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Project Title:

Lake Christina Reclamation: Consequences of Biomanipulation on Use by Nongame Waterbirds

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ABSTRACT

We examined the use of Lake Christina, Minnesota, by nongame waterbirds, following an application of rotenone to eliminate its fish base in the fall of 2003. During weekly shoreline surveys conducted during the open water seasons of 2004 and 2005, individuals of 17 species of nongame waterbirds were counted. Migrant flocks of up to 95 double-crested cormorants (*Phalacrocorax penicillatus*), 74 pied-billed grebes (*Podilymbus podiceps*) and 2,100 ring-billed gulls (*Larus delawarensis*) were seen briefly during spring or fall counts. The most common summer residents were western grebes (*Aechmophorus occidentalis*), American white pelicans (*Pelecanus erythrorhynchos*), great egrets (*Ardea alba*) and black terns (*Chlidonias niger*). Western grebes were the most numerous nesting waterbird on the lake. Although over 240 western grebes were counted on Lake Christina in the spring of 2004, by the middle of June most had left the lake and no successful nesting occurred. During this same period, very few fish of the appropriate size for grebes were being trapped in the lake, and we suggest that although the emergent vegetation (bulrush, *Scirpus spp*.) was suitable for nesting, the lack of food prevented all but a few attempts. Shoreline counts of western grebes on neighboring Pelican Lake suggest that many western grebes originally on Lake Christina temporarily moved to this fish-rich lake in June and July. The only non-game waterbirds observed attempting to nest in 2004 were black terns, but they failed to hatch any young.

In 2005, minnow numbers were much higher throughout the spring and summer, and over 200 western grebes were counted on the lake by early June. Western grebes began nesting on 15 June, with over 100 nests initiated during the next 4 days. We located a total of 315 western grebe nests, of which 198 hatched at least one young (63% of all attempts). Complete clutches averaged 3.1 eggs, and all but one nest had hatched by August 10. Over 50 black terns were counted on Lake Christina in the spring of 2005. Of the 10 black tern nests located, three hatched young. Three additional nongame waterbirds nested successfully during 2005: Clark's grebe (*A. clarkii*), red-necked grebe (*Podiceps grisegena*), and pied-billed grebe.

In addition to the variety of nongame waterbirds observed using lake Christina, 16 species of ducks, geese and coots were also observed, primarily during migration. By far the most numerous species of all was the American coot (*Fulica americana*), with over 41.000 seen in the fall of 2004 and over 132,000 in the fall of 2005. Over 300 blue-winged teal (*Anas discors*), Canada geese (*Branta candensis*), wood ducks (*Aix sponsa*) and ring-necked ducks (*Aythya fuligula*) were also counted within single surveys during spring and fall migrations.

The presence of minnows was critical to the successful breeding of western grebes on Lake Christina. Sufficient emergent vegetation existed to support a large colony of western grebes, with 215 simultaneously active nests in 2005. Considering that many of the 315 nests were probably second or third nesting attempts, this important colony appeared to have very high nesting success in 2005. Lake Christina is clearly an important nesting lake for the colonially nesting western grebe, as well as a major stopover for a variety of both game and nongame waterbirds during the spring and fall migrations.

INTRODUCTION

Shallow lakes in the prairie pothole region can be classified along a water clarity continuum with alternative stable states on each end. On one end is the clear state, which usually consists of macrophyte dominated clear water. At the opposite end is the turbid state, which is characterized by turbid water, few macrophytes, and abundant phytoplankton. Scheffer (1998) provides a more detailed explanation of the alternative stable states, and showed that turbid water can severely impact the growth of aquatic macrophytes (Scheffer et. al. 2005). Lake Christina, a large, shallow lake in west-central Minnesota, has in the past 40 years fluctuated several times between these two alternative states. These changes have been correlated with major fluctuations in counts of waterfowl staging on the lake during the fall migration (Hanson & Butler 1994a).

Several factors can influence whether or not a lake is turbid. Sediment resuspension can be affected by boat traffic in shallow areas (Asplund & Cook 1999, Murphy & Eaton 1983) and by the presence of a high-density rough-fish population (Zambrano et. al 2001) or even large concentrations of feeding migrating waterfowl. Hansel-Welch et. al. (2003) showed that plant communities, especially *Potamogeton spp*. and *Chara spp*., will respond strongly to changes in water clarity. Macrophyte communities are thought to have the ability to reduce sediment resuspension, but water translucence must be high in order to establish long-term viable populations (James, Best, & Barko 2004). Nutrient inputs can also impact water quality (Post et. al. 1998), particularly algal biomass, which will tend to limit light reaching macrophytes (Lauridsen et. al. 2003). Zimmer et. al. (2001) showed that fish populations may also be important in turning small wetlands turbid.

Managers have many options on how to respond to turbid water and return the system to clear water. Biomanipulation involves various treatments such as the use of chemicals and water level manipulation, each of which has a different cost-benefit regime. Liquid rotenone has been a common, though expensive, option for removing rough-fish populations in efforts to return lakes and wetlands to macrophyte-dominated clear water (Van de Bund & Van Donk 2002, Finlayson et. al. 2000, Amey 1984), Public opinion, however, has begun to disapprove of rotenone use (see McClay 2000). In many cases, treatment with rotenone may have profound effects on the food-web dynamics of a lake system, leading to trophic cascades that result in the higher penetration of light needed for stimulating macrophyte growth (Rask et. al. 2003, Pijanowska & Prejs 1997, Prejs et. al. 1997).

Rotenone is commonly used as a piscicide because its direct toxic effects are generally nonpersistent. It kills fish through suffocation by blocking biochemical processes involved in the uptake of dissolved oxygen. Aquatic organisms that respire through gills are the most susceptible because of the rapid rate with which a lethal dose of rotenone can be absorbed through the gills. However, rotenone also affects many non-target organisms, such as aquatic invertebrates and plankton. In a series of studies on the effects of rotenone treatments in Colorado, Hoffman & Olive (1961) found significant decreases in aquatic invertebrates from pretreatment levels in 3 reservoirs, with some species abundances declining to zero. Morrison & Struthers (1975) and Morrison (1977) published similar results from a study on lochs in Scotland, but showed that most groups made rapid recoveries. In fact, populations of important grazing groups, such as *Daphnia spp*. and *Bosmina spp*., increased greatly over pre-treatment levels, both in abundance and body size. In North American similar trends were shown by Engstrom-Heg et. al. (1978) and Hanson & Butler (1994b). Such rapid recolonization could stem from a lack of predation and an abundance of organic material.

An important practical problem associated with using rotenone as a piscicide within larger lake systems is that it is seems to be less than 100% effective with most applications (M.G. Butler, K. D. Zimmer, pers. comm.). Undesirable rough fish species, such as black bullheads (*Ameiurus melas*) may be particularly likely to survive whole-lake treatments. Gilderhus (1982) found that many types of suspended solids (i.e. clay particles) at even moderate concentrations will decrease the effectiveness of rotenone and toxaphene. Soft bottoms and high concentrations of suspended solids are especially common in turbid, shallow lakes such as Lake Christina.

Nongame waterbirds are rarely considered in these types of community-wide manipulations. In a similar experiment, Hoyer & Canfield (1990, 1994) found that higher turbidity predicted greater bird species richness and abundance, and found no significant relationship between general bird species richness and macrophyte communities. Yet many nongame waterbird species are piscivorous, and so fish removal would be expected to have direct adverse effects on their use of a lake for foraging and reproduction. As part of a larger, multifaceted project, we evaluated the effect of biomanipulation on nongame waterbird usage of Lake Christina. Rotenone was used to remove the fish community dominated by rough fish, predominately bigmouth buffalo (*Ictiobus cyprinellus*), common carp (*Cyprinus carpio*), and black bullhead, and to reestablish macrophyte beds preferred by many migrating waterfowl species.

Project Goals:

The primary goal of this portion of the Lake Christina Reclamation project was to determine the effect of the rotenone application to the lake on the nongame waterbird populations. Our purpose was to determine the species and numbers of nongame waterbirds using Lake Christina for both breeding and non-breeding purposes during the open water seasons of 2004-2005. We were particularly interested in documenting any breeding attempts by western grebes (*Aechmophorus occidentalis*), Clark's grebe *(A. clarkii*), red-necked grebes (*Podiceps grisegena*), black terns (*Chlidonias niger*) and Forster's terns (*Sterna forsteri*), with special emphasis on the nesting success of western grebes.

A secondary goal was the completion of a master's thesis by JHA on the effects of wind, waves, and bulrush density on the survival of over-water nests of the western grebe, which has been an important over-water nesting species on Lake Christina.

Funding:

Support for this project was received from the Minnesota Nongame Wildlife Tax Checkoff and the U.S. Fish and Wildlife Service through the Minnesota Department of Natural Resources, Division of Ecological Services. The nongame waterbird monitoring section of the Lake Christina reclamation project cost $36, 260, which provided research funds for examining waterbird use during the open-water seasons of 2004-2005. These funds provided equipment

and travel expenses, a research assistantship to JHA, 2-mo summer salary for DB, and the hiring of a full time field technician during the summer of 2005.

METHODS

Lake Christina

Lake Christina, located in Douglas and Grant counties of west-central Minnesota USA (46° 05'N, 95° 44'W, Minnesota USA), is a soft-bottomed lake that extends over 1600 ha with an average depth of only 1.5 m. To control for rough fish the lake has been treated periodically, with toxaphene in 1965 and with rotenone in 1987 and 2003. A thorough report on the treatment history of Lake Christina is available from the Minnesota DNR (Carlson & Hansel-Welch 2003)

Western grebes have regularly established breeding colonies (ranging from 6 to 177 active nests) on Lake Christiana since the late 1960s (Minnesota DNR data, unpub, D. Anderson pers. comm.). Other nongame waterbirds also reside or breed on Lake Christina including: red-necked grebes, Clark's grebes, pied-billed grebes (*Podilymbus podiceps*), black terns, Forsters' terns, double-crested cormorants (*Phalacrocorax auritus*), American white pelicans (*Pelecanus erythrorhynchos*), and great egrets (*Ardea alba*). Bald eagles (*Haliaeetus leucocephalus*) also commonly forage on Lake Christina. American white pelicans, Forster's terns, and bald eagles are listed as species of special concern in Minnesota.

Ground Surveys

Birds using Lake Christina were surveyed during the open water seasons of 2004-2005. Eight survey sites were established around the lakeshore to allow wide coverage of much of the open water surface of the lake and provide an index to the relative abundance of the most visible, open-water species. The first two survey sites (Sites 1 and 2, Figure 1) were elevated 20 m and 10 m respectively above the lake level, which allowed for extensive coverage of the large southern bay. We conducted weekly count surveys using binoculars and a 15-60x spotting scope during the first four hours of daylight, with the stipulation that visibility was good and that winds were 15 kph or less. Surveys were initiated at Sites 1 and 2 because calm surface waters were especially critical for counting and identifying distant waterbirds. Special care was taken to avoid counting flocks twice.

Nest Surveys

Kayaks were used to conduct weekly over-water nest surveys during the spring and summer of both years. Any nests found were marked with small, 3-cm colored tape flags attached to stems of bulrush. A Garmin ETrex GPS unit was also used to mark the location. Species, clutch size, and fate were monitored until the nest was abandoned, destroyed, or successful. Successful pairs were defined as those hatching at least 1 egg. After the colony completed nesting white plastic bags were attached to the nests. A series of aerial photos were then taken to facilitate spatial analysis of colony formation and nesting success, which will comprise a portion of JHA's master's thesis (Figure 2). The plane was a Cessna 172 rented from Alexandria Aviation, Alexandria MN, and was piloted by JHA. Aerial photos were taken by GLN and by our field assistant, Jessie Stegmeier. Weather data, including peak gust and average wind speed, were also obtained from the Alexandria airport weather station and were locally verified using an anemometer mounted on the shore of Lake Christina.

Other Data

As part of this multi-organizational project, fish communities were studied by Kyle Zimmer and students from the University of St. Thomas, St. Paul, MN. Water chemistry and aquatic invertebrate communities were examined by Malcolm Butler and students from North Dakota State University, Fargo, ND. Aquatic macrophytes and waterfowl were examined by Nicole Hansel-Welch and Tom Carlson of the Minnesota Department of Natural Resources, Bemidji, MN. This report will focus on the nongame waterbird response to the biomanipulation.

Data was analyzed using EXCEL (Microsoft Office XP Standard, Version 2002) and JMP (Version 6. SAS Institute Inc., Cary, NC, 1989-2005). Maps were created with ESRI ArcGIS 9.1 (2005).

RESULTS

Nongame Waterbird Surveys

To facilitate comparisons between game and nongame waterbird species, we counted both groups during ground surveys. Abbreviations in this report follow the USFWS Bird Banding Laboratory alpha coding system (Table 1). During the regular surveys, 32 waterbird species were counted. Table 2 lists all species and their peak counts during each open water season. Fifteen game species were observed using Lake Christina in 2004 and 14 species in 2005. Twelve nongame waterbird species were observed using Lake Christina in 2004 and 16 species in 2005. Figures 3-8 show overall changes in species abundance trends from 2004 to 2005 for various groups, including dabbling ducks and geese, diving ducks, nongame divers (loons, cormorants, and grebes), waders, and other waterbirds. The survey data from which these figures were derived are given in Appendix I.

Canada geese (*Branta candensis*) numbers were relatively high during both years, peaking in October. Wood ducks (*Aix sponsa*) and blue-winged teal (*Anas discors*) numbers peaked earlier in the fall, and were much more numerous during 2004 (Figure 3a, b). Several wood duck broods were also seen during daily work both years. American coots (*Fulica americana*) were by far the most abundant waterbird counted on Lake Christina, with a maximum count of over 141,000 birds. American coot counts peaked in late October and were much higher in 2005 than 2004 (Figure 4a, b). Most diving ducks were less abundant during 2005, except ring-necked ducks (*Aythya fuligula*), which increased greatly during the spring of 2005 (Figure 5a, b). All dabbling and diving ducks peaked in either spring or fall and were seen only in small numbers during the summer. Nongame divers and waders increased in 2005 (Figures 6a, b and 7a, b). Most other waterbirds increased in 2005, except ring-billed gulls (*Larus delawarensis*), which were much less abundant in 2004 (Figure 8). Overall, from 2004-2005 Lake Christina lost 2 species (NOPI, HOME), but gained 5 others (COME, CLGR, CAEG, TRUS, BAEA). In addition to these species counted during surveys, waterbird species seen at other times on Lake Christina included: horned grebe (*Podiceps auritus*), Franklin's gull (*Larus pipixcan*), Bonaparte's gull (*Larus philadelphia*), northern shoveler (*Anas clypeata*), red-breasted merganser (*Mergus serrator*), black crowned night heron (*Nycticorax nycticorax*), American bittern (*Botaurus lentiginosus*), least bittern (*Lxobrychus exilis*), and belted kingfisher (*Ceryle alcyon*).

In early May 2004 large numbers of western grebes began arriving on Lake Christina, but by early June their numbers started declining precipitously. During this same period western grebes began showing up on Pelican Lake, a fishing lake located immediately southwest of Lake Christina. Lake resort owners reported seeing much larger numbers of western grebes than in previous years, and we suspected that birds from Lake Christina were moving over to Pelican Lake. On 19 May, we established four survey points on the major bays of Pelican Lake. Throughout June, western grebes declined on Lake Christina until they stabilized at less than 50 birds through most of August (Figure 9a). During June and July, our counts on the open bays of Pelican Lake showed increasing numbers of western grebes, with a peak number of 165 birds on July 21. In late August western grebe numbers on both Lake Christina and Pelican Lake increased.

Minnow and small fish densities were extremely low on Lake Christina throughout the summer of 2004, with a mean catch of less than 0.5 fish per trap station throughout the breeding season (Figure 9b, fish data provided by Melissa Konsti.). Fish densities during 2005 were much higher, with mean catch rates of over 15 fish per trap throughout June and July (Figure 10b). In 2005 western grebes arrived at Lake Christina and stayed for the breeding season, while less than two dozen were observed on Pelican Lake during the spring and summer (Figure 10a).

Lake Christina hosts a variety of waterbird species throughout the year, and its use by game versus nongame species varied seasonally. Game species mainly occurred during the spring and fall migration months, while many nongame waterbird species arrive in the spring, spend the summer feeding or breeding, and then depart early in the fall (Figure 11a, b).

Monitoring of Over-water Nests

In 2004, black terns were the only waterbird species observed attempting to nest in the emergent beds of Lake Christina. Four nests with eggs were found in late July, but these were destroyed by a storm less than a week after they were located.

In 2005, 7 waterbird species nested in the emergent stands on Lake Christina: western grebe, red-necked grebe, pied-billed grebe, Clark's grebe, black tern, American coot, and canvasback (*Aythya valisineria*) (Figure 12). The only Clark's grebe that used the lake in 2005 was seen paired with a western grebe, though its nest location was undetermined, because their nests and eggs cannot be distinguished from those of western grebes. Successful breeding of the Clark's grebe, however, was confirmed in August when it was observed feeding a chick (Robert Jansen, pers. comm.). Total nest numbers found and monitored for nesting success were: 315 western grebe, 3 red-necked grebe, 3 pied-billed grebe, 10 black tern, 1 canvasback, and 1 American coot. The colony area was fairly well defined, and nests that were destroyed tended to be located at the outer margins of small bulrush islands that compose the larger colony (Figures 12, 13). All grebe species had nest success rates of greater than 60%. Black terns had nesting success rates of 30%. The one canvasback nest also hatched, and the American coot was still incubating on 10 August 2005, the last day of the colony nest checks (Table 3, Figure 14).

Western Grebe Colony Formation and Success

Only western grebes nested in sufficient numbers for further analysis. Detailed GIS analysis of colony formation and nesting success will comprise a portion of a Master's thesis that will be submitted separately from this report. Nest initiation by western grebes began in the dense bulrush beds of southwestern Lake Christina on 15 June 2005. In the first two weeks, nearly 200 nests were established. The maximum number of active nests in the colony at any given colony check was 215 (Figure 15a), and over the 2005 season 315 nests were located (Figure 15b). Average complete clutch sizes decreased with time (from 3.7 to 2.8) with an overall average clutch size of 3.1 eggs (Table 3, Figure 16).

Most of the 315 western grebe nests on Lake Christina were initiated in mid- to late-June. Hatching success was high (60% or more) during all of the nest initiation periods (Figure 17), with an overall hatching success of 63 percent (Table 3). Nest predation rates were very low, although 10 birds were found dead in the colony area. Wind conditions during June 2005 were unusually calm (Figures 18a, b), and by the time winds picked up in July the extensive stands of bulrush surrounding the nests of the colony nests were sufficiently dense to act as wave breaks. Figure 19 shows young/adult ratios for western grebes counted during Lake Christina shoreline surveys.

DISCUSSION

Nongame Waterbird Species Counts: Richness & Abundance

The shoreline counts used in this study were designed to provide an inexpensive and non-invasive index to the relative abundance of several nongame waterbird species of interest, particularly western grebes. These counts appeared to be capable of detecting major emigrations out of the lake (2004), but should not be considered as census data. The precipitous decline in open-water counts during mid-June 2005, for example, undoubtedly reflects the moving of grebe pairs into the dense bulrushes of the colony area, where they could not be easily seen from the shore. Our tower observations revealed this to be a very intense period of nest establishment. Once nests were established, one member of each pair nearly always remained at the nest, where most could not be viewed from open water vantage points.

Lake Christina's waterbird community in the spring and fall is comprised primarily of migratory game species. During the summer, nongame waterbird species become the dominant group, using the lake for breeding and foraging. The dramatic increases in nongame waterbirds from 2004 to 2005 are likely due to increases in fish abundance. Fish density was extremely low during 2004, but quickly rebounded in 2005, not only in minnows but in larger size classes as well (Melissa Konsti, pers. comm.). All nongame waterbird species counted at Lake Christina over the course of both summers were at least partially piscivorous. The fall of 2005 was characterized by unseasonably warm temperatures followed by a quick shift to below freezing temperatures in early November, which appeared to delay the migration of many waterfowl species. This could have caused counts to be low for several species, most notably in the fall of 2005, when there also were gaps in survey dates due to poor weekend weather conditions.

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Nesting Success of Nongame Waterbirds

Most nongame waterbirds attempting to nest on Lake Christina in 2005 were relatively successful.   All three grebe species breeding on the lake had over a 60% nesting success rate, although sample sizes are small for pied-billed grebes and red-necked grebes. Both of these species nested in the same general area as western grebes, and their nests were found in similar habitats. Black terns also nested on the outskirts of the western grebe colony, in some cases taking over abandoned grebe nests. Their smaller nests appeared to be more vulnerable to wind and wave action, and only 3 of the 10 nests were known to have hatched.

Nesting success of western grebes was very high in 2005, due mainly to relatively mild weather and wind conditions and relatively low predation rates during July. Except for a few gusty days, the weather during the breeding season was relatively calm compared to the rest of the summer. This allowed the nesting birds to avoid major wind and wave storms typical of the region. Our best estimation of a minimum total population size for western grebes on Lake Christina is 215 pairs, the maximum number of active nests found during any nest check (Figure 15). Re-nesting is very common in most grebes, and eventually 198 pairs successfully hatched young in 2005. Possibly most pairs that attempted to nest on the lake therefore were eventually successful.

Western Grebe Colony

Western grebes were by far the most abundant nongame nesting species found using Lake Christina and were therefore a major focus of this study. Western grebes have nested regularly on the lake from the late 1960's and in record numbers during the summer of 2003 (Minnesota DNR data, unpub, D. Anderson pers. comm.). Having an abundant fish resource available within the same body of water as their nesting habitat has been thought to be critical for successful breeding in western grebes, which rarely fly except during migration (Storer and Nuechterlein 1992). The application of rotenone to the fish population of Lake Christina during fall 2003 essentially provided a whole-lake test of this prediction.

Following the application of rotenone, our spring 2004 bird counts indicated that western grebes returned in large numbers, but then began leaving the lake precipitously. The lack of forage fish in Lake Christina appeared to cause large numbers of western grebes to move from Lake Christina to Pelican Lake in 2004. On Pelican Lake, western grebes probably were unable to breed due to a lack of suitable nesting habitat, which is a common occurrence within large fishing lakes of Minnesota. This buildup of western grebes on Pelican Lake did not occur in 2005, when fish had recovered in Lake Christina. Instead, western grebes again returned to Lake Christina, and this time established a thriving nesting colony.

Such abandonment and then re-colonization of an entire marsh system has rarely been documented in any grebe species, although GLN observed a similar abandonment of a well-established breeding marsh of western grebes (The Delta Marsh, Delta, Manitoba) after a rare and nearly complete winter-kill of minnows during the winter of 1975-76. Banded birds from the Delta Marsh were found nesting on another marsh 50 km away. In that case, some re-colonization and nesting occurred very late during the same breeding season, when new carp fry hatched, providing the marsh with a fresh influx of suitably-sized fish prey.

Our Lake Christina research suggest that emergent densities sufficient to be used for nesting by western grebes (or other species that build over water nests) may be limited to a single cluster of bulrush stands located in the south western corner (Figure 2). During 2005, peak nesting counts in the Lake Christina breeding colony of western grebes did not occur until the July colony check (Figure 15)**,** which is unusually late for the species. However, a delayed colony initiation may be typical for the Lake Christina colony because of the nature of the breeding habitat. All 315 western grebe nests were located within fresh growth of bulrush islands, most of which are typically sheered off during the spring ice melt. Located over depths of 0.7-1.3 m of water, these bulrush stands take time to reach the surface, and may be the only area on the lake providing sufficient off-shore nesting habitat to protect the over-water nests of western grebes from both wave-action and land predators. The health and re-growth of these bulrush stands therefore are critical to the breeding success of this important nongame species. Western grebes on Lake Christina arrive in early May, and then play a waiting game until late-June, feeding on the abundant fish, while regularly checking the progress of island re-growth. Throughout June, we often saw small groups of western grebes roosting on the water, just outside of the colony area. In stark contrast, western grebes on Lake Osakis, Minnesota, only 50 km to the east, already were establishing nests in late May, using the previous year's old growth of cattail (*Typha spp.*) stands.

On 16 June 2005, nearly the entire western grebe population on Lake Christina moved into the bulrush stands and began to nest. A colony check 4 days later revealed that over 100 nests had been established. During the next colony check, 8 days later, 195 pairs were actively incubating, which probably accounted for nearly all of the grebes on the lake. This extreme synchrony in nest establishment provides additional evidence that western grebes on Lake Christina were simply waiting for the bulrush stands to reach sufficient density for nesting. Once several colony founders began building their nests, other grebes of the population quickly moved in to claim their own territories. This initial colony was more synchronous than those typical of many other areas, such as Lake Osakis or the Delta Marsh, where birds arrive in early spring and, after pairing up, gradually join ongoing colonies. The decrease in numbers of western grebes counted during surveys in June and July is probably primarily due to our inability to see those birds that were working on nests or incubating eggs in the dense emergent vegetation (Fig.10a). By mid July the numbers of grebes counted during surveys increased, coinciding with the abandonment of nests once young begin hatching. Details relating to nest placement and colony formation will be analyzed separately.

Management Recommendations:

- Our shoreline surveys were specifically designed to provide a noninvasive, consistent index to the relative abundance of nongame waterbirds that roost and feed in the open water, such as the main focal species of this study. Windy conditions frequently prevented survey counts, due to the large fetch distances at Lake Christina. However,

informal experimental counts of large bays before and after wind conditions deteriorated confirmed that a calm surface was critical to accurate counts made over long distances.
- If rare (< 25 individuals) nongame species are to be monitored successfully, either a more intensive survey protocol or frequent “non-survey” trips to the lake are required. Many rare species are encountered haphazardly and will not be observed on regular surveys.
- Shoreline surveys were successful at detecting the presence and relative numbers of western grebes on Lake Christina, particularly before nesting began and after its completion. When not on their nests, adult western grebes fed and roosted on the open water, especially in the large open bays.
- Timing of western grebe nesting may vary considerably between lakes and between seasons depending on ice-out conditions and type and density of emergent vegetation, which means that infrequent or single-point colony checks are unlikely to provide consistent data that are very useful in monitoring breeding populations.
- Late-July shoreline surveys could be easily used to detect and monitor lakes suspected of having breeding colonies of western grebes. Pairs with older young are usually feeding conspicuously in open water areas where they could easily be detected and counted by local birders.
- Fish re-colonization was rapid the summer following the rotenone application, but for the presence and breeding of nongame waterbird species, some desirable species of fish should be stocked after rotenone treatments to provide a minimum forage base for piscivorous birds.

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LITERATURE CITED

Amey, M. 1984. The application of liquid Derris (5% Rotenone) to a spring-fed upland pond to eradicate perch (*Perca fluviatilis* L.)- 3 year post-application monitoring. Fisheries Management 15(2): 75.

Asplund, T., C. Cook. 1999. Can no-wake zones effectively protect littoral zone habitat from boating disturbance? LakeLine 19: 16-18, 48-52

Carlson, T., N. Hansel-Welch. 2003. Lake Christina rotenone treatment report. Minnesota Department of Natural Resources: Section of Wildlife Report.

Engstrom-Heg, R., T. Colsante, E. Silco. 1978. Rotenone tolerances of stream-bottom insects. New York Fish and Game Journal 25(1): 31-41.

Finlayson, J., R. Schnick, R. Cailteux, L. DeMong, W. Horton, W. McClay, C. Thompson, G. Tichacek. 2000. Rotenone use in fisheries management: administrative and technical guidelines manual. American Fisheries Society, Bethesda, Maryland.

Gilderhus, P. 1982. Effects of an aquatic plant and suspended clay on the activity of fish toxicants. North American Journal of Fisheries Management 2: 301-306.

Hansel-Welch, N., M.G. Butler, T.J. Carlson, M. A. Hanson. 2003. Changes in macrophyte community structure in Lake Christina (Minnesota), a large shallow lake, following biomanipulation. *Aquatic Botany* 75: 323-337.

Hanson, M., M. Butler. 1994a. Responses to food web manipulation in a shallow waterfowl lake. Hydrobiologia 279/280: 457-466.

Hanson, M., M. Butler. 1994b. Responses of plankton, turbidity, and macrophytes to biomanipulation in a shallow prairie lake. Canadian Journal of Aquatic Science 51: 1181-1188.

Hoffman, D., J. Olive. 1961. The effects of rotenone and toxaphene upon plankton of two Colorado reservoirs. Limnology and Oceanography 6(2): 219-222.

Hoyer, M., D. Canfield. 1994. Bird abundance and species richness on Florida lakes: influence of trophic status, lake morphology, and aquatic macrophytes. Hydrobiologia 297/280: 107-119.

Hoyer, M., D. Canfield. 1990. Limnological factors influencing bird abundance and species richness on Florida lakes. Lake and Reservoir Management 6(2): 133-141.

James, W., E. Best, J. Barko. 2004. Sediment resuspension and light attenuation in Peoria Lake: can macrophytes improve water quality in this shallow lake system? Hydrobiologia 515: 193-201.

James, W., J. Barko, M. Butler. 2004. Shear stress and sediment resuspension in relation to submersed macrophyte biomass. Hydrobiologia 515: 181-191.

Lauridsen, T., J. Jensen, E. Jeppesen, M. Sondergaard. 2003. Responses of submerged macrophytes in Danish lakes to nutrient loading reductions and biomanipulation. Hydrobiologia 506-509: 641-649.

McClay, W. 2000. Rotenone use in North America (1988-1997). Fisheries Management 25(5): 15-21.

Morrison, B. 1977. The effects of rotenone on the invertebrate fauna of three hill streams in Scotland. Fisheries Management 8(4): 128-139.

Morrison, B., G. Struthers. 1975. The effects of rotenone on the invertebrate fauna of three Scottish freshwater lochs. Fisheries Management 6(4): 81-91

Murphy, K., J. Eaton. 1983. Effects of pleasure-boat traffic on macrophyte growth in canals. Journal of Applied Ecology 20: 713-729.

Post, D., J. Taylor, J. Kitchell, M. Olsen, D. Schnidler, B. Herwig. 1998. The role of migratory waterfowl as nutrient vectors in a managed wetland. Conservation Biology 12(4): 910-920.

Pijanowska, J., A. Prejs. 1997. Food-web manipulation in shallow, eutrophic lakes: Bridging the gap between the whole-lake approach and behavioural and demographic studies. Hydrobiologia 342: 305-310.

Prejs, A. J. Pijanowska, P. Koperski, A. Martyniak, S. Boron, P. Hliwa. 1997. Food-web manipulation in a small, eutrophic Lake Wirbel, Poland: Long-term changes in fish biomass and basic measures of water quality. A case study. Hydrobiologia 342: 383-386.

Rask, M., M. Olin, J. Keskitalo, A. Lehtovaara, J. Ruuhijarvi, S. Vesala. 2003. Responses of plankton and fish communities to mass removal of planktivorous fish in a two-basin lake in Southern Finland. Hydrobiologia 506-509: 451-457.

Scheffer, M. 1998. Ecology of Shallow Lakes. Chapman and Hall, London.

Scheffer, M., H. Holmgren, V. Brovkin, M. Claussen. 2005. Synergy between small- and large-scale feedbacks of vegetation on the water cycle. Global Change Biology 11 (7): 1003-1012.

Smith, J. 1946. The canvas-back in Minnesota. Auk 63: 73-81.

Storer, R.W. and G.L. Nuechterlein. 1992. Western and Clark's Grebe. *In* The Birds of North America, No. 26 (A. Poole, P. Stettenhem, and F. Gill, Eds.) Philadelphia: The Acad. of Nat. Sciences; Wash. D.C: The American Ornithologists' Union.

Van de Bund, W., E. Van Donk. 2002. Short-term and long-term effects of zooplanktivorous fish removal in a shallow lake: a synthesis of 15 years of data from Lake Zwemlust. Freshwater Biology 47: 2380-2387.

Zambrano, L., M. Scheffer, M. Martinez-Ramos. 2001. Catastrophic response of lakes to benthivorous fish introductions. Oikos 94: 344-350.

Zimmer, K., M. Hanson, M. Butler. 2001. Effects of fathead minnow colonization and removal on a prairie wetland ecosystem. Ecosystems 4: 346-357.

Table 1. Alpha codes of the U.S. Fish and Wildlife Service Bird Banding Laboratory (BBL) were used for the tables and figures within this report.

	Common Name	Scientific Name
AMCO	American Coot	*Fulica americana*
AWPE	American White Pelican	*Pelecanus erythrorhynchos*
BAEA	Bald Eagle	*Haliaeetus leucocephalus*
BLTE	Black Tern	*Chlidonias niger*
BUFF	Bufflehead	*Bucephala albeola*
BWTE	Blue-winged Teal	*Anas discors*
CAEG	Cattle Egret	*Bubulucus ibis*
CAGO	Canada Goose	*Branta candensis*
CANV	Canvasback	*Aythya valisineria*
CLGR	Clark's Grebe	*Aechmophorus clarkii*
COGO	Common Goldeneye	*Bucephala clangula*
COLO	Common Loon	*Gavia immer*
COME	Common Merganser	*Mergus merganser*
DCCO	Double-crested Cormorant	*Phalacrocorax penicillatus*
EAGR	Eared Grebe	*Podiceps nigricollis*
FOTE	Forster's Tern	*Sterna forsteri*
GADW	Gadwall	*Anas strepera*
GBHE	Great Blue Heron	*Ardea herodias*
GREG	Great Egret	*Ardea Alba*
HOME	Hooded Merganser	*Lophodytes cucullatus*
LESC	Lesser Scaup	*Aythya affinis*
MALL	Mallard	*Anas platyrhynchos*
NOPI	Northern Pintail	*Anas acuta*
PBGR	Pied-billed Grebe	*Podilymbus podiceps*
RBGU	Ring-billed Gull	*Larus delawarensis*
REDH	Red Head	*Aythya americana*
RNDU	Ring-necked Duck	*Aythya fuligula*
RNGR	Red-necked Grebe	*Podiceps grisegena*
RUDU	Ruddy Duck	*Oxyura jamaicensis*
TRUS	Trumpeter Swan	*Cygnus buccinator*
WEGR	Western Grebe	*Aechmophorus occidentalis*
WODU	Wood Duck	*Aix sponsa*

Table 2. Thirty-two waterbird species were observed on surveys of Lake Christina during 2004-2005. For each species the maximum count obtained on a survey during the open-water season is given for each survey.

	2004	2005
Dabbling Ducks/Canada Goose		
AMCO	41515	132600
BWTE	479	40
CAGO	407	300
GADW	18	30
MALL	32	53
NOPI	20	0
WODU	363	38
Diving Ducks		
BUFF	2	36
CANV	25	37
COGO	17	3
COME	0	3
HOME	1	0
LESC	32	68
REDH	1	53
RNDU	75	442
RUDU	16	1
Nongame Divers		
CLGR	0	1
COLO	2	4
DCCO	34	95
EAGR	6	3
PBGR	2	74
RNGR	1	8
WEGR	246	324
Wading Birds		
CAEG	0	1
GBHE	13	16
GREG	4	47
Other Waterbirds		
AWPE	115	320
BAEA	0	3
BLTE	31	60
FOTE	3	12
RBGU	2135	158
TRUS	0	1

Table 3. Summary of waterbird nesting success at Lake Christina, 2005.

Species	Sample Size	Ave. Clutch Size	Number (%) Hatched	Number (%) Failed	Number (%) Unknown
WEGR	315	3.1	198 (62.9)	115 (26.9)	32 (10.2)
RNGR	3	4	2 (66.7)	0 (0)	1 (33.3)
PBGR	3	6.3	2 (66.7)	1 (33.3)	0 (0)
BLTE	10	2.4	3 (30)	4 (40)	3 (30)
CANV	1	8	1 (100)	0 (0)	0 (0)
AMCO	1	9	0 (0)	0 (0)	1 (100)

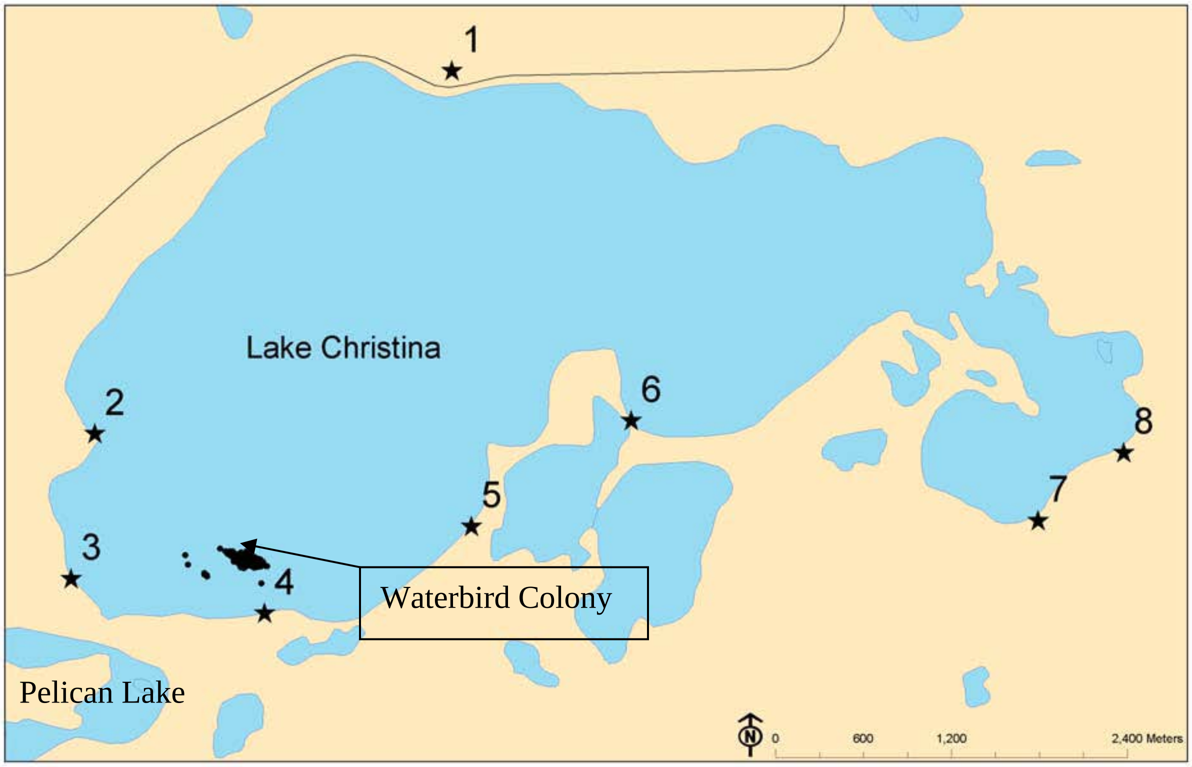
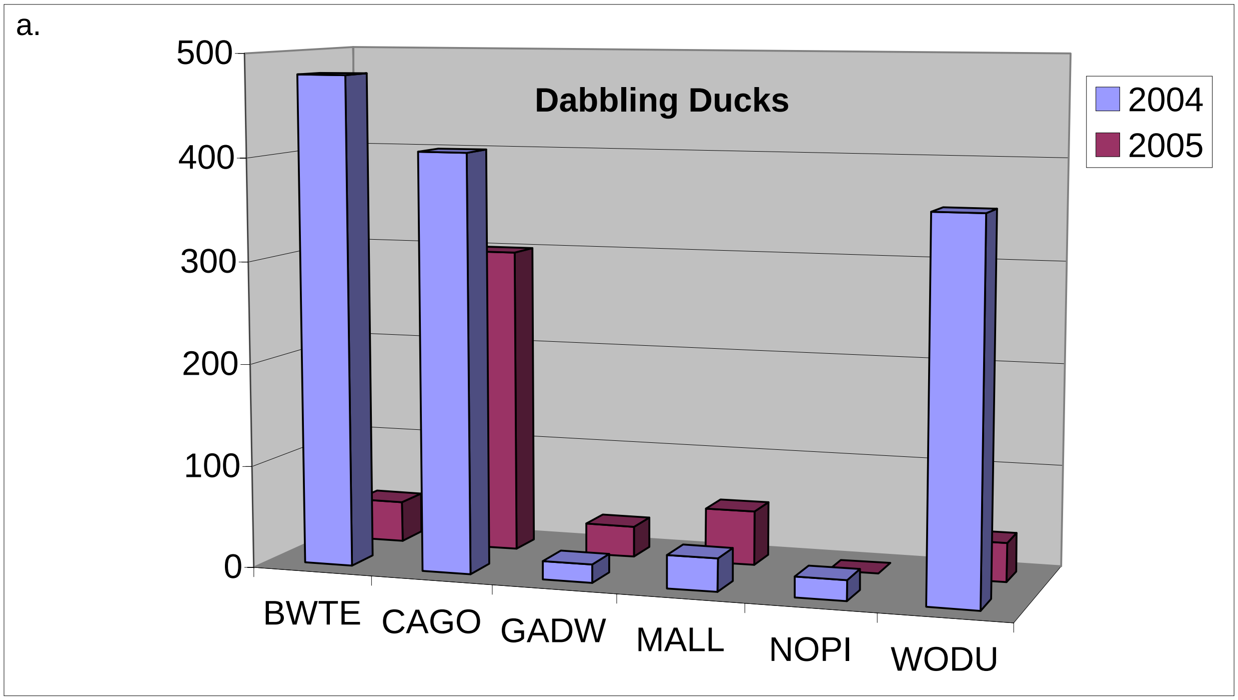


Figure 1. Waterbird survey points located around Lake Christina provided almost complete visual coverage of the lake.

Figure 2. The sequence of three aerial pictures show the dense bulrush beds in the southwest bay used for nesting by western grebes. White dots are plastic bags marking nests after the colony had completed nesting in August 2005 (GLN- photographer, JHA-Pilot).



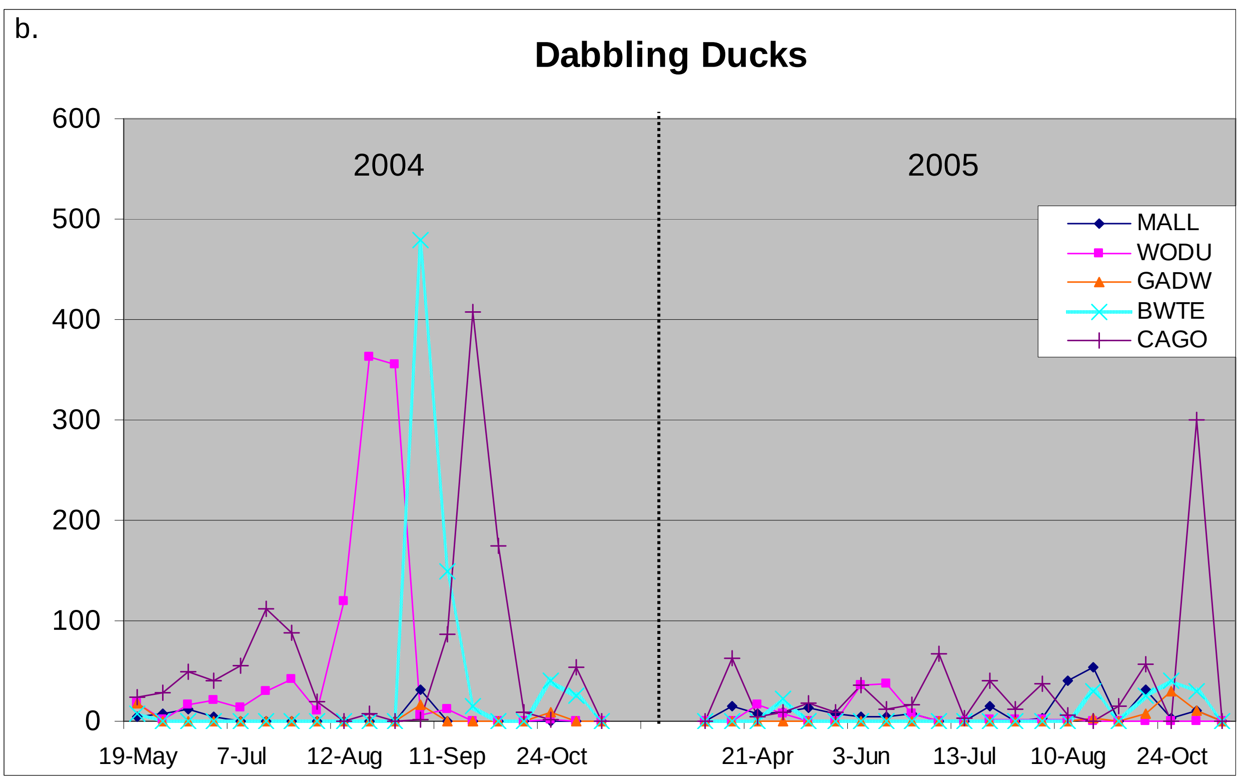
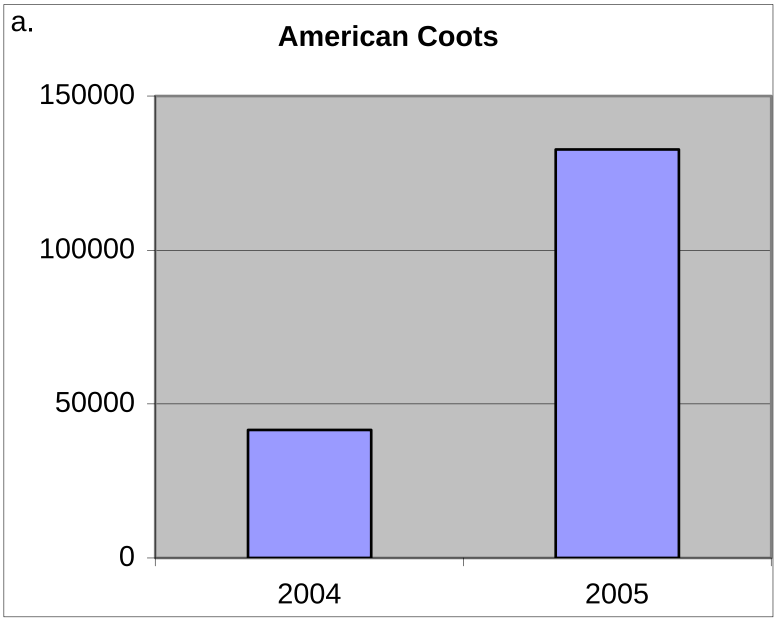


Figure 3. (a) Maximum counts of wood ducks and blue-winged teal reached a much greater abundance during the 2004 surveys compared to 2005. Canada goose counts were relatively high during both years. (b) Survey counts for these species peaked between mid-August and mid-October 2004.



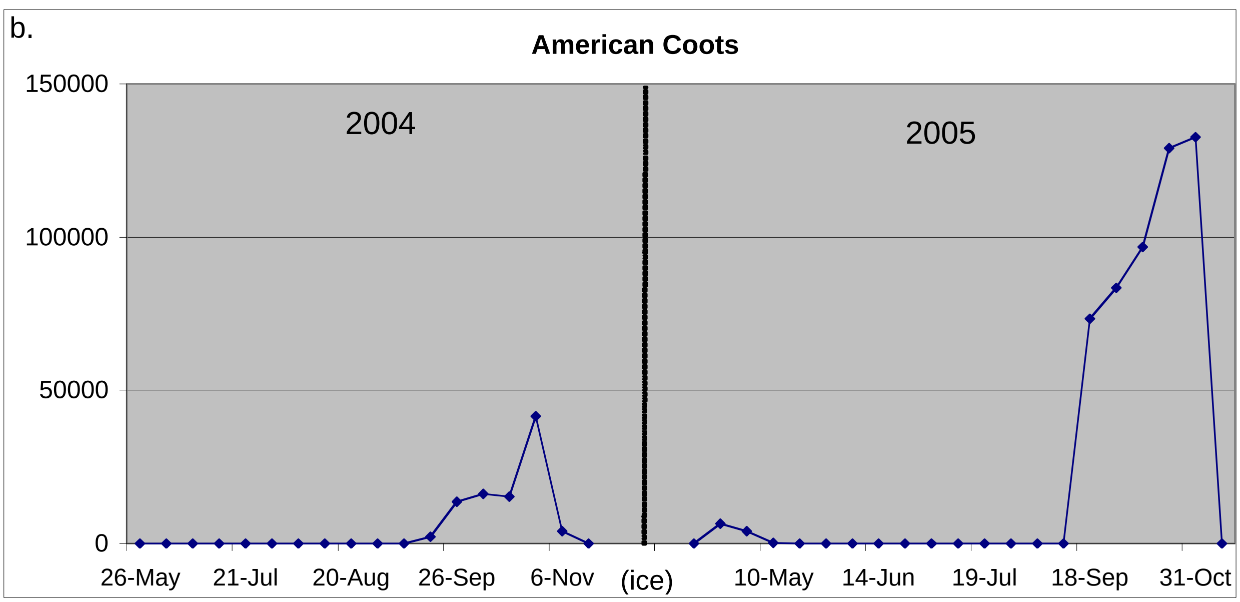
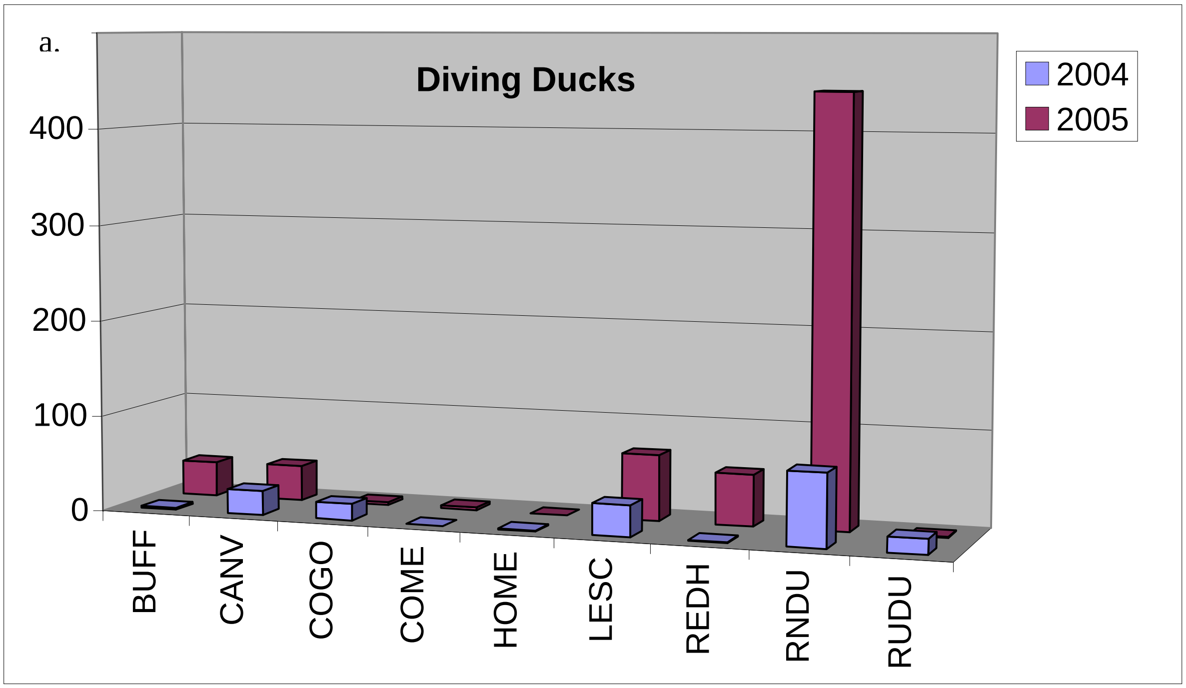


Figure 4. (a) Maximum counts of American coots showed a dramatic increase in2005 relative to 2004. (b) In both years coot numbers peaked in late October.



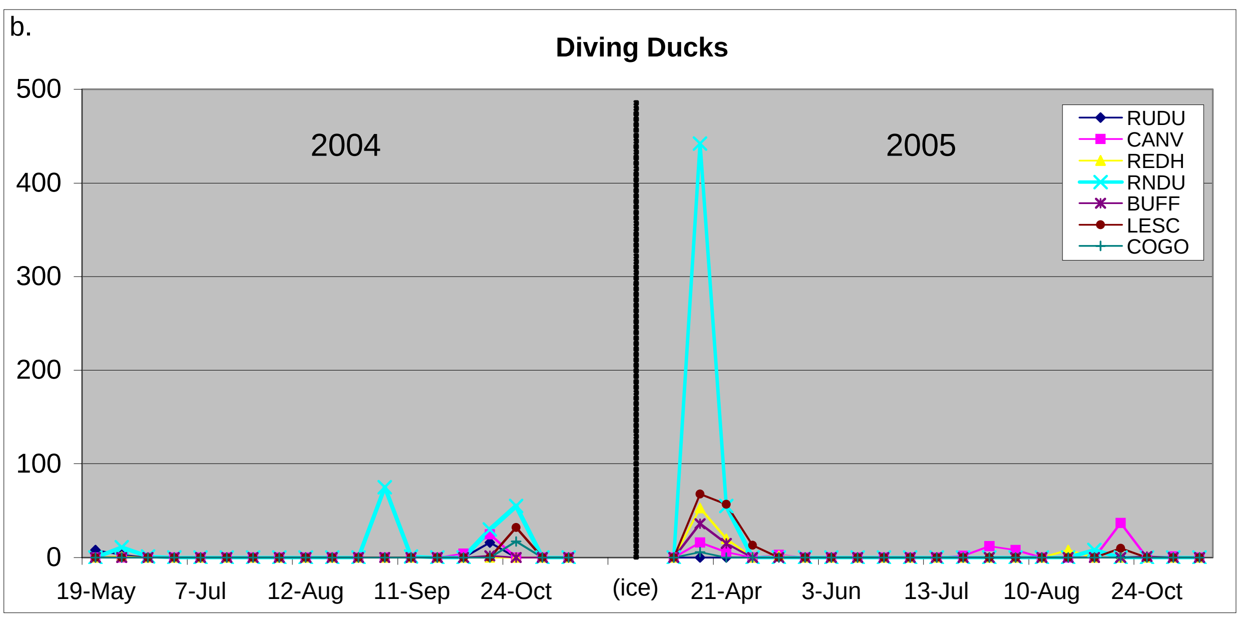
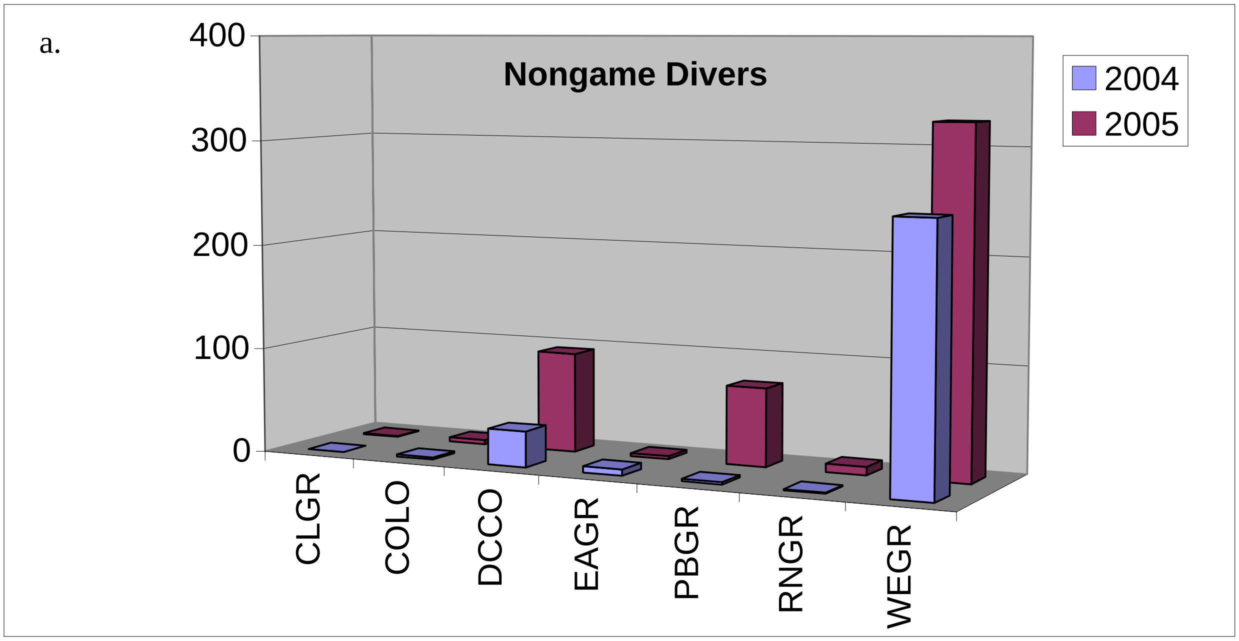


Figure 5. (a) Maximum counts for most species increased in 2005, with ring-necked ducks showing the most dramatic increase in abundance. (b) Survey counts for most divers peaked in mid-April to mid-May 2005.



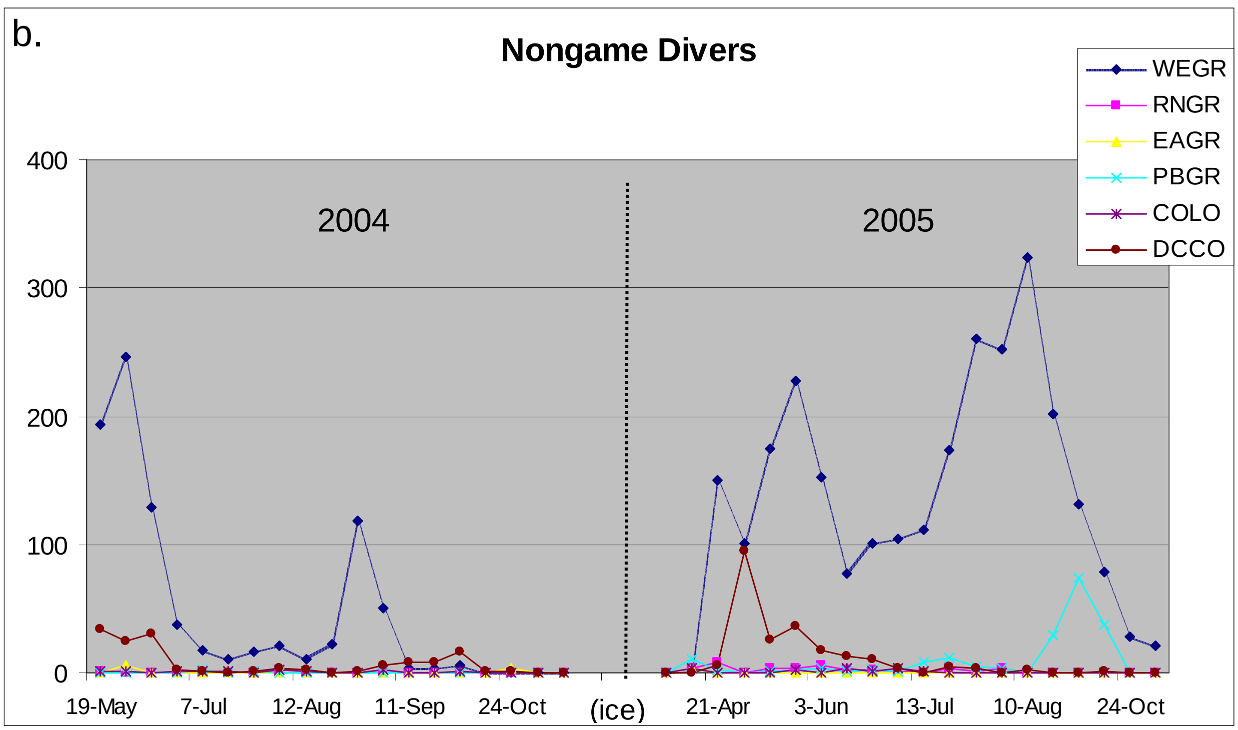
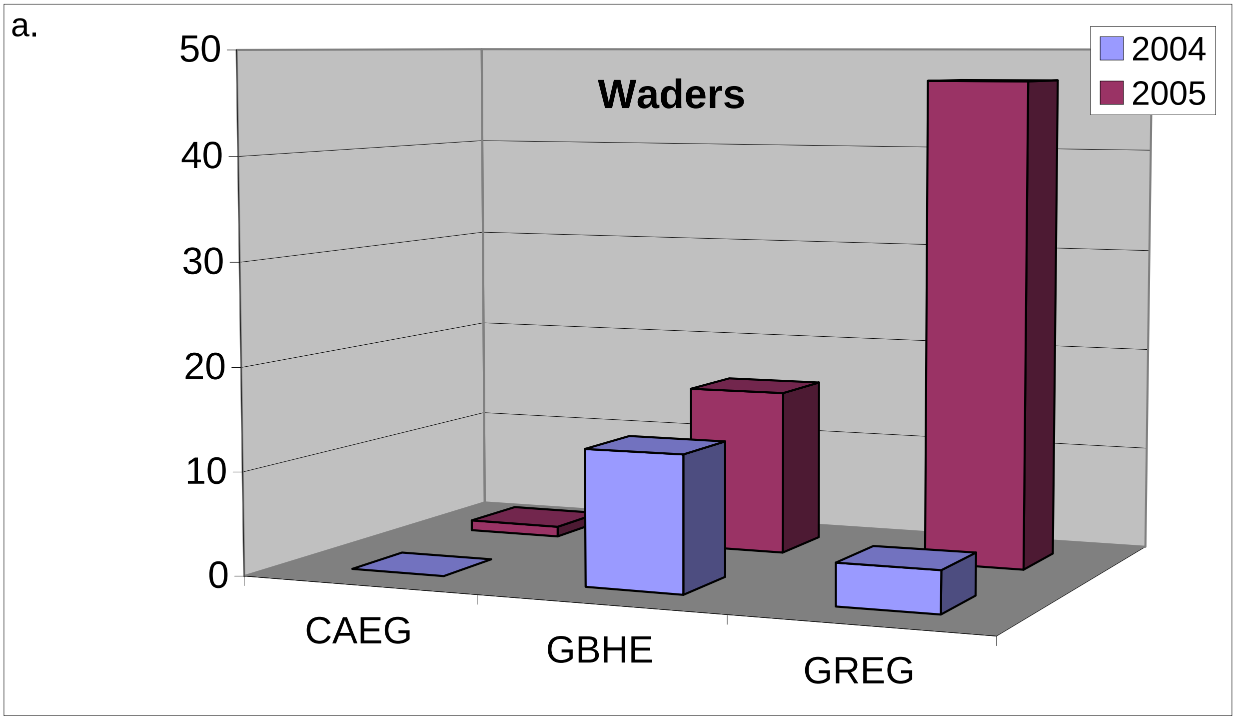


Figure 6. (a) Maximum counts of western grebes, pied-billed grebes, and double-crested cormorants increased in 2005 over 2004. (b) Throughout most of the open-water season of both years, western grebes were the most abundant nongame diver. Double-crested cormorants peaked during the spring of 2005, while the maximum counts of pied-billed grebes occurred during the fall of 2005.



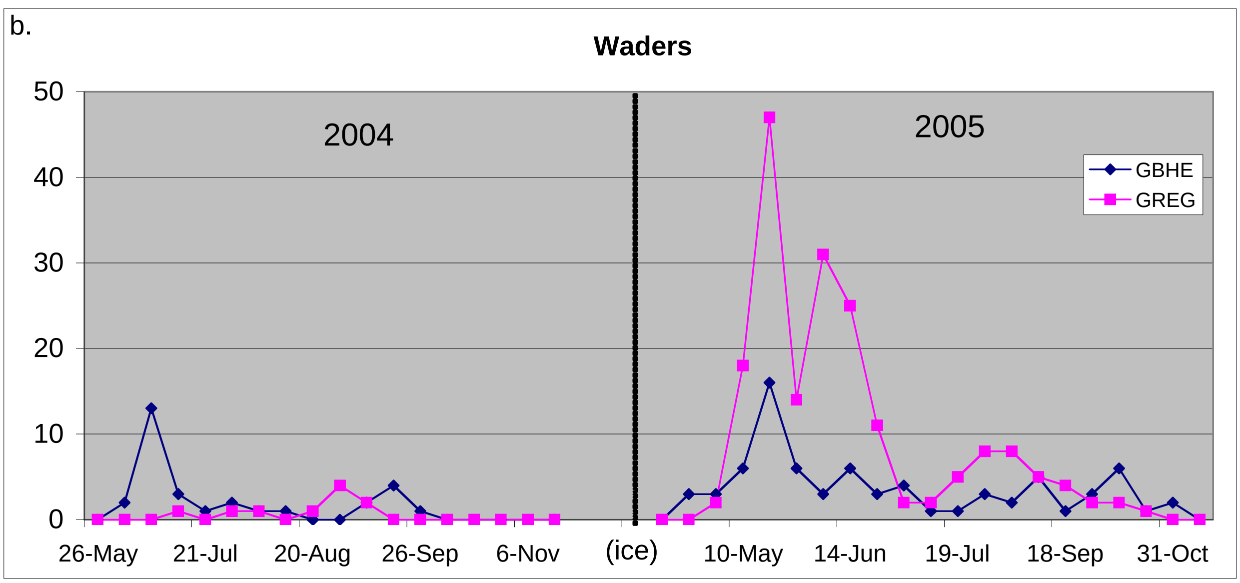
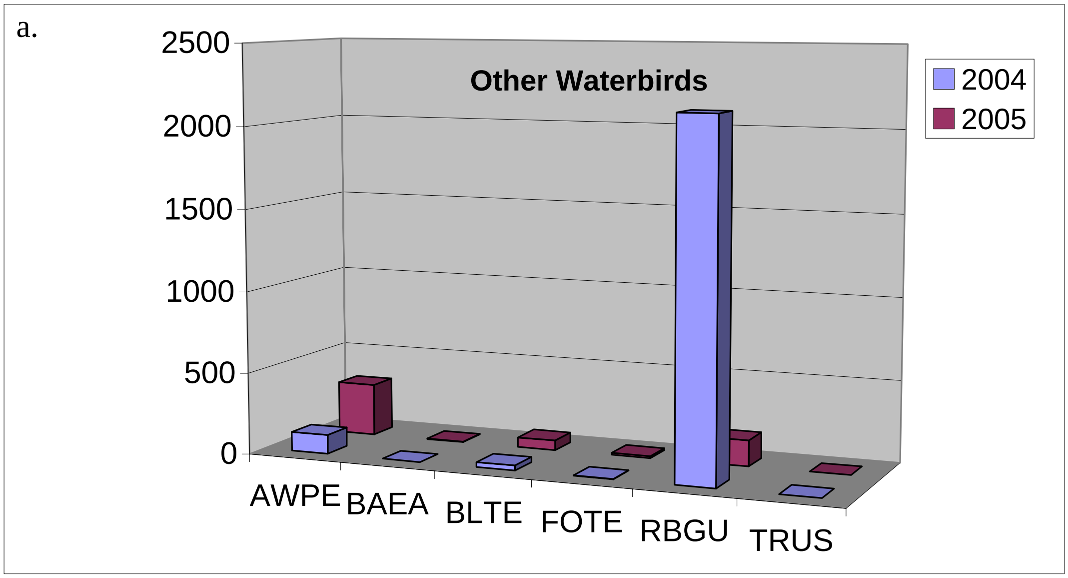
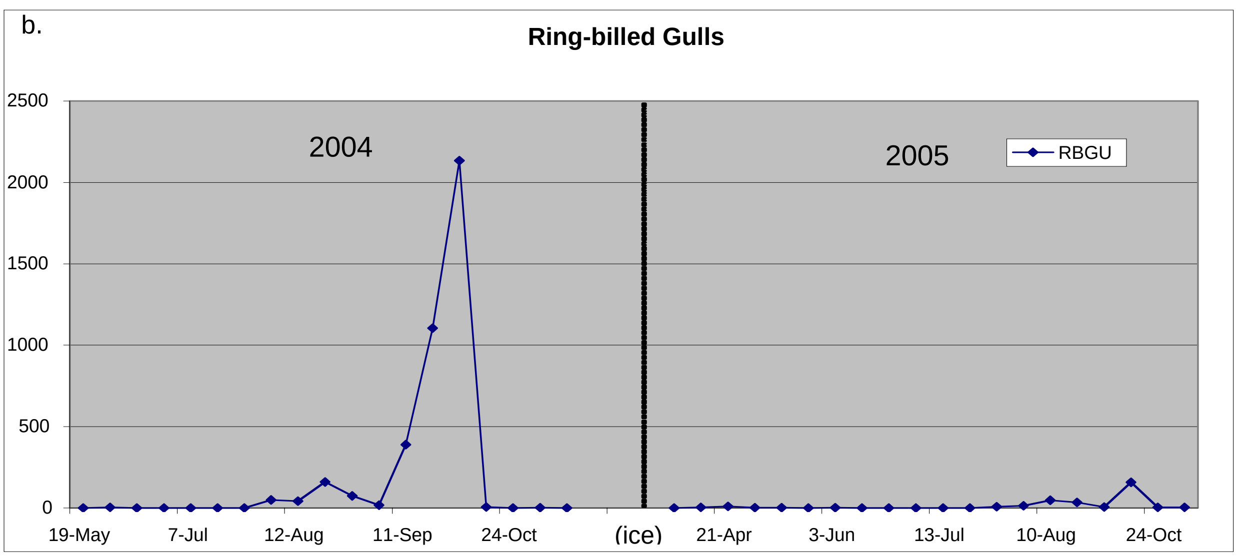


Figure 7. (a) Maximum counts of great egrets increased dramatically in 2005. (b) Survey counts of great blue herons and great egrets peaked during spring counts.





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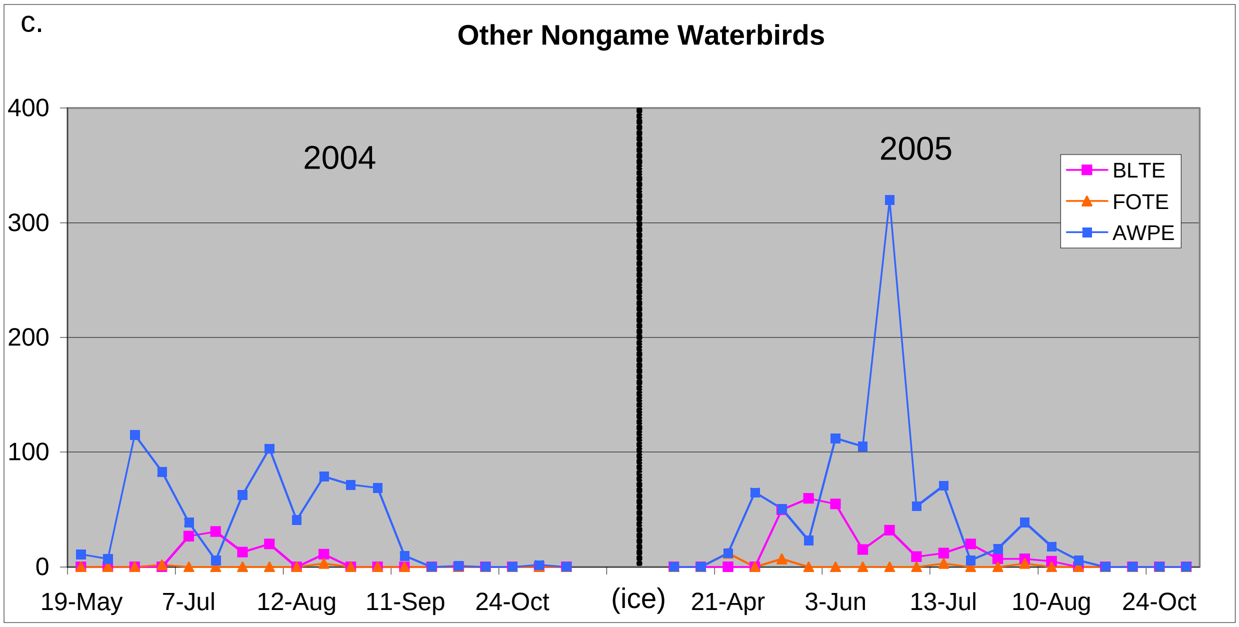


Figure 8. The biggest difference in years for all other waterbird species occurred with RBGU, which were much less abundant in 2005. TRUS was a new species in 2005. BAEA occurred both years, however not seen on survey days in 2004, but still more abundant and feeding with young in 2005.

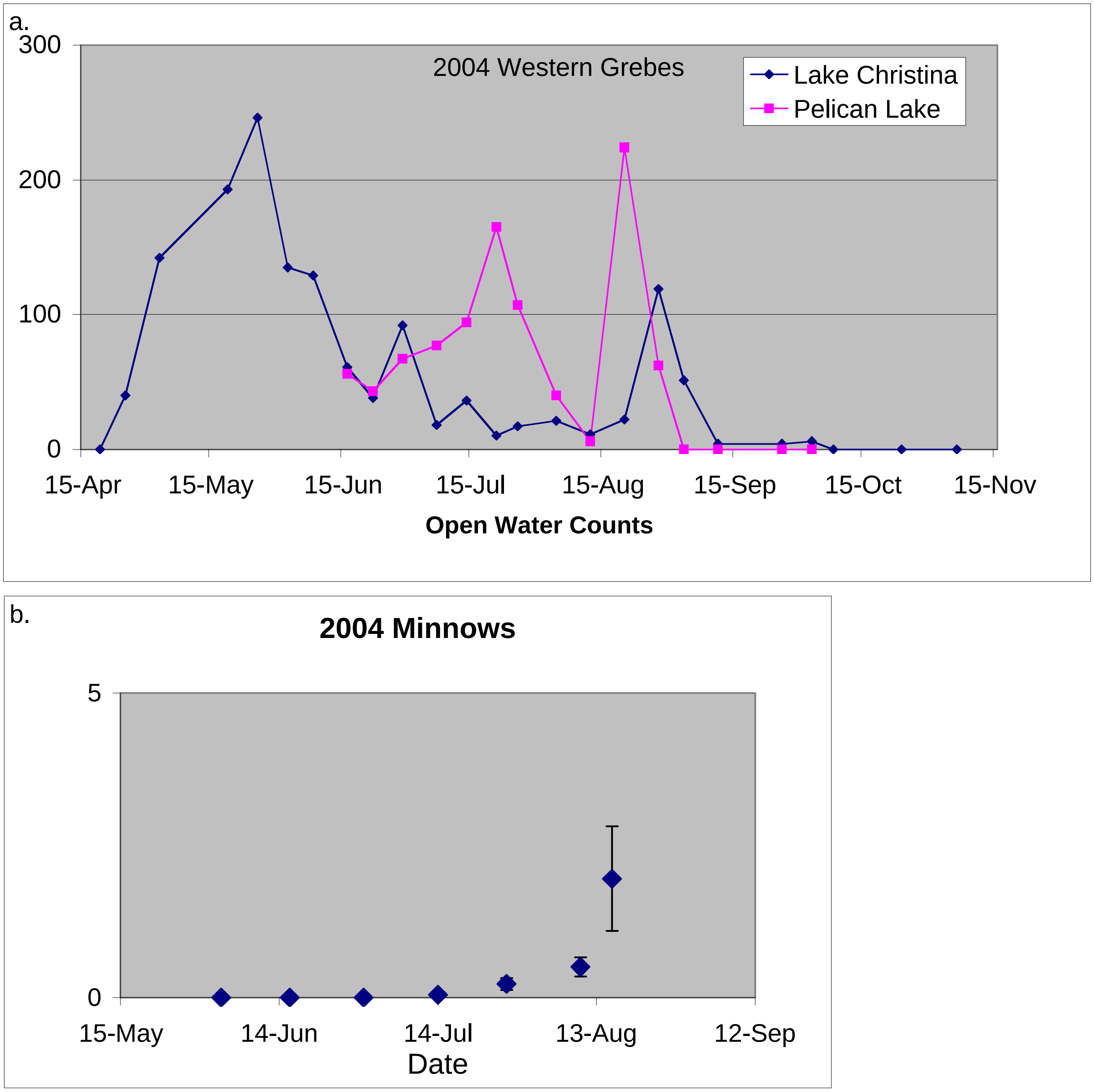
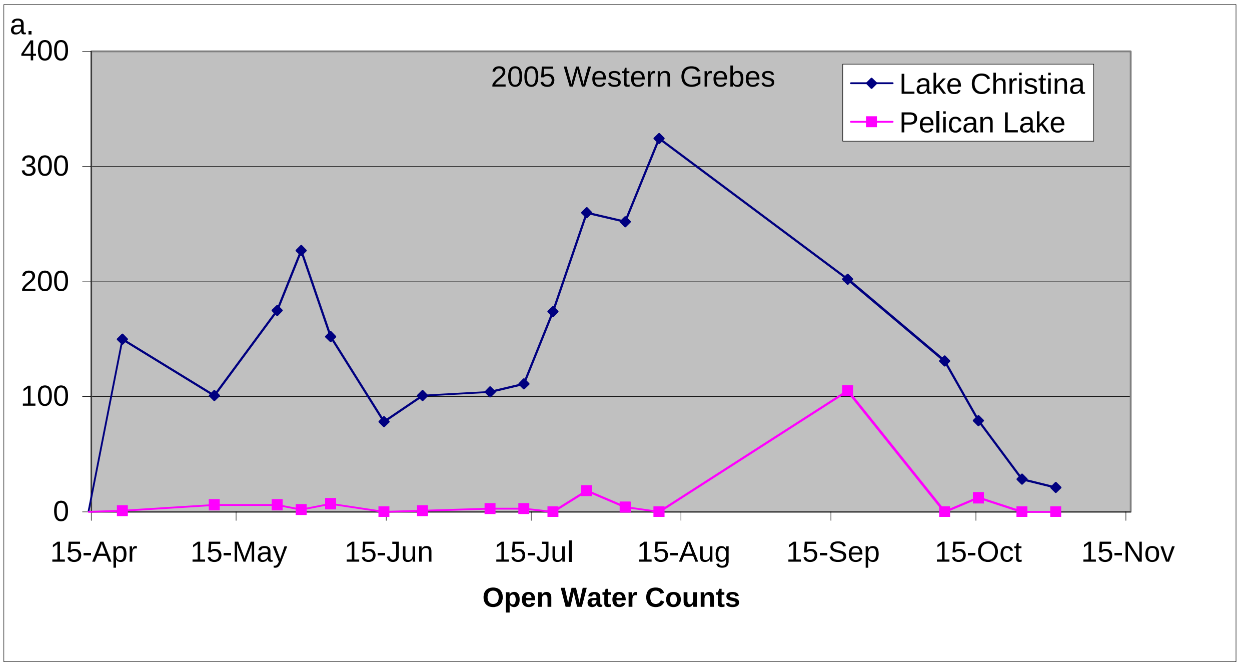


Figure 9. (a) Survey counts of western grebes on Lake Christina and Pelican Lake during 2004 showed many western grebes arriving at Lake Christina in early 2004, but then numbers decreased while Pelican Lake began hosting larger numbers of grebes. (b) trap counts for minnows on Lake Christina began increasing in Fall 2004.



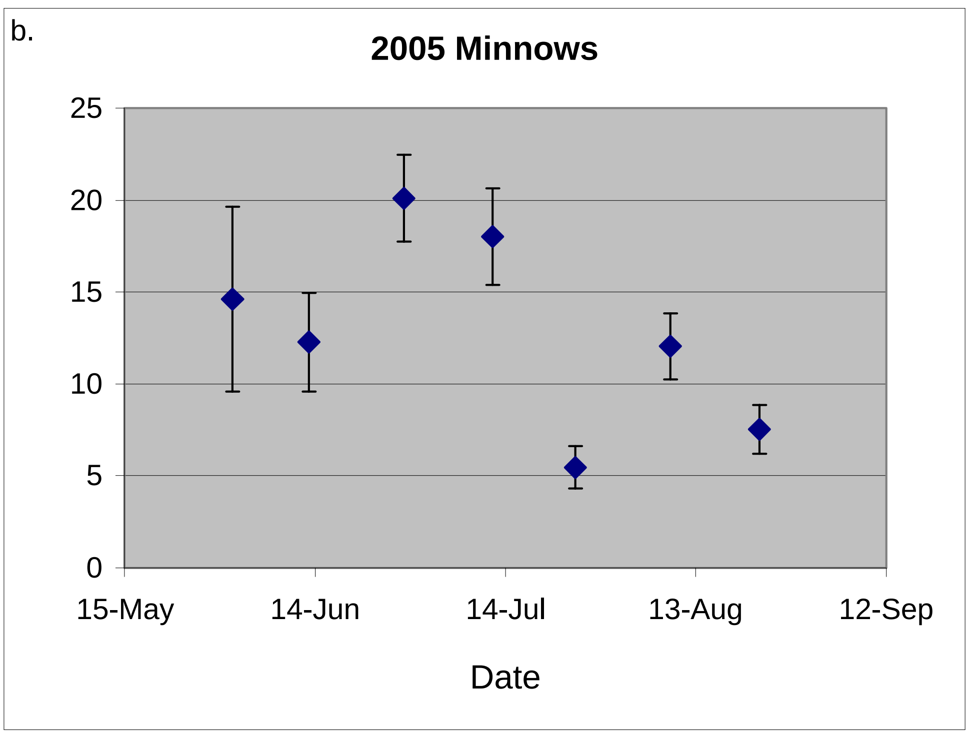
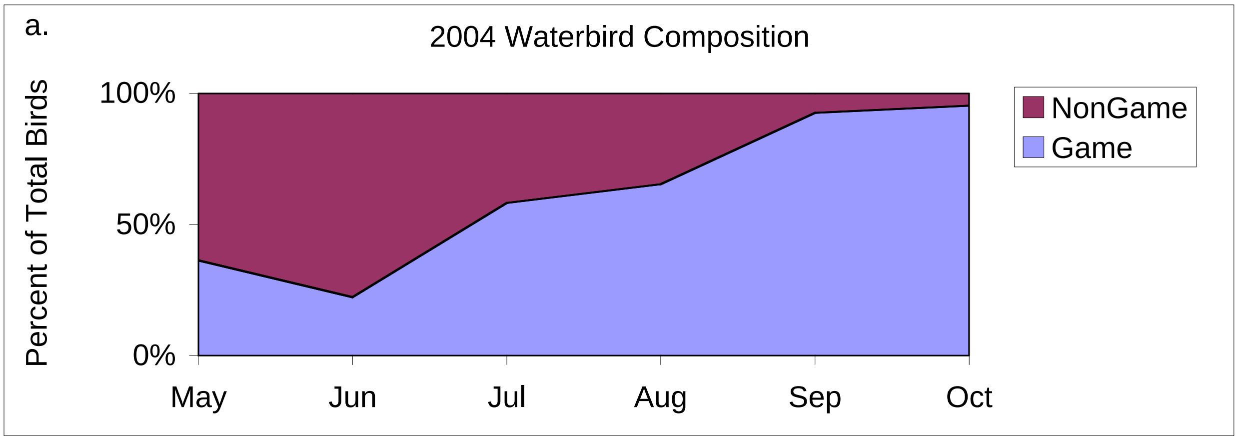


Figure 10. (a) Counts of western grebes on Lake Christina remained high throughout the open-water season of 2005. During incubation open water counts of western grebes were lower. Counts at Pelican Lake remained low throughout 2005. (b) During 2005, trap counts for minnows on Lake Christina were much higher than in 2004, with numbers peaking in the spring.



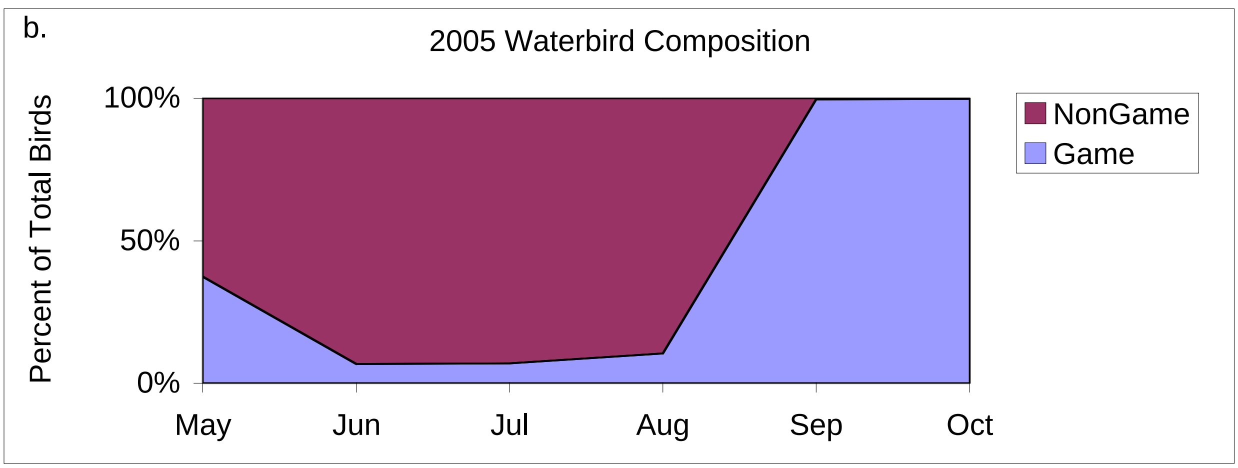


Figure 11. During the summers of both (a) 2004 and (b) 2005, Lake Christina's waterbird community was comprised mainly of nongame species, while the proportion of game species increase during spring and fall migrations.

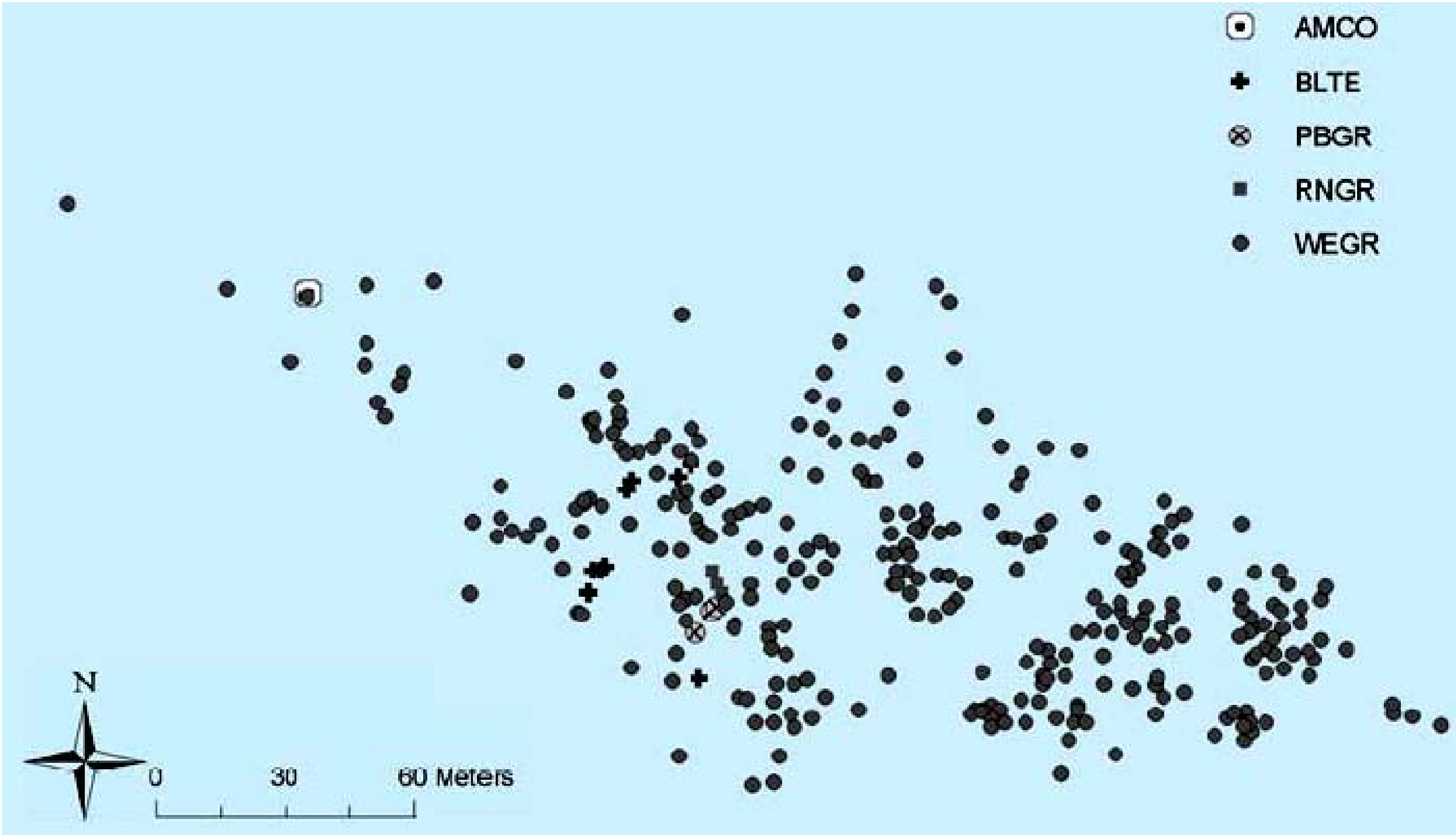


Figure 12. The waterbird nesting colony at Lake Christina was located in the thick bulrush beds in the south central portion of the large, shallow bay. The colony was predominately western grebes, but also contained red-necked grebes, pied-billed grebes, black terns, and one American coot nest.

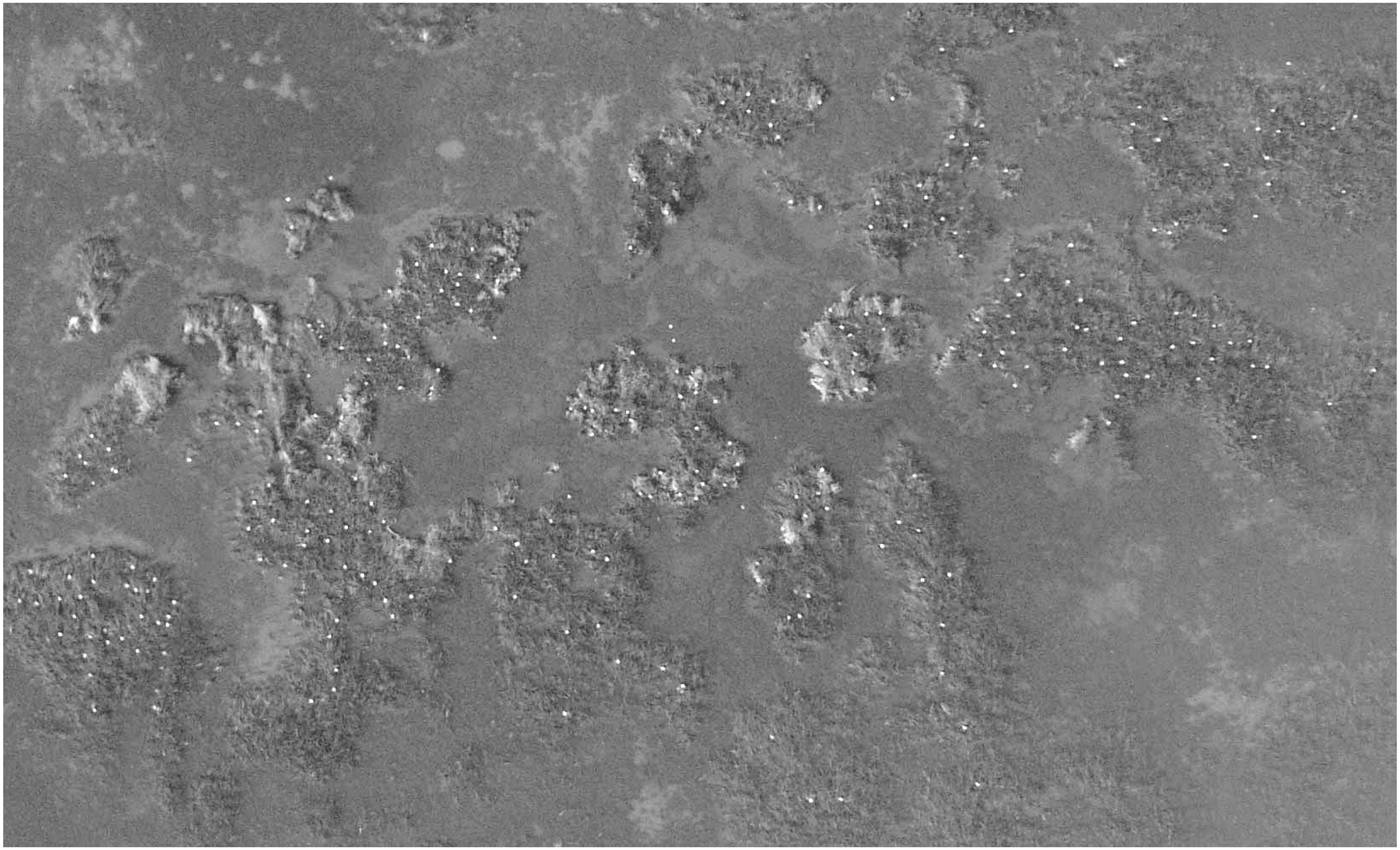


Figure 13. Aerial composite of western grebe colony located in bulrush bed clusters on Lake Christina in 2005. Nests were marked with white plastic bags. (JHA: Pilot, GLN: Photo).

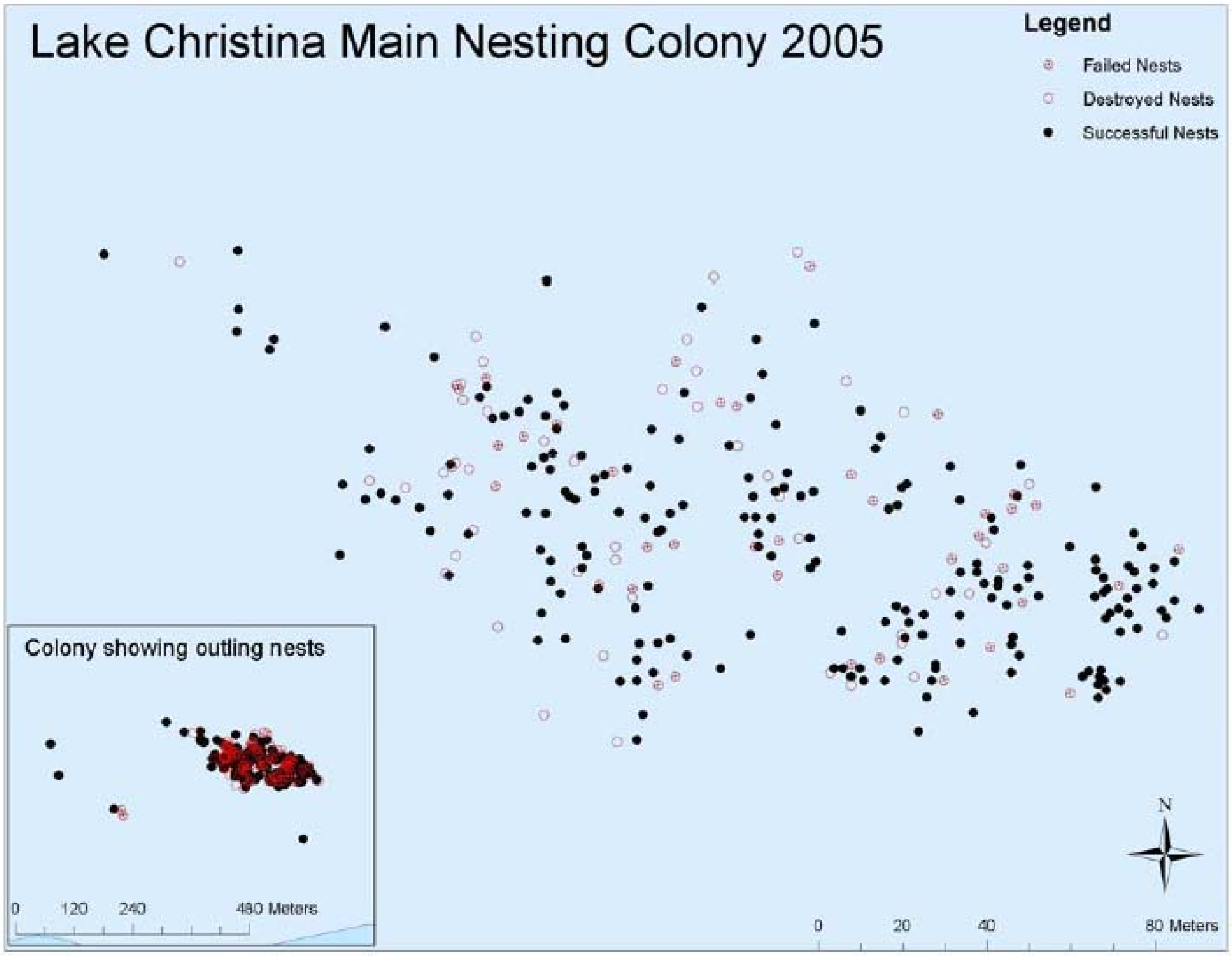


Figure 14. Lake Christina's waterbird colony had high success rates across most nesting species. Nests destroyed by wind and wave action were often located at the edges of bulrush islands (shown by clustered appearance within the main colony area).

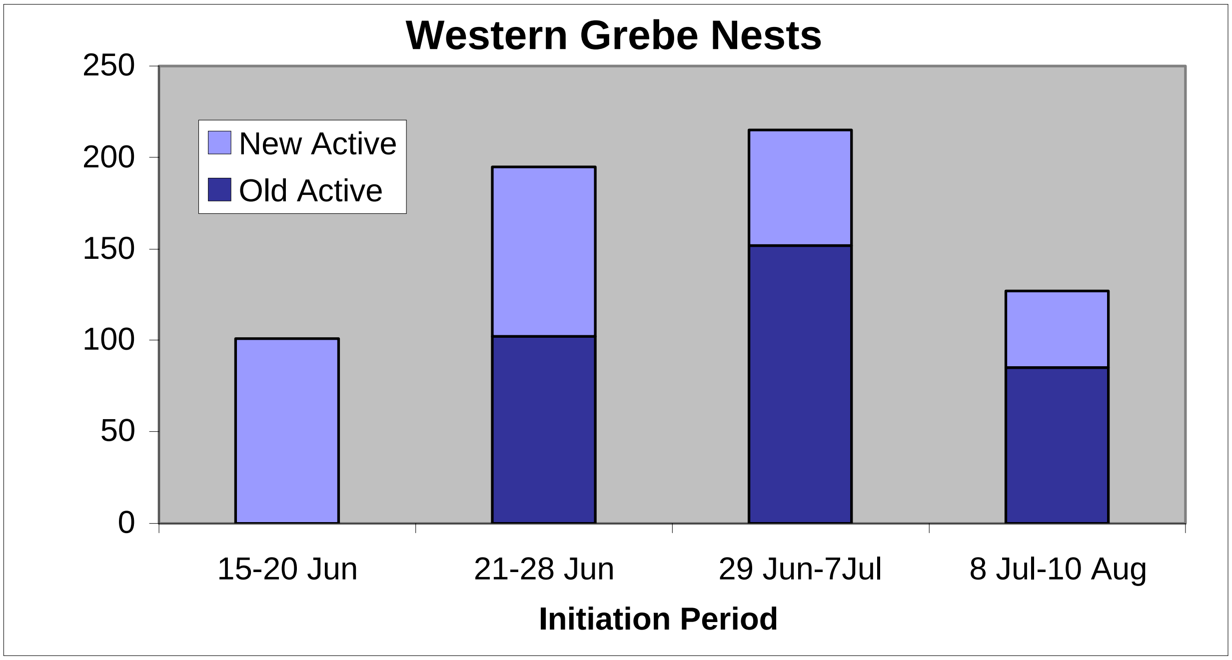


Figure 15. Nesting by western grebes at the Lake Christina colony began in mid-June. The peak number of active western grebe nests occurred in the first week of July with 215 nests.

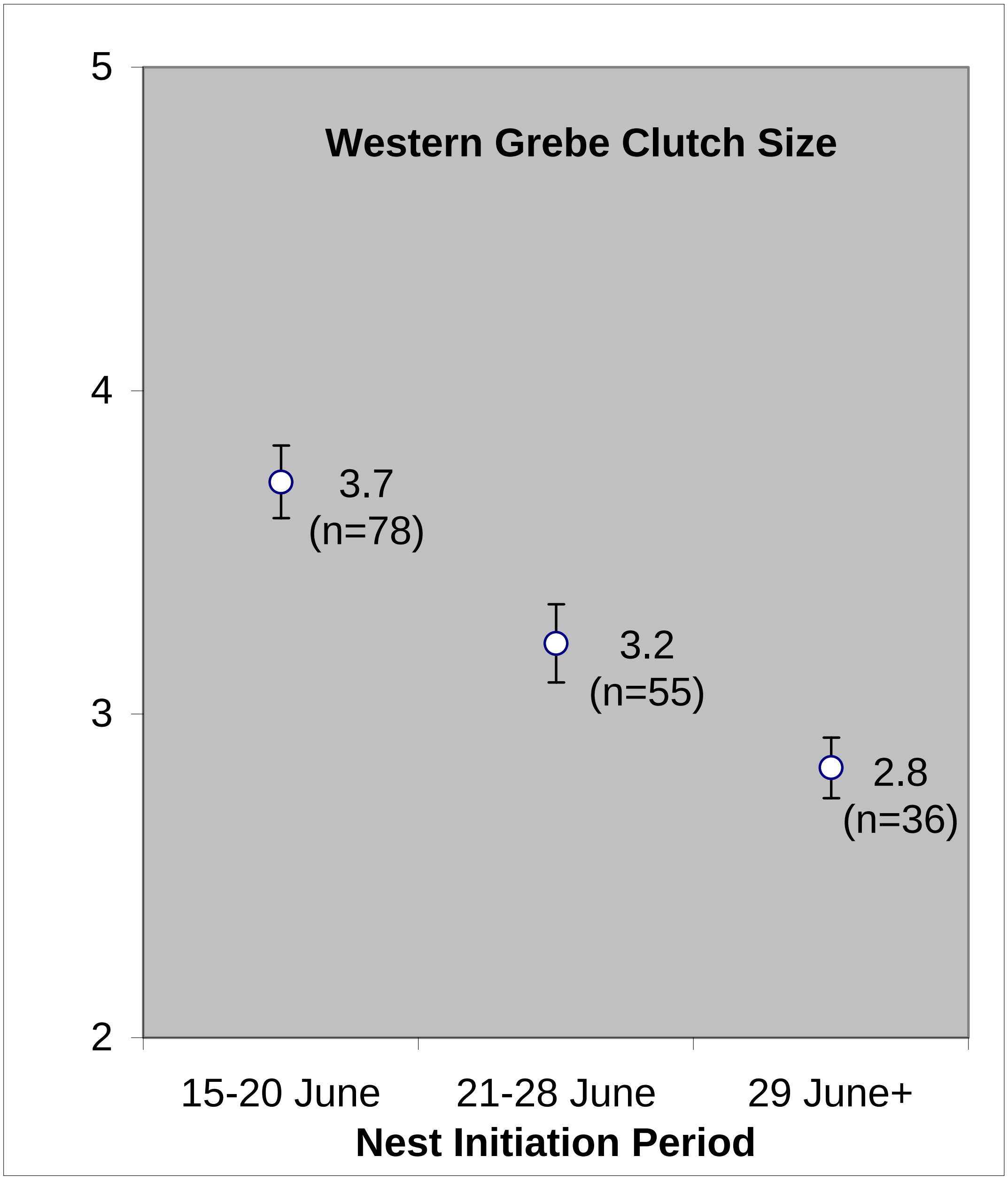


Figure 16. Average clutch size for western grebes decreased throughout the nesting season.

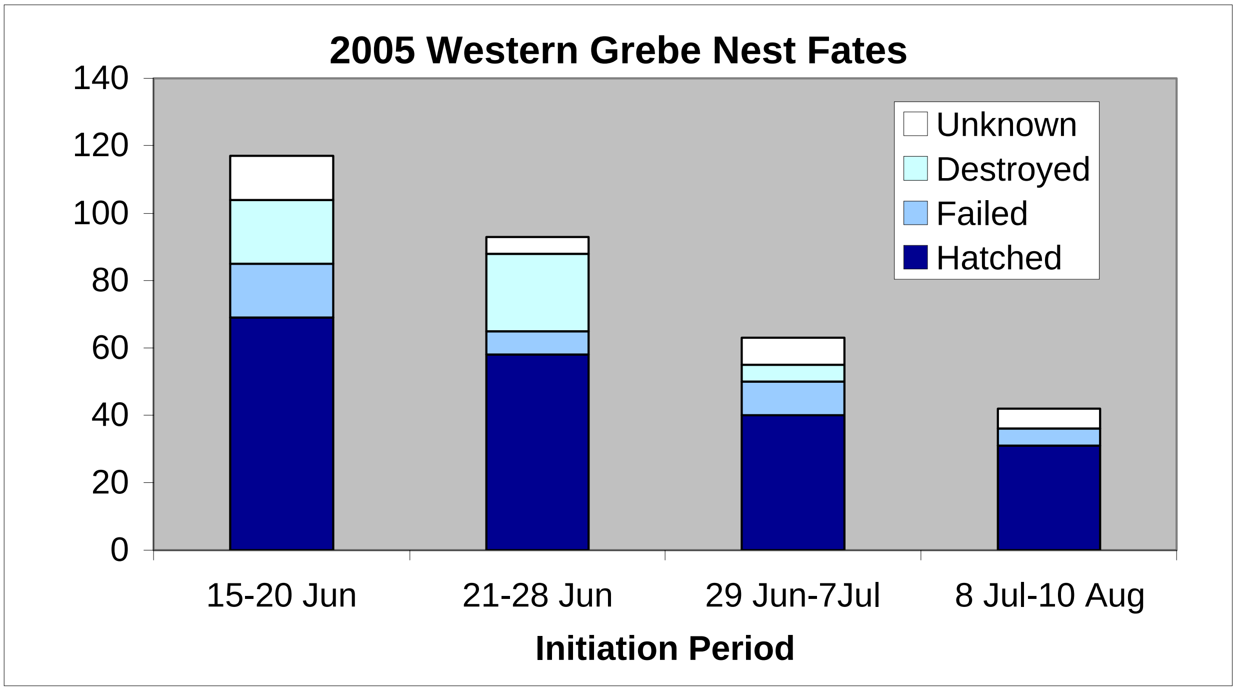


Figure 17. Most western grebe nests on Lake Christina were initiated in mid- to late-June. Hatching success was high during all of the nest initiation periods.

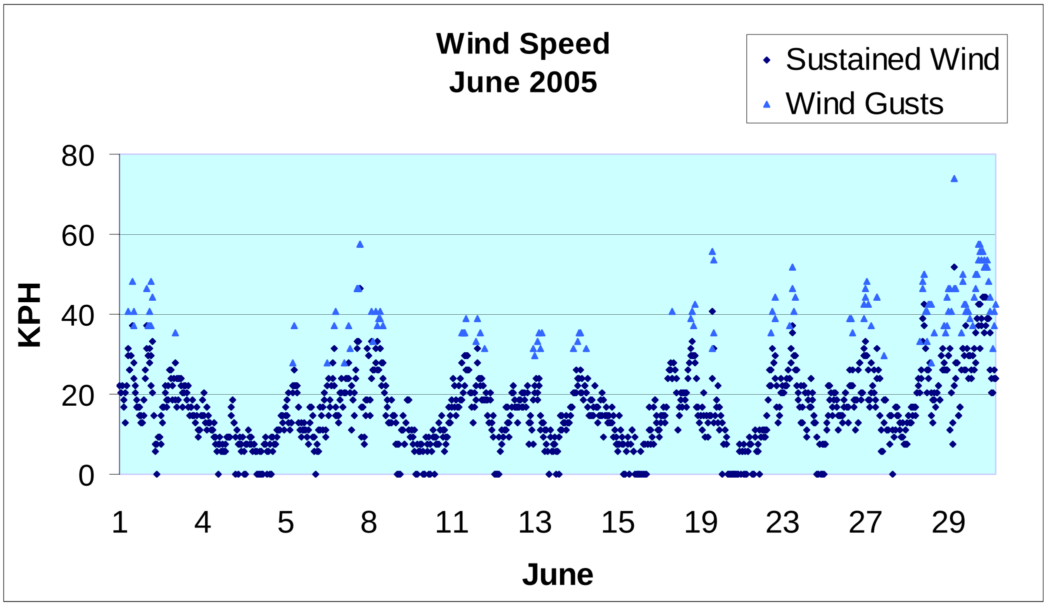


Figure 18. Hourly wind speeds recorded during June 2004 at Alexandria Aviation, MN.

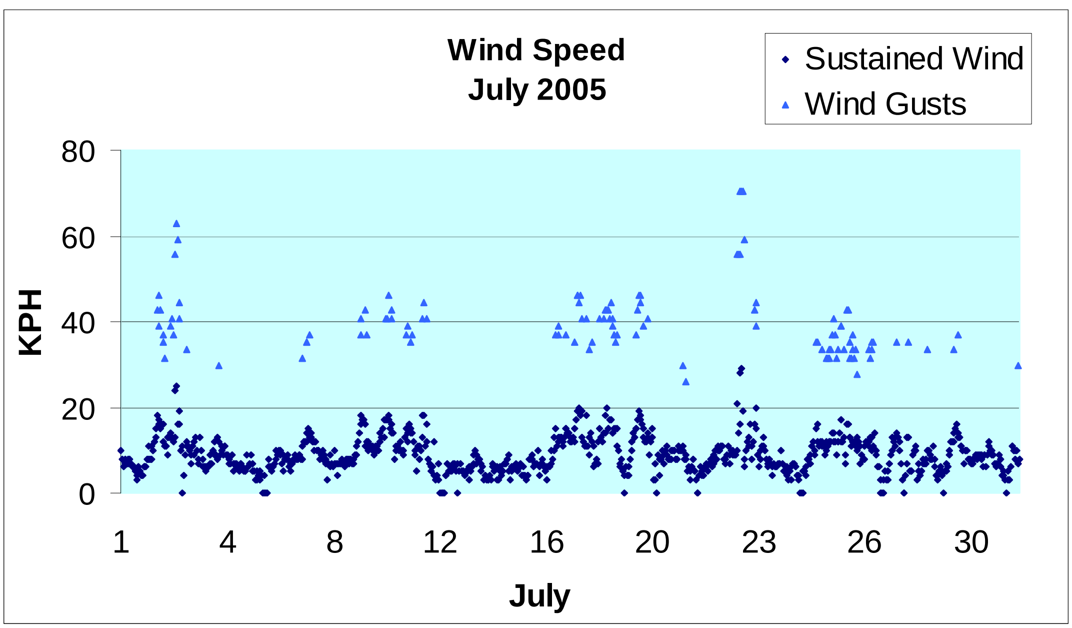


Figure 19. Hourly wind speeds recorded during July 2005 at Alexandria Aviation, MN.

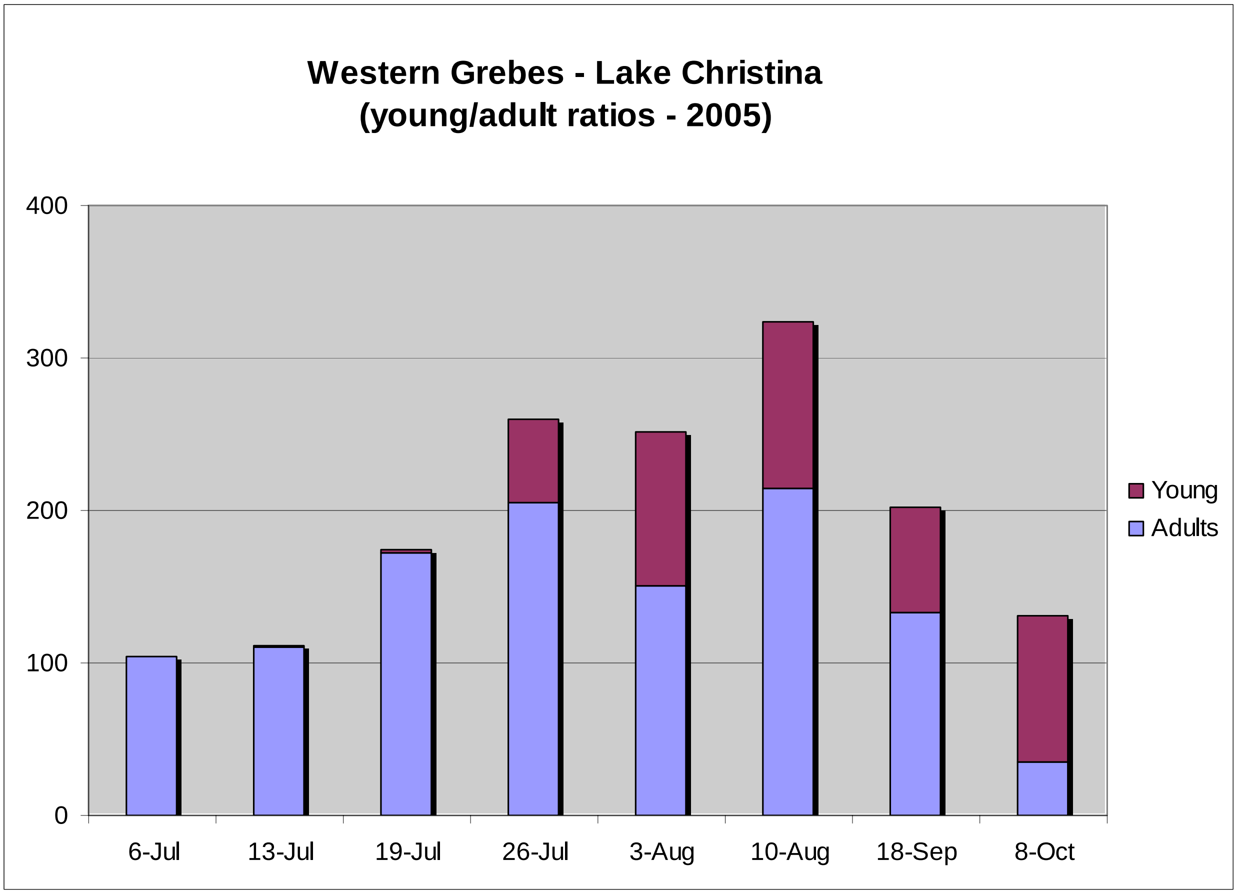


Figure 19. Ratios of young to adult western grebes counted in the Lake Christina shoreline surveys.

APPENDIX I: Shoreline Surveys

Appendix I. Shoreline Survey Data

A. Shoreline Surveys
2004

Dabbling Ducks	19-May	26-May	8-Jun	22-Jun	7-Jul	21-Jul	26-Jul	4-Aug	12-Aug	20-Aug	28-Aug	3-Sep	11-Sep	26-Sep	3-Oct	8-Oct	24-Oct	6-Nov
MALL	5	7	12	5	0	0	0	0	0	0	0	32	0	0	0	0	0	0
WODU	18	2	16	21	13	30	42	11	120	363	355	6	12	0	0	0	1	0
GADW	18	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	9	0
BWTE	8	0	0	0	0	0	0	0	0	0	0	479	150	15	0	0	41	26
NOPI	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
DUCKS	5	0	3	0	9	0	2	0	0	340	311	268	351	549	600	291	1380	41
CAGO	24	29	50	40	55	112	88	20	0	7	0	2	86	407	175	9	2	53

Diving Ducks	19-May	26-May	8-Jun	22-Jun	7-Jul	21-Jul	26-Jul	4-Aug	12-Aug	20-Aug	28-Aug	3-Sep	11-Sep	26-Sep	3-Oct	8-Oct	24-Oct	6-Nov
RUDU	8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0
CANV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	25	0	0
REDH	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOME	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RNDU	0	11	1	0	0	0	0	0	0	0	0	75	1	0	0	30	55	0
BUFF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
LESC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0
COGO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0

Nongame Divers	19-May	26-May	8-Jun	22-Jun	7-Jul	21-Jul	26-Jul	4-Aug	12-Aug	20-Aug	28-Aug	3-Sep	11-Sep	26-Sep	3-Oct	8-Oct	24-Oct	6-Nov
WEGR	193	246	129	38	18	10	17	21	11	22	119	51	4	4	6	0	0	0
RNGR	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EAGR	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
PBGR	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0
COLO	1	1	0	1	1	1	0	2	1	0	0	2	0	0	1	0	0	0
DCCO	34	25	30	2	1	0	1	4	2	0	1	6	8	8	17	1	1	0

Waders	19-May	26-May	8-Jun	22-Jun	7-Jul	21-Jul	26-Jul	4-Aug	12-Aug	20-Aug	28-Aug	3-Sep	11-Sep	26-Sep	3-Oct	8-Oct	24-Oct	6-Nov
GBHE	6	0	2	13	3	1	2	1	1	0	0	2	4	1	0	0	0	0
GREG	0	0	0	0	1	0	1	1	0	1	4	2	0	0	0	0	0	0

Other Waterbirds	19-May	26-May	8-Jun	22-Jun	7-Jul	21-Jul	26-Jul	4-Aug	12-Aug	20-Aug	28-Aug	3-Sep	11-Sep	26-Sep	3-Oct	8-Oct	24-Oct	6-Nov
RBGU	0	3	0	0	0	0	0	50	42	160	74	18	389	1104	2135	5	0	1
BLTE	0	0	0	0	27	31	13	20	0	11	0	0	0	0	0	0	0	0
FOTE	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0
AWPE	11	7	115	83	39	6	63	103	41	79	72	69	10	0	1	0	0	2

B. Shoreline Surveys 2005

Dabbling Ducks	14-Apr	21-Apr	10-May	23-May	28-May	3-Jun	14-Jun	22-Jun	6-Jul	13-Jul	19-Jul	26-Jul	3-Aug	10-Aug	18-Sep	8-Oct	15-Oct	24-Oct	31-Oct
MALL	15	8	9	13	7	5	4	7	0	0	15	0	3	41	53	0	32	3	11
WODU	0	16	8	0	0	36	38	7	0	0	1	1	1	1	0	0	0	0	0
GADW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	7	30	11
BWTE	0	0	22	0	0	0	0	0	0	0	0	0	0	0	30	0	25	40	30
CAGO	63	5	9	18	9	36	12	16	67	3	41	12	38	6	0	15	56	0	300

Diving Ducks	14-Apr	21-Apr	10-May	23-May	28-May	3-Jun	14-Jun	22-Jun	6-Jul	13-Jul	19-Jul	26-Jul	3-Aug	10-Aug	18-Sep	8-Oct	15-Oct	24-Oct	31-Oct
RUDU	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CANV	16	6	0	3	0	0	0	0	0	0	2	12	8	0	0	0	37	0	1
REDH	53	20	0	2	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
HOME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COME	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RNDU	442	55	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0
BUFF	36	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
LESC	68	57	13	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
COGO	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Nongame Divers	14-Apr	21-Apr	10-May	23-May	28-May	3-Jun	14-Jun	22-Jun	6-Jul	13-Jul	19-Jul	26-Jul	3-Aug	10-Aug	18-Sep	8-Oct	15-Oct	24-Oct	31-Oct
WEGR	1	150	101	175	227	152	78	101	104	111	174	260	252	324	202	131	79	28	21
CLGR	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
RNGR	3	8	0	4	4	6	2	2	1	0	3	1	4	0	0	0	0	0	0
EAGR	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PBGR	10	2	0	1	2	3	1	2	1	8	12	5	4	0	29	74	38	0	0
COLO	3	0	0	0	2	0	3	1	4	1	0	0	0	0	0	0	0	0	0
DCCO	0	6	95	26	36	18	13	11	4	0	5	4	0	2	0	0	1	0	0

Waders	14-Apr	21-Apr	10-May	23-May	28-May	3-Jun	14-Jun	22-Jun	6-Jul	13-Jul	19-Jul	26-Jul	3-Aug	10-Aug	18-Sep	8-Oct	15-Oct	24-Oct	31-Oct
GBHE	3	3	6	16	6	3	6	3	4	1	1	3	2	5	1	3	6	1	2
GREG	0	2	18	47	14	31	25	11	2	2	5	8	8	5	4	2	2	1	0
CAEG	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0

Other Waterbirds	14-Apr	21-Apr	10-May	23-May	28-May	3-Jun	14-Jun	22-Jun	6-Jul	13-Jul	19-Jul	26-Jul	3-Aug	10-Aug	18-Sep	8-Oct	15-Oct	24-Oct	31-Oct
RBGU	4	9	1	1	0	2	0	0	0	0	0	8	14	47	35	5	158	4	3
BLTE	0	0	0	50	60	55	15	32	9	12	20	7	7	5	0	0	0	0	0
FOTE	0	12	0	7	0	0	0	0	0	3	0	0	3	0	0	0	0	0	0
AWPE	0	12	65	51	23	112	105	320	53	71	6	16	39	18	6	0	0	0	0
BAEA	0	0	0	3	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0
TRUS	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Appendix II. Nesting Survey Data

Date found	*Nest ID*	*Species*	*#Eggs**	*Clutch**	*Fate**
20-Jul	504	AMCO	9	.	U
20-Jun	153	BLTE	3	.	H
28-Jun	204	BLTE	2	.	FG
28-Jun	267	BLTE	3	.	U
28-Jun	285	BLTE	3	.	FL
28-Jun	287	BLTE	3	.	H
28-Jun	291	BLTE	2	.	U
28-Jun	297	BLTE	2	.	FG
28-Jun	300	BLTE	2	.	U
7-Jul	405	BLTE	3	.	FG
20-Jul	500	BLTE	1	.	H
20-Jun	110	PBGR	8	.	H
20-Jun	125	PBGR	8	.	FD
20-Jul	506	PBGR	3	.	H
20-Jun	130	RNGR	5	.	H
20-Jun	148	RNGR	4	.	H
28-Jun	200	RNGR	3	.	U
20-Jun	1	WEGR	5	IP	U
20-Jun	2	WEGR	2	I	FG
20-Jun	3	WEGR	4	I	FG
20-Jun	4	WEGR	3	C	FI
20-Jun	5	WEGR	3	I	FL
20-Jun	6	WEGR	3	C	FG
20-Jun	7	WEGR	4	C	U
20-Jun	8	WEGR	5	C	H
20-Jun	9	WEGR	3	I	H
20-Jun	10	WEGR	3	I	FG
20-Jun	11	WEGR	5	C	H
20-Jun	12	WEGR	4	C	H
20-Jun	13	WEGR	5	IP	FI
20-Jun	14	WEGR	5	C	H
20-Jun	15	WEGR	5	C	H
20-Jun	16	WEGR	4	C	H
20-Jun	17	WEGR	4	C	H
20-Jun	18	WEGR	3	C	FI
20-Jun	19	WEGR	3	C	H
20-Jun	20	WEGR	4	C	H
20-Jun	21	WEGR	6	IP	H
20-Jun	22	WEGR	4	C	H
20-Jun	23	WEGR	5	C	FI
20-Jun	24	WEGR	4	C	H
20-Jun	25	WEGR	4	C	H
20-Jun	26	WEGR	4	C	H
20-Jun	27	WEGR	3	I	FG
20-Jun	28	WEGR	4	I	FG
20-Jun	29	WEGR	4	C	H
20-Jun	30	WEGR	5	C	H
20-Jun	31	WEGR	4	C	H

Code	Fate of Nest
H	Hatched
FI	Failed with nest intact
FD	Failed with nest destroyed
FG	Failed with nest gone
FL	Failed with nest lost to other species
U	Unknown (fate of nest not known)
C	Complete clutch
I	Incomplete clutch
IP	Intraspecific parasitism

20-Jun	32	WEGR	3	I	FG
20-Jun	33	WEGR	5	IP	FG
20-Jun	34	WEGR	5	C	H
20-Jun	35	WEGR	3	C	H
20-Jun	36	WEGR	4	C	H
20-Jun	37	WEGR	4	C	H
20-Jun	38	WEGR	4	IP	FI
20-Jun	39	WEGR	4	C	H
20-Jun	40	WEGR	2	I	FG
20-Jun	41	WEGR	4	C	H
20-Jun	42	WEGR	4	C	FI
20-Jun	43	WEGR	4	C	H
20-Jun	44	WEGR	4	C	U
20-Jun	45	WEGR	4	C	FI
20-Jun	46	WEGR	5	C	H
20-Jun	47	WEGR	4	C	H
20-Jun	48	WEGR	4	C	H
20-Jun	49	WEGR	2	I	FG
20-Jun	50	WEGR	4	C	FG
20-Jun	51	WEGR	4	C	FI
20-Jun	52	WEGR	4	C	FI
20-Jun	53	WEGR	2	C	H
20-Jun	54	WEGR	4	C	H
20-Jun	55	WEGR	4	C	H
20-Jun	56	WEGR	4	C	U
20-Jun	57	WEGR	5	C	H
20-Jun	58	WEGR	4	C	H
20-Jun	59	WEGR	3	C	H
20-Jun	60	WEGR	3	C	H
20-Jun	61	WEGR	2	C	H
20-Jun	62	WEGR	3	IP	H
20-Jun	63	WEGR	3	C	U
20-Jun	64	WEGR	2	I	U
20-Jun	65	WEGR	3	C	H
20-Jun	101	WEGR	4	C	FG
20-Jun	102	WEGR	4	C	FI
20-Jun	103	WEGR	5	C	U
20-Jun	104	WEGR	4	IP	H
20-Jun	105	WEGR	4	C	H
20-Jun	106	WEGR	3	C	FG
20-Jun	107	WEGR	4	IP	H
20-Jun	108	WEGR	6	IP	U
20-Jun	109	WEGR	4	C	H
20-Jun	111	WEGR	4	C	H
20-Jun	112	WEGR	2	I	U
20-Jun	113	WEGR	4	C	H
20-Jun	114	WEGR	3	IP	U
20-Jun	115	WEGR	2	C	H
20-Jun	116	WEGR	2	C	FI
20-Jun	117	WEGR	6	C	H
20-Jun	118	WEGR	4	C	H

20-Jun	119	WEGR	2	I	FL
20-Jun	120	WEGR	2		U
20-Jun	121	WEGR	4	C	H
20-Jun	122	WEGR	4	C	H
20-Jun	123	WEGR	4	IP	H
20-Jun	124	WEGR	4	I	FG
20-Jun	126	WEGR	3	C	H
20-Jun	127	WEGR	4	IP	FL
20-Jun	128	WEGR	2	IP	FL
20-Jun	129	WEGR	2	IP	FL
20-Jun	131	WEGR	3	IP	H
20-Jun	132	WEGR	4	C	H
20-Jun	133	WEGR	4	C	FG
20-Jun	134	WEGR	4	C	H
20-Jun	135	WEGR	4	C	FG
20-Jun	136	WEGR	5	IP	H
20-Jun	137	WEGR	3	C	H
20-Jun	138	WEGR	4	C	U
20-Jun	139	WEGR	5	C	H
20-Jun	140	WEGR	5	IP	H
20-Jun	141	WEGR	2	IP	H
20-Jun	142	WEGR	4	IP	H
20-Jun	143	WEGR	3	C	H
20-Jun	144	WEGR	3	C	H
20-Jun	145	WEGR	5	IP	H
20-Jun	146	WEGR	3	C	FD
20-Jun	147	WEGR	4	C	H
20-Jun	150	WEGR	3	C	U
20-Jun	152	WEGR	3	C	H
20-Jun	154	WEGR	4	C	H
20-Jun	155	WEGR	4	C	H
20-Jun	156	WEGR	1	IP	FG
20-Jun	157	WEGR	3	IP	H
20-Jun	158	WEGR	4	C	H
20-Jun	159	WEGR	4	C	FG
28-Jun	201	WEGR	3	C	H
28-Jun	202	WEGR	3	C	H
28-Jun	203	WEGR	3	C	H
28-Jun	205	WEGR	3	IP	FG
28-Jun	206	WEGR	1	I	H
28-Jun	207	WEGR	3	I	H
28-Jun	208	WEGR	3	C	FD
28-Jun	209	WEGR	1	I	H
28-Jun	210	WEGR	3	C	FG
28-Jun	211	WEGR	2	C	H
28-Jun	212	WEGR	4	I	FG
28-Jun	213	WEGR	4	I	FG
28-Jun	214	WEGR	3	I	H
28-Jun	215	WEGR	3	IP	FL
28-Jun	216	WEGR	6	IP	FI
28-Jun	217	WEGR	4	C	FI

28-Jun	218	WEGR	3	C	FG
28-Jun	219	WEGR	3	C	FG
28-Jun	220	WEGR	3	C	H
28-Jun	221	WEGR	4	IP	H
28-Jun	222	WEGR	4	C	H
28-Jun	223	WEGR	2	I	FD
28-Jun	224	WEGR	2	C	H
28-Jun	225	WEGR	3	C	H
28-Jun	226	WEGR	5	C	H
28-Jun	227	WEGR	3	C	H
28-Jun	228	WEGR	3	C	H
28-Jun	229	WEGR	3	C	H
28-Jun	230	WEGR	3	C	H
28-Jun	231	WEGR	2	C	H
28-Jun	232	WEGR	2	C	H
28-Jun	233	WEGR	4	C	FD
28-Jun	234	WEGR	1	I	FG
28-Jun	235	WEGR	3	IP	FG
28-Jun	236	WEGR	3	C	H
28-Jun	237	WEGR	3	C	H
28-Jun	238	WEGR	3	I	FG
28-Jun	239	WEGR	4	I	FG
28-Jun	240	WEGR	1	I	FG
28-Jun	241	WEGR	3	I	FG
28-Jun	242	WEGR	3	I	FG
28-Jun	243	WEGR	1	I	U
28-Jun	244	WEGR	3	C	H
28-Jun	245	WEGR	2	C	H
28-Jun	246	WEGR	4	C	H
28-Jun	247	WEGR	4	C	H
28-Jun	248	WEGR	6	IP	FD
28-Jun	249	WEGR	3	C	H
28-Jun	250	WEGR	3	C	FD
28-Jun	251	WEGR	1	IP	FD
28-Jun	252	WEGR	2	C	H
28-Jun	253	WEGR	2	C	H
28-Jun	254	WEGR	1	I	H
28-Jun	255	WEGR	3	C	H
28-Jun	256	WEGR	5	C	FG
28-Jun	257	WEGR	3	C	FI
28-Jun	258	WEGR	3	C	H
28-Jun	259	WEGR	3	C	H
28-Jun	260	WEGR	4	C	H
28-Jun	261	WEGR	2	C	H
28-Jun	262	WEGR	3	C	H
28-Jun	263	WEGR	3	IP	FL
28-Jun	264	WEGR	3	C	H
28-Jun	265	WEGR	2	C	H
28-Jun	266	WEGR	4	C	H
28-Jun	268	WEGR	5	C	H
28-Jun	269	WEGR	3	I	FI

28-Jun	270	WEGR	5	C	H
28-Jun	271	WEGR	4	C	H
28-Jun	272	WEGR	2	C	H
28-Jun	273	WEGR	3	I	FI
28-Jun	274	WEGR	4	C	FI
28-Jun	275	WEGR	2	I	FG
28-Jun	276	WEGR	2	I	U
28-Jun	277	WEGR	4	C	H
28-Jun	279	WEGR	3	C	U
28-Jun	280	WEGR	3	I	H
28-Jun	281	WEGR	3	C	FI
28-Jun	282	WEGR	2	IP	H
28-Jun	283	WEGR	1	I	H
28-Jun	284	WEGR	3	C	H
28-Jun	286	WEGR	2	C	H
28-Jun	288	WEGR	3	C	H
28-Jun	289	WEGR	2	C	H
28-Jun	290	WEGR	4	C	H
28-Jun	292	WEGR	4	C	U
28-Jun	293	WEGR	4	C	H
28-Jun	294	WEGR	3	C	H
28-Jun	295	WEGR	4	C	H
28-Jun	296	WEGR	3	I	U
28-Jun	298	WEGR	4	C	H
28-Jun	299	WEGR	2	C	H
28-Jun	301	WEGR	3	C	H
7-Jul	350	WEGR	3	I	H
7-Jul	351	WEGR	3	I	FI
7-Jul	352	WEGR	3	C	H
7-Jul	353	WEGR	3	C	FG
7-Jul	354	WEGR	3	C	H
7-Jul	355	WEGR	2	C	H
7-Jul	356	WEGR	3	C	H
7-Jul	357	WEGR	3	C	U
7-Jul	358	WEGR	2	C	FI
7-Jul	359	WEGR	3	I	U
7-Jul	360	WEGR	2	C	H
7-Jul	361	WEGR	4	C	H
7-Jul	362	WEGR	1	I	H
7-Jul	363	WEGR	3	C	H
7-Jul	364	WEGR	1	I	U
7-Jul	365	WEGR	3	I	U
7-Jul	366	WEGR	4	IP	FD
7-Jul	367	WEGR	2	I	H
7-Jul	368	WEGR	2	I	H
7-Jul	369	WEGR	3	C	H
7-Jul	370	WEGR	2	I	U
7-Jul	371	WEGR	3	I	H
7-Jul	372	WEGR	3	I	FI
7-Jul	373	WEGR	3	I	FG
7-Jul	374	WEGR	3	C	H

7-Jul	375	WEGR	3	I	H
7-Jul	376	WEGR	3	C	H
7-Jul	377	WEGR	3	C	H
7-Jul	378	WEGR	1	I	FD
7-Jul	379	WEGR	2	IP	FL
7-Jul	380	WEGR	3	C	FI
7-Jul	381	WEGR	3	I	U
7-Jul	382	WEGR	3	C	FI
7-Jul	383	WEGR	3	C	H
7-Jul	384	WEGR	3	I	U
7-Jul	385	WEGR	3	C	H
7-Jul	386	WEGR	3	C	H
7-Jul	387	WEGR	3	C	H
7-Jul	388	WEGR	1	I	H
7-Jul	389	WEGR	1	I	H
7-Jul	390	WEGR	3	C	H
7-Jul	391	WEGR	3	I	H
7-Jul	392	WEGR	2	C	H
7-Jul	393	WEGR	2	C	FI
7-Jul	394	WEGR	3	C	H
7-Jul	395	WEGR	2	I	H
7-Jul	396	WEGR	3	C	H
7-Jul	397	WEGR	3	C	H
7-Jul	398	WEGR	3	C	H
7-Jul	399	WEGR	1	I	H
7-Jul	400	WEGR	3	I	H
7-Jul	401	WEGR	2	C	H
7-Jul	402	WEGR	3	C	H
7-Jul	403	WEGR	3	C	FI
7-Jul	404	WEGR	2	C	H
7-Jul	406	WEGR	2	C	FG
7-Jul	407	WEGR	3	C	FI
7-Jul	408	WEGR	4	C	FI
7-Jul	409	WEGR	3	C	H
7-Jul	410	WEGR	3	C	H
7-Jul	411	WEGR	1	I	H
7-Jul	412	WEGR	4	I	H
7-Jul	413	WEGR	3	I	U
20-Jul	501	WEGR	2	I	U
20-Jul	502	WEGR	2	I	U
20-Jul	503	WEGR	2	I	U
20-Jul	505	WEGR	2	I	U
20-Jul	507	WEGR	2	I	H
20-Jul	508	WEGR	4	I	H
20-Jul	509	WEGR	2	I	H
20-Jul	510	WEGR	2	I	U
20-Jul	511	WEGR	2	I	FI
20-Jul	512	WEGR	2	I	H
20-Jul	513	WEGR	3	I	H
20-Jul	514	WEGR	3	I	H
20-Jul	515	WEGR	2	I	H

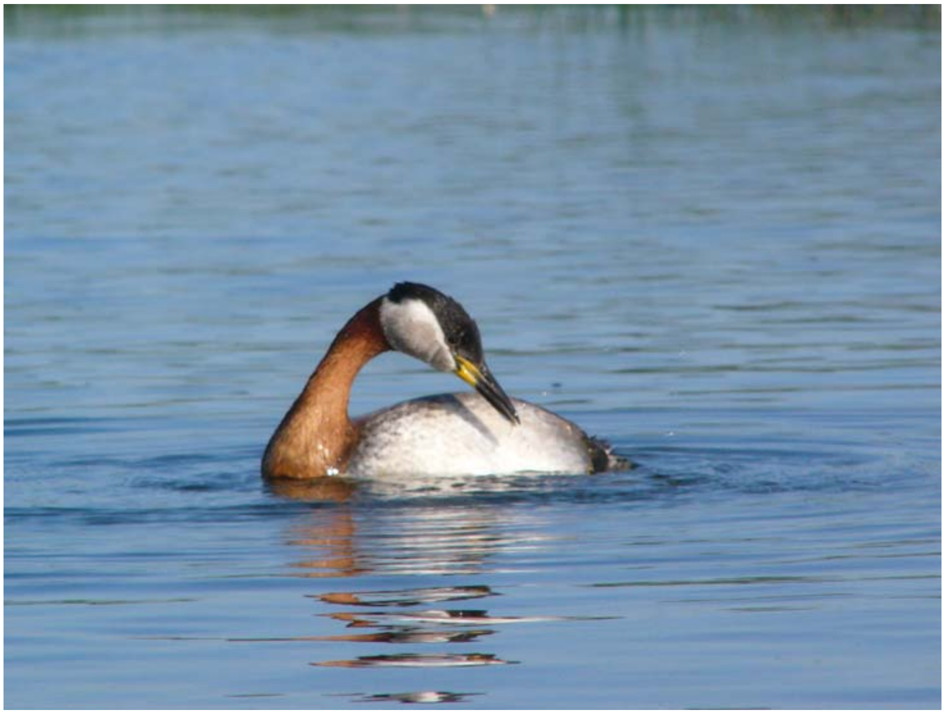
20-Jul	516	WEGR	2	I	H
20-Jul	517	WEGR	1	I	H
20-Jul	518	WEGR	3	I	H
20-Jul	519	WEGR	1	I	H
20-Jul	520	WEGR	2	I	H
20-Jul	521	WEGR	2	I	U
20-Jul	522	WEGR	3	I	FI
20-Jul	538	WEGR	3	I	H
20-Jul	539	WEGR	3	I	H
20-Jul	540	WEGR	3	I	H
20-Jul	541	WEGR	3	I	H
20-Jul	542	WEGR	3	I	H
20-Jul	543	WEGR	2	I	H
20-Jul	544	WEGR	4	I	FI

APPENDIX III: Photos

A. JHA conducting bulrush stem density transects for his thesis.

B. JHA (left) and GLN (right) preparing and testing the tower blind.

C. Western grebe nesting at Lake Christina, 2005 (JHA).



D. Red-necked grebe at Lake Christina (GLN).

E. American white pelican in the colony at Lake Christina (GLN).

F. Two Forster’s terns resting in the colony at Lake Christina (GLN).

G. Black tern incubating eggs at Lake Christina (GLN).

H. Canvasback nest at Lake Christina (JHA).

I. Clark’s grebe at Lake Christina.