced the power of models. Some of this variation was accounted for by treating seasons as blocks.

The survey design of the Alligator Nest Count allowed data to be collected in a systematic fashion with the same annual observer effort and geographic coverage. The primary problem in analyzing this survey was that the number of transects varied among years. Variation among years was considered in the analyses by standardizing for the number of transects flown. However, information about individual transects was consequently obscured and the number of sample values was reduced to one per year. More reliable indices could be developed by sampling the same transects each survey. The alligator night-count survey provided information by location which was then included in all models. Participants made an effort to standardize each survey according to equipment and methodology, thereby further reducing unwanted variation. Although Potter (1981) reported biases related to habitat and other unknown variables, if these factors were consistent among years they would have little effect on annual changes in indices values. The three-year survey interval currently used by TPWD will provide useful data for monitoring alligator populations in the future. However, the three-year interval will require a longer period to detect population changes than the previous one-year interval.

Ideally, surveys designed to monitor population changes should be sufficiently sensitive to detect real changes in numbers and sufficiently cost-effective to be conducted in the same manner over a long period. Sampling consistency among years is an important factor, because lack of consistency cannot be addressed easily during subsequent analyses. Observer effort does not have to be addressed if it remains constant among surveys; however, if observer effort varies, it should be recorded and included in analyses. To ensure adequate coverage of a wide variety of habitats, permanent transects or plots should be established either randomly or systematically, and distributed spatially throughout the Galveston Estuary area. These permanent plots or transects should be surveyed repeatedly so that spatial differences can be accounted for in statistical models. Transects or plots can be surveyed from aircraft, if target organisms are conspicuous and relatively large (e.g. waterfowl, colonial waterbirds, or alligator nests), and from boats or on foot for more inconspicuous organisms such as shorebirds and alligators. Surveys should also reflect adequate temporal coverage and should be conducted on a regular basis throughout the period that target-organisms are present. More than one survey should be conducted during each sampling year, however, surveys need not be conducted annually. Conducting surveys less frequently decreases their overall cost, but increases the amount of time required to detect real population changes.

Although the criteria outlined above represent guidelines to develop surveys for monitoring selected vertebrates in the Galveston Estuary area, the decision to use existing surveys or to initiate new surveys must also consider the availability of human resources and funds. These decisions are best made by appropriate resource managers who can evaluate the costs and benefits of future monitoring for each group of organisms in question.

Trend Analysis

Several groups of birds showed similar trends across independent data bases, thereby providing corroborative support for the results. Most of the shorebird species examined in this study exhibited an increase based on both the Bolivar Flats Shorebird Surveys and the CBC. The exceptions were the American avocets and dunlins which did not show a population change based on the Bolivar Flats Shorebird Surveys. American wigeons, green-winged teal, northern shovelers, and American coots showed no change in numbers based on both the CBC and MWT. Numbers of olivaceous cormorants increased in total numbers based on the CBC and TCWS, and they increased in the total number of colonies based on the TCWS. Increases in cormorant numbers across Texas have been reported previously by Morrison and Slack (1977). Forster's terns and black-crowned night-herons increased in numbers of colonies based on the TCWS and increased in total numbers based on the CBC.

Snowy egrets, black skimmers, tricolored herons, and roseate spoonbills showed a decreasing trend in total numbers based on the TCWS, and either a stable or increasing trend based on the CBC. Data on colony characteristics from the TCWS indicated a decrease in the number of birds per colony for tricolored herons, snowy egrets, great egrets, roseate spoonbills, and black skimmers. Although this trend does not explicitly represent a population decline, it suggests that distributions of some colonial waterbirds are changing. This notion is further supported by the ordination of TCWS colony counts which indicated a change in the structure of the colonial waterbird community from 1973 to 1990.

Mottled ducks, northern pintails, and blue-winged teal decreased based on the MWT and reflected a national trend which has recently caused much concern (U.S. Fish and Wildlife Service 1986). Counts of these birds increased based on the CBC. Similarly, mergansers spp. decreased based on the MWCC and increased based on the CBC.

Models developed from the CBC for ring-necked ducks and scaup spp. should be interpreted cautiously. These models were based on extreme distributions which included several large counts. The large count values did not represent data entry errors and therefore could not be justifiably deleted from subsequent analyses.

A number of species showed conflicting trends between data bases. Models for several of these species had significant interactions and were difficult to evaluate because spatial effects within the Galveston Estuary may have confounded any trend on a "system" level. Additional analyses to determine trends among geographic areas within the Galveston Estuary would be necessary to clearly interpret these interactions.

In addition, the CBC showed an increase in populations of some species of waterfowl (e.g. mottled ducks, northern pintails) and colonial waterbirds (e.g. snowy egrets, roseate spoonbills) while the TCWS and the MWT showed decreases. The two possible explanations for these discrepancies are (1) both trends are accurate but represent different populations of birds (i.e., breeding and wintering), or (2) trends from one data base are not accurate. Data on the ranges of birds in North America (Root 1988) indicate that coastal southeastern Texas receives an influx of colonial waterbirds during the winter season. The migration status of breeding colonial waterbirds in the Galveston Estuary area is less well known and there is no indication that breeding populations are made up of resident birds. Therefore, we feel that apparently conflicting trends for the TCWS and the CBC may actually reflect real trends for two distinct populations. The case for waterfowl is less clear because both data sets were collected during the winter period though during different months. Given that the MWT has a more systematic design than does the CBC, we feel that it more accurately reflects true population trends.

The overall health of the Galveston Estuary is dependent on the interactions among all individual components that comprise the system. A change in abundance of a species or a group of species may indicate a change in the overall health of a system; however, the converse is not necessarily true, and the absence of a population change alone is not evidence that a system is healthy. As discussed previously, the spatial differences and conflicting abundance trends evident from different data bases examined in this study make a definitive conclusion about population trends difficult. Therefore a subjective summary of all trend analyses in light of the weaknesses of each data base consists of four generalizations: (1) populations of American alligators and the six shorebird species examined in this study appear to be stable or increasing; (2) mottled ducks, northern pintails, and blue-winged teal seem to be declining; (3) with the exception of olivaceous cormorants, colonial waterbirds appear to be declining in both numbers of individuals and mean colony size; (4) olivaceous cormorants show the opposite trend and appear to be increasing in numbers.

Although it was directed that this study not examine population trends of brown pelicans (Pelecanus occidentalis), reddish egrets (Egretta rufescens), and piping plovers (Charadrius melodus), these species were recorded in several data bases and could be analyzed in future studies. Brown pelicans were reported frequently on the CBC and rarely on the TCWS and Shorebird Survey of Bolivar Flats. Piping plovers were seen commonly on both the CBC and the Shorebird Surveys of Bolivar Flats. Reddish egrets were reported infrequently on the CBC, TCWS, and the Shorebird Survey of Bolivar Flats.

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