Colonial Waterbird Population Analysis Project, Phase I

Final Report

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Abstract

Since the late 1970's, the Minnesota Department of Natural Resources has collected population data for seventeen species of colonial waterbirds. Because of the enormity of the task not all colony sites are visited every year. Many observers and census methods have been used to collect the data. The objectives of this project were to compare Minnesota's program with that of other states and to assess the utility of the data for determining population trends. Phone and mail surveys of personnel of other states responsible for the monitoring of colonial waterbirds were conducted to see how other states census colonial waterbirds and how they analyze their data. Most states census only a few species of colonial waterbirds, though, some do census most or all species on a regular basis. Most states analyze data by comparing total populations; few states have used sophisticated methods for population analysis that control for variables that affect census numbers. Three methods of trend analysis were examined using three species (Double-crested Cormorants, Common Terns and Great Egrets) in Minnesota's database. The first method, a comparison of total population counts between two years, can be useful if all colonies are counted for all years, but its accuracy can be affected by random annual fluctuations in population numbers if only a few years are censused. The second method, simple regression analysis, can only be used if most of the colonies are censused for several years during a time period. This method does not control for variables affecting population counts. The third method, a more sophisticated population trajectory method used to analyze North American Breeding Bird Survey data, can be used with data where not all colonies have been censused every year and it can control for such factors, e.g., observer effects, that affect population counts. The results for the third method are preliminary, but do show promise for producing accurate population trajectories using Minnesota's data. More analyses need to be conducted to adjust the method for the peculiarities of colonial waterbird population dynamics and Minnesota's database.

Introduction

Seventeen species of colonial waterbirds can be found nesting in the marshes and along the lakes of Minnesota. Species included in this group include most grebe species, pelicans, cormorants, herons, egrets, gulls and terns. Because colonial waterbirds nest in groups and are top carnivores in aquatic environments, there are many special management concerns associated with this group. Disturbance in a colony has the potential to interfere with reproductive success of many individuals, sometimes up to thousands of nesting pairs. Their foraging habitats have been threatened by human activities, such as wetland draining, development and recreation. They may be more vulnerable than aquatic organisms to contaminants in aquatic ecosystems because of biomagnification. For these reasons, colonial waterbirds have drawn the special attention of many natural resource agencies.

Colonial waterbirds have often been proposed as a group that could be used indicators of environmental change (Kushlan 1993). Several aspects of their biology make these birds likely candidates as indicator species. They are high in the trophic pyramid of aquatic ecosystems and can indicate problems with species lower in the pyramid. Because they nest in groups, large sample sizes of specimens may be collected for toxicology work and estimates of the breeding population size are possible. Human interest (both positive and negative) in this group is relatively high compared to some other vertebrate groups and, in some areas, historical data are available on population sizes. There are disadvantages to using colonial waterbirds as bioindicators as well, e.g., they do not randomly sample their environment. A more thorough discussion can be found in Kushlan (1993).

In the mid-1970's, many states initiated colonial waterbird monitoring programs for many of the above reasons. Other reasons include the suspicion that some species might be declining because of direct and indirect anthropogenic sources of disturbance at nesting and foraging sites. Direct sources of disturbance include recreation near beach colonies or destruction of nesting sites for commercial or residential development. Indirect sources of human disturbance include increases in gull populations because of the availability of foraging sites at landfill; some tern populations have suffered from gull predation and competition for nesting sites. To understand the dynamics of these interactions, it is necessary to monitor colonial waterbird populations.

Minnesota Department of Natural Resources (MNDNR) started to increase their efforts in censusing colonial waterbird populations in the late 1970's. Prior to that, some colonies were occasionally censused by state personnel, but more frequently, census data were collected by amateur and professional ornithologists, and National Wildlife Refuge and US Forest Service personnel. In 1977, a systematic census effort was begun by the Nongame Wildlife Program and a consistent statewide plan was implemented in 1985. Figure 1 shows the increase in the number of colonies that were censused by both state personnel and people outside the MNDNR once this census effort began.

The effort involved in censusing all colonial waterbird species every year can be monumental. Minnesota has 492 colony sites that would have to be censused if a complete statewide census were conducted in 1997 (M. Miller, pers. comm.). Some of these colonies are large and can take several hours to conduct total nest counts; others are not easily accessed and can take more than half a day to travel to them. For these reasons the MNDNR's census program does not include a complete census of all colonies. Their censusing protocol encourages Regional Nongame Specialists (RNS) to census tree-nesting colonies of more than 100 pairs every year and other colonies every three years. Special emphasis is placed on certain species, e.g., Common and Forster's terns, and certain colonies, e.g., some grebe colonies. RNS or their technicians may conduct the censuses themselves or collect data from federal personnel, area wildlife managers, other state personnel, or university researchers.

Once the census data are collected, they are entered into a computer database along with information about the site's location, habitat, ownership and possible threats to the colony. There are currently 6725 records for 933 colony sites in the database. The data have been an important source of information for environmental reviews, ecological research, and mapping the geographic distribution of colonial waterbirds, but have not been analyzed to determine population trends. Analysis of this data set is complicated for a number of reasons. Data were collected by many observers using different census techniques. There are gaps in data among years for colonies and census effort is not consistent among years (these problems and effect on data are discussed more thoroughly on pages 6-8).

The objectives of this project were to:

1) compare Minnesota's method of data collection with other state and regional programs,

2) evaluate the data to determine their usefulness in accurately and efficiently monitoring colonial waterbird breeding populations in Minnesota for determining population trends, and,

3) analyze subsets of the data to look trends in Minnesota's colonial waterbird populations.

The project has been divided into two Phases. Phase I focused on Objectives 1 and 2 with pilot efforts directed at Objective 3. Depending on the conclusions of Phase I, Objective 3 will be completed as Phase II. Objective 1 was completed by conducting a mail and phone surveys of other states, provinces, and federal personnel, and also by conducting a literature review. Objective 2 was accomplished by testing three methods of population trend analysis on three sample species of colonial waterbirds. This report will summarize results by objective followed by a general discussion section and recommendations for future data collection and analysis.

Throughout this document, distinctions will be made between colonies and colony sites, and surveys and censuses. A colony site is the physical location at which colonial nesting occurs and a colony is the aggregation of birds nesting at that site. A survey is the process of locating active colony sites and a census records the species and numbers of birds occupying the colony site (Kushlan 1986).

OBJECTIVE 1: COMPARE MINNESOTA'S METHOD OF DATA COLLECTION WITH OTHER STATE AND REGIONAL PROGRAMS

Introduction

Because monitoring of colonial waterbird populations is a widespread practice, information was sought about other approaches to monitoring for comparison to that of the MNDNR. Specifically, I was interested in how population data were collected and how they were analyzed to determine population trends.

Methods

Information on how censuses are conducted and analyzed on a regional basis was collected in two ways. First, a literature review was conducted by accessing computer databases and other sources. Secondly, state and provincial agencies and other sources were contacted directly through either electronic mail, conventional mail, or by phone.

Literature review - Four computer databases (Fish and Wildlife Review, Agricola, Biological and Agricultural Index, and ACAD General Index) were searched for articles pertaining to regional censuses. Key words such as "colonial waterbird" or a genus or common name were used in association with the words "census" or "population". Other sources, such as bibliographies and literature citation section of papers were also consulted. In-house reports from some states were also obtained and included in the review. Once the paper or report was acquired, the following information about the censuses was recorded: region, species group, number of colonies, census technique, census schedule, and type of data analysis. Other papers were also collected in this search for other purposes and an annotated bibliography is included in Appendix I.

Personal contacts - A list of possible people to contact was drawn up by perusing the Conservation Directory, The Nature Conservancy's (TNC) directory of Natural Heritage Programs, and the Colonial Waterbird Information Service (Hanners et al. 1991). Since I did not know who the colonial waterbird expert was, if there was one, in each state, I decided to start with Natural Heritage Programs (NHP). I sent an E-mail with a survey (Appendix II) to all NHP with an electronic mail address in TNC's directory (29 states and four provinces). I asked the recipients to forward my survey to the agency responsible for colonial waterbird monitoring if they were not that agency. NHPs likely to have a large colonial waterbird component in their state that did not respond in two weeks were contacted by phone; eventually the person responsible for colonial waterbirds was contacted and the survey was conducted by phone.

Information and opinions about collecting census data and methods of analysis was also solicited from selected university researchers, non-governmental organization personnel, and federal employees with the US Fish and Wildlife (USFWS) and the US Geological Survey's Biological Resources Division.

Results

Literature review - Nineteen papers and reports based on 18 studies were reviewed that contained information about censusing on a regional basis (Table 1). Regions covered, type of censuses, and analysis methodology among the papers were highly variable. Six studies (33%) covered entire states or provinces, three (17%) included more than one state, three (17%) were conducted along a river floodplain, and six (33%) covered a region within a state or province (Table 1). Almost half (44%) of the studies discussed censusing all colonial waterbirds within the geographic area covered, while 55% looked at only a few species. Half of the studies conducted a mix of aerial surveys and ground nest counts. In general, those studies that utilized only aerial censuses covered large expanses of area and those that utilized only ground counts covered small regions. Aerial photography was used in three studies (Thompson 1977, Pullin 1990, Litwin et al. 1993) and photography from a boat was used in one study (Rodway et al. 1991). One study used Christmas Bird Count and Breeding Bird Survey data (Fleury and Sherry 1995) and McCrimmon et al. (1996) used only Christmas Bird Counts.

Half of the studies collected one or two years of data and compared the data with a complete census conducted several years before or with historical data. Most of the other studies were components of long-term censusing programs. Only one study was conducted under what might be described as ideal conditions: all colony sites were censused by the same observers using the same methodology at the same stage of nesting for all fourteen years of data collection (Williams et al. 1990). Eleven studies (61%) analyzed their data by comparing the total populations of each species among years. Litwin et al. 1993 and Sommers et al. (1996) performed simple regression analysis with no log transformation of the annual population counts. Only four papers used more sophisticated regression analysis (Engstrom et al. 1990, Fleury and Sherry 1995, Brinker et al. 1996, McCrimmon et al. 1996).

Personal contacts - Information on state-sponsored colonial waterbird monitoring programs was received from 17 states & provinces (Arkansas, California, Connecticut, Delaware, Kansas, Maine, Massachusetts, Michigan, New Jersey, Oregon, Pennsylvania, Saskatchewan, Texas, Utah, Vermont, Virginia, West Virginia, and Wisconsin) from throughout the United States. An attempt was made to contact states from different geographic regions (Atlantic, Gulf, and Pacific coasts, and Great Lakes areas and inland states). None of the states that provided information attempt to monitor all colonial waterbird species at every colony site every year. Texas censuses all coastal colonies (approximately 200) every year by using volunteers. New Jersey also depends on volunteers, usually professional biologists, who volunteer time to fly aerial surveys along the Atlantic coastline. Five states and one province (35% of those surveyed) do not conduct regular censuses nor maintain a database on colonial waterbirds. In those states, there is usually a federal agency that monitors some species, especially those on federal lands. In some areas, a non-governmental organization, e.g., Point Reyes Bird Observatory, monitors waterbird species. The remaining states (65%) conduct regular censuses for at least one species of waterbird. The majority of species that are monitored are state-listed species, but many states also track Great Blue Heron (*Ardea herodias*) colonies. Other groups of species that are or have been monitored by state agencies, include urban herons (VA), game species (ME), or beach-nesting species (VA, CT). The Atlantic states have been funded every few years (~10 years) by the USFWS to conduct aerial censuses of all colonial waterbird colonies (called the Atlantic Coast Colonial Waterbird Inventory -ACCWI). Aerial and ground censuses, also funded by federal agencies, are conducted in the Great Lakes region about as frequently as ACCWI.

Data are collected and analyzed in a variety of ways. Twelve states (71%) conduct mostly ground nest counts, but some (23%) count adults from both the ground and boats. Aerial censuses are conducted at least occasionally by seven states (41%) and five (29%) accompany flight counts with aerial photography. Seven states (41%) responded that they compare total number of nesting pairs each year to document trends. New Jersey uses simple regression analysis (Erwin et al. 1984) and Texas is the only state in the survey that uses more sophisticated regression analysis (Geissler and Noon 1981). A summary of the responses received from each state and the person contacted is found in Appendix III.

Twenty professional colonial waterbird biologists were contacted by conventional mail but only five responded. None had specific advice on how to analyze Minnesota's data. Mike Erwin and John Sauer of Patuxent Environmental Research Center suggested analyzing colonial waterbird data using the same methods as are used for Breeding Bird Survey data (see page 8). A list of colonial waterbird biologists that were helpful to the project is found in Appendix IV. A more complete list of colonial waterbird biologists and their area of expertise can be found in the Colonial Waterbird Information Service (Hanners et al. 1991)

Discussion

Of the states surveyed, Minnesota's colonial waterbird program appears to be one of the more thorough state programs in the United States. Many states do not census colonial waterbirds at all or census only listed species. Texas and New Jersey conduct annual censuses of all colonial waterbird species, but they do not census the entire state, e.g., coastline only. Minnesota's program censuses all colonial waterbirds throughout the entire state but not every colony is counted every year.

Erwin et al. (1984) conducted a survey of state programs in the early 1980's and, out of 48 responses, 85% of the states, compared to 65% of those that I surveyed, said they had or had proposed a colonial waterbird monitoring program. Fifteen of 41 states (37%) stated that they were censusing or planning to census all breeding species, while 17% said they were monitoring or planning to monitor all breeding, migrating, and wintering colonial waterbird species. The remaining 46% were interested in censusing only certain species. Only a few of the states that I talked to or studies I reviewed (Texas, New Jersey, Long Island, Maryland) were censusing all species in their state or region. More than half (52%) of the states contacted stated that they wanted to visit all colonies in the state and 56% of 36 responses wanted to census every year, but lacked time, manpower, and funding. I found no state that censuses all colonies every year. It appears that the initial enthusiasm for monitoring colonial waterbirds might have become overwhelmed by the complexity and the magnitude of the task and/or insufficient funding, and therefore less ambitious programs have resulted.

The surveys and review of the literature indicate that data analysis of colonial waterbird data has not fully been explored. When censusing smaller areas with fewer colonies, analysis is not problematic because most of the colonies can be censused. In the few cases where analysis of incomplete data sets for large regions has been attempted, methods used for other groups of birds, e.g., songbirds on the Breeding Bird Surveys (Geissler and Noon 1981), have been used. New methods are being developed that show promise for application of colonial waterbird data (Link and Sauer 1997).

OBJECTIVE 2: EVALUATE THE DATA TO DETERMINE THEIR USEFULNESS IN ACCURATELY AND EFFICIENTLY MONITORING COLONIAL WATERBIRD BREEDING POPULATIONS IN MINNESOTA FOR DETERMINING POPULATION TRENDS

Introduction

Obtaining accurate total population counts of colonial-nesting birds is a very laborintensive task. Although many studies use total counts, rather than sampling, in actuality, a total population count is never achieved and the data should be treated as an estimate at best, and probably more accurately as an index (Kushlan 1992). Analysis of these data can be difficult because of the many sources of variability. In Minnesota's database, sources of variability include the accuracy of different census methods, timing of censuses, observer variability, variability in census effort, and missing data for colonies not censused every year.

The advantages and disadvantages of various census methods have been well-reviewed in the literature (Hutchinson 1979, Kushlan 1979, Erwin 1980, Erwin 1985, Parnell et al. 1988, Kinkel and Koehring 1992, Kushlan 1992). The general consensus is that total ground nest counts are the most accurate method, and can also provide information about factors influencing reproductive success. However, total ground counts also cause the most disturbance in the colony. Ground adult counts and aerial censuses can vary in their accuracy depending on the species. The accuracy of aerial censuses can be improved by using photography, but this only works for conspicuous species, e.g., Great Blue Herons, Great Egrets (*Casmerodius albus*), and Double-crested Cormorants (*Phalocrocrax auritus*). In Minnesota, a variety of methods were used including counts of nests and adults from the air, boats and ground. Rarely was aerial photography used to confirm aerial counts. Variability in census methodology results in variable accuracy of the census data and must be accounted for when analyzing population trends.

When to count colonies during the season is an important aspect of the accuracy of the counts. Ideally, all pairs nesting during a season should be counted in a colony, but not all birds nest simultaneously. Inexperienced nesters tend to breed later and re-nesting is common when nest failure occurs early in the season. If observers count different colonies at different times during the season, then nesting pairs may be double-counted if they fail at one site and re-nest at another site. Therefore, when conducting a single census of colonies in a region, it is best for all observers to count during the same time period when the maximum number of birds is nesting (Blacklock 1978, Erwin 1985, Blodget and Melvin 1996). For many species, this period is at the peak of incubation when most birds are incubating and just before eggs begin to hatch (Nisbet 1973, but see Ewins et al. 1995 about Double-crested Cormorants). For some species, their phenology may vary within the state or region; censuses could be timed to occur during same breeding stage, but only if there is little chance of movement among colonies if nesting failure occurs. Some species, e.g., Great Blue Herons, have been censused two weeks before young are expected to leave the nest so that productivity can also be measured (desGranges 1979). When the census is conducted during the season is not as important as consistency among censuses if the censuses are to be used as indices rather than absolute counts.

Variability may also arise when different observers are estimating colony size. Previous studies have shown differences among observers when counting waterfowl or songbirds (Erwin 1982, Sauer et al. 1994). Different census methods may be more vulnerable to observer differences, e.g., there is probably less variability in ground nest counts than in aerial censuses. Colony size is also a factor that may influence the accuracy of censuses (Erwin 1980). Small colonies can usually be counted with some accuracy, but the sizes of large colonies are often estimated and observers have different methods of estimating the size of large colonies.

Census effort has also varied among years. Minnesota's program, recognizing that they cannot adequately census all colonies in each year, has established a protocol for deciding when to census a colony based on its size, whether the colony has tree-, ground-, or over-water-nesting species, when the colony was last censused, and what the status of the colony was during the last visit. One way of measuring census effort is by calculating the number of colony sites that are censused each year of those colony sites that are active. This information could be helpful in determining total population estimates. The actual number of colony sites that were active in any one year is not known, so census effort, as measured by censused colony sites over all active colony sites, can only be estimated.

Population trends can be difficult to determine when all colonies are not censused every year. Regression analysis can be performed on annual population counts but since these counts are not complete the rate of change will not be as accurate. There are several ways to account for these missing data. One simple method would be to multiply the number of colonies that were not counted by the mean colony size of those that were counted. Example: 40 out of 50 colonies were counted and the mean colony size was 25. Therefore, one would multiply 10 times 25 and add 250 breeding pairs to the population count. The problems are: 1) unless a survey was conducted to know what colony sites were active, the number of colonies that were not counted is not known, and 2) the distribution of colony sizes in any one year is seldom normal, and therefore mean colony size is not appropriate as an estimate. For some species, it is not atypical to have a small percentage of colonies comprising a large percentage of the population. For instance, in 1992, 23% of the Great Egret colonies comprised 96% of the population in Minnesota. If one large colony is missed during a census, the population estimate would be considerably underestimated.

To improve accuracy in estimating population size when not all colonies were counted, it would be better to look at each individual site that was missed and estimate the missing colony size based on that site's own history. Various methods have been used to estimate colony size this way, e.g., smoothing out averages or running regression analysis for each individual colony site. This paper will explore one method that has used regression analysis to project population trends when data were missing (Link and Sauer 1997). This method is a sophisticated method for analyzing North American Breeding Bird Survey (BBS) data where thousands of routes have been run every year to census breeding birds since 1966. BBS data also have missing data since not all routes are run every year. Other similarities between Minnesota's colonial waterbird data and BBS data are that hundreds of observers perform these censuses each year and many routes/colonies have had more than one observer throughout their histories. The advantages of these methods are that they can control for differences among observers and census methods.

Colonial waterbird census data lend itself to BBS analyses because each colony site can be treated as a route. Observers and census method can be included in the methods as covariates. Census effort is not a concern because the methods predict colony sizes for colonies not censused. This project, therefore, compares three methods of analyzing population trends, one of which will involve using the most recently updated method for analyzing BBS data (Link and Sauer 1997).

Methods

Data evaluation - To evaluate the data collection methods and to see if they were sufficient to determine population trends, I first decided to work with three species in Minnesota's colonial waterbird database. I selected the three species based on several factors. Common Terns (*Sterna hirundo*) were selected because it was presumed that the data set for this species was the most complete because it a state-listed species that has drawn much attention from wildlife agencies and university researchers. Double-crested Cormorants were selected because the population has been perceived to be increasing in the last 20 years. Finally, Great Egrets were also selected because anecdotal evidence suggests an increase in the population and they can represent a tree-nesting species that are found in mixed-species colonies.

The data were prepared for analysis by extracting records of censuses of each species from the database and manipulated the data to produce a colony by year matrix so that for each colony (X-axis) the number of estimated breeding pairs, the observer, and the census method were listed for each year (Y-axis) (see Appendix V). The time period selected was from the first year that the state began censusing to the present (Common Terns 1979-1996, Double-crested Cormorants 1977-1995, Great Egrets 1977-1995). Data for Common Terns from 1996 were included but data from 1977 and 1978 were omitted because of significant data gaps in those years.

One problem with the database is that, it does not differentiate between a missing value and a zero. The database does not include records for species known to be absent from a colony site where it had previously nested. It is important to distinguish these data (zeros) from years when the colony was not censused (a missing value), so when composing the matrices, I had to review all the data sheets, first to fill in zeros, and second, to double-check the data. There were a few mistakes in the database, mostly as result of interpretation of observer notes, but on the whole, the database was clean. I will discuss some ideas for improvement in the Discussion section.

Estimates of census effort can be calculated two ways: 1) looking at all colony sites throughout the time period where a species has nested and counting how many colony sites of those were counted each year (Example: there are 25 sites where Common Terns were known to nest between 1979-1996. In 1995, 12 colonies were censused, and therefore census effort was 48%), or, 2) looking at what colonies were believed to be active in any one year and seeing how many of those were censused. This method subtracts from the total number of colony sites active during a time period those colonies that have not been discovered, probably because birds did not nest there yet, and also colonies where birds no longer nest because the site had deteriorated. (Example: in 1995, 16 tern colonies had become inactive, therefore, only nine colony sites were among the pool to be censused. Only seven colonies were censused and therefore census effort was 89%. Note: in the example for Method 1, 12 colonies were censused, because some colonies that were considered inactive were censused anyway). Minnesota's database has a code for colony sites that are considered "gone" or highly unlikely birds will return to nest. Once a colony is considered "gone" it is removed from the list of possible sites to census. Method 2 is used in most analyses. The effect of census effort on population size was tested by a Pearson's correlation test to see if unadjusted annual population sizes increased with census effort and could be used to help adjust population size.

I examined the amount of variability the data might have by counting the number of observers who provided data over the time period selected for these three species, the proportion of each of the census methods used and the proportion of different nesting stages colonies were in when the colony was censused. For the majority of records, more than one observer was involved in the census, but I just looked at the first name listed and assumed s/he was the primary investigator. Sometimes, names were switched around, and they would be often counted as the same observer (e.g., Lenning and Glidden = Glidden and Lenning). Census method involved two variables on Minnesota's data form (Appendix VI). The first, called census technique, reports whether the census was conducted from the ground, boat, air (fixed- or rotary-winged aircraft) and the second, called count method, reports whether the count was a visual estimate, total ground count, or partial count with extrapolation. In the matrices (Appendix V), the two codes are combined into one code, but I looked at the frequency of each variable separately. The frequency of different nesting stages recorded for each colony during a census was also tabulated according to the codes on the data form. Sometimes, an observer would record more than one stage on the data form, but the database manager decided which one of the codes to enter. I used the codes that were entered in the database.

Population trend analysis - The first method of determining population trends is one frequently seen in the literature (Thompson and Tabor 1981, Hatch 1984, Dunn et al. 1985, Koonz and Rakowski 1985, Williams et al. 1990, Rodway et al. 1992, Vermeer et al. 1992, Howes and Montevecchi 1993) and I refer to it as a comparison of totals. In this method, one conducts as complete a census as possible during a 1-2 year period and compares it with another complete census conducted several years later or before. In many of the papers cited above, the authors conducted a census and compared it with a census conducted by other investigators, or sometimes with historical data. The product of this method is a percentage change that has occurred between years A and B, and some authors have calculated r, annual rate of population change. The main drawback with this method is that no statistical inferences can be made.

Since no complete statewide census has ever been completed for Minnesota, this method is not appropriate, but I decided to explore this option by comparing years when census effort (Method 2) was greater than 75% and all known large colonies were censused. Colonies were considered large if they comprised more than 5% of the annual total population for the year before and the year after it was not counted. I also looked at Williams et al. (1990) who conducted a complete census for 14 years and compared several years to see if there were biases involved with choosing which years to census.

The second method of determining population trends also depends on having complete data sets but is less influenced by missing data than the first. Erwin et al. (1984) suggested using a simple regression analysis with log-transformed data. The transformation helps to stabilize the variance and normalize the data. When data are missing, the analysis will be biased, but I tried to minimize that bias by excluding years where census effort was poor and more than one large colony was missing. I was more liberal in my standards of inclusion in this analysis then I was for the comparison of totals, because I wanted to make sure I had enough years to perform a regression. I tested both linear and quadratic models for significant slopes using a t-test with the null hypothesis that the slope is significantly different from zero. A p-value less than or equal to 0.05 was considered significant.

Link and Sauer (1997) discusses the importance of controlling for factors that influence the accuracy of the data. They used several models for developing population trajectories that controlled for observer effects. A Dirichlet compound multinomial vector is used to treat observer effects as a nuisance parameter. Quasi-likelihood is used to estimate other parameters in the trajectory. With these models, they can produce a population trajectory from adjusted average counts/route with 95% confidence limits relative to one point on the trajectory. This method is especially useful for count data that are not normally distributed and it incorporates the time-series structure of census data.

This analysis was used with Minnesota's data and controlled for observer and census method effects. Population trajectories were produced with adjusted average counts/colony (for all colony sites used during the time period) and confidence limits were produced relative to the final year included in the analysis. A Lowess smoothing curve was used to illustrate the direction of the population trajectory. John Sauer of Patuxent Environmental Research Center, Biological Resources Division of the U.S. Geological Survey performed the analyses, but because of time constraints he was able to only perform analyses on the Common Tern and Double-crested Cormorant data.

Results

Evaluation of data - Both calculations of census effort are presented in the matrices in Appendix V. The two methods of calculating census effort are positively correlated (Common Terns: $r = 0.58$, $p = 0.011$, Double-crested Cormorants: $r = 0.46$, $p = 0.047$, Great Egrets: $r = 0.75$, $p < 0.001$). Using Method 2, Common Terns had the best coverage with a mean census effort of 78% each year, and cormorants had the least amount of coverage with a mean census effort of 55% each year. The mean annual census effort for Great Egrets was 61%. Census effort (Method 2) was not always significantly correlated with annual population size (Common Terns: $r = 0.49$, $p = 0.04$, Double-crested Cormorants: $r = 0.37$, $p = 0.12$, Great Egrets: $r = 0.10$, $p = 0.69$). The reason census effort is not always correlated with population size is that population size is dependent on which colonies are censused. If one or two large colonies are missed, but most of the small colonies are counted, the population size might be small while census effort is high. The lack of significant correlation for Double-crested Cormorants and

Great Egrets indicates that the large colonies are not always counted. The major colonies of Common Terns are usually counted each year and so census effort was significantly correlated with population size, but the r-value was not very high. Census effort probably would not be very helpful in adjusting population totals when not all colonies are counted.

Many observers, both MNDNR employees and non-DNR personnel, have been involved in collecting colonial waterbird data. Common Tern data were collected with the fewest observers (23 observers for 270 records = 11.7 records/observer) and Great Egret data with the most observers (77 observers for 199 records = 2.58 records/observer). Double-crested Cormorants had 276 records with a total of 76 observers (3.63 records/observer).

For Common Terns and Great Egrets, counts of nests or adults from the ground were most common, while Double-crested Cormorants were most commonly counted from boats (Table 2). Occasionally, cormorants and egrets were counted by aerial census but Common Terns never were. Common Terns were most commonly counted by total ground counts, but egrets and cormorants by visual estimates (Table 3). Partial counts were occasionally used for cormorants and egrets, but never for Common Terns.

Ideally, most species should be counted during the peak of incubation (Nisbet 1973). Using Minnesota's nesting stage codes (see Appendix VI), most colonies should have been counted during the incubation or hatching stage. Common Terns were censused during these periods for 45% of the censuses, while egrets and cormorants were censused during these times for only 27% and 28%, respectively, of their censuses (Table 4). These two species were most commonly censused during the feathered young stage. Counting at this stage may be more appropriate for cormorants, as a recent study shows greater counts during the mid-nestling stage than at peak of incubation (Ewins et al. 1995). One-third of the censuses on Common Terns were conducted in years when significant nesting failure occurred. Many of these records came not from data sheets, but from reports where the number of nests and information on reproductive success were provided, but the nesting stage was not, so the code for significant nesting failure was entered if reproductive success was poor.

Population trend analysis - The Common Tern data set was the only data set that had enough years that fit the criteria to perform a comparison of totals. Four years (1981, 1983, 1992, 1996) had sufficient census effort (82%, 93%, 85%, and 89%, respectively) and all large colonies were censused. Table 5 shows the percentage change that occurs among these four years when comparing any two years. Depending on what two years are selected to compare, one can get various results from a decrease of 43% to an increase of 107%. To show that this is not just a result of incomplete data, Table 6 shows the population data for Common Terns and Great Egrets along the Virginia Barrier Islands (Williams et al. 1990). If we compared two adjacent years with sufficient time lapsed from 1975, we could find just a slight decrease (-2% for 1984) to a major decrease (-65% for 1985) for Common Terns or, for Great Egrets, a major increase (+161% for 1984) or a moderate increase (+48% for 1985). A log-transformed regression analysis of these data showed an annual decrease of 7.4% for Common Terns ($t = -3.46$, $p = 0.005$) and a 5.4%

annual increase (t =1.84, p = 0.09) for Great Egrets. Using these trends, Common Terns would have decreased by 50-54% and Great Egrets would have increased by 60-69% between 1975 and 1984-85, respectively. Breeding colonial waterbird populations can fluctuate widely from year to year and population trends that result from comparing just two years with several years in between is not necessarily indicative of a trend, but could be more a result of stochastic factors.

The simple regression analyses (Erwin et al. 1984) found a significant quadratic model for Double-crested Cormorant populations (p = 0.0029), but neither linear nor quadratic models were significant for either Common Tern (linear: p = 0.75, quadratic: p = 0.30) or Great Egret populations (linear: p = 0.51, quadratic: p = 0.82) (Table 7). Cormorant data fit the quadratic model well (r^2 = 0.94) indicating that the population increased from 1977-1990 but appears to have decreased since 1992 (Figure 2). Standard errors for the slope were (14-15%). The standard error of the slope was greater than 100% for both Common Terns and Great Egrets and the lack of significant slopes indicated that both populations showed no significant trend but were highly variable for the time period tested. The wide confidence limits in Figures 3 and 4 also show that the data were variable.

The Link and Sauer (1997) method of analysis calculated mean number of pairs per colony using all colony sites occupied at least once during the analyzed time period and a 95% confidence interval around that mean relative to the final year of analysis (Figures 5 and 6). Significant comparisons are determined between any two years by calculating the ratio between any two years (later year/earlier year) and determining whether the adjusted means fall within the confidence intervals of each year. A Lowess smoothing curve is used to transform the adjusted means into a curvilinear trajectory.

Both Figures 5 and 6 show an initially high adjusted mean count per colony with wide confidence intervals. For cormorants, the first year's adjusted mean count is highly suspect as probably are the next three years (see below). These should not be used to determine trends, but do demonstrate the effect the method has when calculating adjusted means for the initial years of censusing when many colonies were not censused. Since many colonies were not discovered, their previous history could only be estimated based on count data available after their discovery. If the colony's population declined after discovery, the method estimates that the population was higher in the years prior to discovery. This results in inflated counts for the first few years in Figures 5 and 6, but once the DNR collected data from more and more colonies and obtained what hopefully can be assumed a fairly comprehensive picture of where colonies were located and where they moved after a colony site was abandoned, then the adjusted means appear more reasonable and confidence intervals are smaller.

It is well-accepted that Double-crested Cormorant populations were present in low numbers during the 1970's throughout North America (Weseloh and Collier 1995) and given the method's way of inflating mean counts when there are large gaps in the data, I believe it is reasonable to ignore the first four years of the adjusted mean counts for cormorants (Figure 5). Therefore, it appears that cormorants increased in population size from 1981-1990 at an estimated rate of 20%/year and then declined at a rate of -8%/year (though, not significantly) until 1995 (Table 8). A few more years data will help to determine whether cormorants are past their peak and are declining or fluctuating around an asymptote.

The first two years for Common Terns also have fairly wide confidence intervals (Figure 6) and so when looking for trends I ignored these two years and used 1981 as the first year for comparison, when census effort was relatively high (81.8%, Appendix V.1). The Lowess curve shows a decrease until about 1988 and then an increase until 1996. The initial decline is estimated at a rate of -15%/year and the subsequent recovery is at a rate of 28%/year (Table 8).

Discussion

Data evaluation - There are three stages involved in building Minnesota's colonial waterbird census database: 1) data collection, 2) data recording, and 3) data entry. At each of these stages are steps that can help minimize sources of error.

When the data are collected, it is best to use standardized and relatively accurate methods. Which method is to be used depends on the manpower, equipment, and money the state is willing to expend in order to achieve population estimates of reasonable accuracy. Some studies have shown that aerial censuses and photography can achieve reasonable accuracy, especially with helicopters, for some species (Great Blue Herons, Great Egrets) at costs less than conducting ground nests when including costs of manpower (Hutchinson 1979, Kushlan 1979). The other advantage is that disturbance to the colony is less. If the state wants more accuracy then ground counts would be preferred. Ground counts also have the advantage of learning more about factors that influence reproductive success. Whatever method is selected, it should be remembered that the census data should be treated as an index, and, as an index, standardization is important for analyzing population trends.

A vital step in standardizing methods is a written protocol about when and how to census. The current protocol is imprecise in several aspects. It does not specify the preferred methods of census technique or count method, e.g., which methods would achieve greater accuracy. If a ground nest count is preferred, then it needs to be specified what nests are to be counted - all nests, occupied nests, nests that look active, etc. It states that censuses should be collected in spring and early summer, but does not specify what nesting stage is best for censusing and how each species varies in their nesting phenology, e.g., Great Blue Herons are earlier than Common Terns. Blodget and Melvin (1996) and Sommers et al. (1996) both provide examples of written instructions given to cooperators in their programs.

While reviewing the data, I did detect some data that were suspect. Some counts were conducted by amateur ornithologists and while some amateur ornithologists can be quite competent, some counts by amateur ornithologists were very rough estimates (e.g., one person reported 400 Great Egret nests at Lake Johanna one year, and the next year remarked that the colony was larger than the year before and estimated 300 nests) that could greatly affect population trends. I also have little confidence in counts conducted after chicks have left the nest (i.e., censuses conducted during the late-nestling to fledgling stage) because it would be difficult to determine which nests were actually active. No judgments were made regarding the inclusion of data in these analyses, but further analyses might consider removing suspect data.

The second stage, data recording, could also use a set of instructions or clarifications on the data form. I found several parts of the data form to be confusing. One code for nesting stage is "significant nesting failure"; this is not a nesting stage but an assessment of productivity. It should be clarified whether this code means that the count was made before or after nesting failure, and, if after, what was counted. The census technique and count method is helpful in assessing the accuracy of the count, but sometimes, these are recorded incorrectly. I found several instances where it was recorded that a ground nest count was used to count large colonies of Common Terns by boat. It seems unlikely that a total nest count of a ground-nesting species was actually conducted by boat, unless the colony was small. Instructions should indicate not to check boat if it was used only for access and not for counting. Also, it would be helpful for assessing accuracy to indicate that the count was made from within the colony or from outside the colony. Many tree colonies were counted from a vantage point away from the colony site. While this method is less disturbing to the birds, it may be less accurate than when counting from below the trees, when overlapping nests may be counted as one nest. It is also unclear on the data sheet whether it is a nest or adult count that is made when the recorder fills out both columns. Is the adult count based on number of nests or the nest count based on the number of adults or are they independently derived numbers? Also, when adults are counted, did the observer count only those within the colony or did s/he include loafers on the shore and in the water? All these points could be clarified by revising the data form and including an instruction sheet.

The third stage, data entry, has the potential to create errors in coding and numerical transcription. I found occasional transcription errors, but few of great consequence. Quality control appears to be good. Errors or confusion arise when the database manager has to interpret the data sheet because of imprecise recording, e.g., several nesting stage codes were recorded. Occasionally, winter nest counts of heronries have been conducted several months after a very rough summer estimate or species composition was submitted. The apportioning of nests to different species has not always been done correctly. It should not be left up to the database manager to interpret and calculate these data. Probably the largest problem with data entry is the failure to turn data in to the database manager. Often, the database manager has to contact field observers to fill in missing or incomplete information. In some of these cases, valuable information such as observer, date of census, nesting stage, and census method has not been recorded when population counts are done. The importance of filling out the data sheet in its entirety should be stressed to all contributors.

Population trend analysis - Not knowing what the true population trends are for these three species makes it difficult to evaluate their accuracy. The disadvantage with the comparison of totals methods was illustrated with the comparisons made using the complete data set of Williams et al. (1990). Annual fluctuations can bias any trend determinations depending on what years are selected for censusing. The inability to make statistical inferences also is a drawback of this method.

Using a simple regression can have good results if most colonies, especially large colonies, are counted during several annual censuses, but the method is limited in its ability to control for observer and method bias. The method was unable to detect a trend for Common Terns that was detected by the Link and Sauer (1997) method. This was probably because Link and Sauer (1997) can compare adjusted mean counts for any two years of interest when the simple regression has to look at several years. Because Common Terns decreased and then increased, the simple regression was unable to detect a trend. Not enough data were available for a quadratic method to be significant.

The Link and Sauer (1997) method has several advantages. Population size can be estimated, even though not all sites are censused every year. It can compensate for some variability by controlling for observer and census method. One drawback is that yearly estimates are less accurate when censusing is first initiated or when a species is colonizing an area (J. Sauer, personal communications: this was a problem also with BBS analysis of the colonizing House Finch, *Carpodacus mexicanus*). If a site's actual population goes suddenly from zero to a large number of nests, and the site was not previously censused, the method will estimate a population size for a site which had no birds nesting. Therefore, the method works best for species that have been well-surveyed but not necessarily censused every year.

These analyses are preliminary and there are problems with them. One problem is evident when the average counts per colony are converted to total population counts (Figures 7 and 8). The first few years are highly inflated as was expected from Figures 5 and 6, but large differences also occur between unadjusted and adjusted total population counts for years when census effort was high, e.g., 1995 and 1996 for Common Terns (Figure 7). Converting to total population magnifies small differences that were not as obvious when just looking at average count per colony. In these analyses, small colonies that were not censused frequently were not weighted less than colonies censused more frequently. These colonies probably exhibited a positive trend that, while smaller in earlier years, starts to contribute much more in the later years to the average count per colony. Therefore, the overall and annual changes in populations in Table 8 are probably exaggerated.

Also evident in Figures 7 and 8 is that some unadjusted total populations are greater than adjusted total populations. This is the case because the method does not just fill in gaps for missing counts and leave any actual data in place, but rather utilizes the calculated trends for each colony to generate estimated average counts per colony, which replace the actual data that were collected that year. This may also have exaggerated the difference between unadjusted and adjusted population totals.

Link and Sauer's (1997) method was developed for count data from the Breeding Bird Survey and works best for songbird populations. There are some fundamental differences between songbird and colonial waterbird populations and the way they are censused. First, the presence or absence of breeding colonial waterbirds at a colony can be easily established whereas a songbird species' absence from a route can not be clearly established. It is not known whether it is truly absent or just not observed while the route was run. Zeros usually really mean no birds were present for colonial waterbirds. Second, colonial waterbirds can move as a group between sites among years. There may be a slight decline before abandonment, but it is not atypical for a large number of birds to move to a new site after a breeding season in which there was poor reproductive success. Songbirds do not move from one site to the next site in such large numbers. If they abandon an area, it is usually a slow process as the site declines in suitability, unless of course there were drastic changes in the habitat, e.g., logging, fire, draining of a wetlands. Therefore, songbird populations are more likely to show a steady declining or increasing trend, whereas the sudden, large-scale movements of colonial waterbirds, which could have hundreds of pairs nesting one year at a site and none the following year, are poorly fitted by smooth curves. It would be desirable to further evaluate the impact of these differences on the utility and appropriateness of the analysis, and how the analysis might be adjusted to accomodate these differences. For example, one possible adjustment might be in the way data are broken into segments for analysis, making sure that data segments are broken at known zeros.

In summary, the utility of the Link and Sauer (1997) method for colonial waterbird population trend analysis shows promise, but further examination and adjustments are necessary to fully determine its ability to accurately detect trends. Further tests could include performing trial runs to see how much data can be missing before the trend analysis becomes too inaccurate, studying the effects of not censusing small colonies as frequently as large colonies, and studying the effects of sudden movements of many birds among colony sites between years. Sites that have been censused less frequently could be weighted less than those that have been censused more frequently. The Minnesota data could be analyzed again with data sets where suspect data are removed or with the assumption that newly discovered colonies were not occupied the year before (i.e., placing a zero instead of a missing value for the year before a colony was discovered at a new site). The trajectories could be calculated using the real data when available and estimated data for when a colony was not censused; total population numbers might be better estimated.. The Link and Sauer (1997) method could also be performed with nesting stage as a controlled parameter. This then could control for variability caused by censuses conducted during different stages of breeding. The main problem at present with running further analyses is the lack of a generalized program that can run these analyses, making the performance of these tests dependent on the availability of John Sauer or William Link at Patuxent Environmental Research Center. MNDNR may want to explore either working collaboratively with John Sauer to further develop the analyses, or alternatively, have their own statistician develop a method especially suited for their database.

General Discussion

Long-term monitoring programs of colonial waterbirds can have many objectives (Erwin 1985). According to an internal MNDNR document titled "Colonial Waterbirds" the objective of the Colonial Waterbird Survey is: "To determine the status of colonial waterbirds statewide by monitoring nesting sites for population trends and geographical distribution."

First, I will discuss whether the program establishes the geographic distribution of colonial waterbirds. The MNDNR does not attempt a systematic survey of colony sites throughout the state; this would most efficiently be accomplished by flying transects throughout the state or along the shorelines of lakes with suitable habitat, which would involve a huge investment in time. Instead, most of what the state knows about the distribution of colonial waterbirds comes from historical data and reports from the public. Some discoveries are made by state personnel as they conduct censuses or other work. Occasionally if a large colony disappears, an aerial survey of the surrounding area may be conducted to locate where the former inhabitants have moved, but aerial surveys have been conducted less in recent years than in earlier years (M. Miller, pers. comm.). Despite the lack of a systematic survey, most suitable habitat probably has been surveyed at least once by state personnel or the public. The MNDNR may wish to determine which areas in the state have been poorly surveyed and place some effort into surveying these areas on a regular basis, such as once every 5-10 years.

Next, can the data collected be used to determine population trends? Although there are some questionable data and data collection methods have not been totally consistent, for the species tested, the data can be analyzed and a population trend can be determined. The Link and Sauer (1997) method can compensate for some inconsistencies in data collection and with further testing of the method, accuracy may be improved. It is important to remember that population counts should be looked at as an index and not as absolute counts. In future years implementing stricter standards for data collection could minimize variability. Some data were removed during analysis because few data were associated with a value for a controlled variable, e.g., if a colony was censused by an observer for only one year it was removed.

The population dynamics of colonial waterbirds are not well known, and therefore, it is not known how well the regressions for each colony track actual changes in colony size, movements between colonies, and recruitment into the colonies. The Link and Sauer (1997) method provided population trajectories with narrow confidence limits (except when censusing first began) and was able to control for variables that affect population estimates. It may give the best estimate for population trends, but whether it truly mimics colonial waterbird behavior is not yet known. Perhaps a study using the Virginia Coastal Reserve data (Williams et al. 1990) and removing various data points will show how well the method mimics colonial waterbird behavior.

Several alternatives to monitoring colony population sizes have been proposed for determining population trends. Some of the published studies on colonial waterbird populations have used Christmas Bird Counts (Fleury and Sherry 1995, McCrimmon et al. 1996). This would not be helpful in Minnesota, because most species do not winter in Minnesota. Other studies have used Breeding Bird Survey data (Fleury and Sherry 1995), but because the BBS conducts roadside counts, waterbirds tend not to be accurately censused by this method. Burger and Gochfeld (1994) remark that BBS data show declines in Franklin Gull (*Larus pipixcan*) populations, while other data support stable or expanding populations. Kushlan (1992) suggests using mark-recapture analysis to study population trends. The advantages are that current estimators using mark-recapture analysis account for failure of the assumptions, provide error estimates, and permit hypothesis testing. The disadvantage is that the time and personnel investment in capturing, marking, and observing birds is probably greater than monitoring nest sites.

The state should review their goals for monitoring colonial waterbird populations and decide what they want to accomplish through monitoring colonial waterbirds. Should the state decide to scale back colonial waterbird censusing, possible alternatives to monitoring all species and all colonies are to census only state-listed species: Horned Grebe (*Podiceps auritus*), Common Terns, Forster's Terns (*Sterna forsteri*), Franklin's Gull, and American White Pelican (*Pelecanus erythrorhynchos*) and/or to census only colonies on state lands to monitor effectiveness of habitat protection. Tracking of colony sites that recorded location and activity only, with no censusing, could provide data for environmental review, geographic distribution, and other research purposes with much less effort than is required to do censuses.

RECOMMENDATIONS

Should the MNDNR decide to continue monitoring all colonial waterbirds, they should review the alternatives of when to monitor colonies (Kinkel and Koehring 1992). These different scheduling strategies vary in their time and cost investments and their usefulness in determining population trends.

1) Total annual censuses. A complete monitoring of all species requires the maximum amount of time of MNDNR personnel and maximum funding. However, the gaps in the data would be minimized and a simple regression with log-transformed data could easily be used to determine trends if methods were well-standardized.

2) Partial annual census-survey. This method would require monitoring all species but only in one portion, e.g., region, of the state each year. Then the total population would be calculated after all colonies had been counted and a simple regression could be used to determine trends. While total personnel time would be reduced, it would leave one year every few years for a RNS to tackle the job of censusing all colonial waterbirds, unless a permanent or seasonal position was created to monitor colonial waterbird populations as was done in Maryland. Costs would be reduced because fewer trips would be made to colonies. One disadvantage is that movements of birds between regions might obscure total population estimates. If a colony occupying a site in one region one year moved to a site in an adjacent region, it could be counted twice or missed altogether. The probability of large-scale movements between adjacent regions that would result in double-counting or not counting a large number of birds is probably not high enough to affect analysis of trends greatly and could be reduced if during off years, the activity of large colonies is monitored, perhaps by aerial surveys.

3) Total periodic censuses. A complete census is conducted every few years. There would be a reduction in time and costs, but again the RNS in each region would have to set aside other work to conduct a major census every few years. Population fluctuations might affect population trend estimates at first but after several censuses, trends could be determined using simple regression analysis. Erwin and Hoover (1994) recommend monitoring ground-nesting species and tree-nesting species in different years and conducting complete surveys every four years. Coordination with adjacent state agencies is advised so that "metapopulations" can be sampled at the same time. This method may not reduce time in half for the four years because those lakes or areas with both tree-nesting and ground-nesting species would have to be accessed twice in a four-year period. It would be advisable to monitor activity of large colony sites between censuses so that any colony movement could easily be detected and colonies more easily found for the total census. The state also could look into getting federal funding for these censuses if they can coincide with censuses conducted in the Great Lakes.

4) Annual large colony censuses. If large colonies constitute a large proportion of the population, then by monitoring only the large colonies, the state could obtain a relatively good estimate of the population. Annual censuses could be conducted with relatively little time and cost investment, if the majority of the population is found in large colonies. The counts from these data could be used as indices and regression analysis could be used to detect population trends. The main disadvantages are that small colonies would be ignored and if a large colony is broken up into smaller colonies, a population decline might be detected. For species whole distribution is more scattered, and that tend to be occur in smaller colonies, this method would not be recommended.

5) Two-strata censusing. All large colonies are sampled regularly to provide a population trend, plus several sample areas are surveyed for small colonies to document colony loss and establishment. Population estimates can be provided with the Link and Sauer (1997) method. Minnesota's current regime is similar to this with large colonies being counted more frequently than small colonies, but they do not survey sample areas for new colony sites.

The two-strata approach can help gather information on annual fluctuations and colony site use, and population trend estimates can be obtained with a reduced amount of time and cost. The MNDNR may want to review their exact protocol for prioritizing colony sites. In each region, all large colonies would be counted annually, or possibly biannually as long as they were counted in the same year for the entire state, and all small colonies in one portion of the region could be counted. Each DNR region could be divided into three to four sections, so that surveying would be alternated among the sections; all colonies would be counted at least every 3-4 years. The definition of large colonies could be redefined so that a known approximation (e.g., 80% based on previous censuses) of the population is censused. This redefinition would reduce the number of colonies that are considered large for some species, e.g., if 200 or more nests was considered large for Double-crested Cormorant, only seven colonies would need to be censused and 85% of the population would be counted. This protocol might reduce travel time because the RNSs would focus their efforts on one section of their region. Aerial censuses could be used for the more remote large colonies that need to be censused annually and are not in the section being surveyed that year.

6) Different approaches for different species. The state could also consider using different schedules for different species. Some species, e.g., Common Terns could be censused every year with relatively little effort, but others requiring more effort might be good candidates for less frequent surveys. Surveying only large colonies might yield reliable statewide estimates for some species, such as cormorants, where most birds are clustered in large colonies. Other species, such as grebes would not be adequately surveyed with this approach because the majority of the population occurs in small dispersed colonies. There is no reason to census all colonial waterbirds on the same schedule.

Even though the Link and Sauer (1997) method can control some variability, it is important to stress standardization at all stages of collecting, recording and entering data. To reiterate recommendations made earlier, I recommend that the following improvements be made at each stage of censusing:

1) data collection - standardize methodology by writing protocol for preferred census method and stage at which censusing should occur;
2) data recording - remove significant failure as a nesting stage,
   - providing written instructions for data form,
   - clarify method of estimating an adult count; and,
3) data entry - clarify method of estimating tree-nesting species from winter counts,
   - when gathering data from non-DNR sources, be sure to collect at least observer, date of census, nesting stage, and census method along with the census estimates.

The preferred method of censusing should be total ground nest counts, but other methods should be considered to reduce time, costs, and disturbance to the colonies as long as they are consistent for that species. Partial counts could be considered in large colonies. Setting up permanent transects or quadrats may require greater initial time investment, but may save time and reduce variability in the long run. Aerial censuses and photography for conspicuous species, e.g., Great Blue Heron, Great Egret, Double-crested Cormorants, and American White Pelican, and possibly some gull colonies, will reduce time with relatively little loss in accuracy for remote colonies.

In conclusion, Minnesota has collected an impressive amount of census data for colonial waterbirds. Although some problems with the data set have been identified above, I believe that by using the Link and Sauer (1997) method, some of the sources of error can be controlled and the data for many of the colonial waterbird species can be used to calculate population trends. Following the recommendations given above will improve the quality of the data for future analyses.

Literature citation - see Appendix I.

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Table 1. Literature reviewed which provided information about censusing on a regional basis.

Paper or report	Region covered	Species studied
Blacklock 1978	Texas	all colonial waterbirds
Brinker et al. 1996	Maryland	all colonial waterbirds
Dunn et al. 1985	Ontario	Great Blue Herons
Engstrom et al. 1990	northeast United States	Least Terns
Fleury & Sherry 1995	Louisiana	wading birds
Galli 1978	New Jersey	all colonial waterbirds
Hatch 1984	southern New England	Double-crested Cormorants
Howes & Montevecchi 1993	Gros Morne NP, Newfoundland	gulls & terns
Koonz & Rakowski 1985	southern Manitoba	all colonial waterbirds
Litwin et al. 1993, Sommers et al. 1996	Long Island, New York	all colonial waterbirds
Ludwig 1984	Michigan & Great Lakes	Double-crested Cormorants
McCrimmon et al. 1996	Florida	6 wading bird species
Pullin 1990	Tennessee River Valley	wading birds
Rodway et al. 1992	Scott Islands, Vancouver Is.	all colonial waterbirds
Thompson & Tabor 1981	upper Columbia River	herons, gulls & terns
Thompson 1977	upper Mississippi River	all colonial waterbirds
Vermeer et al. 1992	western Vancouver Is.	Pelagic Cormorant & Glaucous-winged Gulls
Williams et al. 1990	coastal Virginia	all colonial waterbirds

Table 2. Frequency of census techniques that were recorded for censuses conducted on Common Terns (1979-1996), Double-crested Cormorants (1977-1995), and Great Egrets (1977-1995) in Minnesota. Percentages are in parentheses.

Technique	Common Terns	Double-crested Cormorants	Great Egrets
Ground	46 (79)	87 (39)	82 (53)
Boat	12 (21)	129 (57)	54 (35)
Air	0 (0)	9 (4)	20 (13)

Table 3. Frequency of count methods that were recorded for censuses conducted on Common Terns (1979-1996), Double-crested Cormorants (1977-1995), and Great Egrets (1977-1995) in Minnesota. Percentages are in parentheses.

Method	Common Terns	Double-crested Cormorants	Great Egrets
1 = visual estimate	14 (17)	130 (54)	102 (56)
2 = total ground count	68 (83)	110 (45)	64 (36)
3 = partial count	0 (0)	2 (1)	13 (7)

Table 4. Frequency of nesting stages that were recorded for censuses conducted on Common Terns (1979-1996), Double-crested Cormorants (1977-1995), and Great Egrets (1977-1995) in Minnesota. Percentages are in parentheses.

Nesting Stage	Common Terns	Double-crested Cormorants	Great Egrets
Pairing & nest building	1 (2)	3 (2)	3 (3)
Egg laying	4 (7)	5 (3)	3 (3)
Incubation	23 (40)	37 (20)	21 (21)
Hatching	3 (5)	14 (8)	6 (6)
Downy young	1 (2)	23 (13)	20 (20)
Feathered young	2 (3)	76 (42)	37 (38)
Newly flying young	2 (3)	21 (12)	8 (8)
Renesting	1 (2)	0 (0)	0 (0)
Abandoned during nesting	2 (3)	1 (1)	0 (0)
Significant nesting failure	19 (33)	3 (2)	0 (0)

Table 5. Comparison of totals among the years 1981, 1983, 1992, and 1996 for Common Terns in Minnesota (percentage is increase or decrease as compared to the earlier year).

Year (Colony size)	1981	1983	1992	1996
1981 (729 pairs)	-	+13%	-35%	+34
1983 (824 pairs)	+13%	-	-43%	+19%
1992 (472 pairs)	-35%	-43%	-	+107%
1996 (978 pairs)	+34%	+19%	+107%	-

Table 6. Total number of adults observed per year for Common Terns and Great Egrets on the Virginia Barrier islands between 1975-1988 and the percentage of population change compared to 1975. Data from Williams et al. (1990).

Year	Common Terns (number of adults)	% change	Great Egrets (number of adults)	% change
1975	5218	-	252	-
1976	6710	+28	364	+44
1977	8496	+63	330	+31
1978	3605	-31	99	-61
1979	3347	-36	291	+15
1980	5003	-4	255	+1
1981	5260	+0.8	406	+61
1982	3001	-42	551	+119
1983	5219	0	606	+140
1984	5135	-2	659	+161
1985	1843	-65	373	+48
1986	2220	-57	411	+63
1987	2240	-57	329	+31
1988	2885	-45	423	+68

Table 7. Regression analysis results for population trends for Common Terns, Double-crested Cormorants, and Great Egrets in Minnesota using Erwin et al. (1984). Results are for a log-transformed linear model (number of pairs = $a*b^{year}$) for Common Terns and Great Egrets and for a log-transformed quadratic model (number of pairs = $(a)(b^{year})(c^{year*year})$ for Double-crested Cormorants).

Species	Years included	Regression coefficient	t-test for H_o: slope=0	Significance (P-value)	S.E. of coefficient[a] (%)	r^2
Common Tern	1981, 1983, 1984, 1985, 1986, 1987, 1988,1992,1993, 1995, 1996	0.7	0.32	0.75	308	0.011
Double-crested Cormorant	1981, 1985, 1987, 1989, 1992, 1993, 1995	37[b] -1.1[c]	7.28[b] -6.49[c]	0.0019[b] 0.0029[c]	14%[b] 15%[c]	0.946
Great Egret	1979, 1981, 1984, 1986, 1987, 1989, 1991, 1992	-3.8	-0.70	0.51	143	0.076

[a] standard error of slope calculated as percentage of the regression coefficient estimate
[b] for linear term - year
[c] for quadratic term - $year^2$

Table 8. Overall and annual changes in breeding population (number of pairs) for selected time periods using adjusted mean counts/colony calculated with the Link and Sauer (1997) method for Common Terns and Double-crested Cormorants (Figures 5 and 6).

Species	Year	Overall change in population	Annual change in population
Common Tern	1981-1996	132 %	5.8 %/year
	1981-1988	-68 %	-15.2 %/year
	1988-1996	633 %	28.3 %/year
Double-crested Cormorant	1981-1995	244 %	9.2 %/year
	1981-1990	422 %	20.2 %/year
	1990-1995	-34 %	-8.0 %/year

Figure 1. The number of colonies that have been censused annually from 1895-1995 and from 1975-1995 (inset).

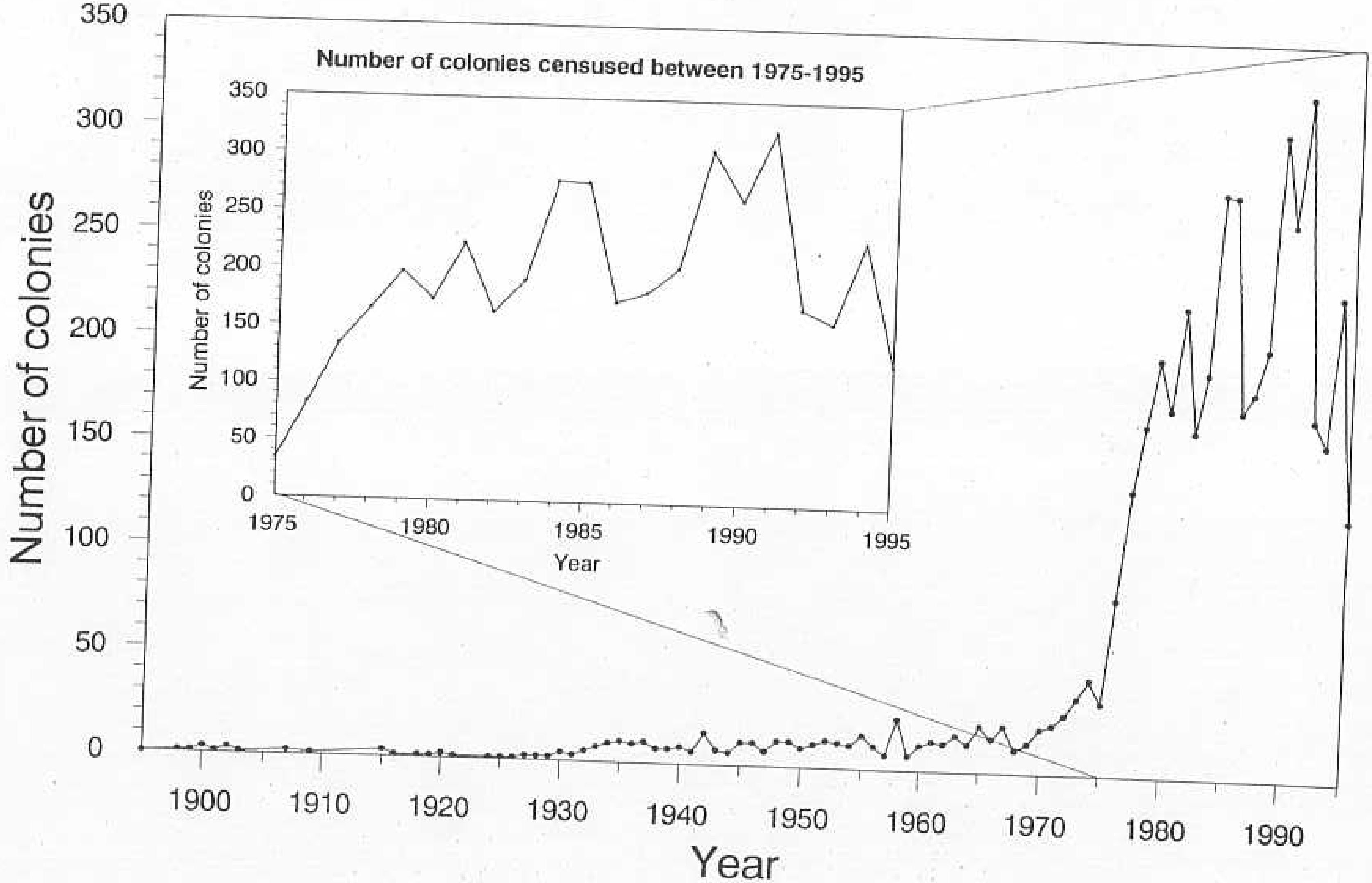


Figure 2. Population trend for Double-crested Cormorants in Minnesota using Erwin et al. (1984). Annual estimates (observed) included are for only years where census effort was adequate and most colonies were counted (see text). Predicted trend is for quadratic model [number of years = $(806)(1.37^{year})(0.99^{year*year})$] and 95% confidence limits are for the mean. The model is significant ($p = 0.0029$)

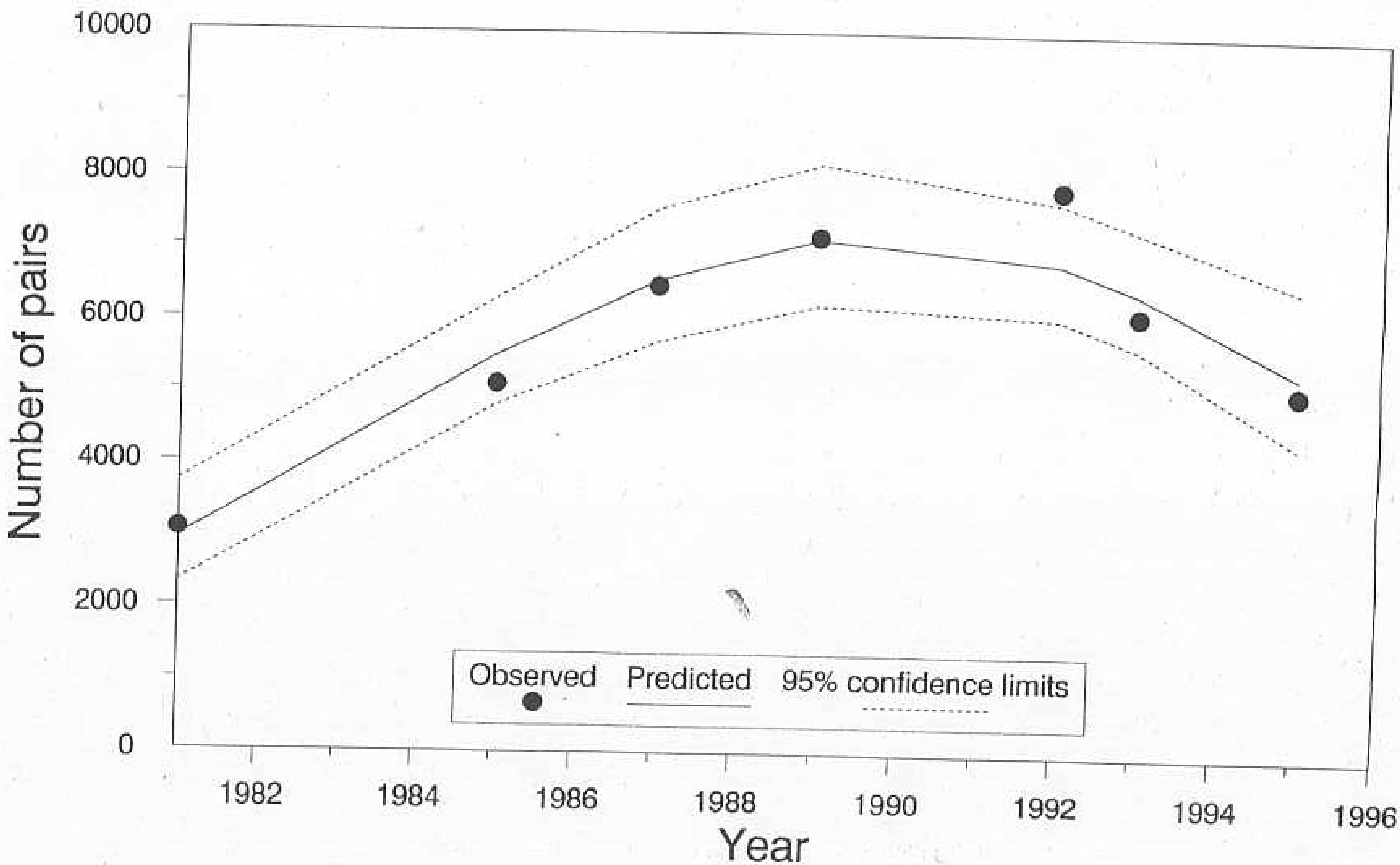


Figure 3. Population trend for Common Terns in Minnesota using Erwin et al. (1984). Annual estimates (observed) included are for only years where census effort was adequate and most colonies were counted (see text). Predicted trend is for linear model [number of years = $(682)(1.007^{year})$] and 95% confidence limits are for the mean. The model is not significant ($p = 0.75$)

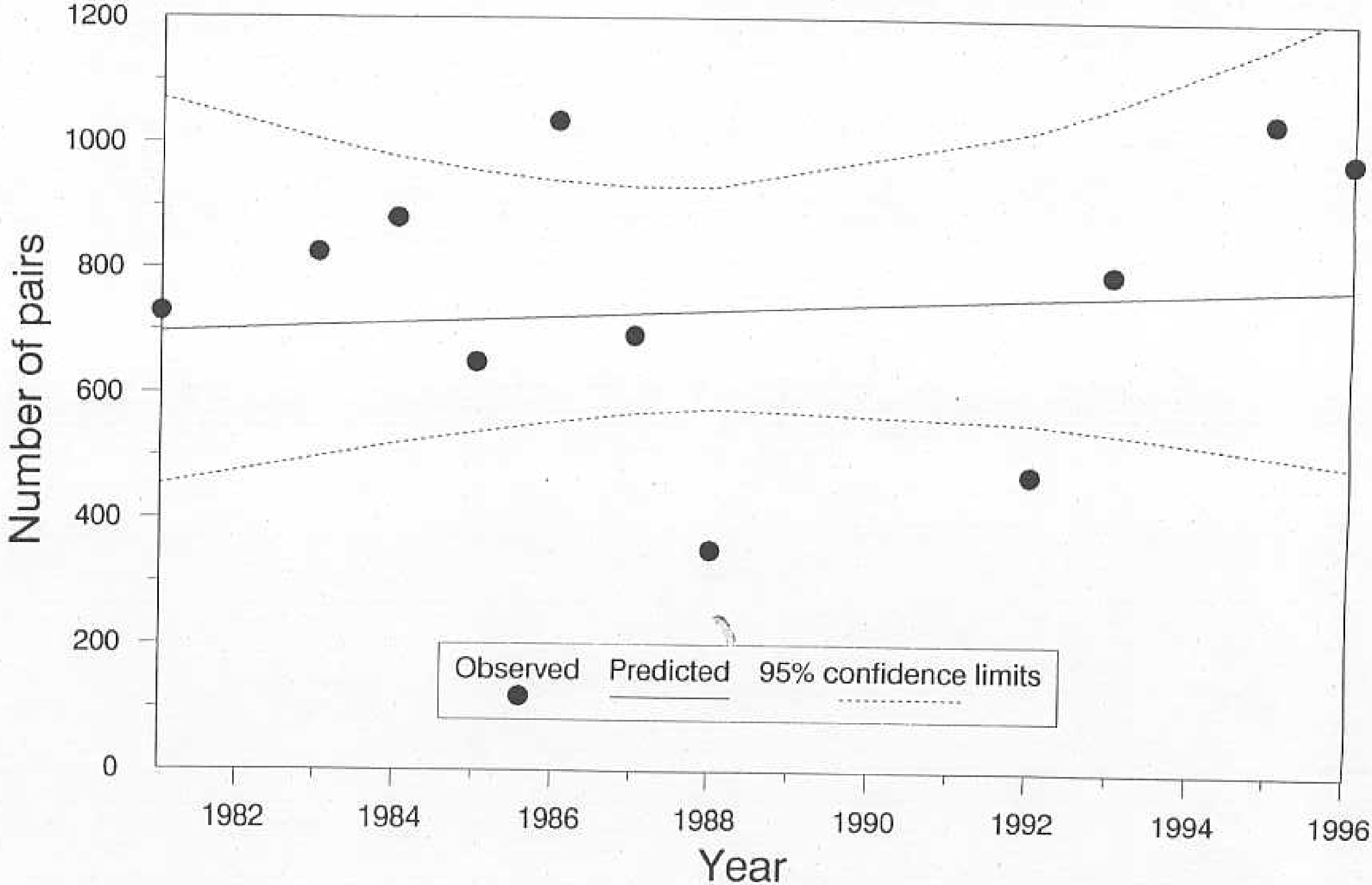


Figure 4. Population trend for Great Egrets in Minnesota using Erwin et al. (1984). Annual estimates (observed) included are for only years where census effort was adequate and most colonies were counted (see text). Predicted trend is for linear model [number of years = (1773)(0.962^{year})] and 95% confidence limits are for the mean. The model is not significant ($p = 0.51$)

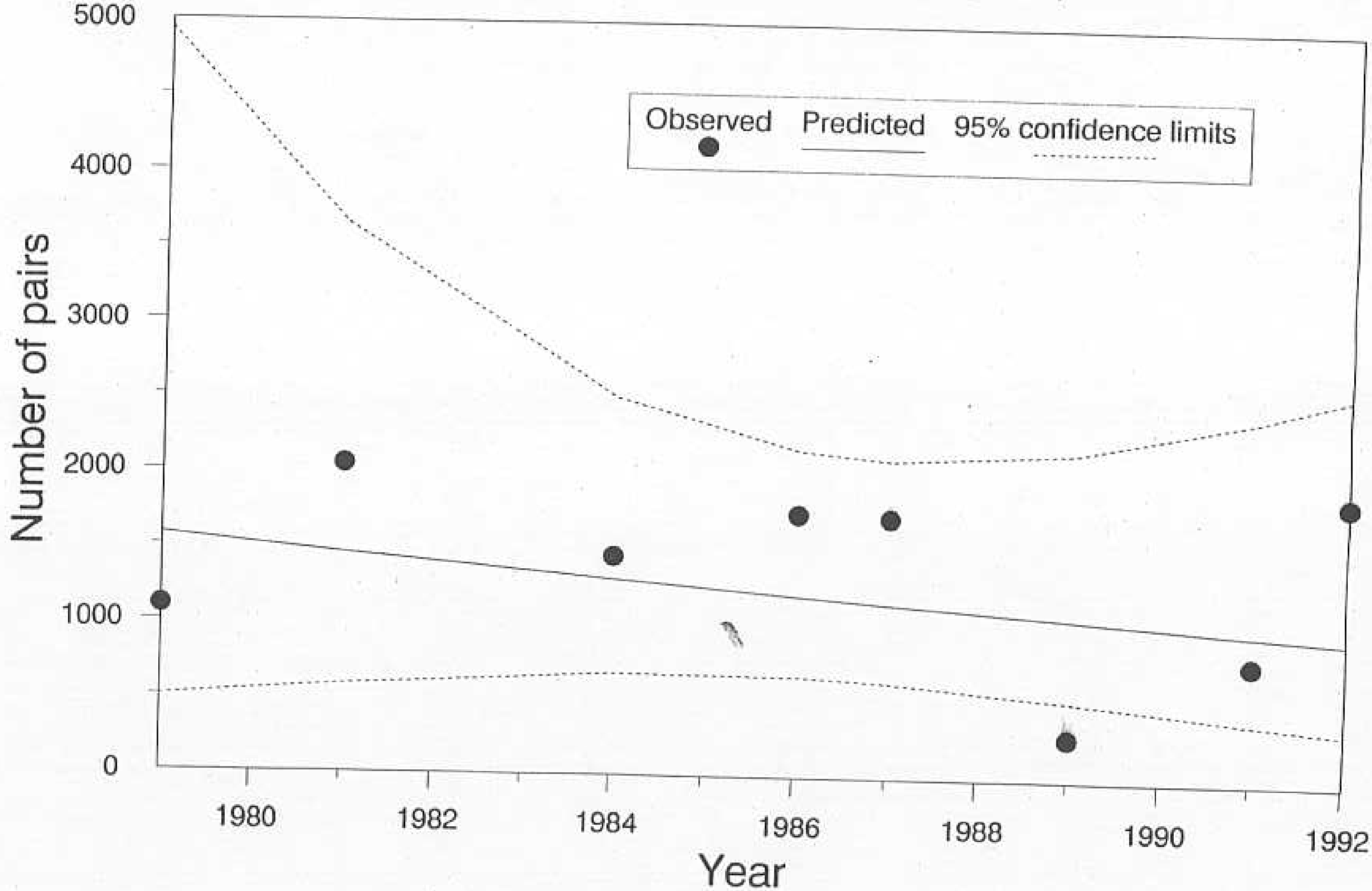


Figure 5. Population trajectory for Double-crested Cormorants in Minnesota. Adjusted mean is mean number of pairs per colony (N = 67) using Link and Sauer (1997). Unadjusted means are mean of number of pairs per colony (N = number of colonies censused in that year). Lowess smoothing curve is based on unadjusted means.

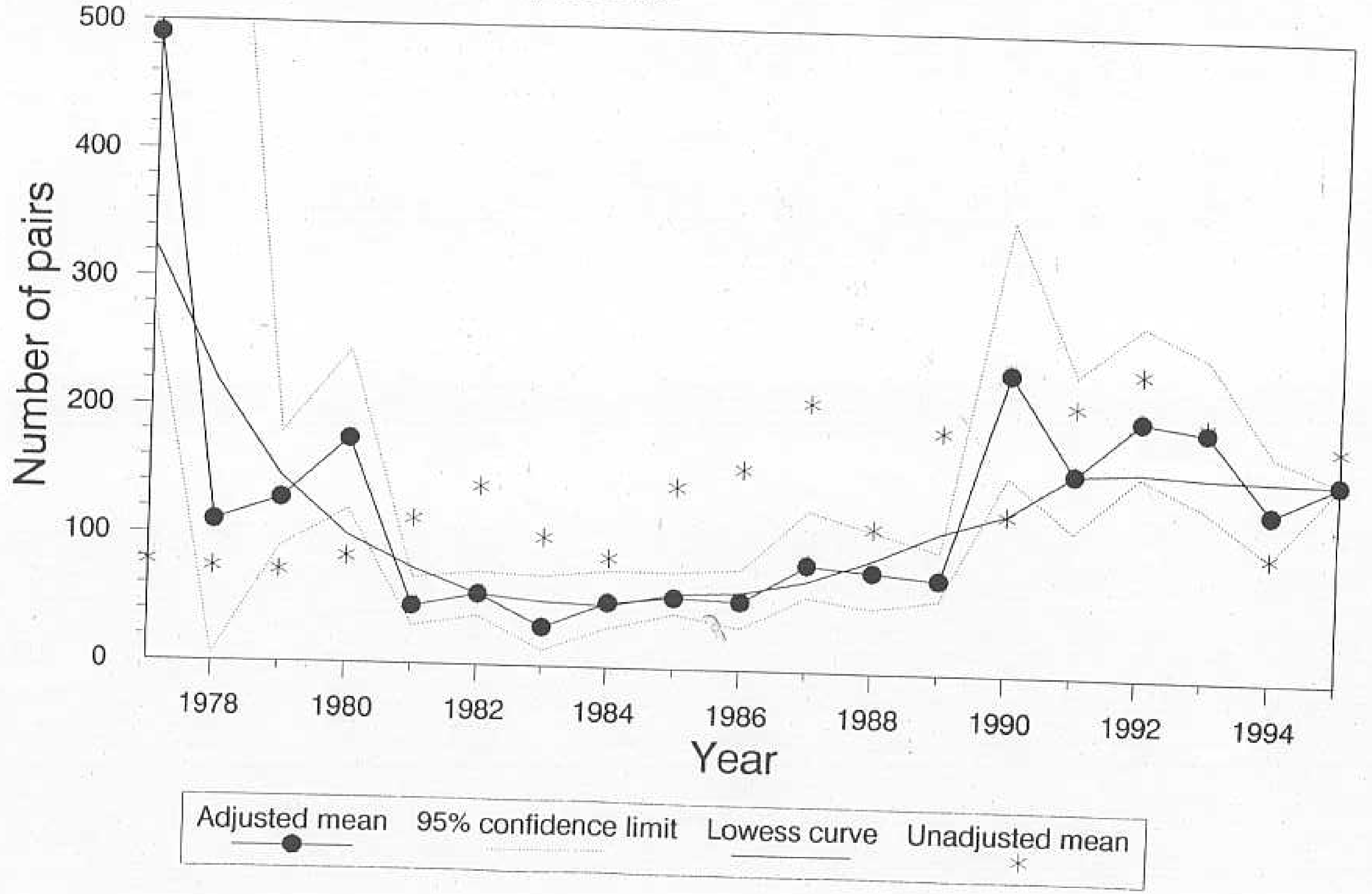


Figure 6. Population trajectory for Common Terns in Minnesota. Adjusted mean is mean number of pairs per colony (N = 25) using Link and Sauer (1997). Unadjusted means are mean of number of pairs per colony (N= number of colonies censused in that year. Lowess smoothing curve is based on unadjusted means.

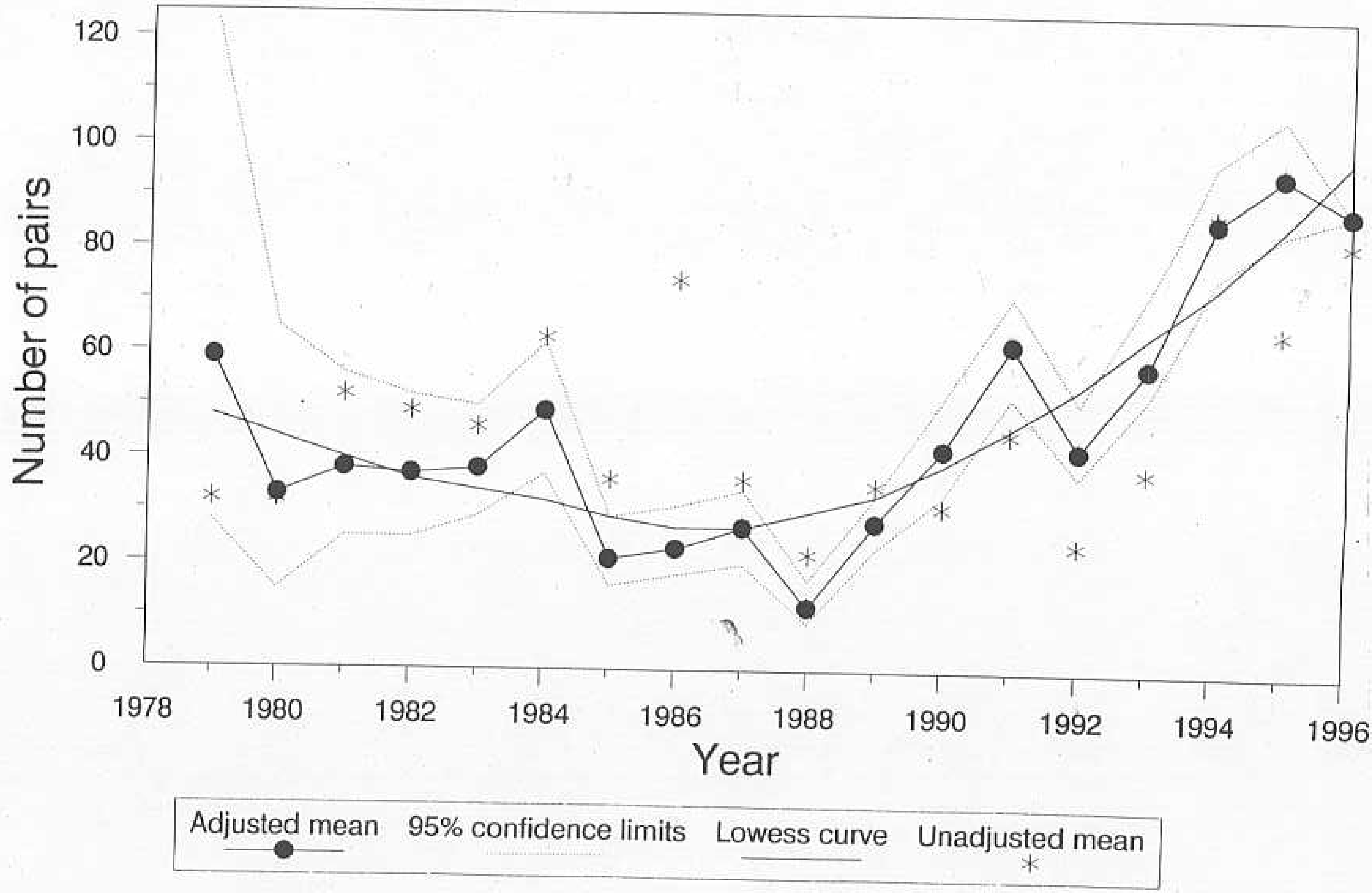


Figure 7. Adjusted (Link and Sauer 1997 method) total population and unadjusted total population for Double-crested Cormorants in Minnesota.

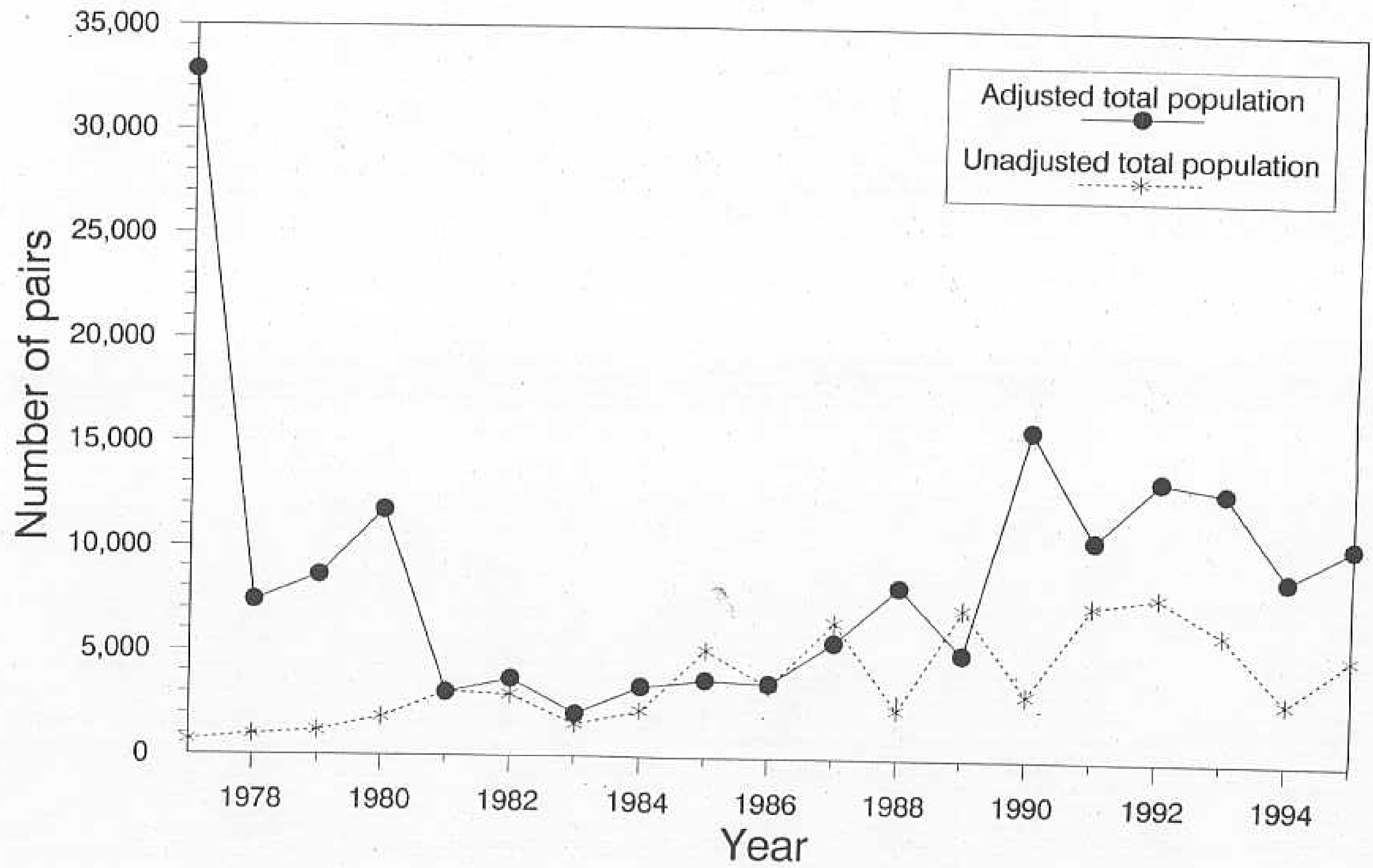
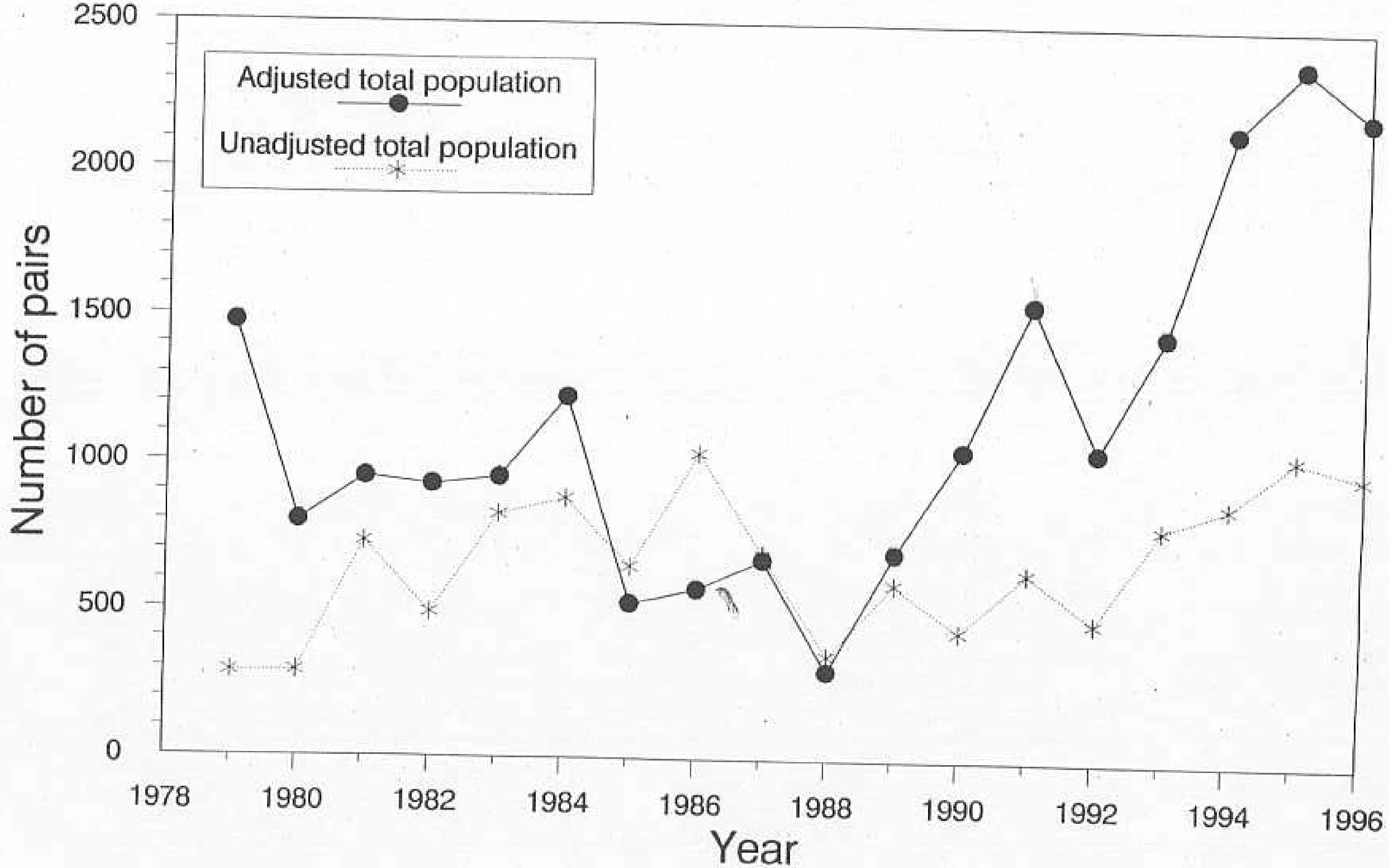


Figure 8. Adjusted (Link and Sauer 1997 method) total population and unadjusted total population for Common Terns in Minnesota.



Appendix I. Annotated bibliography for papers and reports related to population trend analysis of colonial waterbird species.

Blacklock, G. W. 1978. The Texas Colonial Waterbird Census, 1973-1976. Proceedings of the Conference of the Colonial Waterbird Group 1978:99-104.

Summary: The history of twelve years of colonial waterbird census along the Texas coast and some inland areas is discussed. Aerial and ground censuses of 25 species at over 300 colonies are conducted by volunteers who are coordinated by either a state and federal agent. Attempts are made to census all known colonies at the same time and using the same method every year. Distribution of all species and population changes of five species are presented.

Blodget, B. G. and S. M. Melvin. 1996. Chapter 8: Monitoring terns and plovers *in* Massachusetts tern and piping plover handbook: a manual for stewards. Natural Heritage and Endangered Species Program, Massachusetts Division of Fisheries and Wildlife. Westborough, Massachusetts.

Summary: The chapter discusses the protocol for censusing for four species of terns, black skimmers, laughing gulls, and piping plovers. Different census techniques, timing of censuses, and behaviors or individual species are discussed. Sample data sheets and their instructions are included.

Brinker, D. F., L. A. Byrne, P. J. Tango, and G. D. Therres. 1996. Population trends of colonial nesting waterbirds on Maryland's coastal plain. Final report submitted to Coastal and Watershed Resources Division, Tidewater Administration, Maryland Department of Natural Resources. Annapolis, Maryland.

Summary: Twenty species of colonial waterbirds were censused by aerial surveys and ground nest counts. Eleven years of census data were analyzed for population trends using a weighted-slope regression procedure (Geissler and Noon 1981). Three species were found to be increasing in population size and six were decreasing in size. A discussion of the value of the weighted slope-regression procedure for colonial waterbird populations is included.

Buckley, P. A. and F. G. Buckley. 1983. Conservation of colonial waterbirds. Oceanus 26:55-61.

Summary: A five-year helicopter census of Long Island's colonial waterbirds was initiated in 1974 and New Jersey's coastline was included in 1977. Sixteen species were censused and approximately 33-42,000 pairs were counted in Long Island and 52,000 in New Jersey. Threats to colonial waterbirds include development, coastal engineering, recreation, and environmental contamination. Habitat management, land protection, protection of food base, and education are important management tools for the conservation of these species.

Burger, J. and M. Gochfeld. 1994. Franklin's Gull (*Larus pipixcan*) *In* The Bird of North America, No. 116. (A. Poole and F. Gill, Eds.) Philadelphia: The Academy of Natural Sciences, Washington, D.C.: The American Ornithologists Union.

Summary: A natural history account of Franklin's Gulls discusses several subjects including description, taxonomy, geographic distribution, breeding biology, population biology and status, and conservation.

desGranges, J. 1979. A Canadian program for surveillance of Great Blue Heron (*Ardea herodias*) populations. Proceedings of the Colonial Waterbird Group 3:59-68.

Summary: A program to census Great Blue Heron colonies throughout Canada was initiated in 1979 with the help of volunteers and professional ornithologists. The authors tested methodology for determining occupancy of nests from the ground and discussed causes of nesting failure.

Dunn, E. H., D. J. T. Hussell, and J. Siderius 1985. Status of Great Blue Heron, *Ardea herodias*, in Ontario. Canadian Field-Naturalist 99:62-70.

Summary: Volunteers were used to conduct ground nest counts of Great Blue Heron colonies located by aerial surveys and sources from both the public and private sectors within three census areas in southern Ontario in 1980 and 1981. These census results were used to extrapolate the total provincial population size and to examine the accuracy of ground counts.

Engstrom, R. T. 1990. Evaluation of the Colonial Bird Register. Pp. 26-32 *In*: Survey designs and statistical methods for the estimation of avian population trends. (Sauer, J. R. and S. Droege, Eds.). U.S. Fish and Wildlife Service, Biological Report 90(1).

Summary: The Colonial Bird Register (CBR) was established as a national database for census data for colonial waterbirds. The intentions of the project were to encourage monitoring waterbird population, standardize census techniques and data collection, and provide a database for easy access. Caveats with the data include observer variability in censusing, inconsistencies in colony identification, and lack of data for inactive colonies. Because of insufficient funding the CBR was terminated in 1988.

Engstrom, R. T., G. S. Butcher and J. D. Lowe. 1990. Population trends in the Least Tern (*Sterna antillarum*) from Maine to Virginia: 1975-1986. Pp. 130-138 *In:* Survey designs and statistical methods for the estimation of avian population trends. (Sauer, J. R. and S. Droege, Eds.). U.S. Fish and Wildlife Service, Biological Report 90(1).

Summary: Data from the Colonial Bird Register and a weighted linear regression procedure (Geissler and Noon 1981) were used to analyze Least Tern populations from Maine to Virginia. The analysis suits these data because it can accommodate missing data from years that some colonies are not censused. Least Tern populations decreased only in Maryland and regionally the annual increase was 5.0% between 1975-1986.

Erwin, R. M. 1980. Censusing colonial waterbirds: problems and progress. Atlantic Naturalist 33: 19-22.

Summary: Visibility of different species, differences among observers, and magnitude of numbers are discussed as problems associated with censusing colonial waterbirds. Advantages and disadvantages of ground vs. helicopter vs. fixed-wing aircraft are also reviewed. Despite these problems, population trends along the Atlantic Coast were determined by comparing population sizes based on censuses conducted between 1975-1977 and earlier estimates.

Erwin, R. M. 1982. Observer variability in estimating numbers: an experiment. Journal of Field Ornithology 53:159-167.

Summary: Nine of observers with various amounts of experience were asked to count number of rafting ducks from aerial photographs. Photos had different number and density of ducks and in some experiments, the observers were told what the accurate number was after each count. Reinforcement and experience contributed little to achieving accuracy, but inexperienced observers consistently underestimated raft size across all size categories. More experienced observers tended to underestimate for only smaller size categories.

Erwin, R. M. 1984. Colonial bird monitoring: a strategy for regional and national evaluation. Pp. 342-357 *In*: Proceedings of a workshop on Management of Nongame Species and Ecological Communities. (W. McComb, Ed.). University of Kentucky, Lexington, Kentucky.

Summary: Several programs exist for collecting colonial waterbird census data at the national, regional and state level. Goals for such programs include assessing habitat quality, documenting species distribution and abundance, and population trend analysis. A simple log-transformation regression analysis is presented along with alternatives if data are missing from colonies. Sampling designs are also discussed

and the results of a survey of nongame states are provided.

Erwin, R. M. 1985. Monitoring colonial waterbird populations in the Northeast: historical and future perspectives. Transactions of the Northeast Fish and Wildlife Conference 41:97-109.

Summary: The history and present status of colonial waterbird research and management in the northeastern United States is reviewed. The inauguration of many long-term monitoring programs occurred in the 1970's because of concerns of wetland losses and environmental contamination. Monitoring programs need to address the objectives of the waterbird monitoring and standardize survey and census techniques. Different census methods are recommended for various colonial waterbird species.

Erwin, R. M. and B. Hoover. 1994. Colonial waterbird inventory and monitoring.. Patuxent Environmental Research Center. Laurel, Maryland. *Online*. Available: http:\\www.im.nbs.gov./cwb/cwb.html

Summary: The authors recommend a protocol for a regional/national colonial waterbird inventory and monitoring program. They suggest that most species be censused every 4 years except those that are listed or are of special interest. Methods for censusing are also discussed.

Ewins, P. J., D. V. Weseloh, and H. Blokpoel. 1995. Within-season variation in nest numbers of Double-crested Cormorants (*Phalacrocorax auritus*) on the Great Lakes: implications for censusing. Colonial Waterbirds 18:179-192.

Summary: The authors counted number of apparently occupied nests several times during a season at 48 colonies of cormorants in the lakes Superior, Huron and Ontario. Nest counts were greatest at the mid-nestling stage and they concluded more reliable population counts for cormorants are obtained during the mid-nestling stage than at the peak of incubation as is suggested for other colonial waterbirds. Other issues regarding breeding chronology are also discussed.

Fleury, B. E. and T. W. Sherry. 1995. Long-term population trends of colonial wading birds in the southern United States: the impact of crayfish aquaculture on Louisiana populations. Auk 112(3):613-632.

Summary: Using both Christmas Bird Count and Breeding Bird Survey data, the authors documented increases in population for most wading bird species in Louisiana. Species that increased the most were those with a large component of crayfish in their diet. Including other data, the authors argued that wading bird populations increased because of the increased acreage in crayfish aquaculture.

Galli, J. 1978. New Jersey's Colonial Waterbird Project. Proceedings of the Conference of the Colonial Waterbird Group 1978:92-98.

Summary: Private and state field biologists cooperated to survey and census over 150 colonies of 17 species of colonial waterbirds along 90 miles of New Jersey's Atlantic coastline in 1977. Both aerial and ground surveys were conducted and cooperating biologists also helped post and monitor many of the colony sites. The expectation was to continue this project as an annual survey and census of all colonies in along that 90-mile stretch of Atlantic coastline.

Geissler, P. H. and B. R. Noon. 1981. Estimates of avian population trends from the North American Breeding Bird Survey. Pp. 42-51 *In:* Estimating the numbers of terrestrial birds. (C. J. Ralph and J. M. Scott, Eds.). Studies in Avian Biology No. 6.

Summary: The authors develop and test alternative methodologies (other than calculating annual ratios) for determining population trends using Breeding Bird Survey routes. The methods allow for weighting certain parameters, e.g. years, population size, etc., and using parametric and non-parametric regression analysis. They concluded that the weighted parametric analysis is the best estimator in most cases. Non-parametric is advised if there is reason to make extreme points less influential.

Green, J. C. 1985. A strategy for monitoring colonial waterbirds in Minnesota. submitted to the Nongame Wildlife Program, Minnesota Department of Natural Resources, St. Paul, Minnesota.

Summary: Recommendations for monitoring schedules and methodology are provided for breeding grebes, pelicans, cormorants, wading birds, gulls and terns are discussed. Coordination of MNDNR efforts with other agencies is vital to colonial waterbird monitoring.

Guertin, D. S. and L. A. Pfannmuller. 1985. Colonial waterbirds in Minnesota: an update of their distribution and abundance. Loon 57: 67-78.

Summary: Species accounts discuss distribution and population size for each of Minnesota's breeding colonial waterbird species and maps are provided showing distribution of each species throughout the state.

Hanners, L. A., L. K. Kinkel, and R. B. Clapp. 1991. Colonial waterbird information service. publication of the Colonial Waterbird Society.

Summary: Names of ornithologists who have studied colonial waterbirds have been compiled along with their addresses, phone numbers, areas of interests and the geographic areas in which they worked.

Hatch, J. J. 1984. Rapid increase of Double-crested Cormorants nesting in southern New England. American Birds 38:984-988.

Summary: Double-crested Cormorants from New Hampshire to Long Island Sound were censused by ground nest counts and aerial censuses from 1972-1982. Populations expanded at an annual rate of 20% and expanded their range into Long Island Sound. Causes for expansion may include termination of a cormorant control program, possible increases in cormorant prey population, or some yet unstudied factor.

Howes, L. and W. A. Montevecchi. 1993. Population trends and interactions among terns and gulls in Gros Morne National Park, Newfoundland. Canadian Journal of Zoology 71:1516-1520.

Summary: The population dynamics of Arctic and Common terns and Great Black-backed and Herring gulls were studied on five islands in western Newfoundland in 1990 and 1991 and compared with a census conducted in 1973. Although, the total tern population did not decrease, terns moved from islands were gulls were increasing to smaller islands where they encountered low productivity. Immigration may be helping to maintain the tern population in Gros Morne National Park.

Hutchinson, A. E. 1979. Estimating numbers of colonial nesting seabirds: a comparison of techniques. Proceedings of the Colonial Waterbird Group 3:235-244.

Summary: Emphasizing the importance of reliable census methods, the author compares the accuracy of direct nest counts, ground-visual estimates, aerial (fixed-wing)-visual estimates, and aerial photographic counts of gulls and cormorants at 14 island colonies in Maine. Variability among 4-6 observers was lowest for ground nest counts and, therefore, considered to be the most accurate. Photo counts were the next most accurate followed by ground-visual estimates, and lastly, aerial-visual estimates. The author also compares costs and disturbances levels of the various methods.

King, Kirke A. 1978. Colonial wading bird survey and census techniques. Pp. 155-159 *In:* Wading Birds. (A. Sprunt IV, J. C. Ogden, and S. Winckler, Eds.). Research Report No. 7 of the National Audubon Society. New York.

Summary: Survey and census techniques are compared and two ground sampling techniques for single-species colonies (strip census and point-center quarter) are discussed. The topics of data recording and amount of disturbance during censusing are also covered.

Kinkel, L. K. and D. Koehring. 1992. Survey methodology and population trends of herons, egrets, and cormorants on the upper Mississippi River National Wildlife and Fish Refuge. Report submitted to Upper Mississippi River National Wildlife and

Fish Refuge. Winona, Minnesota

Summary: Census data for several rookeries along the Mississippi River were evaluated and found to be insufficient for determining population trends. Recommendations were offered as to how to improve future data collection depending on the specific goals of the Refuge. Other management regarding nesting habitat management, foraging habitat management, and animal damage control.

Koonz, W. H. 1985. Status of colonial waterbirds nesting in southern Manitoba. Canadian Field-Naturalist 99(1):19-29.

Summary: Aerial censuses were conducted to determine the population size of 12 species of colonial waterbirds in southern Manitoba in 1979. Comparisons with historical data and other evidence were used to determine the population trends of these species. Gulls and pelecaniforms were believed to be increasing in numbers, while grebes and Common Terns were decreasing.

Kushlan, J. A., 1979. Effects of helicopter censuses on wading bird colonies. Journal of Wildlife Management 43:756-760.

Summary: The effects of helicopter censuses were compared with effects of fixed-wing aircraft at small and large colonies of wading birds. Helicopters approached colonies slowly and circled the periphery of colonies. Helicopter censuses achieved greater accuracy (as compared to ground nest counts) than those conducted by fixed-winged aircraft for conspicuous species, e.g. egrets, or species that nest on top of trees, e.g., cormorants. Total costs of censusing by helicopters, including manpower, proved to be more economical than ground nest counts.

Kushlan, J. A. 1986. Colonies, sites, and surveys: the terminology of colonial waterbird studies. Colonial Waterbirds 9:119-120.

Summary: To avoid confusion when discussing monitoring colonial waterbird populations, the author distinguishes between surveys (the act of locating colony sites) and censuses (the enumeration of the inhabitants of a colony site) and between colony sites (the physical location of colonial nesting) and colonies (the avian assemblage occupying a colony site).

Kushlan, J. A. 1992. Population biology and conservation of colonial wading birds. Colonial Waterbirds 15:1-7.

Summary: The author discusses several of the problems of managing wading bird populations, including understanding breeding biology, foraging ecology, and population biology. Total nest counts are not always possible and therefore estimates that are precise and accurate are desirable.

Kushlan, J. A., 1993. Colonial Waterbirds as bioindicators of environmental change. Colonial Waterbirds 16(2):223-251.

Summary: The author discusses the justification of using colonial waterbirds as biological indicators at two levels: suborganismal and superorganismal (population/community/ ecosystem). The advantages to using colonial waterbirds are the ability to collect large sample sizes, their place in the food web, and their use of human-influenced environments. Disadvantages include their wide-ranging habits which allow them to choose foraging and nesting sites, the difficulty in handling these species, especially in captivity, and statistical and sampling problems involved with population monitoring. Caution must be exercised when deciding whether a species has value as a bioindicator for the parameter to be measured.

Link, W. A. and J. R. Sauer. 1997. Estimation of population trajectories from count data. Biometrics 53:488-497.

Summary: Several models are developed and incorporated into a method used to analyze North American Breeding Bird Survey data for population trends. The method is able to control for two types of observer effects: differences among observers and improved accuracy within an observer as s/he gains experience. An example using Wood Thrush data from the upper coastal plain of Maryland is provided.

Litwin, T. S., A. Ducey-Ortiz, R. A. Lent, and C. E. Liebelt. 1993. 1990-1991 Long Island colonial waterbird and piping plover survey. New York State Department of Environmental Conservation. Stony Brook, New York and the Seatuck Research Program, Islip, New York.

Summary: Annual aerial and ground censuses begun in 1983 on least terns and piping plovers expanded to 22 species by 1985. Linear regressions on untransformed count data found ten species increasing in numbers and five decreasing in numbers. The appendices includes data sheets and their instructions.

Ludwig, J. P. 1984. Decline, resurgence, and population dynamics of Michigan and Great Lakes Double-crested Cormorants. Jack-pine Warbler 62:91-102.

Summary: Cormorant population size appeared to be at its lowest during DDT years according to census data collected since 1959 in Lake Michigan and surrounding areas. Since then population have increased exponentially at an average rate of 40% a year. Possible reasons for this increase include the banning of DDT, protective legislation, decreased human depredation, and declines in commercial fisheries that may increase the cormorant prey base.

McCrimmon, D. A., S. T. Fryska, J. C. Ogden, and G. S. Butcher. 1997. Non-linear

population dynamics of six species of Florida ciconiiformes assessed by Christmas Bid Counts. Ecological Applications, in press.

Summary: Thirty years of Christmas Bird Count data was analyzed to determine population trends for wintering Great, Snowy, and Cattle egrets, Little Blue and Tricolored herons, and Wood Storks. Several statistical tests are performed to assess the non-linear population dynamics of these species. In recent years, Cattle and Snowy egrets, and Tricolored herons have been declining and Wood storks have been slowly recovering from low populations.

Neuman, J. and H. Blokpoel. 1997. The terns of the Canadian Great Lakes. Great Lakes Fact Sheet. Public Works and Government Services Canada.

Summary: Information on the biology of the four tern species (Caspian, Common, Black and Forster's tens) are presented. Conservation-oriented issues discussed include: population trends, distribution of the species and factors affecting the survival of tern populations in the Canadian Great Lakes.

Nisbet, I. C. T. 1973. Terns in Massachusetts: present numbers and historical changes. Bird-banding 44:27-55.

Summary: The author documents population sizes for four species of terns in Massachusetts, presenting data that suggests that population numbers were lowest from 1880-1900 but recovered after protective legislation was passed. Their numbers peaked around 1920-1950 but have since decreased. A shift from more protected offshore islands to vulnerable inshore islands because of usurpation by gulls and other factors is cited as probable reasons for the declines. Census techniques are also discussed.

Parnell, J. F., D. G. Ainley, H. Blokpoel, B. Cain, T. W. Custer, J. L. Dusi, S. Kress, J. A. Kushlan, W. E. Southern, L. E. Stenzel, and B. C. Thompson. 1988. Colonial waterbird management in North America. Colonial Waterbirds 11:129-169.

Summary: Many topics on colonial waterbird management are reviewed, including a discussion of the appropriate management unit for managing waterbirds (a regional population was better than a local colony site or an entire species), the advantages and disadvantages of different census techniques, and the importance of statistically sound census methods that can detect single-year deviations of at least 20%.

Penning, W. L. and F. J. Cuthbert. 1993. The history of colonial waterbird management in the Duluth-Superior Harbor 1937-1990. Loon 65:163-174.

Summary: The history of Common Terns and Ring-billed Gulls in the St. Louis River estuary is reviewed with particular focus on attempts to protect tern populations while the gull population increased. Censuses were mostly conducted by ground nest counts and total population numbers were estimated for and compared for many of the years between 1937-1990.

Portnoy, J. W. 1978. A wading bird inventory of coastal Louisiana. Pp. 227-234 *In:* Wading Birds. (A. Sprunt IV, J. C. Ogden, and S. Winckler, Eds.). Research Report No. 7 of the National Audubon Society. New York.

Summary: Censuses of 25 wading bird colonies were conducted using a belt transect sampling scheme and aerial photography. These two techniques and the relationship between nest density and nesting area are examined. Descriptions of wading bird nests are also provided as a guide for distinguishing nests in mixed-species colonies.

Pullin, B. P. 1990. Size and trends of wading bird populations in Tennessee during 1977-1988. The Migrant 61(4): 95-104.

Summary: Population data for five species of herons and egrets in the Tennessee River Valley were collected at 51 colonies for twelve years using aerial surveys and photography, and ground nest counts. Censuses were conducted every year and few colonies were missed in any one year. Great Blue Herons and Black-crowned Night-Heron populations were sufficiently abundant to graph population trends and were found to be increasing. Annual population growth, *r*, was calculated for several Great Blue Heron colonies.

Rodway, M. S. and M. J .F. Lemon, and K. R. Summers. 1991. Seabird breeding populations in the Scott Islands on the west coast of Vancouver Island, 1982-89. Pp. 52-59 *In*: The ecology, status, and conservation of marine and shoreline birds on the west coast of Vancouver Island (K. Vermeer, R. W. Butler, and K. H. Morgan, Eds.). Occasional Paper No. 75 of the Canadian Wildlife Service, Ottawa, Ontario.

Summary: Authors censused storm-petrels, cormorants, gull, and alcids on five-island archipelago in Canadian Pacific coast using total nest counts, strip transects, line transects with quadrats, and photographic counts five times between 1982-89. They compared totals of breeding pairs for population trend analysis and found most populations were larger in 1989 than in 1982.

Sauer, J. R. and B. G. Peterjohn, and W. A. Link. 1994. Observer differences in the North American Breeding Bird Survey. Auk 111(1):50-62.

Summary: Variability among observers that conduct Breeding Bird Survey routes is documented and shown that if a trend analysis does not include observer as a covariable the trend tends to indicate an increasing population more frequently than if an observer covariable is included.

Sommers, L. A., M. L. Alfieri, K. J. Meskill, and R. L. Miller. 1996. 1995 Long Island colonial waterbird and piping plover survey. New York State Department of Environmental Conservation, Stony Brook, New York and the Seatuck Research Program, Islip, New York.

Summary: Annual aerial and ground censuses begun in 1983 on least terns and piping plovers expanded to 21 species by 1985. Linear regressions on untransformed count data found six species increasing in numbers and three decreasing in numbers. The appendices includes data sheets and their instructions.

Thompson, B. C. and J. E. Tabor. 1981. Nesting populations and breeding chronologies of gulls, terns, and herons on the upper Columbia River, Oregon and Washington. Northwest Science 55 (3):209-218.

Summary: Ground nest counts were conducted at 17 colonies of 6 species of gulls and larids to assess the population size along 467 km of the Columbia River. Partial nest counts were conducted at three gull colonies by transect and quadrat methods, otherwise all counts total nest counts. Data were collected for two years at all sites and compared between the two years. Breeding chronologies were also determined by frequent visits to some colonies.

Thompson, D. H. 1977. Declines in populations of colonial waterbirds nesting within the floodplain of the upper Mississippi River. Proceedings of the Conference of Colonial Waterbird Group 1977:26-37.

Summary: A one-year pilot study was conducted to census six species of colonial waterbirds nesting in the Mississippi River floodplain between St. Louis and Minneapolis. Thirty-six colonies were located by aerial survey and censused by either aerial estimates or photography, or total ground nest counts. Comparisons of population size were made with historical data and four species were found to be declining. Habitat data for Great Blue Herons and Great Egrets were also collected and analyzed.

Vermeer, K., K. H. Morgan, and P. J. Ewins. 1991. Population trends of Pelagic Cormorants and Glacous-winged Gulls nesting on the west coast of Vancouver Island. Pp. 60-70 *In*: The ecology, status, and conservation of marine and shoreline birds on the west coast of Vancouver Island (K. Vermeer, R. W. Butler, and K. H. Morgan, Eds.). Occasional Paper No. 75 of the Canadian Wildlife Service, Ottawa, Ontario.

Summary: Pelagic Cormorants and Glacous-winged Gulls were censused monitored at 67 colony sites along the western coast of Vancouver Island in 1989. Nest or territory counts were used to determine colony size. This census was compared with censuses conducted in 1974-5 and both populations had decreased.

Weseloh, D. V., and B. Collier. 1995. The rise of the Double-crested Cormorant on the Great Lakes: winning the war against contaminants. Great Lakes Fact Sheet. Public Works and Government Services Canada.

Summary: The history of Double-crested Cormorants on the Great Lakes and the reasons for population changes are discussed. Most recent increases appear to be a result of decreasing toxic chemicals and changes in fish populations. The authors also present data which do not support the hypothesis that cormorants are competing with sport fisherman for game fish species.

Williams, B., R. A. Beck, B. Akers, and J. W. Via. 1990. Longitudinal surveys of the beach nesting and colonial waterbirds of the Virginia barrier islands. Virginia Journal of Science 41:381-388.

Summary: Eighteen islands of the Virginia Coastal Reserve were ground censused by the same observers using the same methodology for 14 consecutive years. Twenty-seven species of colonial-nesting and other beach-nesting species were counted. Total population sizes were compared to ascertain population trends and twelve species were found to be declining and four increasing.

Appendix II. Survey sent to state agencies asking for information about state colonial waterbird monitoring programs.

COLONIAL WATERBIRD POPULATION ANALYSIS SURVEY

State:

Questions:

1. About how many colonies are located in your state?

2. How many species do you monitor?

3. Approximately what percentage of your colonies do you census every year?

3A. If you don't census every colony every year, what is your protocol for determining what colonies do get censused (e.g. census only large colonies or listed species every year):

4. Approximately what percentage of those colonies that you census are censused by: (Or just check off which methods you use if you use a wide variety)

ground counts:	nest -	adults -	photography -
boat counts:	nest -	adults -	photography -
aerial survey	nest -	adults -	photography -

other (specify):

5. How do you analyze these data for population trends?

Appendix III. Addresses and phone numbers of state personnel responsible for colonial waterbird monitoring and a summary of e-mail responses to survey or phone interviews.

Arkansas
Mr. Tom Foti
Arkansas Natural Heritage Commission
Suite 1500 Tower Building
Little Rock, AR 95814

Phone: 501-324-9150
E-mail: tom@dah.state.ar.us

Summary of e-mail: no state program, Army Corps of Engineers monitors interior Least Terns

California
Mr. John Gustafson
California Natural Heritage Division
Department of Fish and Game
1220 S St.
Sacramento, CA 95814

Phone: 916-322-2493

Summary of phone call: no formalized program, though has taken the lead in monitoring Brown Pelicans, a listed species, which nests mostly on National Park Service lands. They conduct boat observations of nests and adults and count nests after season. USFWS has recently funded a project to use aerial photography for pelicans. Other species are monitored by feds on federal land, NGOs (e.g., bird observatories), or university researchers, (e.g., Dan Anderson on white pelicans)

Connecticut
Ms. Jenny Dickson
Department of Environmental Protection
Session Woods WMA
P.O. 1238
Burlington, CT 06103-1238

Phone: 860-675-8130

Summary of phone call: conduct comprehensive survey of 30-35 colonies every 3 years, annual census of coastal terns and herons and egrets that are in 14 colonies vulnerable to human disturbance. all censuses are ground counts. compare total populations for population trends

<u>Delaware</u>
Ms. Lisa Gelvin-Innvaer
Division of of Fish and Wildlife
Department of Natural Resources & Environmental Control
R.D. 1 P.O. Box 81
Smyrna, DE 19977

Phone: 302-653-2882
E-mail: lgelvin-inn@state.de.us

Summary of phone call: monitor beach-nesters in state parks, amount of censusing depends on funding. participate in Atlantic Coastal Colonial Watebird Inventory (ACCWI), feds analyze data. Manomet Bird Observatory helped collect baseline data and refine methodology in censusing large heronry in Delaware Bay. conducts both ground nest counts and aerial censuses (with federal funding)

<u>Kansas</u>
Mr. Jerry Horak
Kansas Department of Wildlife & Parks
1830 Merchant, PO Box 1525
Emporia, KS 66801-1525

Phone: 316-342-0658

Summary of e-mail survey response: 200-300 colonies in state, mostly Great Blue Herons. also has egrets night-herons, White-faced Ibis, Least Terns, and cormorants. endangered Least Terns only species monitored annually (2 colonies) - both nests and adults counted from ground. compare total populations. cormorants counted in fall & winter waterfowl counts.

<u>Maine</u>
Ms. Brad Allen
Wildlife Division
Department of Inland Fisheries & Wildlife
650 State St.
Bangor, ME 04401-5654

Phone: 207-941-4478

Summary of e-mail survey response: has ~500 coastal colonies, ~30 inland heronries. count only island-nesting terns & puffins every year because they are listed species. also do Common Eiders because they are a game species. participates in ACCWI. count terns, eiders, gulls, & herons from ground, black guillemots from boat and use aerial censuses & photography for Great Blue Herons, cormorants & gulls

Maryland
Mr. Glenn Therres
Division of Wildlife and Natural Heritage
Department of Natural Resources
Tawes State Office Building E-1
Annapolis, MD 21401

Phone: 410-974-3195
E-mail: gtherres@dnr.state.md.us

- sent Brinker et al. (1996)

Massachusetts
Mr. Brad Blodgett
Natural Heritage and Endangered Species Program
Division of Fisheries and Wildlife
Rt. 135
Westborough, MA 01581

Phone: 508-792-7270 ext.200
E-mail: bblodgett@state.ma.us

Summary of phone call: 137 coastal clonies, 64 inland heronries. conducts annual census on 4 tern species, black skimmers, and Laughing Gulls using ground nest counts. census inland Great Blue Heron colonies every 5 years. participates in ACCWI. compares total population counts for terns

Michigan
Mr. Tom Weise
Michigan Natural Features Inventory
Mason Bldg, 5th floor, Box 30444
Lansing, MI 48909-7944

Phone: 517-373-9318

Summary of phone call: DNR has no formalized program, but does fund reasearch. USFWS has monitored some regions for contaminant studies. Common and Caspian terns are lsited and usually someone censuses these colonies (feds, university researchers, etc.). collected specimens and some census data on cormorants when population increased to study effect on fisheries

New Jersey
Mr. Dave Jenkins
Endangered and Nongame Species Program
Department of Environmental Protection
CN400
Trenton, NJ 08625-0400

Phone: 609-292-9101

Summary of phone call: conduct ground nest counts of Black Skimmers and Least Terns and winter nest counts for inland heronries every year. participates in ACCWI and conducts helicopter surveys using volunteers. uses simple regressions for population trends because they miss few colonies when they census, they just don't census every year

New York
Ms. Bob Miller
Dept. of Environmental Conservation
Latham, NY 12110-2400

Phone: 518-439-0198
E-mail: bob.miller@dec.mailnet.state.ny.us

- sent Sommers et al. 1996

Oregon
Mr. Mark Stern
Natural Heritage Program
Oregon Field Office
821 SE 14th Ave.
Portland, OR 97214

Phone: 503-731-3070
E-mail: mstern@tnc.org

Summary of phone call: no formalized state program, though, Natural heritage Program tracks locations of American White Pelican, egret, Franklin's gull, and Fork-tailed Petrel colonies. censusing also conducted at NWRs and some Wildlife Manager Areas. gave numbers for Malheur NWR - Garry Ivey (541-493-2612) and Klamath Basin - Jim Hainline (916-667-2231)

Pennsylvania
Mr. Dan Brauning
Pennsylvania Game Commission

E-mail: D_M.brauning@prodigy.com

Summary of e-mail survey response: monitors listed species (Great Egrets, Black-crowned Night-Herons in 6-8 colonies), uncommon species (Snowy Egrets, Double-crested Cormorants) and large (>50 nests) Great Blue Heron colonies (>60 colonies). annually plus haphazard sample of other colonies. approximately every five years attempt to count all colonies using technicians & volunteers. conduct ground nest counts and have not analyzed for population trends

Texas
Mr. Lee Elliott
Parks and Wildlife Dept.
Endangered Resource Branch
3000 IH-35 South, Suite 100
Austin, TX 78704

Phone: 512-912-7011

Summary of phone call: Texas Colonial Waterbird Project conducts annual censuses of all coastal colonies by using ~40 volunteers who count nests from the ground at the same time of year. aerial censuses of nests and adults(correction factor 1.5 adults/nest) are sometimes obtained. The current coordinator of this project is Phil Glass, Army Corps of Engineers, (713-286-8282). In 1992, Mike Lange, Brazoria NWR (409-849-7771) started to analyze the data using Geissler & Noon's (1981) method.

Utah
Mr. Don Paul
Division of Wildlife Resources
Department of Natural Resources
515 E. 5300 South
Ogden, UT 84405-4599

Phone: 801-479-5143

Summary of e-mail survey response: estimate 150-200 colonies in state, systematically census 11 species and census 10-20% of the colonies each year. developing protocol for censuing Great Salt Lake region. use ground nest and adult counts, and aerial counts of adults and photography. look at year to year trends for some colonies and measure fledging success for White Pelicans

Vermont

Mr. Mark Ferguson
Nongame & Natural Heritage Program
Fish and Wildlife Department
103 S. Main St
Waterbury, VT 05671-0501

Phone: 802-241-3700
E-mail: mferguson@fpr.anr.state.vt.us

Summary of e-mail survey response: monitors 13 terneries annually for two tern species. all colonies censused from boats (nests & adults); about half by ground nest counts

Virginia

Mr. Dana Bradshaw
Virginia Fish and Game
Dept. of Conservation & Recreation
1500 E. Main St., Suite 312 ?
Richmond, VA 23219

Phone: 804-221-1645

Summary of phone call: estimates 400 heronries, 40 tern and/or skimmer colonies, 100 gull colonies. used to census urban heronries annually - no more funding. census Great Blue Herons every 3-4 years. nonstate personnel conduct other censuses, e.g. Virginia Coastal reserve colonies. participates in ACCWI. conducts aerial surveys, occasionally aerial photography, but most counts are from ground of nests or adults

Washington

Mr. Eric Larsen
Department of Fish and Wildlife
Olympia, WA 98504-7016

Phone: 360-902-2618
E-mail: larseeml@dfw.wa.gov

West Virginia

Mr. Scott Blackburn
West Virginia Natural Heritage
DNR Operations Center
Ward Rd, P.O. Box 67
Elkins, WV 26241

Phone: 304-637-0245
E-mail: sblackburn@mail.dnr.state.wv.us

Summary of e-mail: Natural Heritage Program tracks only Great Blue Heron colony locations, but censusing only conducted by Ohio River Island NWR personnel

Wisconsin

Mr. Sumner Matteson
Bureau of Endangered Resources
Department of Natural Resources
101 S. Webster St., Box 7921
Madison, WI 53707

Phone: 608-266-1571

Summary of phone call: establishing a state colonial waterbird register which will compile census data collected since the 1970's and eventually set up a volunteer program to census more colonies. Common, Forster's, and Caspian terns censused every year by ground nest counts. Great Egrets incomplete count every year - aerial census of adults. every 5 years cormorants coloniesfrom air and colonies along Lake Superior are counted. there are periodic counts in Green Bay. Matteson is currently analyzing 20 years of data for cormorants

Saskatchewan

Mr. Jeff Keith

E-mail: jkeith@unibase.unibase.com

Summary: no provincial program for monitoring colonial waterbirds

Appendix IV. Names, addresses, and phone numbers of colonial waterbird biologists and statisticians who have helped by commenting on analysis techniques

Dr. R. Michael Erwin
Department of Environmental Sciences
Clark Hall
University of Virginia
Charlottesville, VA 22903

Phone: 804-924-3207
E-mail: rme5g@virginia.edu

Resource: works for USGS Biological Resource Division and University of Virginia. active in testing of census methodology and encouraging regional and state-wide census programs. helps coordinate Atlantic Coast Colonial Waterbird Inventory

Dr. Jeremy Hatch
Department of Biology/Harbor Campus
University of Massachusetts
Boston, MA 02125-3393

Phone: 617-287-6615
E-mail: hatch@umbsky.cc.umb.edu

Resource: censuses colonial waterbirds along the New England coast

Dr. Joseph Jehl
Hubbs-Sea World Research Institute
2595 Ingraham St.
San Diego, CA 92109

Phone: 619-226-3870
E-mail: jjehl@hubbs.sdsu.edu

Resource: censuses colonial waterbirds on the West Coast

Mr. John P. Kelly
Audubon Cypress Grove Preserve
P.O. Box 808
Marshall, CA 94940

Phone: 415-663-8203
E-mail: kellyjp@nbn.com

Resource: has been analyzing continuous annual coverage but has heron/egret data with problems similar to Minnesota's

Mr. Michael Lange
Brazoria National Wildlife Refuge
1212 Velasco, Suite 200
Angleton, TX 77515
Phone: 409-849-7771

Resource: analyzing Texas waterbird data using Geissler & Noon 1981 and LOWESS smoothing averages techniques

Dr. Donald McCrimmon
Office of Research
Oakland University
520 O'Dowd Hall
Rochester, MI 48309

Phone: 313-370-3222
Resource: analyzing Florida waterbird populations with Christmas Bird Count data

Dr. John Sauer
Patuxent Environmental Research Center
Nelson Lab
Laurel, MD 20708-4015

Phone: 301-497-5662mid-Atlantic
E-mail: john_r_sauer@nbs.gov

Resource: analyzes Breeding Bird Survey data at Patuxent Environmental Research Center. suggested using their most recent technique for analyzing BBS data for colonial waterbird data.

Appendix V.1 Colony site by year matrix of Common Terns in Minnesota between 1979-1995. Underlining indicates the years that the colony was active. Each year includes three columns: the census estimate (number of pairs) or status code, a code for the observer (not given), and a code for the census method (given below).

OTCN*	Site Name	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
2	Pine & Curry Is.	50 b G2	25 b G2	44 g G2	125 a G1	130 a G1	139 d G2	209 a G2	485 a G2	168 a G2	52 b G2	123 b G2	177 b G2	273 b G2	188 b G2	153 d G2	379 b G2	378 b G2	375 b G2
102	Spirit Is.	14 j G2	25 j G1	10 l G2	3 j G2	6 l G2	46 d G2	41 k G2	30 j G2	48 l G2	13 l G2	2 l G2	NC . .	4 l G2	30 l G2	14 l G2	18 l G2	14 l G2	11 l G2
103	Harvepin Is.	12 j G2	50 l G2	39 l G2	A j G2	22 l G2	47 d G2	2 j G2	20 j G2	42 l G2	78 l G2	84 l G2	NC . .	48 l G2	81 l G2	104 l G2	82 l G2	95 l G2	125 l G2
114	Cotton Lake	0 . .	0 . .	NC . .	NC . .	NC . .	NC . .	0 a B1	NC . .	NC . .	NC . .	NC . .	0 c G2	NC . .	8 c G1	0 c G2	NCI . .	NCI . .	NCI . .
128	Port Terminal	178 m G2	161 m G2	227 m G2	180 m G2	140 d G2	113 d G2	2 m G2	4 m G2	30 m G2	0 o .	0 o .	0 o .	0 o .	0 p .	0 p .	0 p .	0 p .	0 . .
129	Sky Harbor	9 n G2	13 m G2	10 m G2	17 m G2	25 m G2	27 m G2	79 m G2	33 m G2	4 m G2	0 o G2	0 o G2	0 o G2	NCI . .	NCI . .	NCI . .	NCI . .	NCI . .	NCI . .
130	Hibbard Power	5 n G2	0 m G2	0 m G2	NCI . .	0 m G2	0 m G2	0 m G2	0 m G2	0 m G2	0 o G2	0 o G2	0 o G2	0 o G2	0 p G2	0 p G2	0 p G2	0 p G2	0 . .
132	Grassy Point	18 n G2	NC . .	NC . .	NC . .	20 m G2	0 m G2	0 m G2	0 m G2	0 m G2	0 o G2	0 o G2	0 o G2	NCI . .	NCI . .	NCI . .	NCI . .	NCI . .	NCI . .
162	Gull Island	A . .	A . .	150 q G1	150 q G1	375 q G2	489 q G2	219 q G2	242 q G2	276 q G2	142 q G2	NC . .	NC . .	0 c G2	0 a G2	0 r G2	0 r G2	0 r G2	66 r G2
224	Rocky Point	NC . .	NC . .	4 q G1	0 a G2	0 a G2	0 a G2	NC . .	175 a G1	0 a G2	0 a G2	48 a G2	0 b G2	0 b G2	0 b G2	0 b G2	NCI . .	0 b G2	NCI . .
228	Four Block Is	NC . .	NC . .	232 a G2	NC . .	50 a G1	NC . .	24 a G2	NC . .	100 a B1	NC . .	0 a G2	NCI . .	0 c G1	0 a G1	0 c B1	NCI . .	0 a B1	NCI . .
229	Crowduck Is.	NC . .	NC . .	0 a G2	0 a G2	0 a G1	NC . .	0 a G2	NC . .	0 a B1	NC . .	0 a G2	NC . .	0 c G2	0 a G2	10 c G2	NC . .	0 a G2	NCI . .
230	Red Lake Rock	NC . .	NC . .	0 a G2	NCI . .	0 a G2	NCI . .	0 a G2	NCI . .	0 a G2	NCI . .	0 a G2	NCI . .	0 c G2	0 a G2	0 c G2	NC . .	31 a G2	NC . .
235	Techout Is.	NC . .	NC . .	0 a G1	0 a .	0 a G1	NC . .	0 a G2	NC . .	0 a B1	NC . .	237 a G2	NC . .	100 c G1	0 a G2	198 c G2	NC . .	0 a B1	NCI . .
322	Erie Pier	NC . .	NC . .	NC . .	NC . .	24 d G2	4 d G2	1 m G2	0 m G2	0 m G2	0 o G2	0 o G2	0 o G2	NCI . .	0 p G2	0 p G2	NCI . .	NCI . .	NCI . .
479	Morris Point	NC . .	NC . .	NC . .	5 a G1	5 a G1	0 a G2	NC . .	NC . .	NC . .	16 a G2	NC . .	NC . .	NC . .	NC . .	0 d G2	NCI . .	0 b G2	NCI . .
501	Shipwreck Is.	A l .	13 l G2	13 l G2	A l .	20 l G2	15 t G2	15 l G2	15 l G2	0 l G2	NC l .	20 l .	0 l .	NCI . .	NCI . .	0 t .	NCI . .	NCI . .	NCI . .
502	Hearding Is.	NCI . .	NCI . .	NCI . .	NCI . .	1 d G2	0 d G2	8 m G2	31 m G2	0 m G2	8 o G2	0 o G2	0 o G2	0 o G2	0 o G2	NCI . .	NCI . .	NCI . .	NCI . .
617	Interstate Is.	NCI . .	NCI . .	NCI . .	NCI . .	NCI . .	NCI . .	50 m G2	0 m G2	0 m G2	0 o G2	81 o G2	124 o G2	152 p G2	107 p G2	182 p G2	212 p G2	284 p G2	231 x G2
668	Fish Lake	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	25 m G1	NCI . .	NCI . .	NCI . .	NCI . .	0 v G2	0 v G2	NCI . .	NCI . .	NCI . .
716	Little Pelican Spit	A w .	A w .	A w .	A w .	A w .	A w .	A w .	A w .	A w .	35 q G2	NC . .	0 u G2	61 c G2	0 . .	0 . .	NCI . .	NCI . .	0 . .
717	Little Pipe Is.	NC . .	NC . .	NC . .	NC . .	NC . .	A w .	A w .	A w .	A w .	8 q G2	NC . .	10 u G2	NC . .	NC . .	8 r G2	11 r G2	2 r G2	5 r G2
867	Fish Lake 2	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NCI . .	NCI . .	NCI . .	NCI . .	NCI . .	5 v G2	30 p G2	5 y G2	0 . .	0 . .
918	Little Pelican Is.	0 u G2	0 u G2	0 u G2	0 u G2	0 u G2	0 u G2	0 u G2	0 u G2	0 u G2	0 u G2	20 u G2	126 u G2	NC . .	0 . .	116 r G2	184 r G2	256 r G2	185 r G2
917	Sand Bar	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	NC . .	75 a G1	A . .	NC . .	NC . .	0 . .
	Total no. of pairs	286	287	729	490	824	880	650	1035	693	352	595	437	636	472	793	871	1039	978
	Total number colonies censused	9	9	14	10	18	14	18	14	19	16	17	14	14	20	21	10	16	12
	% colonies censused**	40	36	56	40	72	56	72	56	76	64	68	56	56	80	84	40	64	48
	No. of known active colonies	10	10	11	12	14	15	15	15	15	14	14	12	10	13	13	11	12	9
	No. of known active colonies censused	7	7	9	7	13	12	11	11	12	12	10	7	7	11	12	8	11	8
	% colonies censused***	70	70	81.8	58.3	92.9	80	73.3	73.3	80	85.7	71.4	58.3	70	84.6	92.3	72.7	91.7	88.9

* OTCN = NHP occurrence number
** Method 1 as described in text
*** Method 2 as described in text

Census Methods
G1 = ground estimate
G2 = total ground nest count
B1 = estimate from boat

Status codes
A = colony known to be active, but not censused
NC = colony not censused, activity unknown
NCI = colony not censused, presumed inactive

Appendix V.2 Colony site by year matrix of Double-crested Cormorants in Minnesota between 1977-1995. Underlining indicates the years that the colony was active. Each year includes three columns: the census estimate (number of pairs) or status code, a code for the observer (not given), and a code for the census method (given below).

OTCN*	Site	1977			1978			1979			1980		
5	AMWR-Cormorant Is.	5	ca	1	NC			13	ca	1	10	da	
10	Egret Is.	A	cn		A			355	cn	B2	150	cn	B1
30	E. Black Cinder Sw.	NCI			0			0			0		
33	Pelican Lake	NC			NC			38	l	B1	11	l	B2
36	Dassel Marsh	A			70	w	1	194	ck	B2	273	ck	B2
37	L. Jefferson	0	ca	G	0			0	en	G	0	en	G
39	Marsh Lake Is.	80	g	1	345	cm		A			300	bd	G1
43	L. Monongalia	NC			NC			NC			0	ak	G2
44	Cedar Lake	NC			NC			NC			A	ak	
47	L. Hassel	NC			25	cl	1	NC			12	cl	B2
62	Blue Lake	0			0			0			0		
63	Pigeon Lake	NC			NC			NC			200	z	1
68	Chautauqua Lake	NC			NC			A	cd		30	cd	1
69	Minnesota Lake	NC			NC			NC			NC		
71	Taconite Pond	0			NCI			NCI			0		
90	Pigs Eye Lake	NC			0	da		0	da		0	da	
95	Howard Lake	NC			NC			A	w	G1	20	w	G1
101	Rush Lake	NC			NC			0			0	aa	
112	Gull Rock	NC			NC			NC			NC		
117	Lake Johanna	100	by	G1	50	by	1	25	by	G1	100	by	
152	Artichoke Lake	3	by		NC			NC			NC		
153	Big Stone NWR	500	ac	1	312	cu	1	159	cu	B2	300	cl	1
162	Gull Is.-Leech L.	0			0			0			0		
177	South Heron Lake	NC			NC			30	w	2	NC		
206	Long Lake	NC			100	ak	1	300	ak	G1	300	ak	G1
218	Sand Lake	NC			NC			NC			NC		
229	Crowduck Island	NC			NC			NC			NC		
230	Red Lake Rock	NC			NC			NC			NC		
231	O'Dell Island	NC			NC			NC			NC		
235	Techout Island	NC			NC			NC			NC		
251	Boyer Lake	NC			NC			NC			NC		
319	L. Massacre Is	NC			NC			NC			NC		
320	Bridges Island	NC			NC			NC			NC		
325	W. Two Rivers Res.	NC			NC			NC			NC		
326	Dark R. Tailings P.	NC			NC			NC			NC		
340	Encampment Is	NC			A			NC			NC		
341	Lura Lake	NC			1	a		NC			NC		
379	Potato Island	NC			NC			NC			NC		
481	Titlow Lake	NC			NC			NC			NC		
508	Blackduck Lake Is	NC			NC			NC			NC		
518	Sunburg L. Peninsula	NC			NC			NC			NC		
522	Elysian Lake	NC			NC			NC			NC		
542	Moonan WMA	NC			NC			NC			NC		
570	Lone Pine - 1	NC			NC			NC			NC		
582	Sugar Impoundment	NC			NC			NC			NC		
590	Pelican Lake South	NC			NC			NC			NC		
601	AMWR - Ditch 11 Ban	NC			NC			12	ca	1	10		
602	AMWR - Madsen Pool	NC			80	b	1	12	ca	1	10		
611	Stuntz	NC			NC			NC			NC		
634	Lake Reno South	NC			NC			NC			NC		
638	W. Toqua L. Mainland	NC			NC			NC			NC		
648	Halvorsen Lake	NC			NC			NC			NC		
720	Goose Lake	NC			NC			NC			NC		
733	L. Charlotte Main	NC			NC			NC			NC		
749	Vermilion Rocks #1	NC			NC			NC			NC		
751	Lake Oliver	NC			NC			NC			NC		
764	N. School Section L.	NC			NC			NC			NC		
788	Otter Lake	NC			NC			NC			NC		
805	Little Elk WMA	NC			NC			NC			NC		
806	Staples WMA	NC			NC			NC			NC		
839	New Germany	NC			NC			NC			NC		
850	Red Lake	NC			NC			NC			NC		
879	Swartout Lake	NC			NC			NC			NC		
883	Maplewood	NC			NC			NC			NC		
897	O'Brien Lake	NC			NC			NC			NC		
940	Anderson Lake WMA	NC			NC			NC			NC		
941	Coon Creek WMA	NC			NC			NC			NC		
	Total number of pairs	898			983			1148			1818		
	Total number colonies censused	8			13			18			22		
	% colonies censused**	13			19			24			33		
	Number of known active colonies	9			14			19			21		
	Number of known active colonies censused	5			8			10			15		
	% colonies censused***	55.6			57.1			52.6			71.4		

OTCN*	Site	1981			1982			1983			1984		
5	AMWR-Cormorant Is.	NCI			NCI			NCI			NCI		
10	Egret Is.	598	bc	G2	400	bs	1	A	bs	1	335	y	G2
30	E. Black Cinder Sw.	0			0			0			10	ca	
33	Pelican Lake	A	bm	B	150	ag	B1	NC			NC		
36	Dassel Marsh	81	ck	B2	78	ck	B2	22	ac	G2	17	am	G2
37	L. Jefferson	0	en	G	NC			NC			8	am	G2
39	Marsh Lake Is.	200	cm	G1	A			A	bw		A	bw	
43	L. Monongalia	0	ak	G2	NC			NC			3	am	G2
44	Cedar Lake	0	ak	G2	NC			NC			0	am	G
47	L. Hassel	15	cm	B2	NC			NC			40	am	G1
62	Blue Lake	0			0			0			0		
63	Pigeon Lake	80	ck	G1	NC			800	ac	1	600	am	G1
68	Chautauqua Lake	70	aa	B2	150	v	G1	NC			NC		
69	Minnesota Lake	125	en	G1	NC			NC			208	am	G2
71	Taconite Pond	0			NCI			NCI			NCI		
90	Pigs Eye Lake	0	da		0	da		4	aa	G2	28	da	G2
95	Howard Lake	8	v	B2	8	aa	G1	NC			0	l	G2
101	Rush Lake	0	aa		NCI			NCI			0	aq	B2
112	Gull Rock	0	ax	B	10	x	2	13	v	B2	NC		
117	Lake Johanna	302	cm	G2	200	bs	1	A	bx		632	x	G1
152	Artichoke Lake	0			NCI			NCI			0		
153	Big Stone NWR	382	cl	B3	320	cl	B1	367	db	B2	314	ac	B1
162	Gull Is.-Leech L.	0			0			0			0		
177	South Heron Lake	NC			NC			NC			NC		
206	Long Lake	158	ak	G2	NC			NC			40	am	G1
218	Sand Lake	10	ao	G1	NC			22	bl	G1	A	g	G
229	Crowduck Island	871	v	B2	1024	v	B2	A			NC		
230	Red Lake Rock	117	v	B2	NC			110	v	B2	NC		
231	O'Dell Island	10	v	B2	NC			11	v	B2	NC		
235	Techout Island	A	v	G	110	v	B2	NC			NC		
251	Boyer Lake	30	ax	G1	11	ax	G2	NC			NC		
319	L. Massacre Is	NC			53	v	B2	110	v	2	NC		
320	Bridges Island	NC			170	v		NC			NC		
325	W. Two Rivers Res.	NC			40	ag	G1	25	ch	B2	NC		
326	Dark R. Tailings P.	NC			100	ag	G1	NC			NC		
340	Encampment Is	NC			NC			NC			0		
341	Lura Lake	NC			NC			NC			0		
379	Potato Island	NC			NC			NC			NC		
481	Titlow Lake	NC			NC			0			0		
508	Blackduck Lake Is	NC			18			0	bl	B	0		
518	Sunburg L. Peninsula	NC			NC			NC			8	am	B2
522	Elysian Lake	NC			NC			NC			47	am	G1
542	Moonan WMA	NC			NC			NC			5	ag	B2
570	Lone Pine - 1	NC			NC			A	cl	G	NC		
582	Sugar Impoundment	NC			NC			NC			NC		
590	Pelican Lake South	NC			NC			NC			NC		
601	AMWR - Ditch 11 Ban	NC			15	da		NC			15	da	
602	AMWR - Madsen Pool	NC			NC			NC			NC		
611	Stuntz	NC			NC			NC			NC		
634	Lake Reno South	NC			NC			NC			NC		
638	W. Toqua L. Mainland	NC			NC			NC			NC		
648	Halvorsen Lake	NC			NC			NC			NC		
720	Goose Lake	NC			NC			NC			NC		
733	L. Charlotte Main	NC			NC			NC			NC		
749	Vermilion Rocks #1	NC			NC			NC			NC		
751	Lake Oliver	NC			NC			NC			NC		
764	N. School Section L.	NC			NC			NC			NC		
788	Otter Lake	NC			NC			A	sp		NC		
805	Little Elk WMA	NC			NC			NC			NC		
806	Staples WMA	NC			NC			NC			NC		
839	New Germany	NC			NC			NC			NC		
850	Red Lake	NC			NC			NC			NC		
879	Swartout Lake	NC			NC			NC			NC		
883	Maplewood	NC			NC			NC			NC		
897	O'Brien Lake	NC			NC			NC			NC		
940	Anderson Lake WMA	NC			NC			NC			NC		
941	Coon Creek WMA	NC			NC			NC			NC		
	Total number of pairs	3058			2915			1502			2205		
	Total number colonies censused	27			21			15			29		
	% colonies censused**	40			31			22			39		
	Number of known active colonies	26			31			34			38		
	Number of known active colonies censused	19			17			11			20		
	% colonies censused***	73.1			54.8			32.4			52.6		

OTCN*	Site	1985			1986			1987			1988		
5	AMWR-Cormorant Is.	0			NCI			NCI			NCI		
10	Egret Is.	A	bx	B1	301	y	G2	A	bx		300	v	A1
30	E. Black Cinder Sw.	NC			NCI			NCI			0		
33	Pelican Lake	A	ch		210	ch	B2	NC			508	aq	B2
36	Dassel Marsh	8	u	G	4	ck	G	0	bl	B2	2	ck	G2
37	L. Jefferson	13	ac	G2	8	aa	G2	40	bl	G1	0	bl	B
39	Marsh Lake Is.	A			200	ac	G1	A	ac	G1	A	bw	
43	L. Monongalia	0	u	G	15	ac	B1	20	bl	B1	5	bl	B1
44	Cedar Lake	34	u	G1	NC			0	bl	B1	0	bl	B1
47	L. Hassel	40	bl	B1	NC			NC			0	bl	B1
62	Blue Lake	0			0			0			0		
63	Pigeon Lake	575	u	G1	550	aa	G1	510	bl	B1	150	bl	B1
68	Chautauqua Lake	284	v	B2	A	cn		293	y	B2	NC		
69	Minnesota Lake	290	u	G1	300	ac	B1	300	bl	B1	250	bl	B1
71	Taconite Pond	0	e		NC			NC			NC		
90	Pigs Eye Lake	NC			78	da	G1	84	da	G1	50	t	A1
95	Howard Lake	NCI			NCI			0	r	G1	NCI		
101	Rush Lake	NC			NC			0	w	B	NC		
112	Gull Rock	1	v	B2	NC			75	v	A1	NC		
117	Lake Johanna	A	bx		378	y	B1	820	x	B1	NC		
152	Artichoke Lake	NCI			NCI			0			NCI		
153	Big Stone NWR	853	cr	B1	330	db	B1	540	db	B1	448	db	B1
162	Gull Is.-Leech L.	0			0			0			0		
177	South Heron Lake	0	bl	B1	NCI			NCI			NCI		
206	Long Lake	430	u	G1	645	ac	G3	881	bl	G3	NC		
218	Sand Lake	30	v	G	NC			71	y	G2	NC		
229	Crowduck Island	698	v	B2	NC			1097	v	B1	NC		
230	Red Lake Rock	755	v	G1	NC			782	v	B3	NC		
231	O'Dell Island	78	v	B	NC			198	v	B3	NC		
235	Techout Island	20	v	B1	NC			8	v	B2	NC		
251	Boyer Lake	0			NCI			NCI			NCI		
319	L. Massacre Is	548	v	1	NC			408	v	B1	NC		
320	Bridges Island	0	v	B1	NCI			0	v		NCI		
325	W. Two Rivers Res.	NC			NC			18	bo	B2	NC		
326	Dark R. Tailings P.	50	a	A1	NC			NC			130	bc	B1
340	Encampment Is	NC			NC			NC			NC		
341	Lura Lake	0			NCI			NCI			0		
379	Potato Island	5	ah	G2	NC			NC			NC		
481	Titlow Lake	0	ah	G2	0			0			0		
508	Blackduck Lake Is	NCI			NCI			NCI			NCI		
518	Sunburg L. Peninsula	1	u	B2	0			NCI			NCI		
522	Elysian Lake	29	u	G2	38	aa	G2	85	bl	B1	100	bl	B1
542	Moonan WMA	0	u	B	NCI			NCI			NCI		
570	Lone Pine - 1	NC			150	at	A1	NC			NC		
582	Sugar Impoundment	0	cr	G	NCI			NCI			0		
590	Pelican Lake South	0	cb		0	cb	B2	0	bo		0	bo	
601	AMWR - Ditch 11 Ban	40	da	B1	70	ca		75	da	B1	NC		
602	AMWR - Madsen Pool	0			NCI			NCI			NCI		
611	Stuntz	25	a	A2	NC			NC			NC		
634	Lake Reno South	NC			80	bo		129	bx	G2	NC		
638	W. Toqua L. Mainland	NC			28	a	B2	NC			0		
648	Halvorsen Lake	A	m		NC			NC			NC		
720	Goose Lake	NC			NC			NC			A	bz	
733	L. Charlotte Main	NC			NC			NC			NC		
749	Vermilion Rocks #1	NC			NC			NC			NC		
751	Lake Oliver	NC			NC			15	ba		NC		
764	N. School Section L.	NC			NC			NC			NC		
788	Otter Lake	NC			NC			NC			NC		
805	Little Elk WMA	NC			NC			NC			NC		
806	Staples WMA	NC			NC			NC			NC		
839	New Germany	NC			NC			NC			NC		
850	Red Lake	NC			NC			NC			NC		
879	Swartout Lake	NC			NC			NC			NC		
883	Maplewood	NC			NC			NC			NC		
897	O'Brien Lake	NC			NC			NC			NC		
940	Anderson Lake WMA	NC			NC			NC			NC		
941	Coon Creek WMA	NC			NC			NC			NC		
	Total number of pairs	5091			3439			6469			2343		
	Total number colonies censused	38			22			31			21		
	% colonies censused**	54			33			46			31		
	Number of known active colonies	39			36			36			36		
	Number of known active colonies censused	28			17			24			12		
	% colonies censused***	71.8			47.2			66.7			33.3		

OTCN*	Site	1989			1990			1991			1992		
5	AMWR-Cormorant Is.	NCI			NCI			0			NCI		
10	Egret Is.	310	af	B1	A			810	af	G2	800	af	B1
30	E. Black Cinder Sw.	0			0			0			NCI		
33	Pelican Lake	227	bo	B2	399	bo	B2	115	bu	B2	233	bo	B2
36	Dassel Marsh	0	bl	G2	0			0			0		
37	L. Jefferson	10	bl	G1	0	bg	G2	0			0		
39	Marsh Lake Is.	A			A			A			A		
43	L. Monongalia	0	bl	B1	0	ay	B	0	ay	B	0	ay	B
44	Cedar Lake	0	bl	B1	0	ay	B	0	ay	B	0	ay	B
47	L. Hassel	NC			NC			21	ay	G2	NC		
62	Blue Lake	0			0			0			0		
63	Pigeon Lake	500	bl	B1	310	bg	B1	394	ay	G2	214	ay	B2
68	Chautauqua Lake	NC			388	af	B2	NC			545	af	B2
69	Minnesota Lake	200	bl	G1	258	bg	G2	204	ay	G2	346	ay	B2
71	Taconite Pond	8	x	A1	NC			NC			NC		
90	Pigs Eye Lake	NC			NC			A	t	B	179	t	G1
95	Howard Lake	0	ac	G1	0	ac	B1	82	ca	G2	28	ce	G2
101	Rush Lake	0	bo		NC			10	bf	A1	0	ag	A1
112	Gull Rock	2	v	B2	NC			NC			NC		
117	Lake Johanna	400	ad	B1	NC			83	af	B2	85	af	B1
152	Artichoke Lake	0			NCI			NCI			NCI		
153	Big Stone NWR	287	db	B2	819	db	G2	811	db	G2	672	db	G2
162	Gull Is.-Leech L.	0			0			0			3	af	G2
177	South Heron Lake	NCI			NCI			NCI			NCI		
206	Long Lake	NC			230	ay	B2	148	ax	B2	NC		
218	Sand Lake	10	ad	G1	NC			5	af	B1	30	af	G2
229	Crowduck Island	1202	v	B2	NC			2000	af	G1	1000	v	G1
230	Red Lake Rock	1327	x	B1	NC			2500	af	G1	800	v	G1
231	O'Dell Island	700	v	B2	NC			0	af		300	v	G1
235	Techout Island	0			NCI			0			0		
251	Boyer Lake	NCI			NCI			0			NCI		
319	L. Massacre Is	1483	v	B2	NC			NC			2000	v	1
320	Bridges Island	NCI			NCI			NCI			NCI		
325	W. Two Rivers Res.	NC			NC			NC			NC		
326	Dark R. Tailings P.	NC			143	bo	B2	NC			NC		
340	Encampment Is	87	dc	G2	NC			NC			0		
341	Lura Lake	0			0			0			NCI		
379	Potato Island	0			NCI			NCI			NCI		
481	Titlow Lake	0			0			0			25	ax	B2
508	Blackduck Lake Is	NCI			NCI			NCI			NCI		
518	Sunburg L. Peninsula	0			0			0			NCI		
522	Elysian Lake	150	bl	B1	250	ax	G1	153	ax	B1	238	ax	B2
542	Moonan WMA	NCI			0	bg	G	NCI			NCI		
570	Lone Pine - 1	NC			71	a	A1	NC			NC		
582	Sugar Impoundment	NC			158	cl	A1	100	ct	A	NC		
590	Pelican Lake South	0	bo		0	bo		0	bo	B2	197	bo	B2
601	AMWR - Ditch 11 Ban	NC			NC			0			7	bl	1
602	AMWR - Madsen Pool	NCI			NCI			0			NCI		
611	Stuntz	40	x	A1	NC			NC			NC		
634	Lake Reno South	12	ad	B1	NC			NC			NC		
638	W. Toqua L. Mainland	5	a	G2	NC			NC			NC		
648	Halvorsen Lake	54	af	G1	NC			NC			NC		
720	Goose Lake	25	by	1	NC			NC			NC		
733	L. Charlotte Main	12	ad	B1	NC			NC			NC		
749	Vermilion Rocks #1	37	bh	G2	NC			NC			40	bh	G1
751	Lake Oliver	NC			NC			NC			NC		
764	N. School Section L.	NC			80	ca	1	0			NCI		
788	Otter Lake	NC			77	bg	G2	44	ay	B2	53	ax	B2
805	Little Elk WMA	NC			NC			1	bh	G2	NC		
806	Staples WMA	NC			NC			NC			NC		
839	New Germany	NC			NC			NC			3	ca	G2
850	Red Lake	NC			NC			NC			100	ai	G1
879	Swartout Lake	NC			NC			NC			12		2
883	Maplewood	NC			NC			NC			7	ax	1
897	O'Brien Lake	NC			NC			NC			NC		
940	Anderson Lake WMA	NC			NC			NC			NC		
941	Coon Creek WMA	NC			NC			NC			NC		
	Total number of pairs	7159			3098			7351			7835		
	Total number colonies censused	38			25			35			33		
	% colonies censused**	57			37			52			49		
	Number of known active colonies	39			37			38			44		
	Number of known active colonies censused	28			15			20			27		
	% colonies censused***	71.8			40.5			52.6			61.4		

OTCN*	Site	1993			1994			1995		
5	AMWR-Cormorant Is.	NCI			NCI			0		
10	Egret Is.	850	af	B1	545	af	B1	805	af	G
30	E. Black Cinder Sw.	NCI			0			NCI		
33	Pelican Lake	43	bo	B2	13	bo	B2	10	bo	B
36	Dassel Marsh	0			0			0		
37	L. Jefferson	0			0			0		
39	Marsh Lake Is.	A			A			A		
43	L. Monongalia	NCI			0	be	B	NCI		
44	Cedar Lake	NCI			0	be	B	NCI		
47	L. Hassel	NC			12	bm	B2	NC		
62	Blue Lake	2	db	B1	0	db		2	db	G1
63	Pigeon Lake	370	bu	G2	245	be	B1	NC		
68	Chautauqua Lake	472	af	B2	491	af	B2	252	af	B2
69	Minnesota Lake	400	bw	G2	300	be	G1	NC		
71	Taconite Pond	NC			35	ax	G1	148	bo	G1
90	Pigs Eye Lake	100	cl	1	NC			NC		
95	Howard Lake	2	cc		NC			0	t	A1
101	Rush Lake	NCI			0	bo	A1	0	bo	A1
112	Gull Rock	0	af	G2	NCI			NCI		
117	Lake Johanna	165	af	B2	177	af	G1	170	af	B1
152	Artichoke Lake	NCI			NCI			NCI		
153	Big Stone NWR	320	db	G2	308	db	G2	154	db	G2
162	Gull Is.-Leech L.	1	c	G2	0	c	G2	0	c	
177	South Heron Lake	NCI			NCI			NCI		
206	Long Lake	NC			175	ba	G1	NC		
218	Sand Lake	20	af	G	NC			NC		
229	Crowduck Island	107	af	G3	NC			837	v	G2
230	Red Lake Rock	1400	af	B1	NC			855	v	B2
231	O'Dell Island	595	af	G3	NC			832	v	B2
235	Techout Island	0			NCI			0		
251	Boyer Lake	NCI			NCI			NCI		
319	L. Massacre Is	810	af	G3	NC			888	v	B2
320	Bridges Island	NCI			NCI			0	v	
325	W. Two Rivers Res.	75	bo	B1	99	bo	B1	79	bo	B1
326	Dark R. Tailings P.	NC			NC			NC		
340	Encampment Is	NCI			NCI			NCI		
341	Lura Lake	NCI			0			NCI		
379	Potato Island	NCI			NCI			NCI		
481	Titlow Lake	NC			0			NCI		
508	Blackduck Lake Is	NCI			NCI			NCI		
518	Sunburg L. Peninsula	NCI			NCI			NCI		
522	Elysian Lake	NC			NC			NC		
542	Moonan WMA	NCI			NCI			NCI		
570	Lone Pine - 1	0	a	A1	NCI			NCI		
582	Sugar Impoundment	NC			NC			NC		
590	Pelican Lake South	338	bo	G1	338	bo	B2	294	bo	B
601	AMWR - Ditch 11 Ban	21	bz	2	NC			32	bz	B2
602	AMWR - Madsen Pool	NCI			NCI			NCI		
611	Stuntz	55	a	B2	NC			0	x	
634	Lake Reno South	18	af	B2	NC			NC		
638	W. Toqua L. Mainland	NC			43	ba	B1	NC		
648	Halvorsen Lake	0	af	G2	NCI			NCI		
720	Goose Lake	80	af	G1	NC			NC		
733	L. Charlotte Main	NC			38	af	B1	40	af	B2
749	Vermilion Rocks #1	NC			NC			83	bh	G2
751	Lake Oliver	NC			NC			NC		
764	N. School Section L.	NCI			NCI			NCI		
788	Otter Lake	NC			0	bm	B2	NCI		
805	Little Elk WMA	8	ba	G1	A	bm	G2	A	n	G
806	Staples WMA	8	ba	G1	2	bh	G2	0		
839	New Germany	NC			0	au	G1	NCI		
850	Red Lake	NC			NC			NC		
879	Swartout Lake	NC			60	ba	G2	2	n	G2
883	Maplewood	NC			A	af		0	af	G1
897	O'Brien Lake	70	af	B1	NC			NC		
940	Anderson Lake WMA	NC			4	ba	G2	NC		
941	Coon Creek WMA	NC			3	ba	G2	NC		
	Total number of pairs	8110			2894			5058		
	Total number colonies censused	31			30			28		
	% colonies censused**	46			45			42		
	Number of known active colonies	45			44			40		
	Number of known active colonies censused	27			23			21		
	% colonies censused***	60			52.3			52.5		

* OTCN = NHP occurrence number
** Method 1 as described in text
*** Method 2 as described in text

Census methods (may or may not be concatenated)
G = ground census; 1 = visual estimate
B = boat census; 2 = total ground count
A = aerial census; 3 = partial count with extrapolation

Status code
A = colony known to be active, but not censused
NC = colony not censused, activity unknown
NCI = colony not censused, presumed inactive

Appendix V.3 Colony site by year matrix of Great Egrets in Minnesota between 1977-1995. Underlining indicates the years that the colony was considered active. Each year includes three columns: the census estimate (number of pairs) or status code, a code for the observer (not given), and a code for the census method (given below).

OTCN* Colony	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
4 Agassiz NWR	0 q A1	1 d	2 cl G2	3 cm 2	NC	5 cm 2	NC	NC	4 cm A	12 ca	0 cm 1	NCI	NCI	NCI	NCI	NCI	NCI	NCI	NCI
10 Egret Is.	A bq	50 bq 1	188 bx B2	NC	743 az G2	500 bq 1	400 bq 1	109 l 2	A bq	374 l 2	A bq	A l A1	2 y B1	NC	365 aa G2	950 aa B1	1150 aa B1	478 aa B1	730 aa G
25 Maddens #1	NC	0	1 bl G2	1 ab G2	NC	0	0	0	0	0	0	NCI	NCI	0	0	0	0	0	0
30 E. Black Cinder Sw	NC	0	13 ch B1	0 cq B2	0 cd 1	0	0	0	NCI	NCI	NCI	0	NCI	NCI	0	NCI	NCI	0	NCI
33 Pelican Lake	NC	NC	0	0	0	1 ah B1	NC	NC	A bq	5 bq B2	NC	0 al B	0 l B2	0 al B2	0	0 al B2	0 al B1	0	0
34 Pelican Lake	NC	5 j G2	19 j G1	23 j G2	A ax B	0	NCI	NCI	0	NCI	NCI	NCI	NCI	NCI	NCI	NCI	NCI	NCI	NCI
37 L. Jefferson	4 bl G	NC	5 aq G2	5 aq G2	15 aq G1	NC	NC	3 af G2	1 ar G2	NC	0 av	0 av	1 o A1	0	0	0	NCI	NCI	NCI
43 L. Monongalia	NC	NC	0 ad	0 ad	0 ad	NCI	NCI	0	0 r	0 ar B1	2 av B1	0 av	0 av	0 ap	0 ap	0 ap	NCI	0 aa	NCI
47 L. Hassel	NC	NC	NC	0	0 bw	NC	NC	0 af	8 au B1	NC	NC	0 ay	NC	NC	0 ap	NCI	NCI	0 aa B2	NCI
52 Blue Lake	4 da G3	NC	8 bf G3	0 da	18 bf G1	2 bl G1	NC	NC	NC	4 cn G3	8 cn G3	4 cn G3	NC	11 cn G3	28 cn G	42 cn G	A cn B1	4 bv G1	8 bv G3
58 Pigeon Lake	NC	NC	NC	50 w 1	NC	NC	10 ar 1	18 al G1	22 r G	19 z G2	45 av B1	30 av B1	20 av B1	NC	1 ao G2	1 ao B2	0 be	1 aa B2	NC
64 Root River Delta	90 cq	NC	51 cq G1	NC	37 cl G1	NC	NC	80 cu A1	NC	150 aa A1	A	A	85 k A1	NC	12 k A1	NC	NC	NC	NC
69 Minnesota Lake	NC	NC	NC	NC	1 aq G2	NC	NC	8 af G2	2 r G2	2 ac B1	5 av B1	8 av B2	2 av G1	0 ao G2	3 ao G2	3 ao B2	3 be G2	10 be B1	NC
83 Rice Lake	0	0	0 bm G2	0	0	NC	NC	0	NC	NC	0	0	NC	0	5 aw G1	0	0	NCI	NCI
86 Sioux Lake	0	NC	0	20 cy 1	NC	NC	0	NCI	NCI	NCI	NCI	NCI	NCI	NCI	NCI	NCI	NCI	NCI	NCI
89 Durgin Slough	NC	NC	NC	NC	NC	A	10 cr B2	0 cs B	0 cs	0	0	NCI	NCI	0	0	NCI	NCI	NCI	NCI
90 Pigs Eye Lake	NC	149	180 bc 1	197 bk G3	90 bl G3	120	91 al G2	272 cl B3	NC	529 ct G1	540 ct G1	275 k A1	NC	NC	A k B	635 k G3	A k A	NC	NC
95 Howard Lake	NC	NC	180 s G3	135 s G3	65 l B	125 al G3	NC	125 q G3	NC	NC	25 k A1	NC	1 br G1	4 x G1	11 bl G1	0 k	0 br G1	NC	0 k
96 Cold Spring	0	0	1 bx G2	0	0	0	0	0	0	0	NC	0	0	0	0	0	NC	NC	0
99 Lovell Lake	NC	0	0	0	0	NC	3 ck G2	NC	NC	0	NC	0	0	NC	0	0	NC	2 ay G2	0
100 Breyen Egret	NC	NC	75 u G1	NC	0 al	NCI	NCI	NCI	NCI	NCI	0 k	NCI	NCI	NCI	0 k	NCI	NCI	NCI	NCI
101 Rush Lake	NC	NC	4 m 1	4 a G2	10 al G1	NC	NC	10 al B2	NC	NC	30 ak B2	NC	3 al B2	NC	75 al A1	10 al A1	NC	1 al A1	10 al A1
115 Dead Lake	NC	2 bx	NC	NC	NC	2 l G2	7 l G2	NC	NC	0	NCI	0	NCI	0 aa	NCI	NCI	NCI	0 aa	NCI
117 Lake Johanna	10 bh G1	3 bh 1	25 bq 1	100 bq 1	113 bw G2	400 bq 1	300 bq 1	242 l 1	A bq	127 l B1	275 u B1	NC	15 y B1	NC	30 aa B2	0 aa B1	32 aa B2	120 aa G1	120 aa B1
153 Big Stone NWR	55 ar 1	34 cf 1	48 cf B2	100 cc 1	80 cc B3	60 cc B1	41 cc B2	53 ar B1	96 cq B1	57 co B1	60 co B1	77 co B1	35 co B2	A	240 co G2	190 co G2	60 cq G2	89 co G2	28 co G2
179 Kellogg	3 bz A1	NC	NC	NC	NC	NC	NC	57 bu G2	NC	NC	NC	0 k	NCI	0 k	NCI	NCI	NCI	NCI	NCI
185 Shields Lake	2 bx	NC	10 v G1	NC	8 v G1	NC	NC	55 al G3	NC	NC	75 k A1	NC	25 k A1	NC	1 k A1	NC	NC	NC	NC
186 Rieno	NC	NC	NC	NC	NC	NC	NC	120 cu A2	NC	170 k A1	3 cb B1	NC	3 k A1	NC	1 cb 2	NC	NC	NC	NC
191 Grey Cloud Is.	10 bn	NC	NC	NC	NC	NC	0 k A	NCI	NCI	NCI	NCI	NCI	NCI	NCI	0 h	NCI	NCI	NCI	NCI
199 Lake of the Isles	NC	NC	NC	NC	7 l 2	NC	8 k G2	19 k G2	13 k G1	25 k G1	25 k G1	NC	0 aa G	21 h G2	0 k	NCI	NCI	NCI	NCI
206 Long Lake	NC	323 ad	330 ad G1	340 ad G1	660 ad G1	NC	NC	275 al G1	270 r G1	250 az G1	492 av B1	NC	50 av B1	0 ao B2	4 ao B2	NC	NC	1 aa G2	NC
216 Sand Lake	NC	NC	NC	NC	0	NC	10 av G1	NC	6 l G	NC	36 u G2	NC	8 y G1	NC	10 aa B1	1 aa G2	0 aa G2	NCI	NCI
481 Titlow Lake	NC	NC	NC	NC	NC	NC	6 ar	3 af B	0 r G2	0 z G2	0 av B1	0 av B1	0 av B1	0 db	1 ao G2	1 ao B2	NC	0 aa B1	NCI
522 Elysian Lake	NC	NC	NC	NC	NC	NC	NC	0 af G	8 r G	[illegible] z G2	10 av B1	2 av B2	5 av B1	7 ao G1	1 ao B1	2 ao B1	NC	NC	NC
533 Cedar Creek	NC	NC	NC	NC	2 ab	NC	NC	0 dc G1	0 dd G1	NC	NCI	NCI	0	NCI	NCI	NCI	NCI	0	NCI
598 Bow-Dodge Lake	NC	NC	NC	NC	NC	NC	NC	NC	25 c 1	NC	72 ow G3	NC	50 aa G2	NC	0	NCI	NCI	0	NCI
721 Peltier Lake	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0 k A2	0 dt G1	0 k B2	0 k G2	200 k A1	A am G	NC
788 Otter Lake	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0 de G2	0 ap	1 ao B2	NC	0 aa B2	NC
797 N. Dumam Is.	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0	NC	0	1 k G1	9	NCI	0	NCI	0
862 Louisville Swamp	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0	NC	NC	NC	0	1 bv B2	0 bv G2	0 bv G2
863 Corey Is.	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	A bq	NC	15 am G1	7 k B1
879 Swartout Lake	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	7 df 2	NC	44 ay G2	50 n G2
883 Maplewood	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	11 am 1	NC	NC	0 aa G
Total number of pairs	178	587	1098	978	2049	1221	888	1447	453	1740	1724	306	285	44	788	1662	1452	765	953
Total number of colonies censused	12	13	22	20	23	13	16	25	18	21	24	18	24	19	31	24	13	21	14
% colonies censused **	28	30	51	47	53	30	37	58	42	49	56	42	56	44	72	56	30	49	33
Number of known active colonies	11	15	20	23	24	24	26	24	25	24	22	22	19	20	20	21	21	21	19
Number of known active colonies censused	8	8	16	12	15	11	13	18	12	16	17	11	17	9	18	15	7	13	7
% colonies censused***	73	53	80	52	63	46	50	75	48	67	77	50	89	45	90	71	33	62	37

* NHP occurrence number
** Method 1 as described in text
*** Method 2 as described in text

Census methods (may or may not be concatenated)
G = ground census
B = boat census
A = aerial census
1 = visual estimate
2 = total ground count
3 = partial count with extrapolation

Status code
A = colony known to be active, but not censused
NC = colony not censused, activity unknown
NCI = colony not censused, presumed inactive

Appendix VI. Most recent data form for Minnesota Colonial Waterbird Survey.

MINNESOTA COLONIAL BIRD SURVEY FORM

Occurrence No. _____ Colony Name ______________________________ Region _____ Year _____

Status: active _____ inactive _____ not found _____ unknown _____ gone _____

County ________________ Parcel ________ Section __________ Twp ______ Rg ______

Colony size (acres) ________________ Site Ownership ________________

Best access route ____

____

Habitat and Site

(check one)

1 marsh _____
2 beaver pond _____
3 lake _____
4 stream/creek _____
5 river _____
6 impoundment _____
7 swamp/bog _____
8 not near water _____

(check one if appropriate)

A on water _____
B shoreline _____
C floodplain _____
D beach _____
E island _____
F peninsula _____
G upland _____

Nesting substrate: 1 ground _____ 2 trees _____ 3 emergent vegetation _____

4 floating vegetation _____ 5 artificial nest structures and natural vegetation _____

Condition of substrate (dead of dying trees, flooded, etc.) ________________

____

Vegetation, tree species, etc. ________________________________

____

Threats to colony (natural and/or human) ________________________

____

Survey Details

Date ______________________________ Time: from ______ to ______

Observer ______________________________ phone no. ______

Address ____

Photos taken: yes ____ no ____ where kept ________________

Census technique: ground ____ boat ____ air (type of aircarft) ____________

RETURN TO: DNR Nongame Wildlife Program
Box 7, 500 Lafayette Road, St. Paul, MN 55155-4007

Species	Count method	Nesting stage	Total adult population	Total active nests	Total broods
White Pelican					
Double-crested Cormorant					
Great Blue Heron					
Great Egret					
Black-crowned Night Heron					
Other (attach details)					
Horned Grebe					
Eared Grebe					
Western Grebe					
Red-necked Grebe					
Ring-billed Gull					
Herring Gull					
Common Tern					
Franklin's Gull					
Forster's Tern					

Count Method (Place appropriate number in column 1 above)

1 Visual estimate 2 Total ground count 3 Partial count with extrapolation (sketch area on map) - describe: ____________

Nesting Stage (Place the most appropriate letter in column 2 above)

A Not present (late summer, fall or winter)
B Pairing and nest building
C Egg laying
D Incubation
E Hatching
F Downy young
G Feathered young
H Newly flying young
I Renesting
J Loafing on or near colony
K Species seen, nesting not determined
L Abandoned during nesting season/nesting probable, no young produced
M Adult behavior suggests nestin
N Nesting, count not available
O Significant nesting failure

Comments: ____________

____

____

If this is a new site or a site you have not surveyed before, attach a copy of a ASCA photo, USGS quadrangle map, county map, or sketch the colony (showing the prominent landmarks) in the space below. If part of the colony was counted and the rest estimated, show which census technique was used in which part of colony.