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Fish-Eating Bird Predation at Aquaculture Facilities in Minnesota: a First Step Towards Bridging the Information Gap

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INTRODUCTION

Baitfish farming and production of sport fish fingerlings for stocking in lakes are significant forms of aquaculture in Minnesota. Increasingly, the production of fish for food is gaining ground as an aquaculture industry. The Minnesota Department of Agriculture reported that growers estimated bait sales in 1996 worth $1.7 million, and sport fish fingerling sales for stocking at roughly $1 million (MN Dept. Ag. 1997). These figures likely underestimate the value of these industries (MN Dept. Ag. 1997; M. Lint and P. Goeden, Co-Presidents of MN Fish and Bait Farming Association, pers. comm.). Based on more recent data, sales of baitfish from just 16 farms (about 20% of the licensed aquaculturalists) were estimated at $817,000 (USDA-NASS 1998).

While various factors limit commercial fish production in Minnesota, waterbird predation is the greatest concern to producers. Substantial losses are attributed to many avian fish-eaters (e.g., herons, pelicans), but the double-crested cormorant (*Phalacrocorax auritus*) (DCCO) is considered the most important avian predator at baitfish and other fish farms. This species is federally protected under the Migratory Bird Treaty Act of 1972; the taking of any migratory bird species protected by this act is illegal unless a special permit is obtained.

In 1998, the U.S. Fish and Wildlife Service established a depredation order in 13 states that allows commercial aquaculturalists to kill unlimited numbers of cormorants causing or about to cause losses at their farms without obtaining a permit (USDI-FWS 1998). Minnesota was the only northeastern state to be included in the depredation order; the other 12 states were in the southeastern U.S. where cormorant predation is believed to impact catfish production.

More recently, the U.S. Fish and Wildlife Service published its Final Rule on Double-crested Cormorant management in the U.S. (USDI/FWS 2003; Federal Register, Vol. 68, No. 196, October 2003). Under the rulemaking, a Public Resource Depredation Order (PRDO) has been established that allows state fish and wildlife agencies, federally-recognized tribes (on tribal lands), and USDA Wildlife Services to control cormorants, without a federal permit in 24 states (including all states in the Upper Midwest) when the birds are causing conflicts with public resources, provided that the agencies have landowner permission and fulfill certain reporting and monitoring requirements. The rulemaking also modifies the existing Aquaculture Depredation Order for cormorants to allow birds to be killed (with landowner permission) at winter roost sites near aquaculture facilities.

Though precise estimates of financial loss due to avian predation are very difficult to obtain for multiple reasons, some producers have estimated annual individual losses of up to $100,000 due to combined predation losses and bird control expenses (M. Lint, pers. comm.). Minnesota Sea Grant identified reduction of aquaculture loss to fish-eating birds as a high priority for the state (Gunderson and Tucker 2000).

Despite the economic importance of the problem, no prior studies have characterized operations experiencing intense bird predation or the types of methods producers use to prevent or reduce losses. Additionally, no information is available about the distribution and abundance of fish-eating birds in Minnesota in relation to loss. To contribute to the understanding and reduction of bird-related losses, we compiled information on Minnesota fish production operations and integrated it with information on distribution and abundance of the three primary avian fish predators reported at aquacultural facilities in Minnesota: double-crested cormorant, American white pelican (*Pelecanus erythrorhynchos*) (AWPE) and great blue heron (*Ardea herodias*) (GBHE). In this report we identify producers and characterize fish production operations experiencing loss to fish-eating birds, describe the scale of the problem, document use and acceptability of management practices to control bird predation, and identify present and potential areas and seasons in which losses to fish-eating birds are or are expected to be significant.

METHODS

Minnesota Fish Producers Survey

To identify Minnesota fish producers, we obtained the 2002 Private Hatchery and Aquatic Farm license holder list from the MN DNR. In May 2002, we mailed questionnaires and a cover letter (Appendix 1) to all commercial fish producers identified with outdoor facilities that could experience fish loss due to predation by fish-eating birds. In July 2002, we mailed a second letter requesting that producers complete the survey if they had not already done so. In August and September 2002, we conducted telephone surveys with individuals who did not respond by mail. The questionnaire consisted of three sections:

1) *Characterization of fish production operations* – types of production practiced and percent total production contributed by each type; fish species produced; scope of operation (full or part-time business); pond types (refers to all waterbodies used and ranges from artificial to type 3 and 4 wetlands to lakes with basins as large as 300 acres (R. Johannes, pers. comm.)); pond sizes; numbers of ponds used and stocked; factors affecting stocking decisions; counties in which ponds are located; and primary pond location (defined as the county containing the majority of a producer's ponds).

2) *Problem scale: extent of problems with fish-eating birds relative to other sources of loss* – identified producers experiencing losses to fish-eating birds; months when losses occur; extent to which various fish-eating bird species created problems for producers; extent to which other sources of mortality posed a problem; and months when losses to other sources occur.

We determined extent of loss to fish-eating birds relative to other sources of loss and the maximum percent of profits producers could lose to fish-eating birds that they would consider an acceptable cost of doing business. It was impossible to accurately quantify dollar amounts lost to fish-eating birds or other factors. Therefore, we asked producers to categorize losses as slight, moderate or severe based on their subjective experience. These loss categories provide a relative index to the extent of loss most producers believe they experience to fish-eating birds. Responses were not compared among producers.

3) *Effectiveness and acceptability of management practices* – strategies used to minimize losses to fish-eating birds; their effectiveness and costliness; percent of yearly earnings spent to minimize losses to fish-eating birds; percent producers are willing to spend; acceptability of various loss reduction strategies; and extent of responsibility producers felt various agencies have for managing losses to fish-eating birds.

Distribution and Abundance of Fish-Eating Birds in Relation to Fish Production Activities

To describe distribution and abundance of the top three avian fish-predators (DCCO, AWPE and GBHE), we obtained data on historic and recent breeding site locations for these species in Minnesota. Historic breeding records (late 1800s to mid-1900s) were obtained from state ornithological journals/books and unpublished reports. Current breeding records (1977-2000) were obtained from the MN Department of Natural Resources' (MN DNR) Nongame Wildlife Program, which initiated a systematic breeding census effort in 1977 for all colonial waterbirds. MN DNR protocol encourages annual censusing for tree nesting colonies larger than 100 pairs, and censusing of other colonies every three years (McKearnan 1997). Because all sites are not censused every year, it is not possible to precisely estimate the population size or number of nesting sites used by these species in a given year. However, the monitoring effort has been consistent and frequent enough to document breeding distribution and important breeding areas, and many colonies have been regularly tracked. We assessed the importance of a site to each species based on average colony size ($\geq$ 100 pairs for DCCO) and history of site use in relation to the frequency with which a known site was monitored.

To map and examine the breeding distribution of cormorants and pelicans in relation to fish producer activities, a Geographic Information System (GIS Arc View) was utilized. A buffer zone was created around each colony based on nesting requirements for proximity to foraging areas to denote areas of potential conflict with fish producers. The DCCO is believed to require an adequate food supply within a short (8-16 km) foraging range (Palmer 1962). At both coastal and inland sites, studies examining distances flown from nest sites to foraging areas found DCCOs typically travel < 3 km (Custer and Bunck 1992; Coleman 2003). However, studies on Lake Winnepegosis, Manitoba, and on Lake Ontario islands indicate that nesting DCCOs may fly as far as 20 – 51 km to foraging sites (Hobson et al. 1989; Mazzocchi 2001). A distance of 20 km was chosen to buffer DCCO colony sites; this distance was large enough to cover clumping in nesting and foraging travel during the breeding season.

For AWPE, we chose a distance of 50 km to buffer colony sites, because they commonly fly this distance, or more, from breeding colonies to foraging areas (Evans and Knopf 1993). GBHE colony sites were not buffered because colony sites of this species are abundant and widespread throughout the state. Geographic regions in Minnesota (Figure A) were taken from Janssen (1992).

Recent (1990s) spring and fall observational records for cormorants and pelicans in Minnesota obtained from state ornithological journals/books, and unpublished reports were reviewed to describe seasonal occurrence along important flyways in the state. Great blue herons typically are not a problem for fish producers during migration, thus migratory patterns were not reviewed for this species.

RESULTS

Minnesota Fish Producers Survey

Characterization of fish production operations (summarized in Appendix 2).

Number of respondents: We identified 78 license holders engaged in commercial fish production with outdoor facilities. As of August 1, 2002, 54 surveys representing 69% of the license holders were completed enough to be included in our analysis. This survey excluded producers who only engaged in wild harvest and who were not involved in stocking.

Distribution of ponds used by producers and fish species cultured: Ninety-four percent of respondents provided information on county locations of waters that they used for fish production. Ponds across most of Minnesota were utilized, with producers reporting ponds in 40 counties (Figure 1). Most fish producers operate in a band that crosses the central and northwest portions of the state. The most-frequently-reported counties used for fish production were Douglas (24%), Otter Tail (24%), Grant (20%), Pope (20%) and Becker (18%). Producers identified 25 counties as *primary pond locations* (counties where the majority of ponds occur); the most-frequently-reported counties in this category included Otter Tail (18%), Pine (8%), and Polk (8%) (Figure 2).

The distribution of the main baitfish species, white sucker (*Catostomus commersoni*) and shiners (Cyprinidae sp., mostly golden shiners (*Notemigonus crysoleucas*)), corresponded closely with the general distribution of fish farms. Producers stocking and harvesting these species operated ponds in 32 counties (Table 1); the most important counties included:

- 26% of white sucker producers and 30% of shiner producers operated ponds in Otter Tail County
- 24% of white sucker producers and 30% of shiner producers operated ponds in Douglas County
- 24% of white sucker producers and 26% of shiner producers operated ponds in Pope County
- 21% of white sucker producers and 26% of shiner producers operated ponds in Grant County
- 24% of white sucker producers and 13% of shiner producers operated ponds in Becker County

Producers stocking and harvesting fry and fingerling walleye (*Stizostedion vitreum*) and yellow perch (*Perca flavescens*) used ponds in 29 counties (Table 1). The most important counties for these types of production include:

- 36% of producers stocking walleye and 31% stocking yellow perch operated ponds in Pope County
- 27% of producers stocking walleye and 38% stocking yellow perch operated ponds in Grant County
- 23% of producers stocking walleye and 38% stocking yellow perch operated ponds in Douglas County
- 23% of producers stocking walleye and yellow perch operated ponds in Otter Tail County
- 23% of producers stocking walleye operated ponds in Kandiyohi County

Problems with fish-eating birds relative to other sources of loss **(summarized in Appendix 2)**

Bird species identified and extent of losses: Of the 54 respondents, most (91%) experienced losses to fish-eating birds. Losses were most frequently characterized as severe or moderate (Figure 3). The most commonly identified bird species were GBHE, DCCO and AWPE (Table 2). Losses to GBHE were reported most frequently, while losses to DCCO were reportedly the most severe.

Months of losses to birds: Forty-eight producers listed months in which they experienced losses. Losses occurred during each month of the breeding and migration periods (April-November; Figure 4). The greatest concentrations of and losses to fish-eating birds occurred during spring (May) and fall (September) (Figures 5 and 6).

Distribution of bird-caused losses: We approximated areas where farmers experienced losses by relating fishpond distribution data to data about fish losses to birds. Losses to fish-eating birds were reported in all counties where producers utilized fish ponds (Figure 1) with the exception of Aitken, Mille Lacs, Sherburne, and Yellow Medicine. Fish producers experiencing losses to GBHE, DCCO and AWPE most frequently referenced ponds in Otter Tail, Grant, Douglas, and Pope counties. Otter Tail County was the most frequently identified primary pond location for farmers experiencing losses to these three species, followed by Kandiyohi and Stearns counties (Figures 7-12).

Because GBHE, AWPE and DCCO were the most-frequently-reported species causing losses, we compared the extent of losses (slight, moderate, severe) to these species reported by each producer with the counties each producer reported using (Figures 7-9). To identify the most important areas of loss, we examined extent of losses associated with the three species in relation to counties producers identified as primary pond locations (Figures 10-12).

Losses to GBHE were the most widespread and frequently noted, recorded by farmers with ponds in 34 counties (23 counties held the majority of their ponds; Figure 10) across central and northern MN and in the southeastern corner of the state. Most losses were considered slight or moderate (Table 2, Figure 7). With the exception of Norman County, all severe losses to GBHEs were reported from the eastern part of the state.

The majority of losses to DCCO were considered severe as reported by farmers in 30 counties, primarily in the central and western portions of the state (Figure 8, Table 2). In a more narrowly defined west-central region, severe losses were reported from almost all of the 21 counties that were classified as primary pond locations (Figure 11).

With a geographic distribution similar to DCCO reports (Figure 8), producers in 28 counties reported losses to AWPE (Figure 9). Producers categorized the severity of losses fairly evenly among slight, moderate and severe (Table 2, Figure 9). Losses to AWPE occurred in 19 counties identified as primary pond locations; in this more narrowly defined west-central region, losses to pelicans were more frequently categorized as moderate and severe (Figure 12).

Fish species and losses to birds: We examined severity of losses to fish-eating birds reported by sucker, shiner, walleye and yellow perch producers (47 recipients provided information on these categories). The majority of these producers (45%) reported that losses to fish-eating birds in general were severe; for 36% of the respondents losses were moderate (Figure 13). Losses to cormorants were reported as severe more frequently than losses to other species and losses to fish-eating birds in general (57%) (Figure 14).

Pond size and losses to birds: Most (83%) of the producers that reported the size of their natural ponds indicated more severe losses to birds in large ponds (> 60 acres) than in smaller ponds (Figure 15). Additionally, producers reporting severe losses tended to have many ponds (on average 49) in several size categories (Figure 16). Producers reporting moderate losses utilized smaller pond sizes (only 20% farmed ponds in the largest size category) (Figure 17) and averaged less than half the number of ponds (22) than producers reporting severe losses (Figure 18).

Percent lost to fish-eating birds: Annual loss estimates to birds from 43 producers ranged from 1% to 95% with an average loss estimate of 25%.

Other sources of loss: Producers identified several sources of loss in addition to fish-eating birds (Figure 19); the most important appears to be low dissolved oxygen levels. This problem occurs primarily in the extreme temperature months of summer and winter (Figure 20). While most producers indicated losses to disease were not or only a slight problem, some noted that they often could not tell how fish died. Thus, it is possible that losses to disease occur more frequently than producers report. Although some producers provided estimates of approximate loss to other sources, too few data were obtained to estimate average loss. However, producers generally believed losses to other sources were slight compared to losses to birds (Figure 19).

Effectiveness and acceptability of management practices

Effectiveness and costliness of strategies to minimize bird depredation: Producers reported on the effectiveness and costliness of 20 strategies to minimize losses to birds (Table 3). Most strategies were considered ineffective or effectiveness varied among individuals. The strategies most producers were familiar with included simulated human harassment (e.g., scarecrows, noisemakers, cannons), shooting to reinforce non-lethal tactics and shooting to kill individual birds. Most producers felt simulated human harassment was not effective. Shooting-to-reinforce was considered ineffective by 59% of producers that commented. Shooting-to-kill was the most frequently employed and currently used strategy, considered highly effective by 66% of producers commenting on its use. Strategies that were most frequently considered cost-prohibitive included netting, shooting-to-reinforce, shooting-to-kill, altering stocking practices, and altering fish densities.

Thirty-eight producers commented on the effectiveness of the USFWS cormorant depredation order to reduce losses to cormorants. Most (61%) felt the order had not been helpful or was only slightly helpful in reducing loss to cormorants (Figure 21).

Producer costs in minimizing losses to fish-eating birds: Forty-eight producers provided estimates of the proportion of their yearly earnings spent and that they were willing to spend on efforts to minimize losses to birds. Most (67%) estimated that they spent 1-10% of yearly earnings on such efforts; no one reported spending more than 20% (Figure 22). Over half (58%) were willing to spend 1-5% of their yearly earnings on this effort (Figure 23).

Acceptability of strategies to minimize losses to fish-eating birds: Nearly all respondents (94-98%) commented on the acceptability of various management practices aimed at reducing fish losses to birds. Most (96%) felt mechanical improvements at ponds (e.g., netting, ropes, wires) were only slightly acceptable if at all. The methods with greatest acceptability included lethal control at ponds (69%) and lethal control away from ponds (60%) (Figure 24).

Responsibility for managing losses due to fish-eating birds: About 85% of producers commented on extent of responsibility individual producers and government agencies have for managing losses due to birds. Most felt that federal and state governments as well as fish producers should share this responsibility equally. Fish producers felt each of these parties had a moderate role in managing losses to birds (Figure 25).

Distribution and Abundance of Fish-Eating Birds in Relation to Fish Production Activities

Double-crested cormorant

Current Breeding: Between 1977-1999, colonial waterbird census efforts recorded cormorants at 95 sites during the breeding season; nesting was documented at 77 of these sites (Figure 26). During the 1990s, 56 of the previously documented nest sites were active (Figure 27); the remaining 21 were either visibly inactive or assumed to be inactive based on earlier cormorant nesting patterns.

Historic Breeding: In the late 19th century, local observers from around Minnesota reported cormorants from "occasional" to "innumerable," according to how near their breeding sites observations had been made (Hatch 1892). The species was a common summer resident throughout the state (Roberts 1919), and multiple records were collected between the late 1700s and late 1800s (A. Hertzell, pers. comm.). Significant colonies were documented at Elbow Lake in Grant County, Dead Lake in Otter Tail County, and Lake Andrew in Kandiyohi County, prior to 1925 (Lewis 1929; Hatch 1892).

Colonies and areas important for Minnesota's population of breeding cormorants: Based on colony size and history of site use, we identified 26 sites that appear important for a significant proportion of Minnesota's breeding population of cormorants (Figure 28). Most (73%) averaged $\geq$ 100 pairs; the remainder were either growing towards or recently reached $\geq$ 100 pairs. Although a statewide census has not been undertaken, recent (mid-late 1990s) population size is roughly thought to be between 8,000-10,000 pairs (Henderson 2001).

We identified 16 distinct areas across the state where cormorant colonies are found (Figure 28); these are areas in which several colonies sometimes occur and encompass the areas likely used by cormorants for foraging during the breeding season.

The most important breeding area in terms of colony size and history is in the north-central region in Lake of the Woods County. Based on the MN DNR's population estimate, this area alone constitutes >50% of the state's breeding population. Nesting has been documented here since the early 1900s (Roberts 1932); however, nesting may have occurred earlier than this because cormorants were known to nest on the Canadian side of Lake of the Woods since the late 1700s (Peck and James 1983). In 1999, four of the five colonies in this area were censused and 4,688 nests were reported; the one site that was not counted has averaged approximately 1,000 pairs since 1981.

Geographically, the largest breeding area spans across the central region, from Traverse, Big Stone, and Lac Qui Parle counties in the west, to Chisago, Washington, and Dakota counties in the east; this area extends as far south as northern Nicollet County and as far north as central Grant and Douglas counties (Figure 28). The four largest colonies occur in Big Stone, Kandiyohi, Lac Qui Parle, and Pope counties, and have ranged from 237 to 415 pairs (based on intermittent counts between the late-1970s and late-1990s). These large colonies have been active since census efforts began or earlier and have been regularly monitored.

A third major breeding area overlaps portions of the northwest and west-central regions, extending from central Clay County in the west, to eastern Otter Tail and northeastern Douglas in the east, and from northern Norman and Mahnomen counties in the north to northern Grant and Douglas counties in the south. The two largest colonies in this region occur in Grant and Otter Tail counties, with average sizes ranging from 288 to 500 pairs. Both colony sites have long histories of use by cormorants and have been regularly monitored since the census effort was initiated in 1977.

Current migration: Cormorants are common spring and fall migrants throughout most of the state, and utilize the Minnesota, Mississippi and St. Croix River valleys during migration. Flock sizes are increasing but usually are still smaller than the flocks commonly observed prior to the 1950s (1,000-5,000 individuals; Janssen 1992). In the 1990s, the peak flock size reported was 2,000 in Dakota County, fall 1996 (Loon 1997); in spring, 2001 a high count of 4,147 birds was made at Hastings-Prescott (Loon 2001). Spring migrants typically occur from late March to mid-May, reaching peak numbers in the second half of April (Janssen 1992). Fall migrants are usually observed from mid-September to early December, with a peak during the third week of October (Janssen 1992). During some years the species over-wintered in small numbers in Dakota County (The Loon 1992, 1993, 1995). (See Appendix 3 for additional migration information.)

Historic migration: During spring and fall migration, significant numbers of cormorants were reported passing through the state on their way to and from Canadian breeding sites in the late 1800s and early 1900s. Numbers of migrants seen on one day alone were variously estimated at 10,000 to 100,000 to 1,000,000 birds (Roberts 1932). In the spring of 1922, enormous north-bound flocks were reported; such flocks often aggregated at a particular locale for weeks at a time, and were noted to consume an "unbelievable number of small game fish" and were "regarded as a serious menace in the southern and central lake region" (Roberts 1932).

Distribution in relation to fish producer activities: DCCO nesting distribution in relation to fish production activities is shown in Figure 28. In terms of fish farming, the most important area of overlap is in the west-central and central regions. Large and well-established colonies occur in Otter Tail, Grant, Pope, and Kandiyohi counties. These counties are primary fish farming areas, with the heaviest concentrations of fish ponds. The majority of large, well-established colonies, however, occur outside areas intensely used for fish production (Figure 28).

American white pelican

Current breeding: Between 1977-2002, colonial waterbird censuses indicated pelican nesting activity at 16 sites in Minnesota (Figure 29). During the 1990s, 14 sites were active; one site was inactive, and no data were available for the other site.

During most years, colony estimates were not available for the majority of sites; colonies were noted as active or inactive and no statewide population estimate exists. However, for Lake of the Woods and Marsh Lake colonies, where the largest concentrations of breeding pelicans occur, careful monitoring produced multiple colony size estimates. Based on these estimates, the state's breeding population is substantial. In 1997, researchers estimated 8,000-10,000 pairs at Marsh Lake, Big Stone County, and roughly 1,000 pairs at the Lake of the Woods combined colonies, indicating that the statewide population was likely > 9,000 pairs (Katie Haws, pers. comm.).

Historic breeding: Up until the late 1800s, AWPEs were common summer residents throughout Minnesota; multiple summer records document occurrence between the late 1700s and 1800s (Roberts 1932; A. Hertzell, pers. comm.). Pelicans bred in large colonies at a number of places, chiefly in the western half of the state, from Heron Lake, Jackson County, northward (Roberts 1919, 1932). A "large community" of breeding pelicans was documented in Grant County; this colony occupied a traditional breeding site, used for many years until abandoned in 1878 due to human persecution (Hatch 1892; Roberts 1932). Pelicans also nested at Pelican Lake, Grant County, until about 1895 (Roberts 1932).

Colonies and areas important for Minnesota's population of breeding pelicans: We identified five areas across the state used by pelicans during breeding season (Figure 29). The largest geographical unit occurs in the west-central and central regions, and includes the Marsh Lake colony; this breeding site, based on colony size and history of use, is by far the state's most important breeding area. Marsh Lake has been active since the late 1960s, supports the bulk of breeding pairs in the state, and recently has produced thousands of chicks annually.

Lake of the Woods in the north-central region is another major breeding area (Figure 29). Sites here are consistently active and productive, ranging from several to several hundreds of pairs.

Current migration: The pelican is a common migrant in the west-central, southwestern, and south-central regions and in adjacent counties in the central region. The species is locally abundant in the southwestern region (as many as 5,000 birds), mainly in the fall (Janssen 1992). In spring, migrants are usually observed at large water bodies; in fall, migrants are wide ranging and can be seen across much of the state (A. Hertzel, pers. comm.). In the 1990s, large fall flocks of up to several thousand birds were regularly recorded in Big Stone, Jackson, and Dakota counties. Spring migrants typically occur early April to late May, reaching peak numbers during the third week of April. Fall migrants typically occur August through early November, with a peak in the second half of September (Janssen 1992). During some years AWPE over-wintered in Dakota County (The Loon 1993, 1995, 1997). (See Appendix 3 for additional migration information.)

Historic migration: Although the pelican disappeared as a nesting species in the late 1800s, flocks of migrant pelicans continued to occur regularly on lakes Big Stone, Big Stone County, and Traverse, Traverse County, in the west-central region (Roberts 1932). Spring migrants arrived in April and remained until late May; in fall, flocks arrived late summer and lingered until sometime in October. Migrants were also recorded along the Minnesota River in the fall (Featherstonhaugh 1847).

Distribution in relation to fish producer activities: AWPE nesting distribution in relation to fish farming activities is shown in Figure 29. In terms of fish farming, the most important area of overlap is in the west-central region, where the Marsh Lake colony occurs in Big Stone County. Most of the other large, well-established colonies occur outside areas intensely used for fish production; however, these colonies have small numbers of breeding pairs in comparison to the Marsh Lake colony.

Great blue heron

Current breeding: From 1977-2002, colonial waterbird censuses recorded GBHE nesting activity at 519 sites; of these, 228 were active in the last year they were visited (Figure 30). With the exception of the southwest corner, breeding occurs throughout Minnesota; colony sites are particularly abundant in the eastern portion of the state. Of the 228 recently active sites, census data were available for 194; most of these (88%) were visited since 1990. No statewide population estimate is available.

Historic breeding: Multiple summer records from around the state document the occurrence of the GBHE as a breeding species prior to 1900 (A. Hertzell, pers. comm.; Hatch 1892; Roberts 1932). Hatch (1892) noted that its distribution was co-extensive with the state, and wrote that the Crane Island colony on Lake Minnetonka "was a heronry earlier than the Indian traditions began." He also reported a large colony in Douglas or Grant County. Roberts (1932) noted that aside from a few colonies, most of the large heronries were located in the eastern half of the state.

Colonies important for Minnesota's population of breeding great blue herons: Though GBHE breeding sites are abundant, most colonies are small. Based on the most recent data available for each site (e.g., estimate obtained during last site visit), the majority of colonies (62%) had $\leq$25 nests; a smaller proportion (30%) had between 26-100 nests; and a few (8%) had > 100 nests. The two largest colonies were at Bolfing Lake, Stearns County, with an estimated 800 nests in 1995, and at Smith Slough, Winona County, with an estimated 701 nests in 1996. The eastern half of the state appears to provide abundant nesting habitat.

Distribution in relation to fish producer activities: Because GBHE colony sites are so widely and abundantly distributed across the state, we did not define buffer zones indicating potential areas of conflict with fish producers. Their widespread nesting distribution suggests most of the state will be utilized by foraging GBHE where habitat is available. Most fish producers can expect to encounter this species. However, because most colonies are small and this species is solitary in its foraging habits, the number of individual birds aggregating at fishponds is relatively small. Of the 19 colonies that had $\geq$100 pairs and were censused since 1990, four were in counties important for fish production. These include: Egret Island, Grant County; Pelican River, Becker County; Bolfing Lake, Stearns County; and Hart Lake, Mahnomen County. Most large colonies do not occur in areas intensely used for fish production.

DISCUSSION

Growth of the Minnesota Aquaculture Industry

In the U.S. and many parts of the world, aquaculture is a rapidly expanding industry. In North America, aquaculture production experienced strong growth between 1988 and 1997, increasing from 379,000 metric tons (mt) to 521,000 mt, representing a 38% increase at an annual rate of growth of 4.0%. During this same period, aquaculture products rose in value from $620 million to $1.1 billion, an increase of 80% and an annual rate of growth of 6.5% (Olin 2001). In Minnesota, aquaculture is a growing multi-million dollar industry (Booth 1998).

Although forms of aquaculture have been practiced for thousands of years, the advent of large-scale aquaculture is fairly recent, developing mostly over the last 50 years. In Minnesota, the Aquaculture Development Project was initiated in 1979. The goal of this project was to obtain information on biological, technical, and economic aspects of fish farming in Minnesota to better utilize the state's vast water resources (including privately owned lakes and ponds and wetlands considered unsuitable for traditional agriculture) for aquacultural development (Murnyak 1982). Today most waters with potential for fish farming in preferred areas (e.g., west-central MN) are leased out to aquaculturalists for the production of bait, food or sport fish (M. Lint, pers. comm.).

Changes in Bird Populations Concurrent with Aquaculture Development

Populations of cormorants and pelicans have undergone significant changes over the last 50 years. Between the 1940s-1970s, populations of DCCOs and AWPEs declined across much of their continental range. Declines in cormorant numbers, due mostly to contaminants and human persecution, resulted in the species being Blue Listed 1972-1982 (a list developed by the National Audubon Society, 1971 to 1986, calling attention to bird species of conservation concern that were not listed by the federal Endangered Species Act). DCCO were added to the Migratory Bird Treaty act protected bird list (1972) and listed as endangered, rare or species of special concern in several states and provinces in the 1970s and 1980s (Wires et al. 2001).

Declines in AWPE numbers, attributed mostly to combinations of changing water levels and human disturbance resulted in this species being listed as threatened until the early 1970s (Evans and Knopf 1993).

Beginning in the late 1970s and early 1980s, both species began significant population recoveries, re-colonizing much of their former ranges across the continent in the 1980s and 1990s. Breeding Bird

Survey data indicate Minnesota's AWPE population increased at a rate of 15.5% between 1966-2000, and between 1980-2000 at a rate of 18.6% (Sauer et al. 2001). The Marsh Lake colony, Big Stone County, grew from an estimated 25 pairs at the time of discovery (1968, the first documented nesting since demise of the last known MN colony in 1878) to an estimated 8,000-10,000 pairs and 5,400 young in 1997 (K. Haws, pers. comm). In addition to this colony, other colonies became established in Lake of the Woods and Fairbault counties.

Breeding Bird Survey data for the state's DCCO population indicate an increase of 2.4% between 1980-2000 (Sauer et al. 2001). Most of the increase appeared to occur between 1981-1990, when the population was estimated to be growing at a rate of 20% per year; the population was then estimated to decline at a rate of –8% per year until 1995 (McKearnan 1997). The decline was attributed to Newcastle disease (Henderson 2001). Between 1981-1995, 75 nesting sites were recorded; several occur in the western and central portion of the state (Wires et al. 2001).

At the time aquaculture began to undergo large-scale expansion in the state of Minnesota, cormorants and pelicans were at record lows, and their presence as a potential limiting factor was unknown. Dobie et al. (1956) published a circular on raising baitfish in Midwestern states that assembled information on baitfish culture and pond investigations collected between 1946-1953. The only avian species he identified as predators and pests were herons and kingfishers; cormorants and pelicans were not even mentioned. However, as these species began to recover and re-colonize breeding sites and migrate through the state in large numbers, conflicts with aquaculturalists began to occur. Currently, DCCO and AWPE are much more significant predators at fishponds than GBHEs, whose breeding numbers in MN have remained relatively stable or declined slightly since 1966 (Sauer et al. 2001). Additionally, the tendency of GBHE to forage alone rather than in large groups minimizes their impact at concentrated resources.

Location of Fish Farms and Occurrence of Breeding and Migrant Birds

In terms of pond productivity, several factors limit locations producers can use. Two of the most important are temperature and soil fertility. Wetlands and natural ponds used for fish production are primarily in the west-central portion of the state because ponds in this area are believed to provide the best overall conditions for growing fish (M. Lint, pers. comm.).

However, this area falls within historic and current breeding and migration ranges of the DCCO, AWPE and to a limited extent the GBHE. As noted earlier, large numbers of cormorants and pelicans occur in the west-central portion of the state during both the breeding and migration periods. Significant cormorant and pelican colonies and migrant aggregations occur in Grant and Otter Tail counties, two of the most important counties for fish production. Additionally, a large heronry occurs in Grant County.

Particularly problematic for fish producers is that in spring and fall damaging groups of pelicans and cormorants may include resident birds (non-breeders, breeders and their young (autumn) and birds originating from other portions of North America's interior range (e.g., the Dakotas; Saskatchewan and Manitoba, Canada)). For cormorants breeding east of the Rockies, two primary migration routes have been described: birds travel along the Atlantic coast or they travel along the Mississippi-Missouri valleys to the Gulf Coast (Palmer 1962; Johnsgard 1993). Cormorants nesting in the interior from Alberta to the Great Lakes use two major wintering areas along the Gulf Coast: southeastern Texas and the lower Mississippi Valley (Dolbeer 1991). To reach these areas, cormorants nesting on the Great Lakes may fly directly south along the Mississippi River drainage while others may first travel east to the Atlantic Coast and then south to the Gulf Coast (Weseloh and Collier 1995). Eastern populations of AWPE breeding in the northern Great Plains primarily migrate southward and eastward towards the Lower Mississippi Valley and the Gulf of Mexico, following inland river valleys (Evans and Knopf 1993; King and Michot 2002). Because of Minnesota's central position and connection to important flyways, migrant cormorants and pelicans passing through the state likely originate from a wide geographic area.

Use of Natural Ponds and Wetlands versus Artificial Ponds for Fish Production

In Minnesota, natural ponds and wetlands are used far more frequently for fish production than artificial ponds. Their use affords certain advantages to fish producers: excavation, construction and purchase costs are avoided; dams and control structures are not required; lease fees are relatively low; large areas can be utilized to increase the number of fish produced; and often little or no fertilizer is needed. These advantages minimize production costs. However, factors affecting these waters (e.g., predators, disease) are usually more difficult to control than factors affecting artificial ponds, especially if ponds are large. Additionally, natural ponds densely stocked with fish within a piscivorous bird's breeding range or migratory route are likely to be discovered and used by these birds. Because such ponds occur in natural environments where humans are usually not present or scarce, shifting birds from these sites once they have discovered the resource will require intensive and ongoing efforts.

Preventative Methods and Recommendations to Reduce Loss to Fish-Eating Birds

Preventative methods and strategies aimed at reducing loss to fish-eating birds are greatly limited by the size and type of ponds in use (large and natural). Exclusion devices (e.g., netting, overhead wires, ropes) and harassment are not practical at most ponds because of their scale and the fact that most producers are not willing to use them. Although fish producers identified shooting as the most effective and acceptable way to disperse cormorants, pond sizes and numbers limit the success of this method and it's costly. Lethal control away from ponds is acceptable to many producers, but this method is problematic for several reasons (e.g., determining focal areas away from ponds where problem birds originate; willingness of state agencies to control birds away from ponds, especially at nesting colonies where other non-target species may be negatively impacted; fulfillment of monitoring requirements).

Below we recommend ways that producers might be able to reduce their losses to fish-eating birds. These suggestions are presented within the framework of current laws; the question of who should pay for such actions is beyond the scope of this work.

1) Maintain aquaculture ponds beyond the migratory routes and breeding areas of fish-eating birds. The aquaculture industry is likely to continue to grow in Minnesota; one of the most important factors that new and expanding producers should carefully consider when selecting pond locations is the distribution and abundance of fish-eating birds in potential production areas. This study suggests that producers in the central-eastern portion of the state report fewer and less severe problems with fish-eating birds. Additionally, cormorants and pelicans historically utilized few sites in this area for breeding (Wires et al. 2001; Roberts 1932). For example, one white sucker producer utilized > 25 natural ponds ranging in size from 10-200 acres located in Aiken, Crow Wing, Mille Lacs and Pine counties; he reported no problems with fish-eating birds and attributed this to being outside migratory flyways.

2) Locate important cormorant roosts and staging areas and explore potential for roost dispersal. In the southeastern U.S., catfish producers have significant problems with several avian fish-eaters that migrate and winter in the Mississippi Delta area. A night roost dispersal program for cormorants has been effective at temporarily dispersing large numbers of cormorants from roosts located near catfish ponds in this region (Glahn et al. 2000; Tobin et al. 2002). This strategy requires a regular, synchronized, and coordinated effort to effectively disperse birds. In Minnesota, information on location of important roosting and staging areas in relation to primary fish production areas should be compiled and the benefits of a roost dispersal program explored. Because migrant birds constitute a significant portion of the problem in Minnesota, such an effort may help producers effectively shift large numbers of depredating birds away from the more intense fish farming areas.

3) Monitor ponds and coordinate efforts to disperse birds at critical times. Some producers reported that a coordinated effort by a number of individual shooters early in the season effectively dispersed large numbers of DCCO from important ponds for significant periods (M. Lint, pers. comm.). This effort requires regular surveillance of ponds to prevent concentrations of fish-eating birds from amassing and to disperse large migrant flocks. Other birds, such as pelicans, readily leave the area when coordinated dispersal efforts for cormorants are undertaken. Foraging herons and egrets may attract cormorants and pelicans, so efforts to disperse these species should be made as soon as they are sighted at ponds. Overall, increased vigilance and proactive strategies at ponds during peak migration periods may be key to avoiding significant losses. Additionally, a simple Web site could be developed for producers to monitor and communicate sightings and movements of pelicans and cormorants. This information may help producers anticipate arrivals of large flocks, and help them identify which ponds to monitor if all ponds can't be watched. Producers should regularly monitor important ponds as soon as ice-out occurs.

4) Amplify protection efforts at ponds that have fish in size ranges that are most vulnerable to avian predators. Cormorants are reported to consume fish ranging in size from 3-40 cm; however, the most commonly taken size range is < 15 cm (Hatch and Weseloh 1999). AWPE primarily eat small schooling fish ranging from 13.5-18 cm (Evans and Knopf 1993).

5) Use ponds where avian predation can be effectively and efficiently monitored. Some farmers reported losses at ponds that were too large to effectively monitor. Although large ponds have the potential to produce more fish, avian predators are much harder to control at such ponds; thus profits realized at these ponds may be less than those realized at smaller ponds where predators can be more easily controlled and dispersed. Large numbers of ponds spread over a wide area are also difficult to monitor. In planning numbers and locations of ponds, producers need to consider their ability to regularly and frequently monitor ponds, and if necessary, make a sustained effort to disperse birds.

6) Periodically rotate fish among ponds. Ponds that are stocked and used yearly are more likely to be discovered by foraging birds. Letting ponds periodically lie fallow prevents them from becoming traditional foraging sites for birds. Additionally, if ponds are discovered, letting them go un-stocked will force birds to relocate to other areas.

7) Remove potential roost sites adjacent to ponds. Ponds being considered for aquacultural use should also be considered in terms of their attractiveness to and likelihood of discovery by fish-eating birds, especially if they occur within or near traditional flyways and breeding areas. Several producers noted that if dead trees were not around ponds, cormorants had no place to roost and were not as likely to hang around a pond. Dead trees provide attractive roost sites, and when possible, their removal may help minimize loss in certain areas. Some producers removed trees and cormorants left the area. However, some producers also reported that ponds located within wooded areas experienced no or minimal fish losses to birds, while ponds that were located in prairie or open areas experienced much greater losses.

Ponds in heavily wooded areas may be harder for birds to discover and may make access more difficult. Ponds closer to human activity will also be less attractive to birds. The physical characteristics of the environment surrounding each pond should be considered when selecting ponds for stocking and production and in anticipating avian predation problems.

8) Deter predators with dogs and other animals. Several producers reported dogs strongly deter avian predators. Producers who had bald eagles (*Haliaeetus leucocephalus*) in the area also reported fewer problems with other fish-eating birds. One producer successfully controlled and dispersed fish-eating birds by placing nest boxes for tree swallows (*Tachycineta bicolor*) around his ponds. Nesting tree swallows are very aggressive and attack wading birds that come to ponds to forage. In Minnesota, tree swallows nest from early April to mid-July. They will often nest in boxes intended for bluebirds and in trees over water.

Potential for Control Away from Fish Ponds to Reduce Losses

Many producers believe lethal control of birds away from ponds will provide an effective solution to their problems with fish-eating birds. We do not recommend this method for the following reasons:

Legal protection under Migratory Bird Treaty Act (MBTA): Cormorants, pelicans and herons are protected under the MBTA. Acquiring permits to kill birds at an aquaculture facility requires special documentation, even for the take of cormorants under the Depredation Order. Killing birds at breeding areas because of impacts that may be attributable to them requires complex documentation and fulfillment of monitoring protocols. Currently, the only species that this strategy could target is cormorants (due to Public Resource Depredation Order that gives state, federal and tribal agencies the authority to use lethal control at breeding and roosting sites (USDI/FWS 2003)). Lethal control away from ponds of other fish-eating bird species identified as problematic in Minnesota is not under consideration, and losses to these other species would continue to occur. Although the recently modified Depredation Order allows killing birds at winter roosts, fall roosting and staging areas in Minnesota have not been identified and a dispersal program has not been tried. We recommend undertaking a roost dispersal program before lethal activities are employed, as this may be very successful in dispersing birds that are using areas for short periods during the fall and already on the move.

Fish ponds are high quality foraging habitat: Aquaculture ponds constitute high quality foraging habitat for fish-eating birds because of the density and availability of fish they hold, and are likely first choice areas for foraging birds. Thus, overall population reductions may not result in equivalent reductions in the number of birds occurring at high quality foraging areas; rather birds may disappear from low quality areas first and declines will likely be less marked in high quality areas (Hodges 1989, Bregnballe et al. 1997, Van Erden and van Rijn 1997).

The greatest losses of fish are to migrating birds: Results from our survey and examination of breeding distributions within the state suggest that migrant birds more significantly affect fish producers than do breeding birds. While control at the colony level will reduce numbers of breeding cormorants during the breeding season, birds from other areas will likely replace these birds during fall migration. Studies in Europe and the southeastern U.S. have demonstrated that there is substantial movement among birds and/or a very high turnover of individuals as birds migrate (Aderman and Hill 1995, Keller et al. 1998, Glahn et al. 2000). Lethal control on a large scale at roosting or staging areas will be logistically difficult to accomplish because large numbers of cormorants are difficult to shoot at any one time; efforts will likely have a similar effect as a roost dispersal program.

Birds can fly large distances to forage: Nesting and roosting birds sometimes fly large distances from colonies and roosts to forage (Mazzocchi 2001; Tobin et al. 2002). Targeting nearby colonies to protect local fisheries may not be sufficient because birds from more distant colonies may also be using high quality foraging resources (Mazzocchi 2001).

Large numbers of migrating birds pass through Minnesota: The Mississippi River is one of the most important flyways between breeding and wintering grounds for many fish-eating bird species; many thousands of migrating cormorants from northern areas within the interior region of the continent funnel through Minnesota. Thus, control at Minnesota breeding colonies may not significantly diminish the number of cormorants in the state and frequenting prime foraging sites during migration, particularly in the fall.

Lethal control impacts other waterbirds: Activities undertaken during lethal control efforts at colonies disturb other nesting, non-target colonial waterbirds. Cormorants frequently nest in association with herons, egrets, pelicans and gulls; all of these species are vulnerable to human disturbance and will likely experience reproductive failures and may abandon sites if control activities are conducted at multi-species colonies.

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LITERATURE CITED

Aderman, A.R. and E.P. Hill. 1995. Locations and numbers of double-crested cormorants using winter roosts in the delta region of Mississippi. Colonial Waterbirds Special Publication I, Vol. 18: 143-151.

Booth, G. 1998. Fisherman farmer. Ag Innovation News, Vol 7 (3): 11.

Bregnballe, T., J.D. Goss-Custard and S.E.A. le V. Dit Durell. 1997. Management of cormorant (*Phalacrocorax carbo sinensis*) numbers in Europe: a second step towards a European conservation and management plan. p. 62-122 *In* C. van Dam and S. Asbirk [eds.] Cormorants and Human Interests: Proceedings of the Workshop Towards an International Conservation and Management Plan for the Great Cormorant (*Phalacrocorax carbo*), 3 and 4 October 1996, Lelystad, The Netherlands.

Coleman, J.T.H. 2003. Foraging Movements and Habitat Utilization of the Double-crested Cormorant (*Phalacrocorax auritus*) as Revealed by Radio Telemetry and GIS Techniques. M.S. Thesis. Cornell University.

Custer, T.W. and C. Bunck. 1992. Feeding flights of breeding double-crested cormorants at two Wisconsin colonies. J. Field Ornith. 63: 203-211.

Dobie, J., O.L. Meehean, S.F. Snieszko and G.N. Washburn. 1956. Raising bait fishes. Circular 35. U.S. Fish and Wildlife Service, U.S. Dept. of the Interior. U.S. Govt. Printing Office, Washington.

Dolbeer, R.A. 1991. Migration patterns of double-crested cormorants east of the Rocky Mountains. J. Field Ornith. 62:83-93.

Evans, R.M. and F.L. Knopf. 1993. American White Pelican. In: The Birds of North America, No. 57 (A. Poole, P. Stettenheim, and F. Gill, Eds.). Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologists Union.

Featherstonhaugh, G.W. 1847. A canoe voyage up the Minnay Sotor. London, R. Bentley.

Glahn, J.F., D.S. Reinhold and C.A. Sloan. 2000. Recent population trends of double-crested cormorants wintering in the delta region of Mississippi: responses to roost dispersal and removal under a recent depredation order. Waterbirds 23: 38-44.

Gunderson, J.L. and P.Tucker. 2000. A white paper on the status and needs of baitfish aquaculture in the north central region. Prepared for the North Central Regional Aqauculture Center. Draft, March 2002.

Hatch, P.L. 1892. Notes on the birds of Minnesota, with specific characters. The geological and natural history survey of Minnesota. First report of the state zoologist. H.F. Nachtrieb. Minneapolis, Harrison and Smith, printers.

Henderson, C. 2001. Minnesota profile: double-crested cormorant (*Phalacrocorax auritus*). Minnesota Conservation Volunteer (May-June 2001).

Hobson, K.A., R.W. Knapton, and W. Lysack. 1989. Population, diet and reproductive success of double-crested cormorants breeding on Lake Winnipegosis, Manitoba in 1987. Colonial Waterbirds 12: 191-197.

Hodges, M.F. 1989. Foraging by piscivorous birds on commercial fish farms in Mississippi. M.S. Thesis, Mississippi State University, Mississippi State, Mississippi.

Janssen, R.F. 1992. Birds in Minnesota. University of Minnesota Press. Minneapolis.

Johnsgard, P.A. 1993. Cormorants, Darters and Pelicans of the World. Smithson. Inst. Press, Washington, D.C.

Keller, T., A. von Lindeiner and U. Lanz. 1998. Cormorant management in Bavaria, Southern Germany—shooting as a proper management tool? Cormorant Research Group Bulletin 3:11-15.

King, D.T. and T.C. Michot. 2002. Distribution, abundance and habitat use of American white pelicans in the delta region of Mississippi and along the western Gulf of Mexico Coast. Waterbirds 25: 410-416.

Lewis, H.F. 1929. The Natural History of the double-crested cormorant (*Phalacrocorax auritus auritus* (Lesson)). Ph.D. Thesis, Cornell University, Ithaca, New York.

Mazzocchi, I. 2001. Double-crested Cormorants and VHF Telemetry on Lake Ontario, 2001. NYSDEC Lake Ontario Annual Report. Section 18: 1-7.

McKearnan, J.E. 1997. Colonial Waterbird Population Analysis Project, Phase I. Final Report. Submitted to MN DNR, Natural Heritage and Non-Game Research Program.

MN Dept. of Ag. 1997. 1996 Minnesota Private Aquaculture Industry Report. MN Dept. of Ag. Aquaculture Development Program. St. Paul, MN. 7pp.

Murnyak, M.E. 1982. Developing Methods of Fish Farming in Minnesota: Final Report, Aquaculture Development Project. Waverly, MN, Aquaculture Development Project. 28pp.

Olin, P.G. 2001. Current status of aquaculture in North America. *In* R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millenium. Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand, 20-25 February 2000. pp. 377-396. NACA, Bangkok and FAO, Rome.

Palmer, R.S. 1962. Handbook of North American Birds, Volume 1. Yale University Press, New Haven, Connecticut. 567 pp.

Peck, G.K. and R.D. James. 1983. Breeding birds of Ontario: nidology and distribution. Vol I. Toronto, ROM.

Roberts, T.S. 1919. Waterbirds of Minnesota; Past and Present. Bien. Rept. State Game and Fish Commissioner of Minnesota for the Biennial Period Ending July 31, 1918, pp.56-91.

Roberts, T.S. 1932. The Birds of Minnesota, Vol 1. University of Minnesota Press. Minneapolis. 691 pp.

Sauer, J.R., J.E. Hines, and J. Fallon. 2001. The North American Breeding Bird Survey, Results and Analysis 1966 - 2000. Version 2001.2, USGS Patuxent Wildlife Research Center, Laurel, MD.

The Loon. 1990-2001. Spring and Fall reports, Vol. 60-73.

Tobin, M.E., D.T. King, B.S. Dorr, S.J. Werner and D.S. Reinhold. 2002. Effect of roost harassment on cormorant movements and roosting in the Delta region of Mississippi. Waterbirds 25: 44-51.

USDA-NASS (U.S. Department of Agriculture, National Agricultural Statistics Service). 1998. 1998 Census of Aquaculture (http://www.nass.usda.gov/census/census97/aquaculture/aquaculture.htm).

USDI-FWS (U.S. Fish and Wildlife Service). 1998. Migratory bird permits; establishment of a depredation order for the double-crested cormorant (Final rule). USDI/Fish and Wildlife Service, 50 CFR Part 21, RIN 1018-AE11.

USDI-FWS (U.S. Fish and Wildlife Service). 2003. Migratory Bird Permits: Regulations for Double-crested Cormorant Management. USDI/Fish and Wildlife Service, 50 CFR Part 21, RIN 1018-A139.

Van Eerden, M.R. and S. van Rijn. 1997. Population developments of the great cormorant (*Phalacrocorax carbo sinensis*) in Europe in relation to the question of damage to fisheries. p34-44. *in* C. van Dam and S. Asbirk [eds.] Cormorants and Human Interests: Proceedings of the Workshop Towards an International Conservation and Management Plan for the Great Cormorant (*Phalacrocorax carbo*), 3 and 4 October 1996, Lelystad, The Netherlands.

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. Canadian Wildlife Service, Environment Canada and Long Point Observatory.

Wires, L.R., F.J. Cuthbert, D.R. Trexel and A.R. Joshi. 2001. Status of the Double-crested Cormorant (*Phalacrocorax auritus*) in North America. Final report to USFWS.

Table 1. The number of producers farming white suckers and shiners (baitfish) and yellow perch and walleye (for stocking) operating in MN counties.*

	Number of farmers			
County	W.Suckers	Shiners**	Y.Perch	Walleye
Otter Tail	9	7	3	5
Becker	8	3	2	4
Douglas	8	7	5	5
Pope	8	6	4	8
Grant	7	6	5	6
Mahnomen	5	2	1	2
Stearns	5	4	2	2
Todd	5	4	2	1
Clay	4	2	0	1
Clearwater	4	2	0	1
Kandiyohi	4	3	0	5
Polk	4	2	1	1
Stevens	4	2	2	3
Big Stone	3	3	2	3
Crow Wing	3	1	2	1
Morrison	3	0	0	0
Norman	3	0	3	4
Anoka	2	1	0	1
Itasca	2	2	3	0
Swift	2	1	2	3
Wright	2	0	0	0
Aitken	1	0	0	0
Benton	1	0	0	0
Chisago	1	1	0	1
Hennepin	1	0	0	1
Hubbard	1	1	1	1
Isanti	1	2	0	1
Meeker	1	1	3	3
Mille Lacs	1	0	0	0
Pine	1	0	2	3
St. Louis	1	1	0	0
Sherburne	1	0	0	0
Carver	0	0	0	1
Dodge	0	0	0	1
Kittson	0	0	0	1
Wadena	0	0	1	1
Yellow Medicine	0	0	2	0

* 37 counties

** Mostly golden shiners

Table 2. Bird species identified as source of loss and extent to which they are considered problematic.

	Severity of Problem			
Species	Not at all # (%)	Slight # (%)	Moderate # (%)	Severe # (%)
American White Pelican	18 (33)	12 (22)	13 (24)	11 (20)
Double-crested Cormorant	14 (26)	4 (7)	9 (17)	28 (52)
Great Blue Heron	11 (20)	20 (37)	16 (30)	9 (17)
Other Birds				
Common Loon	52 (96)	1 (2)	1 (2)	0 (0)
Gulls	53 (98)	1 (2)	0 (0)	0 (0)
Egrets	48 (89)	3 (6)	2 (4)	1 (2)
Green Heron	51 (94)	1 (2)	2 (4)	0 (0)
Black-crowned Night-Heron	53 (98)	1 (2)	0 (0)	0 (0)
Osprey	52 (96)	0 (0)	0 (0)	2 (4)
Bald Eagle	51 (94)	1 (2)	1 (2)	1 (2)
Terns	52 (96)	2 (4)	0 (0)	0 (0)
Belted Kingfisher	45 (83)	4 (7)	2 (4)	3 (6)
Unidentified	53 (98)	1 (2)	0 (0)	0 (0)

Table 3. Effectiveness and costliness of strategies to prevent losses to fish-eating birds.

Strategy	Effectiveness				Costliness			Currently Use	Responses
	Not	Slightly	Moderate	Very	Minimal	Moderate	Cost Prohibitive	Number Farmers	Number Farmers
Netting	4	2	2	1	2	1	8	2	12
Wires	4	3	1	0	2	2	2	1	9
Ropes	6	2	0	0	4	1	1	0	9
Other Flight Inhibitors	5	0	0	0	2	1	1	0	6
Underwater Exclusion	3	1	0	0	1	1	2	0	5
Pyrotechnics	7	5	1	0	6	3	2	0	13
Sim. Human Harassment	13	9	1	1	7	10	3	9	24
Other Harassment	8	7	0	1	7	4	1	2	16
Decrease Fish	4	0	2	3	1	2	4	0	9
Pond Dyes	4	2	0	0	3	2	0	0	7
Water Turbulence	2	0	0	0	1	0	1	0	3
Alter Stocking	6	1	3	1	2	1	5	0	11
Shoot to Reinforce	11	5	7	4	6	9	8	3	27
Shoot to Kill	6	5	8	13	6	8	10	21	32
OTHER									
Rotate Ponds	0	1	0	1	0	1	1	2	
Actual Human Harassment	0	0	2	0	0	0	2	3	
Dogs	0	1	1	2	2	1	1	5	
Traps	0	0	1	1	2	0	0	2	
Tree Swallows	0	0	1	0	1	0	0	1	
Cutting Trees								2	

Figure A. Geographic regions in Minnesota (from Janssen, 1992).

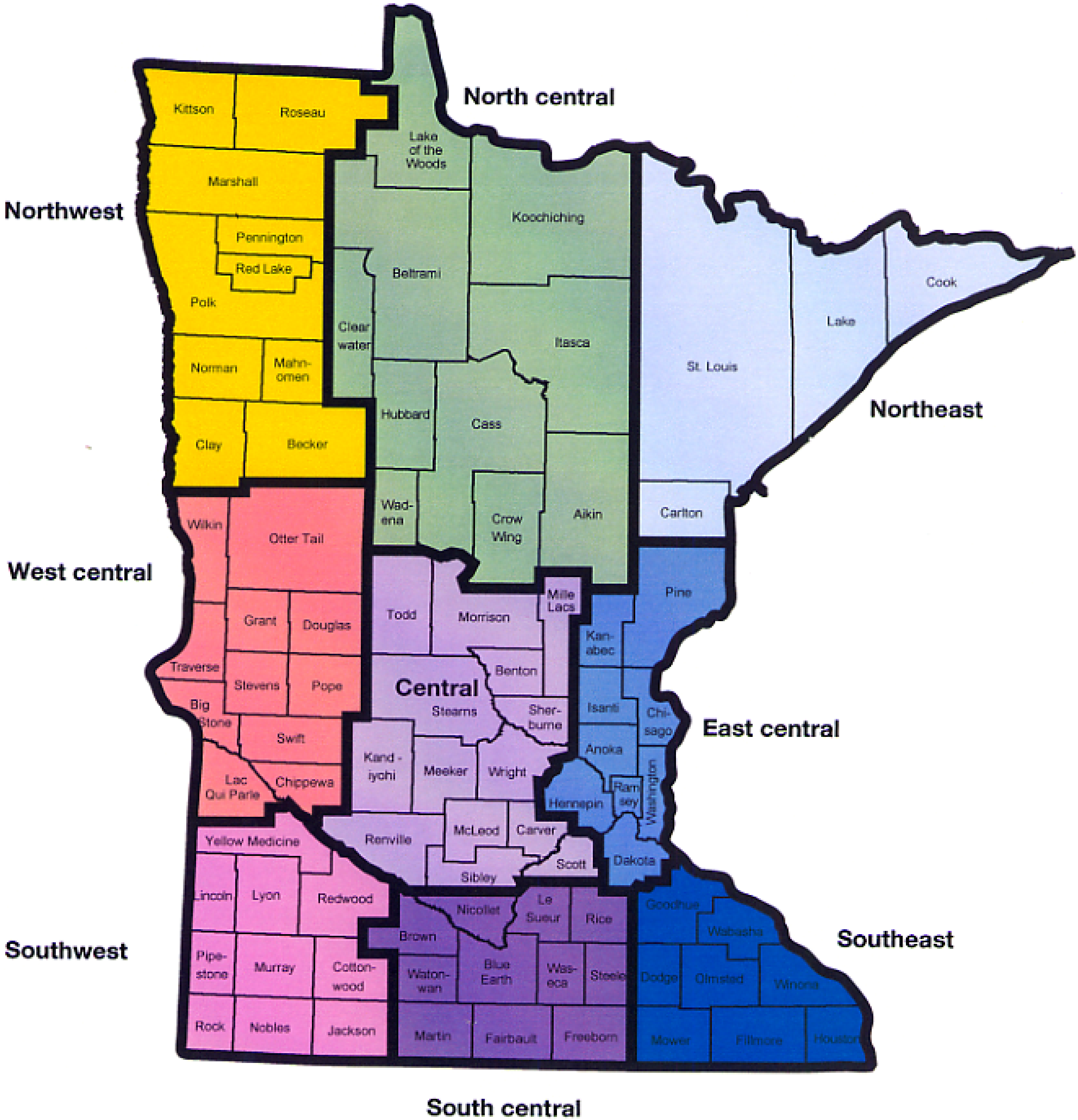
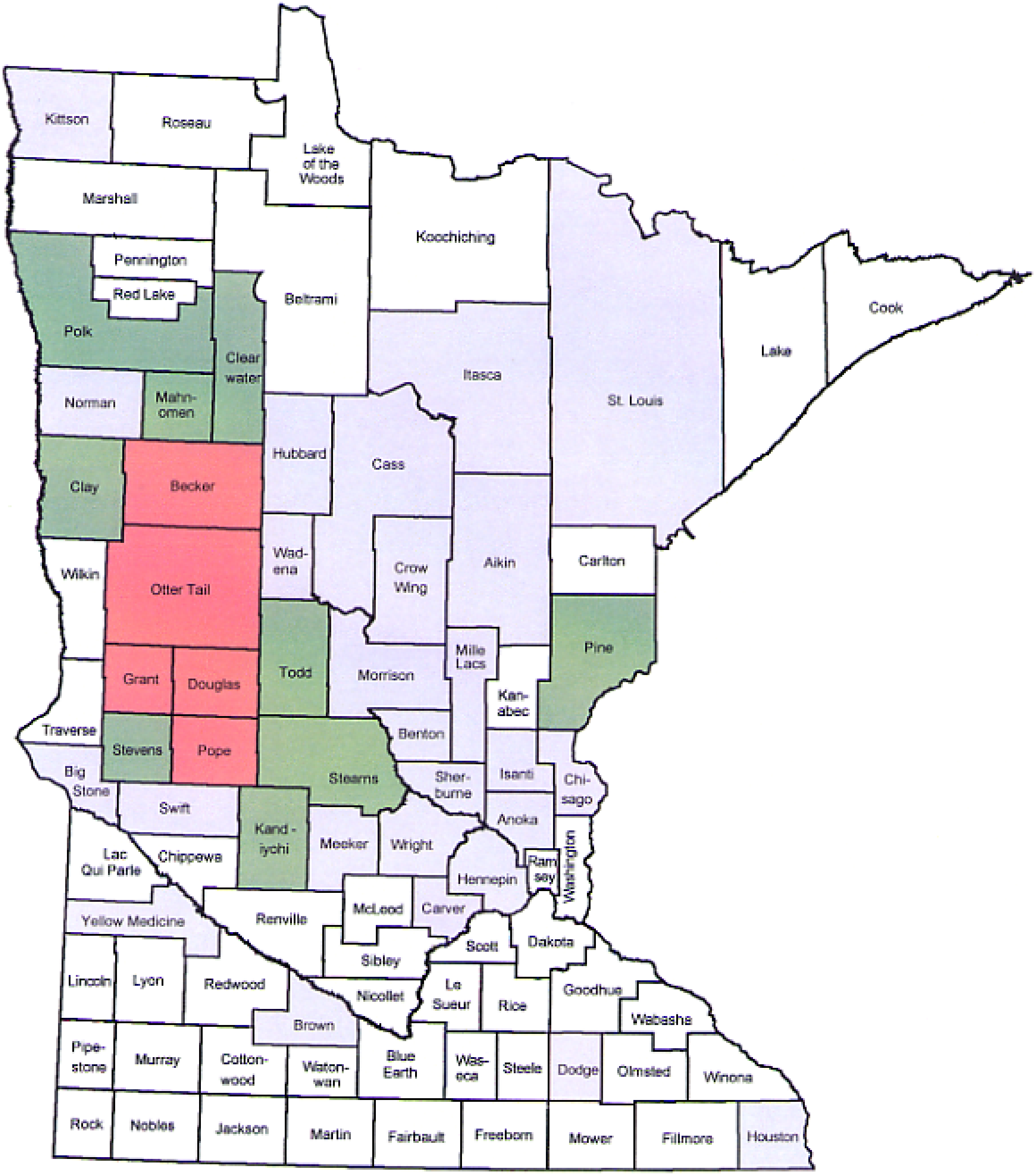


Figure 1. MN counties used by commercial fish farmers



Number of individual farmers reporting ponds in county:

- 1-3
- 4-6
- 9-12

Figure 2. MN counties identified as primary pond locations (where majority of farmers' ponds occur).

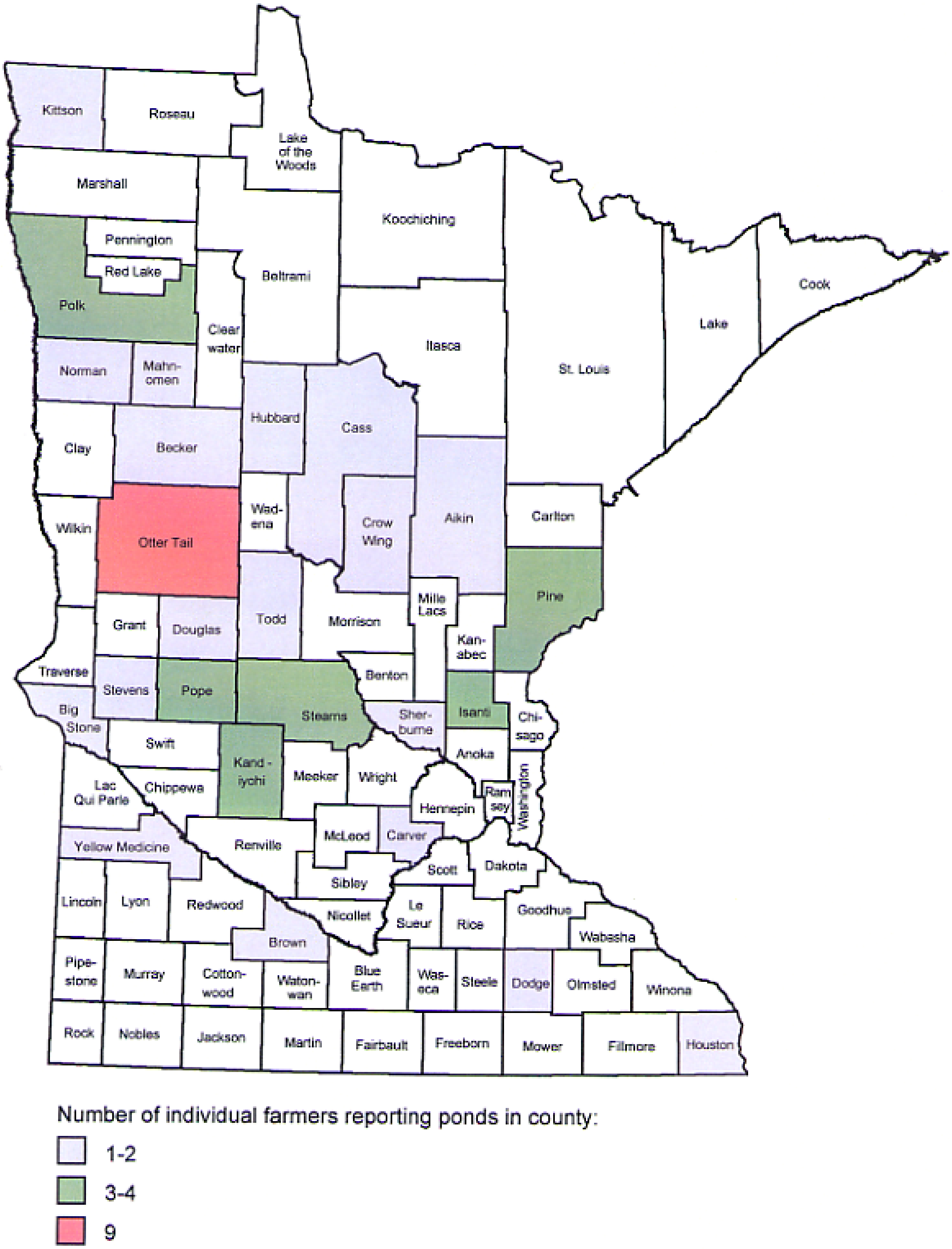


Figure 3. Percentage of farmers reporting loss to fish-eating birds.

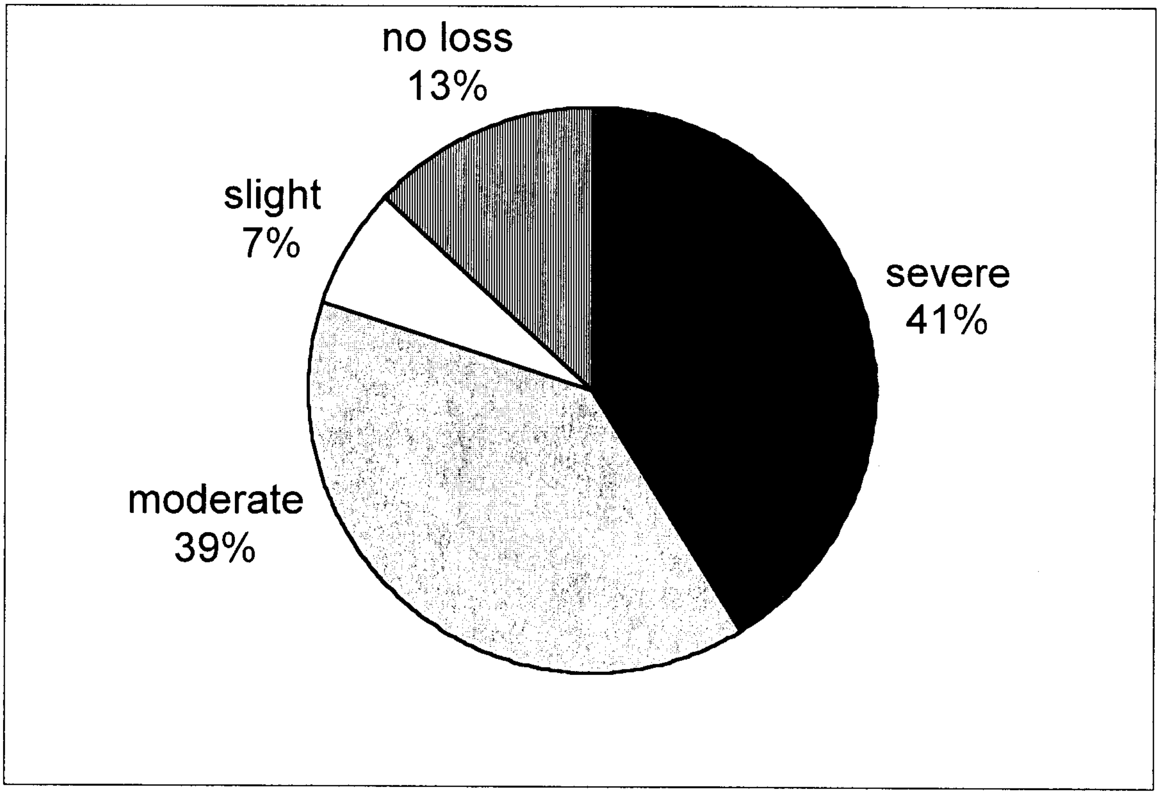


Figure 4. Months of loss to fish-eating birds.

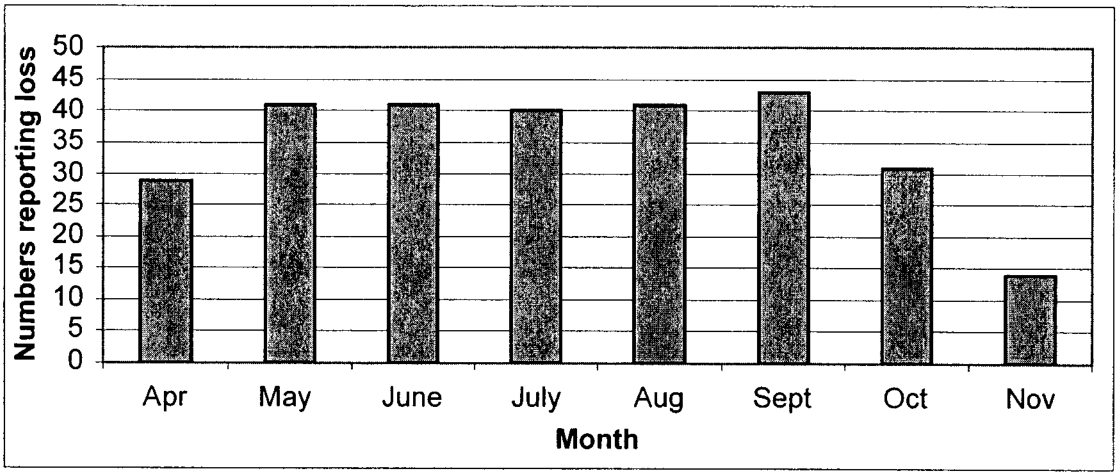


Figure 5. Months of greatest fish-eating bird concentrations.

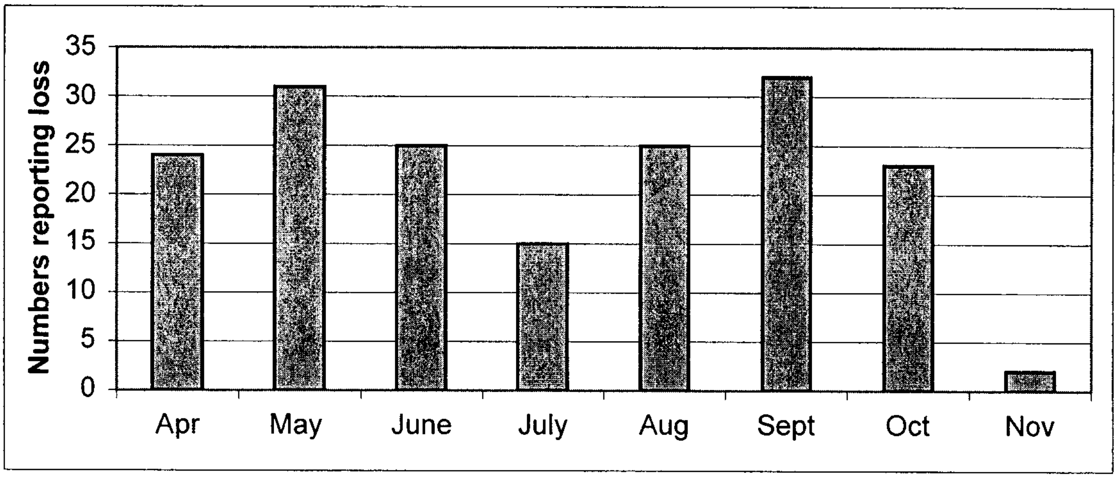


Figure 6. Months of greatest fish-eating bird caused loss.

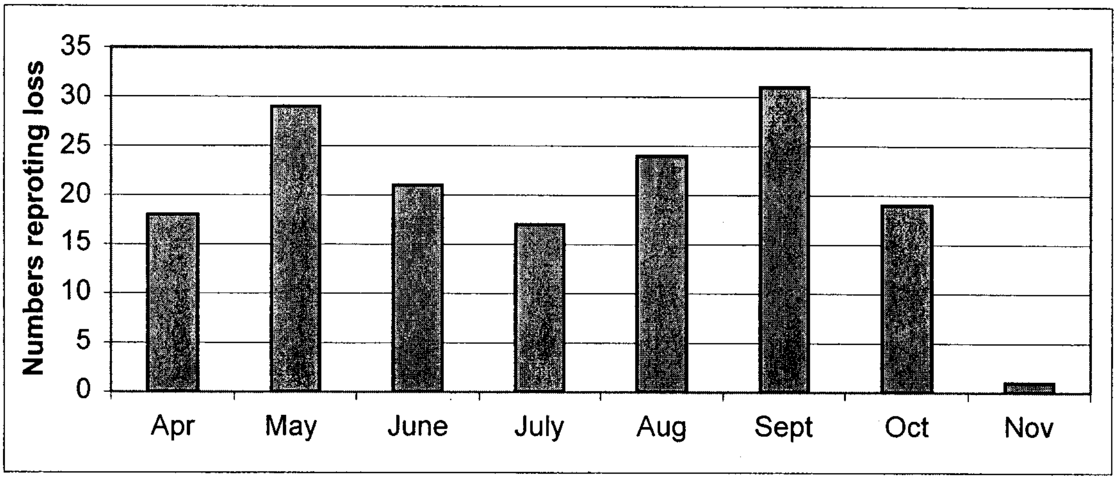
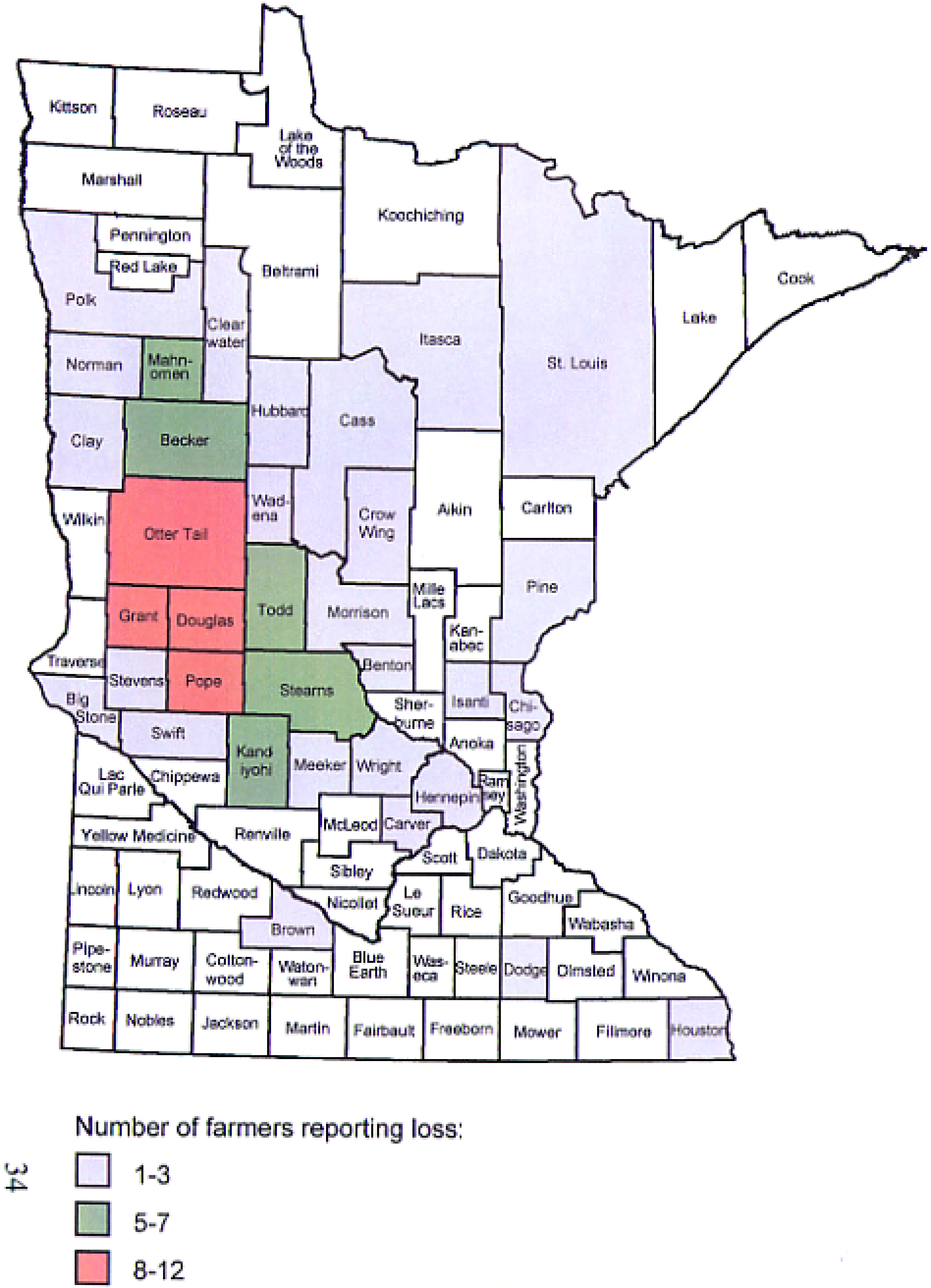


Figure 7. MN counties utilized by farmers that reported loss to GBHE.



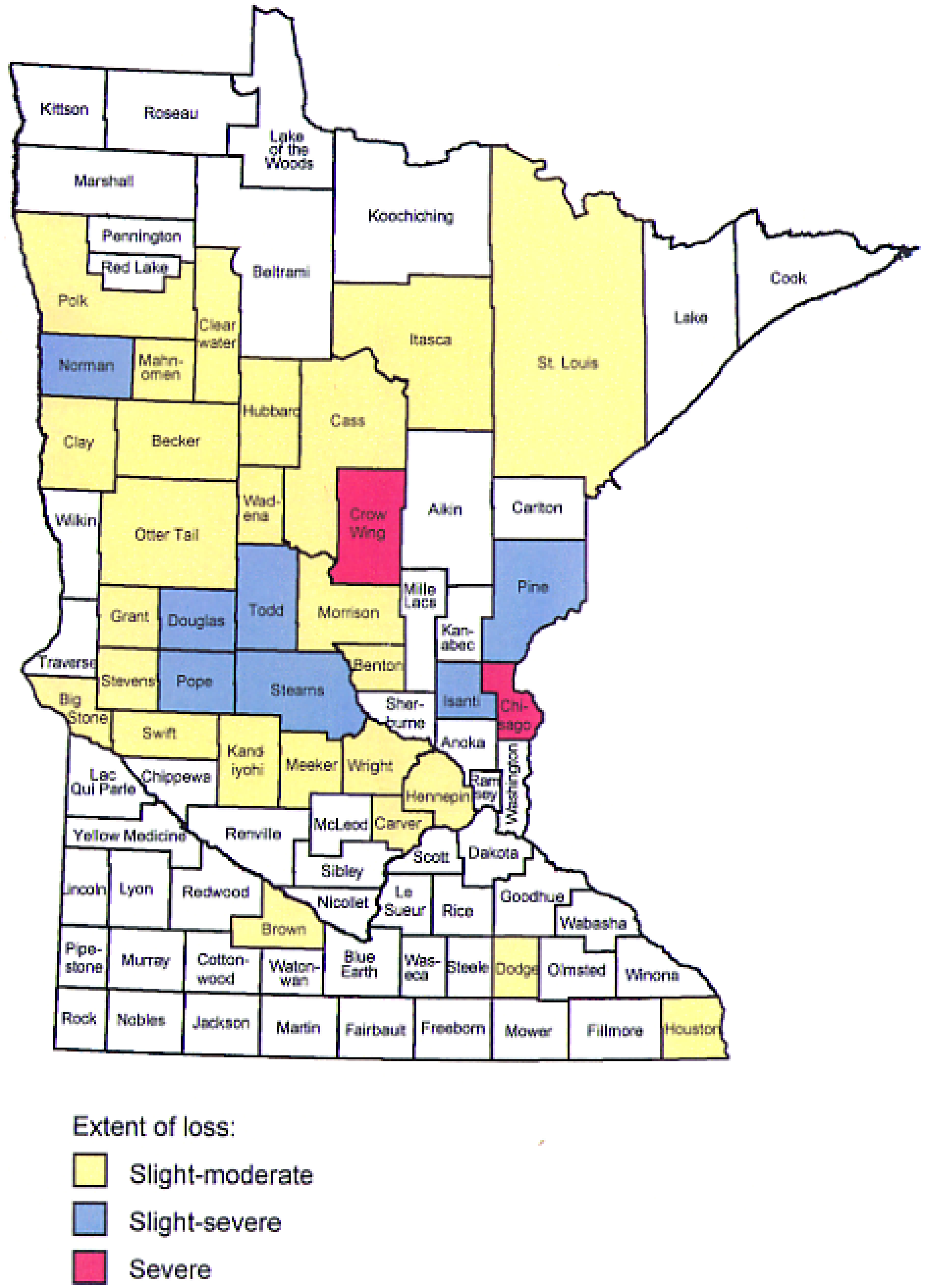
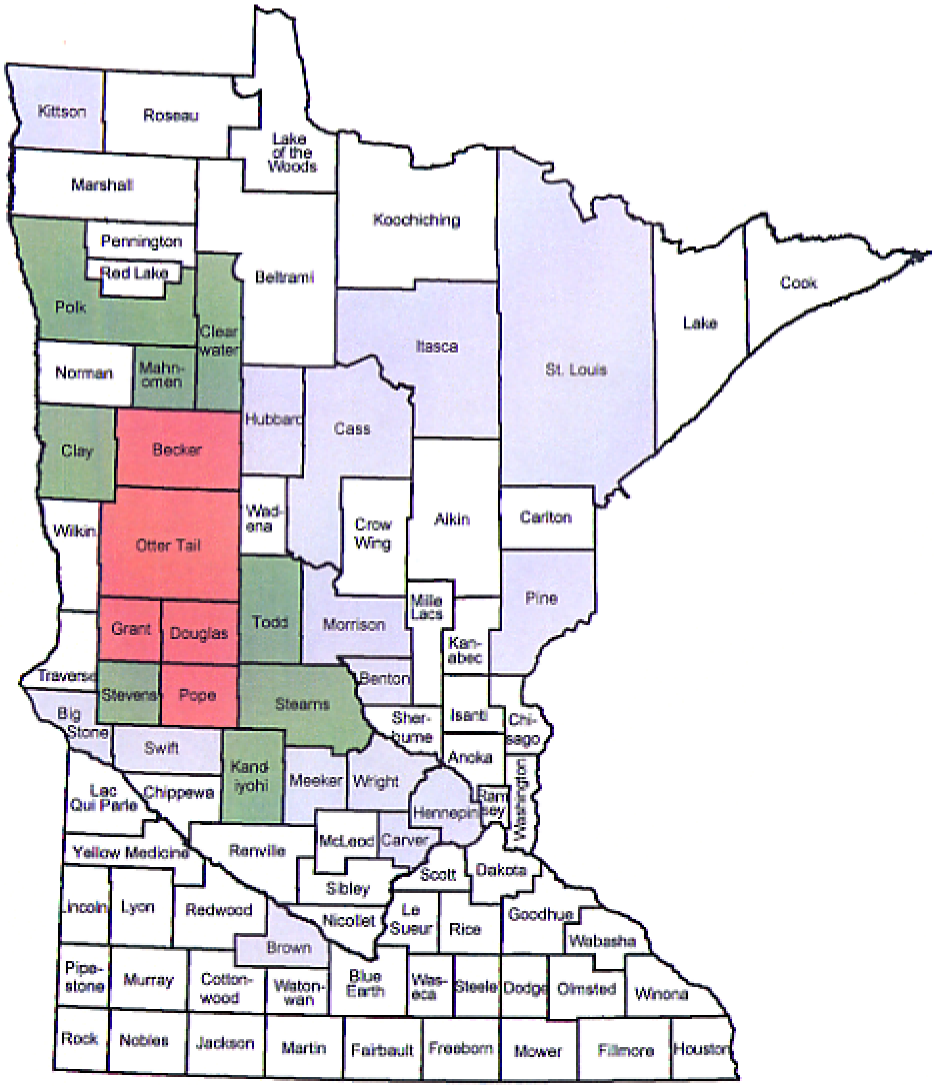
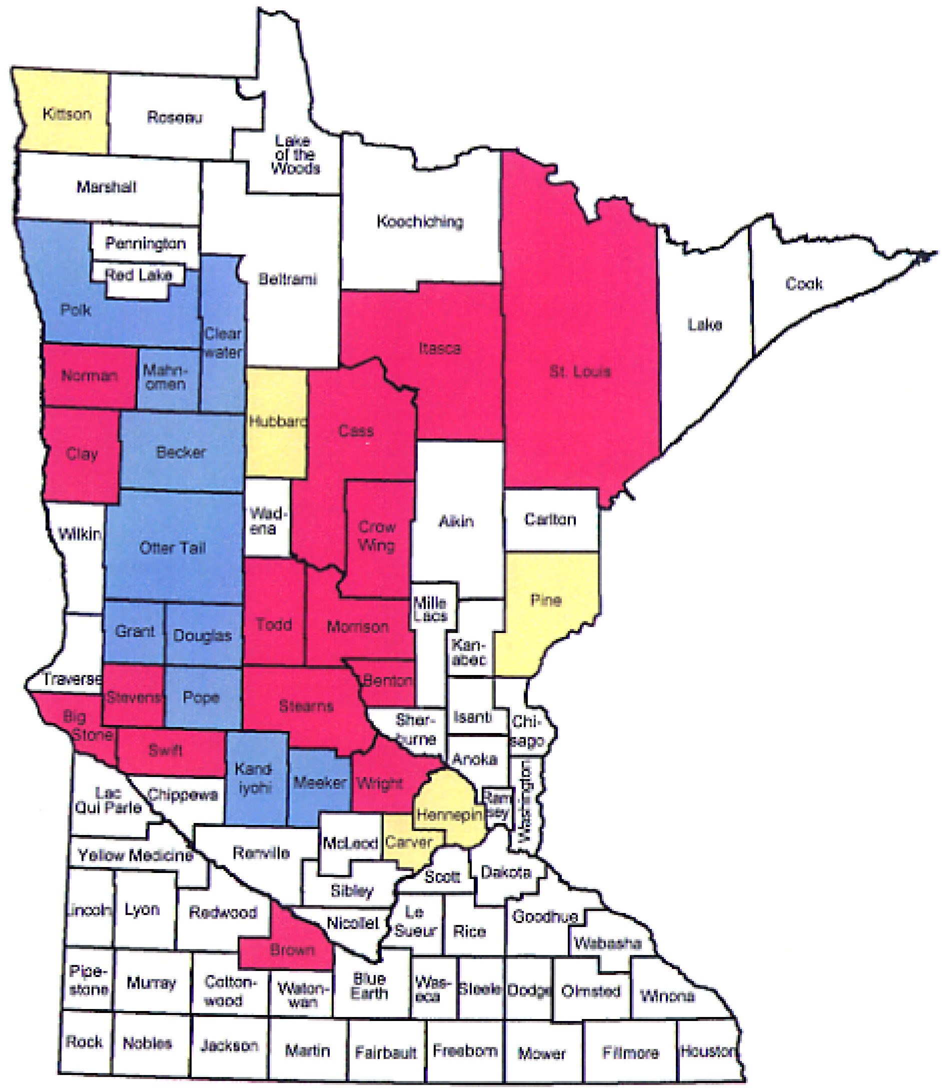


Figure 8. MN counties utilized by farmers that reported loss to DCCO.



Number of farmers reporting loss:

- 1-3
- 4-6
- 9-11



Extent of loss:

- Slight-moderate
- Slight-severe
- Severe

Figure 9. MN counties utilized by farmers that reported loss to AWPE.

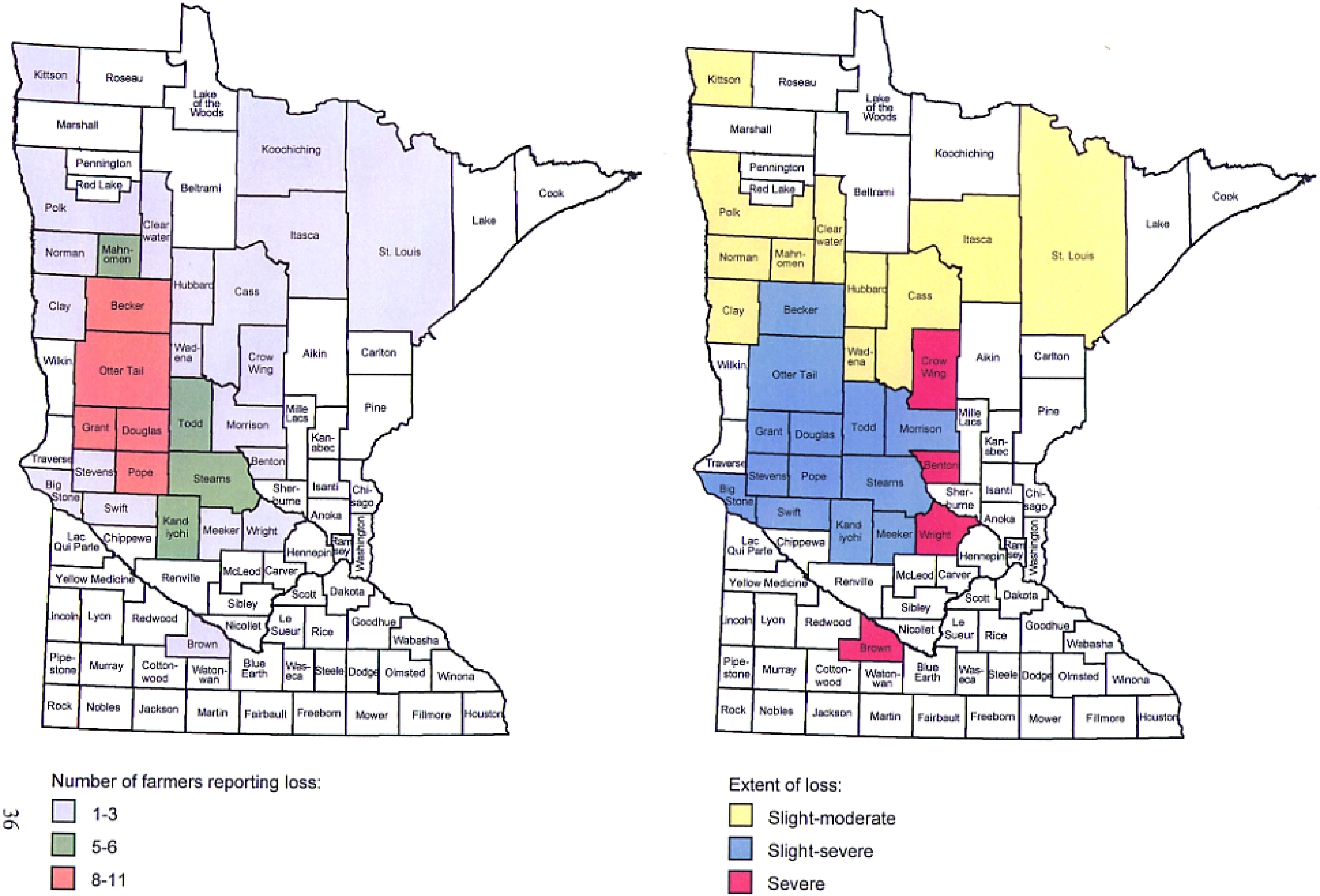
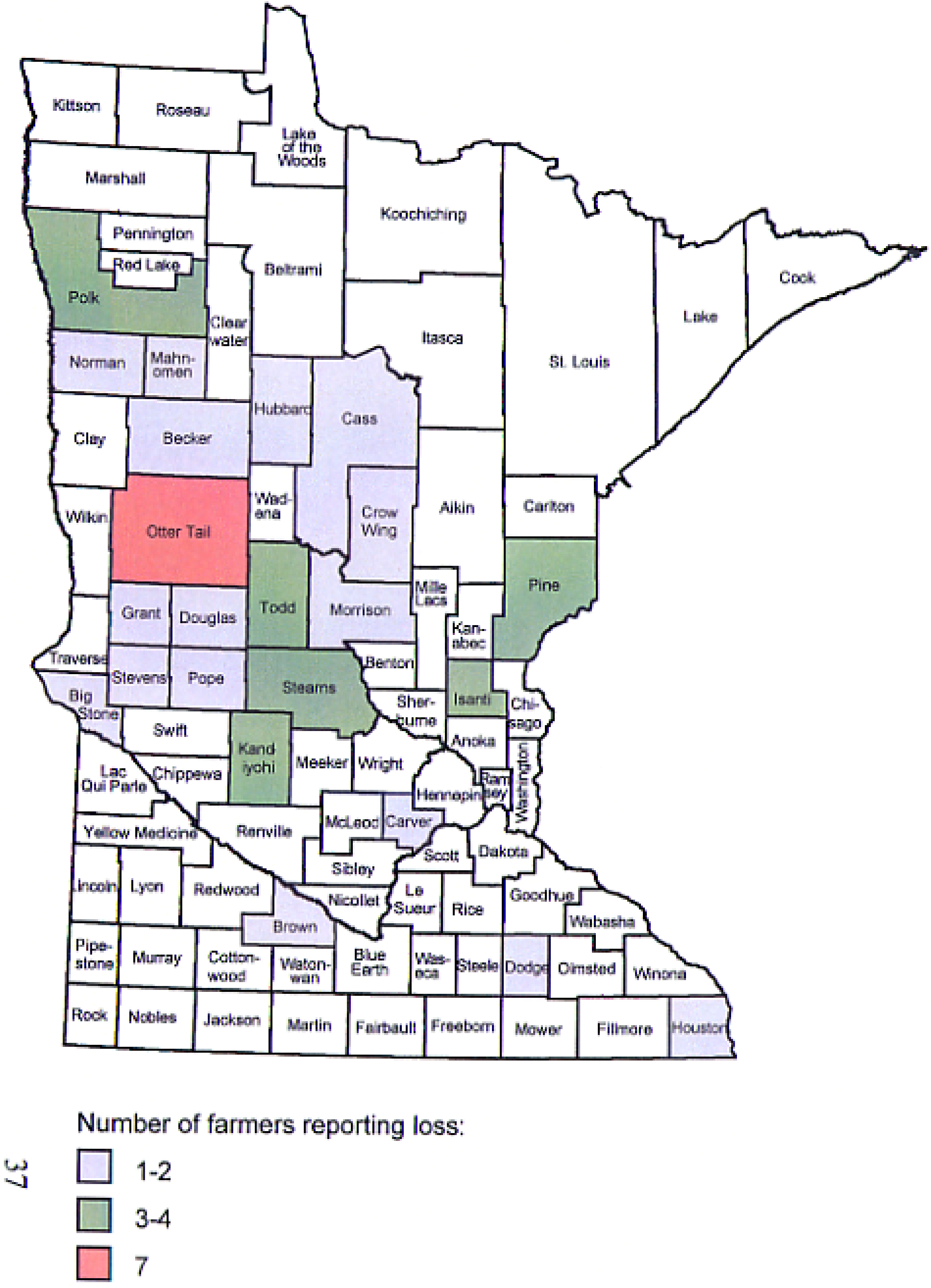


Figure 10. MN counties identified as *primary pond locations* (where majority of farmers' ponds occur) utilized by farmers reporting loss to GBHE.



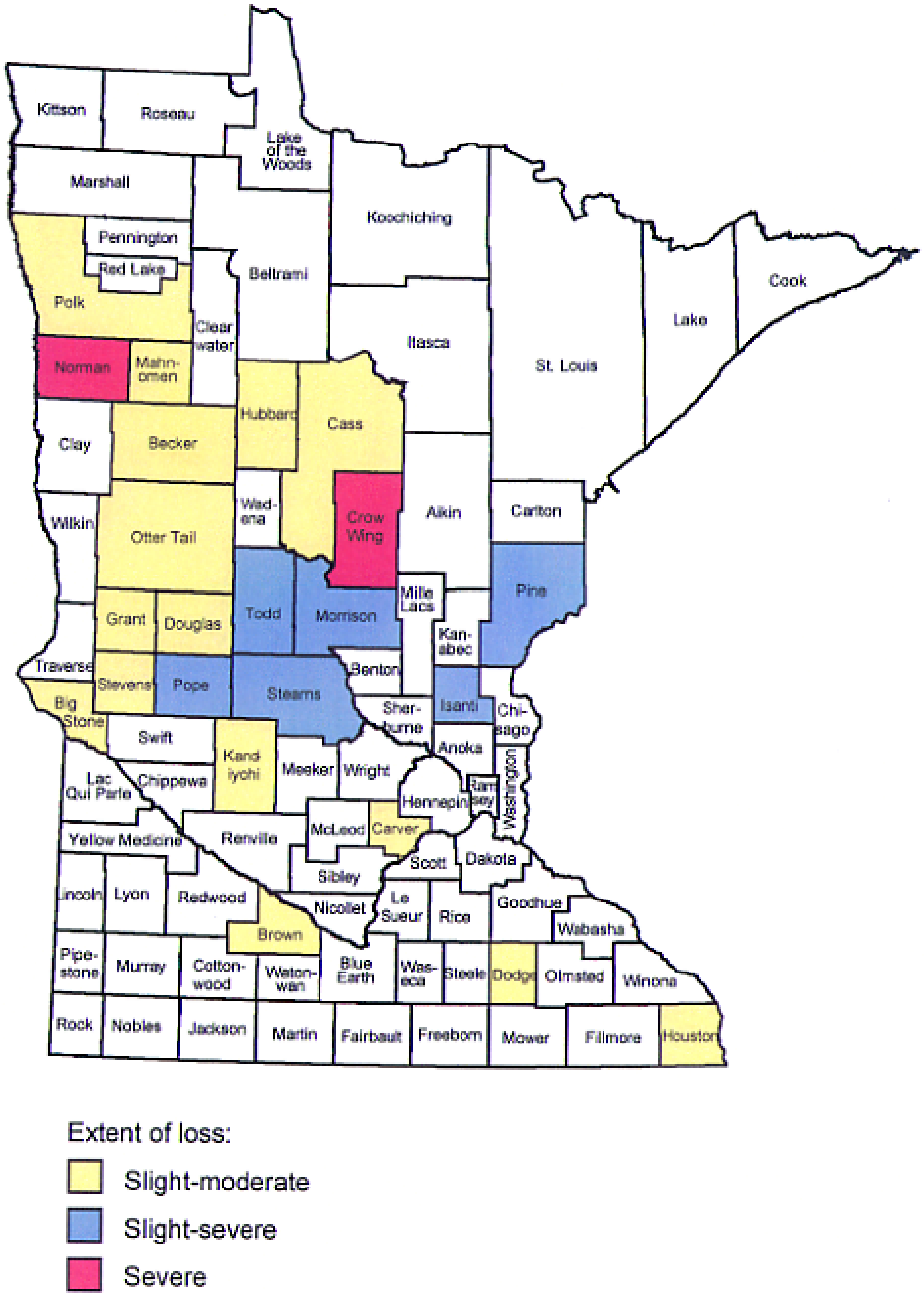


Figure 11. MN counties identified as *primary pond locations* (where majority of farmers' ponds occur) utilized by farmers reporting loss to DCCO.

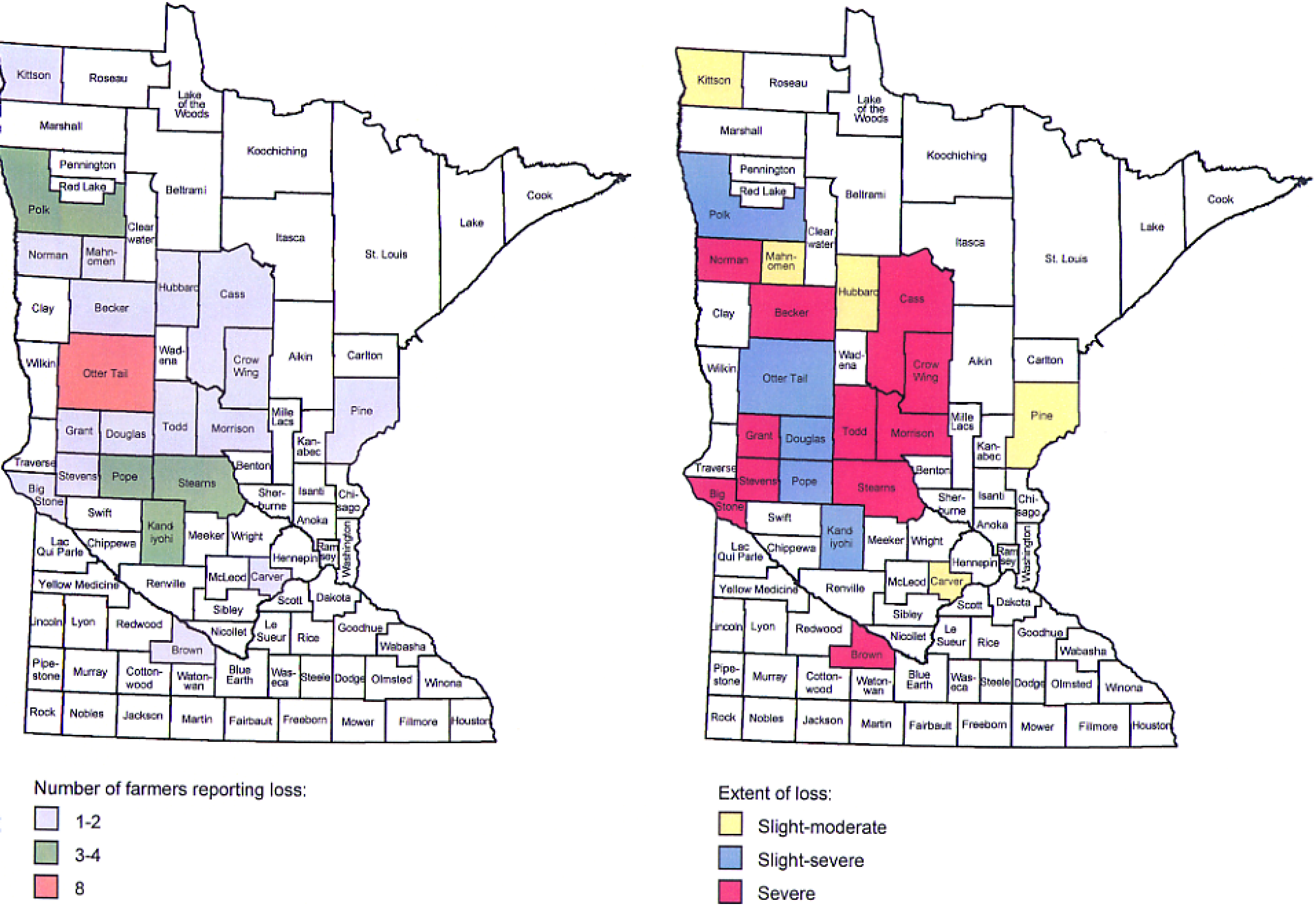


Figure 12. MN counties identified as *primary pond locations* (where majority of farmers' ponds occur) utilized by farmers reporting loss to AWPE.

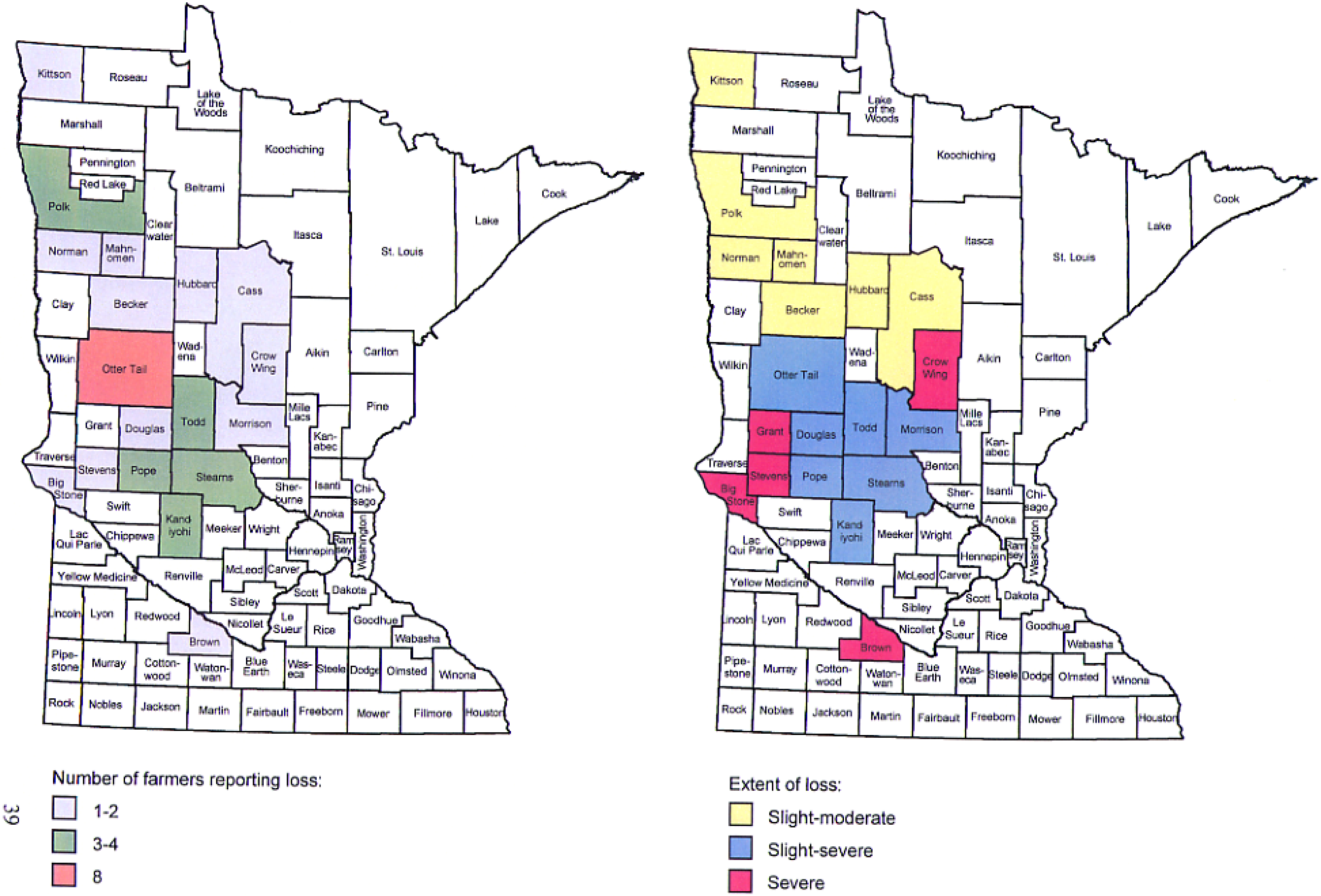


Figure 13. Severity of loss to fish eating birds experienced by sucker, shiner*, walleye and yellow perch producers.

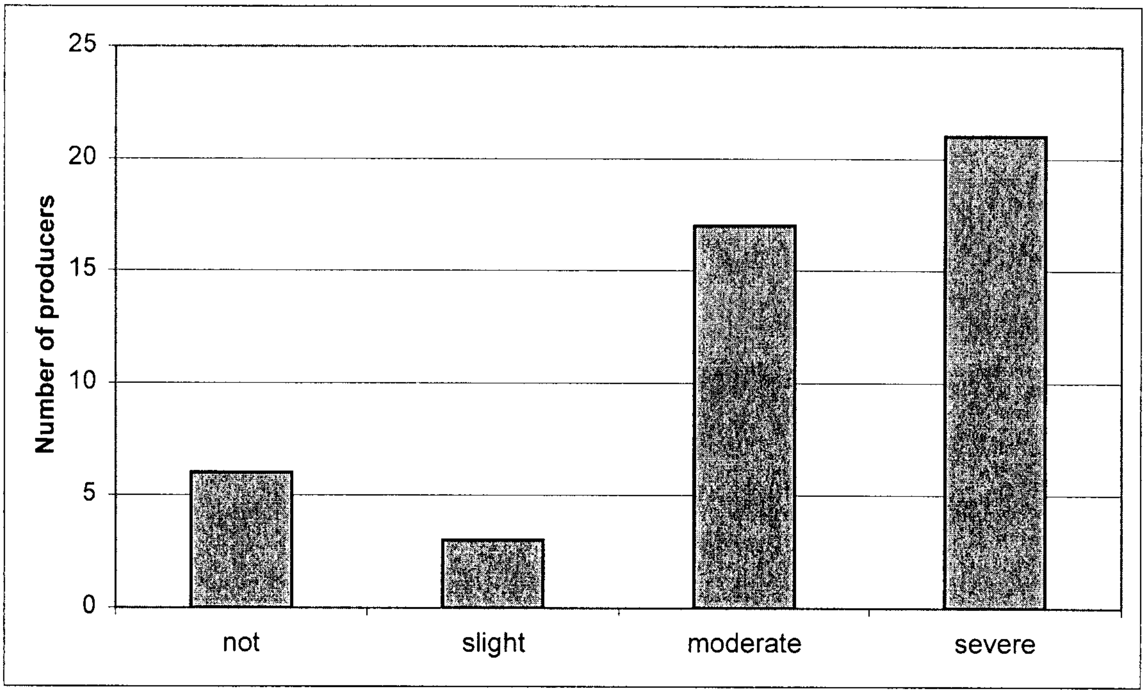
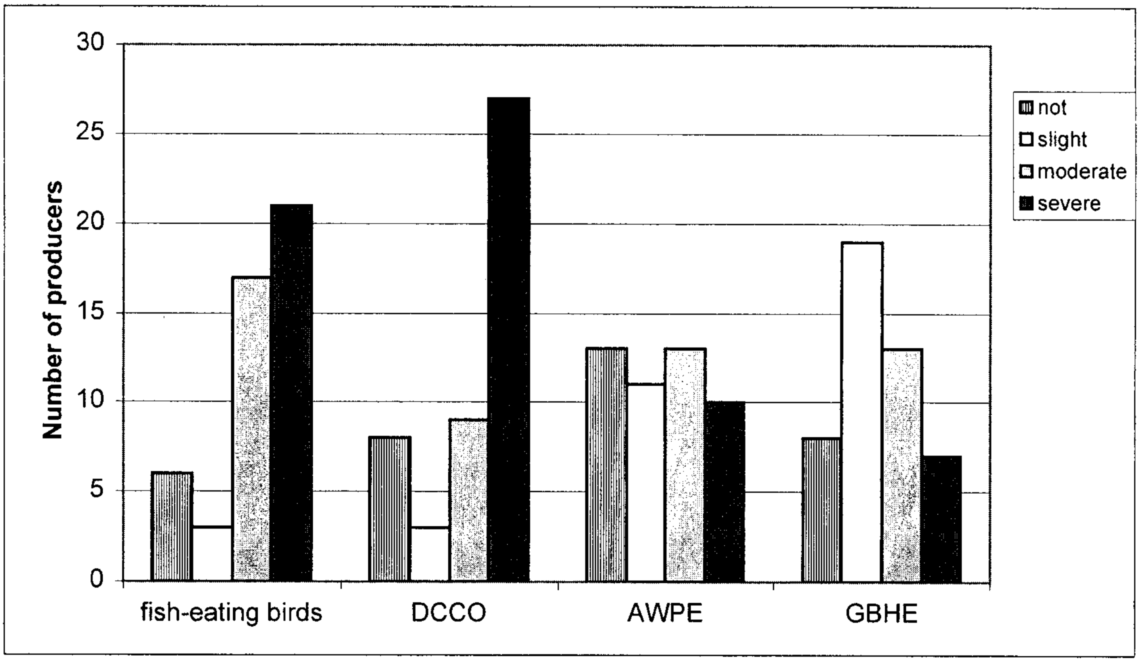


Figure 14. Severity of loss to fish-eating birds reported by sucker, shiner*, walleye and yellow perch producers.



*mostly golden shiners

Figure 15. Pond sizes used by farmers reporting severe loss to fish-eating birds.

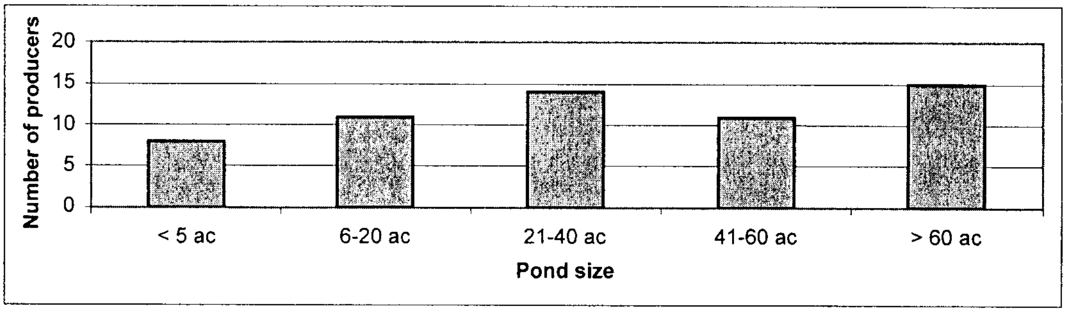


Figure 16. Numbers of ponds used by farmers reporting severe loss to fish-eating birds.

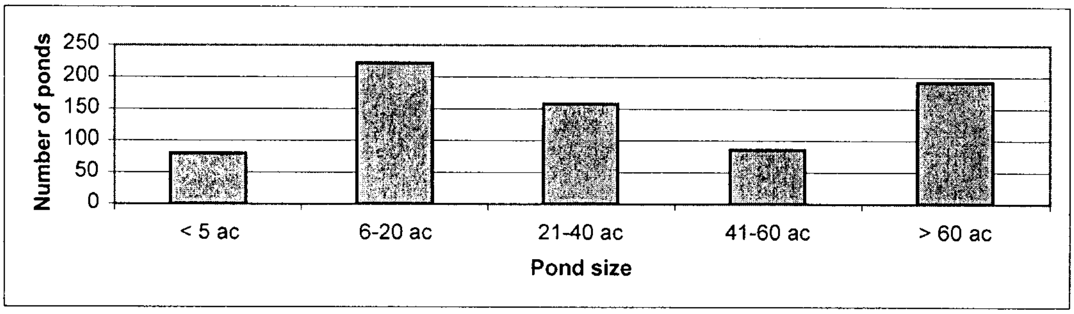


Figure 17. Pond sizes used by farmers reporting moderate loss to fish-eating birds.

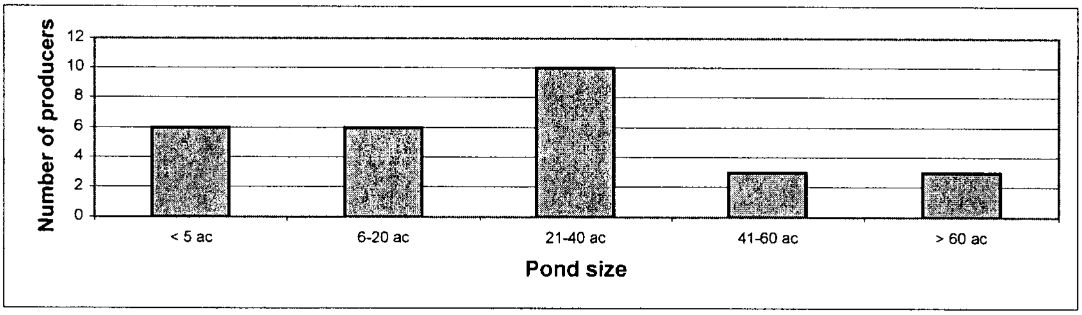


Figure 18. Number of ponds used by farmers reporting moderate loss to fish-eating birds.

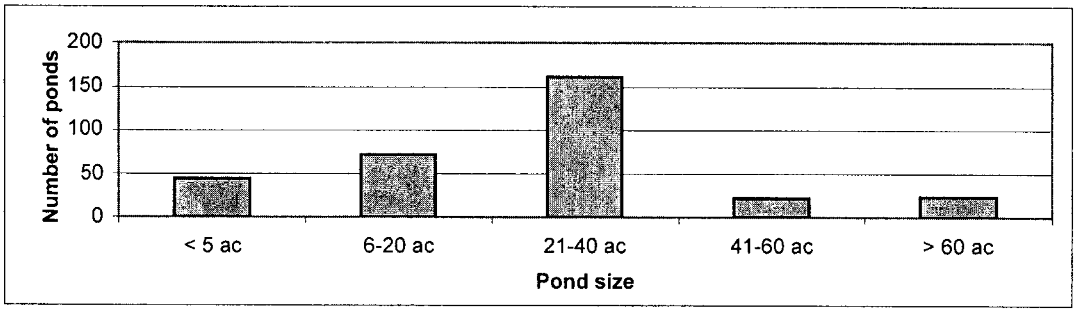


Figure 19. Sources of loss and extent each is categorized as a problem by MN fish farmers.

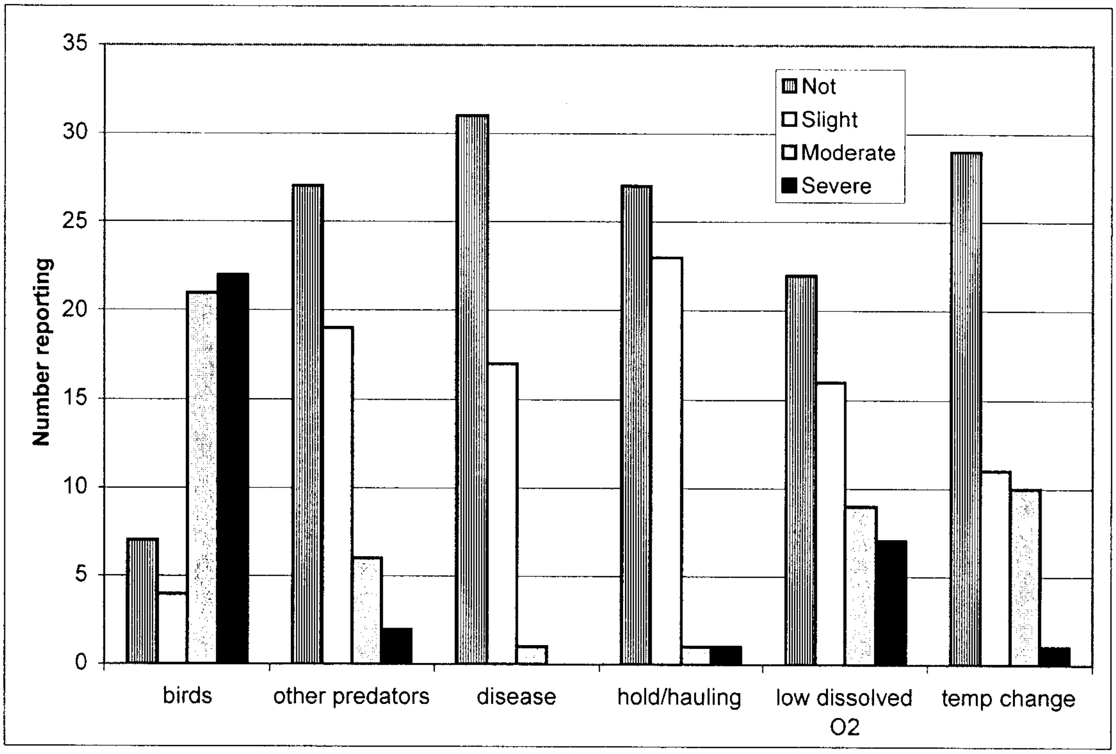


Figure 20. Months of loss to low dissolved O_2.

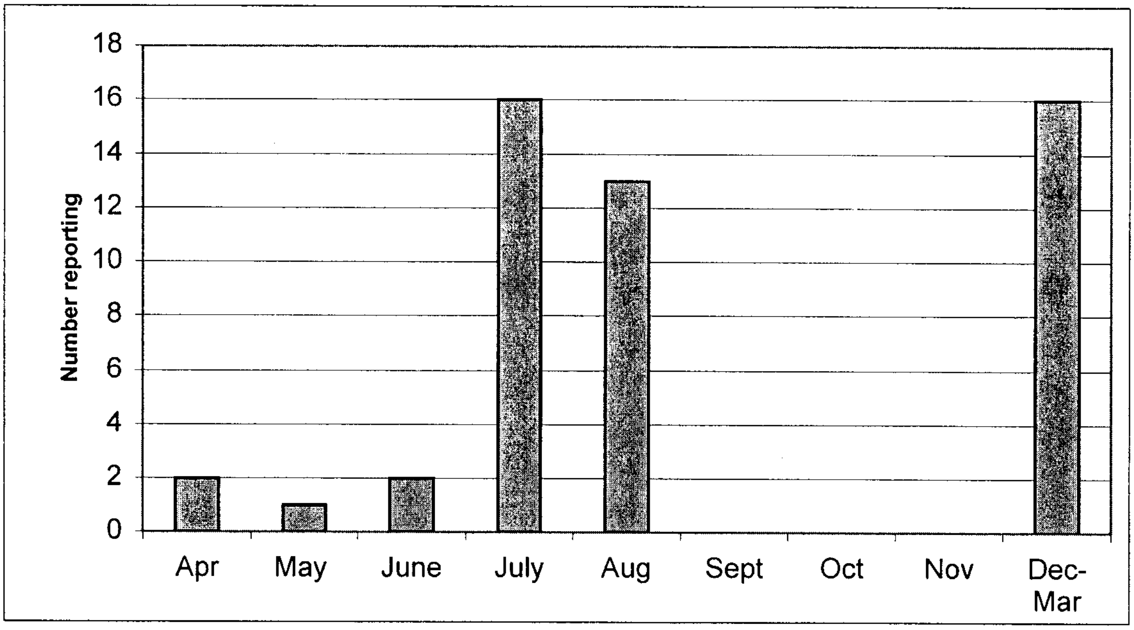


Figure 21. Effectiveness of Depredation Order in minimizing losses to DCCO.

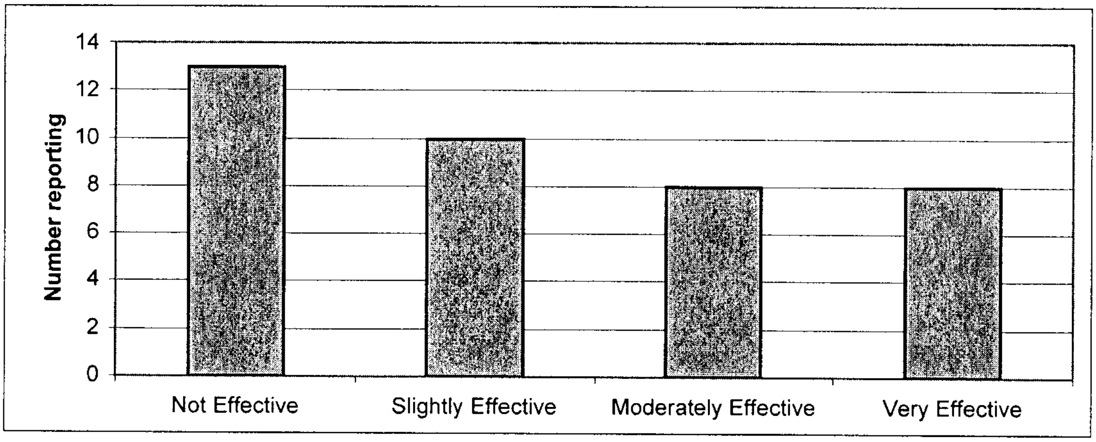


Figure 22. Estimated % of yearly earnings spent on efforts to minimize losses.

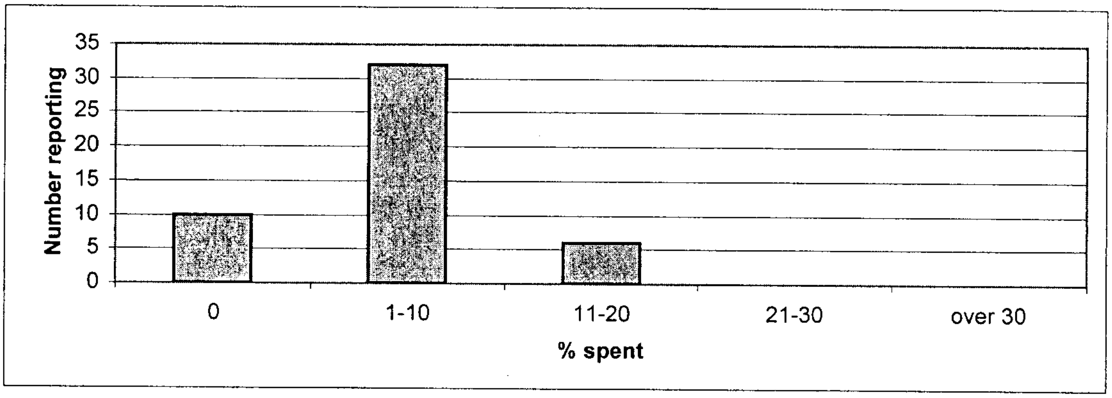


Figure 23. Percent yearly earnings producers are willing to spend to minmize loss to birds.

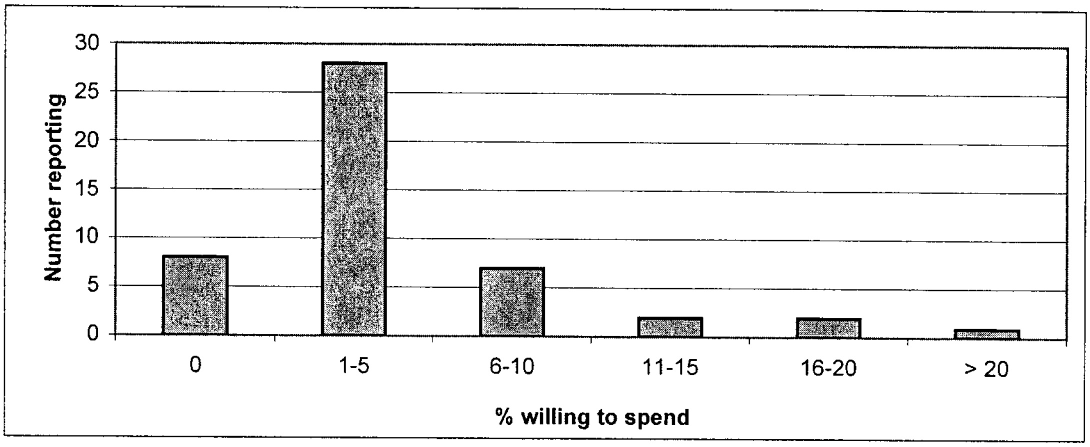


Figure 24. Acceptability of strategies to minimize losses to fish-eating birds.

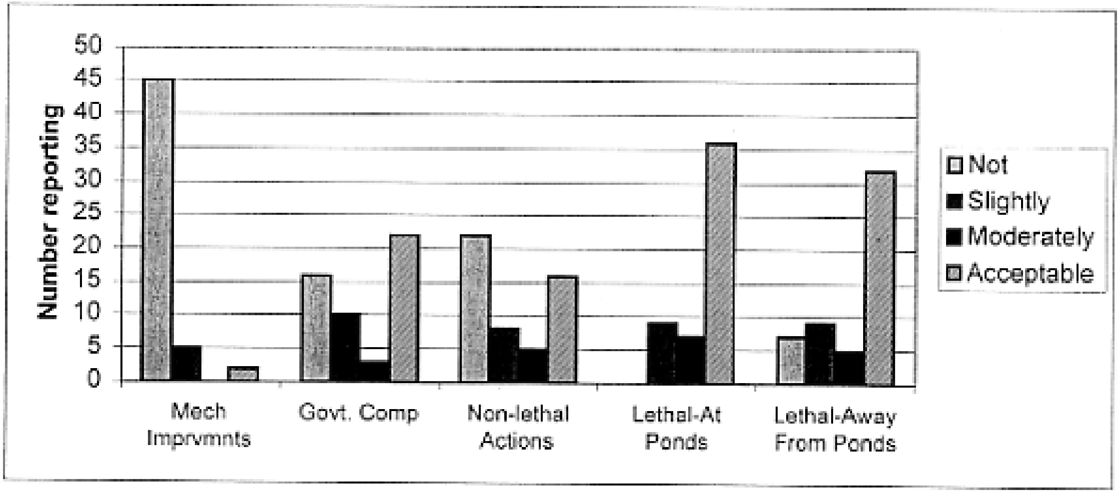
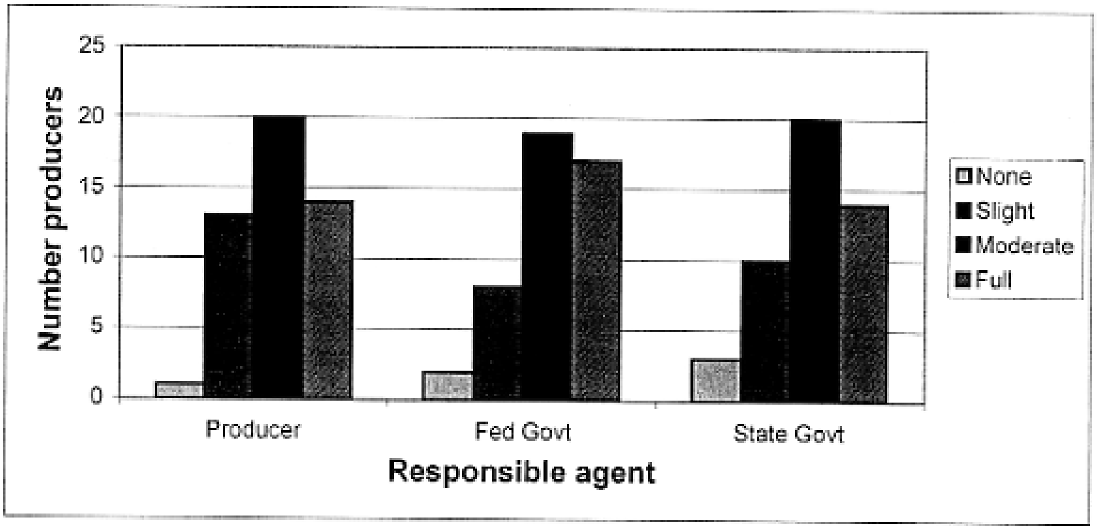


Figure 25. Responsibility for managing losses due to fish-eating birds.



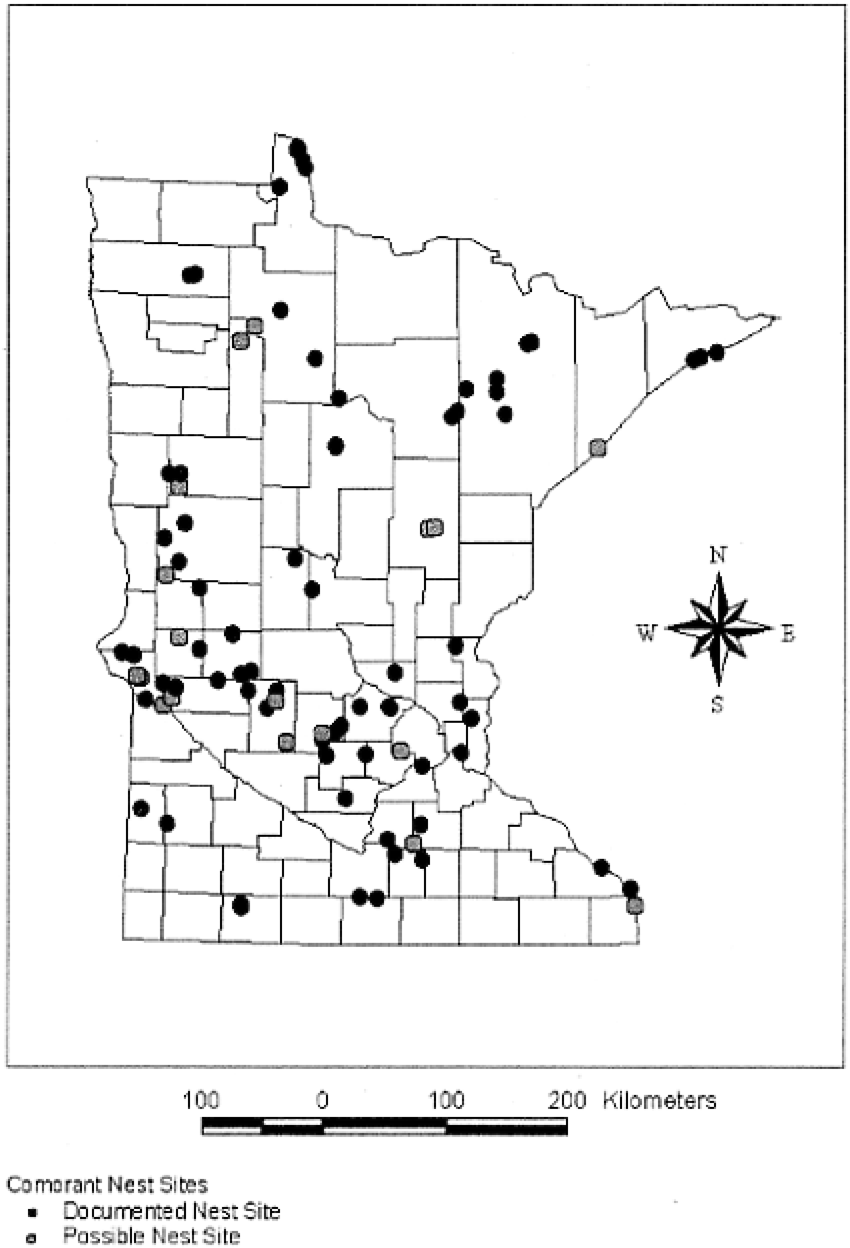


Figure 26. Location of cormorant colonies (nesting sites) during breeding season, 1977-2001.

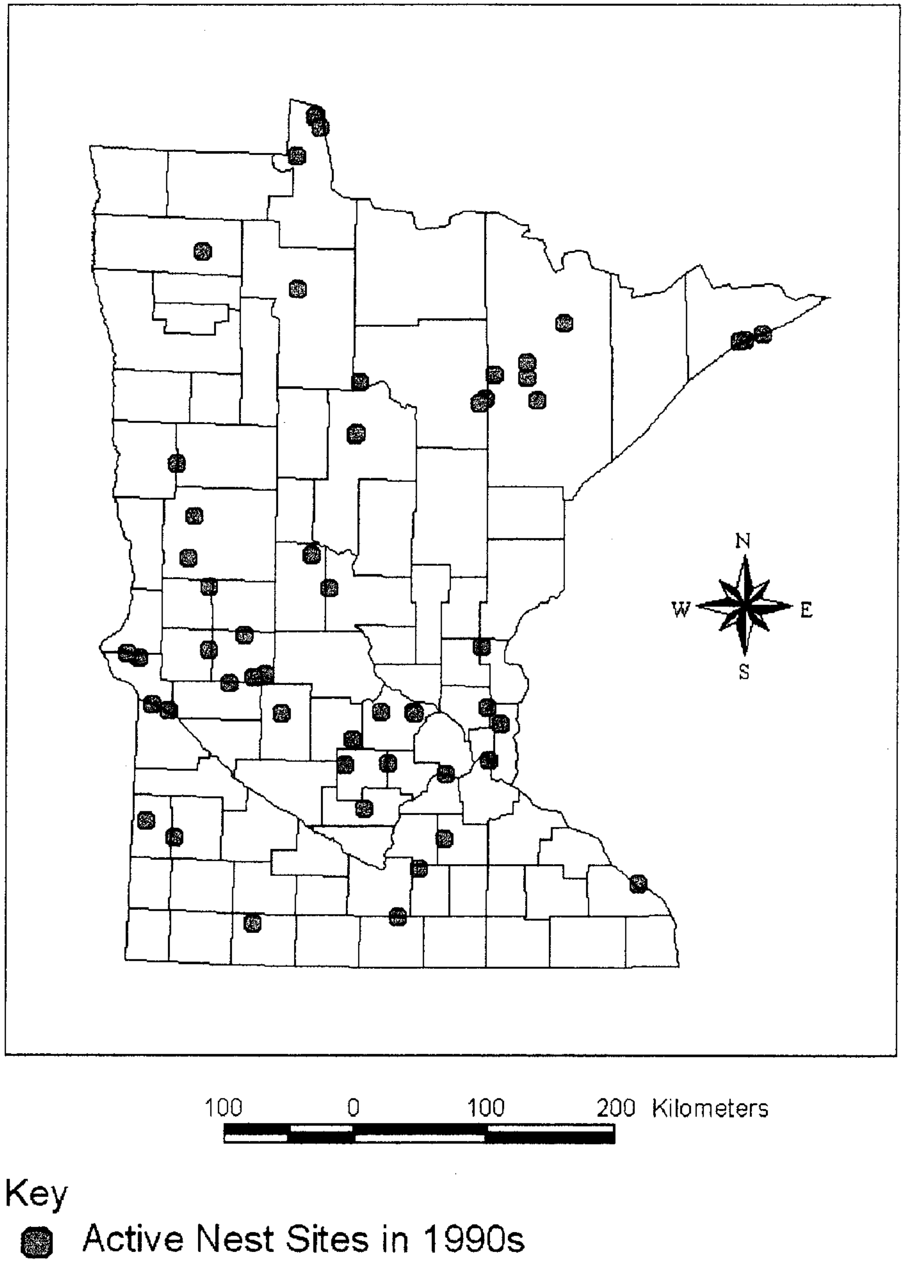


Figure 27. Active cormorant colonies (nesting sites) during 1990s.

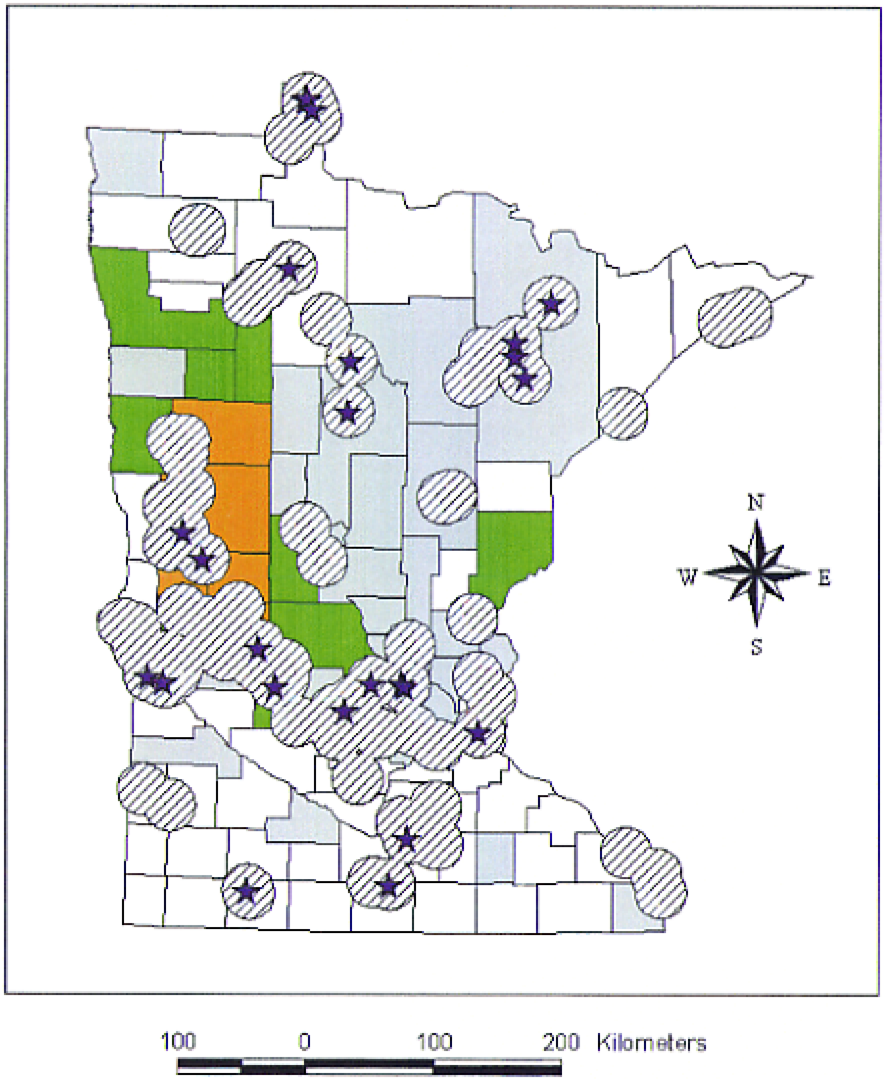


Figure 28. Cormorant nesting distribution (colonies surrounded by buffer representing presumed foraging range) in relation to fish farmer activity.

★ Important nest sites
20km Buffer around nest sites

Number of producers reporting ponds

1-3
4-6
9-12

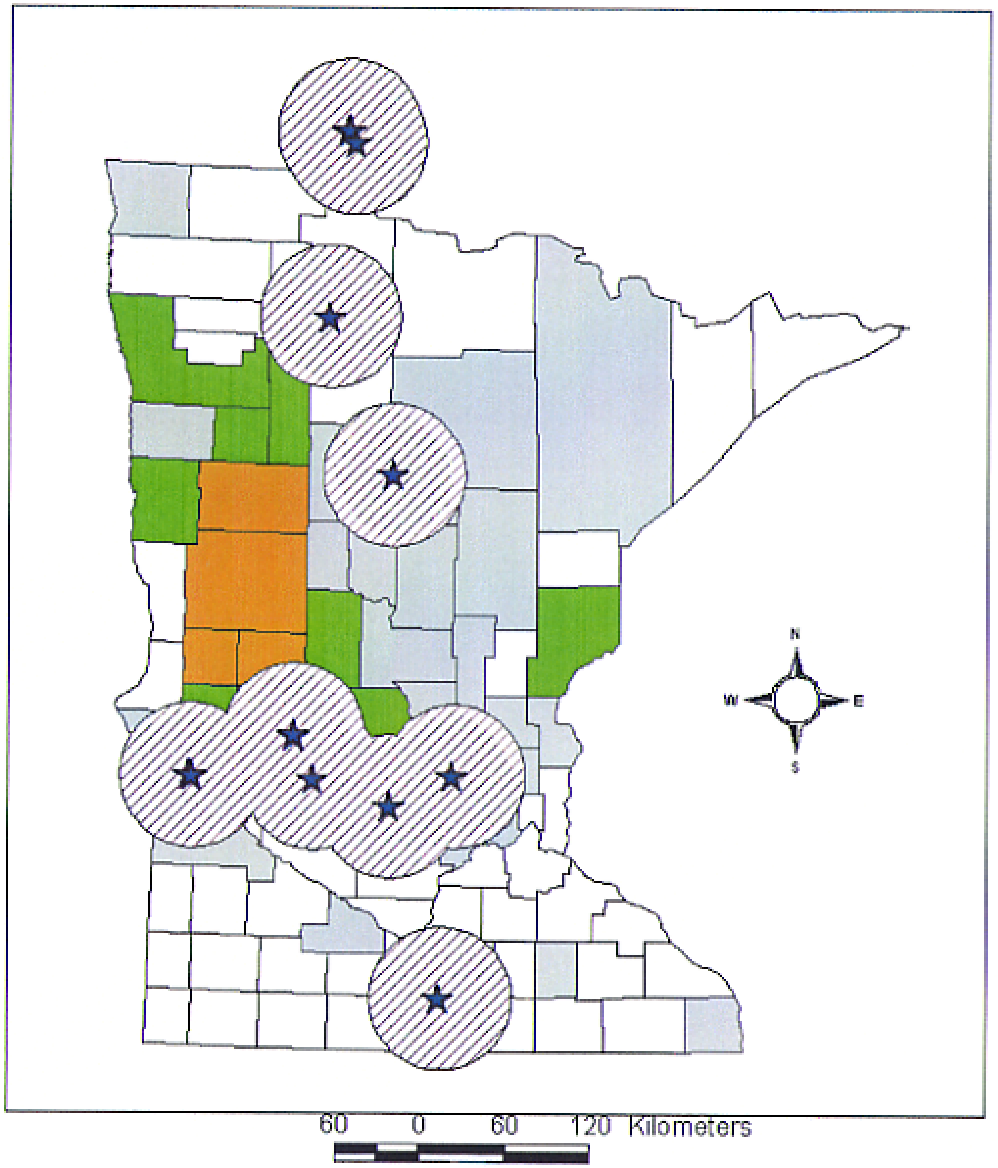
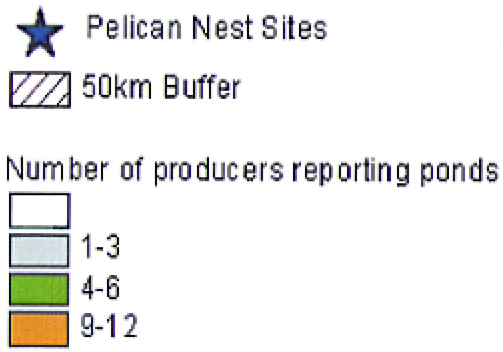


Figure 29. Pelican nesting distribution (colonies surrounded by buffer representing presumed foraging range) in relation to fish farmer activity.



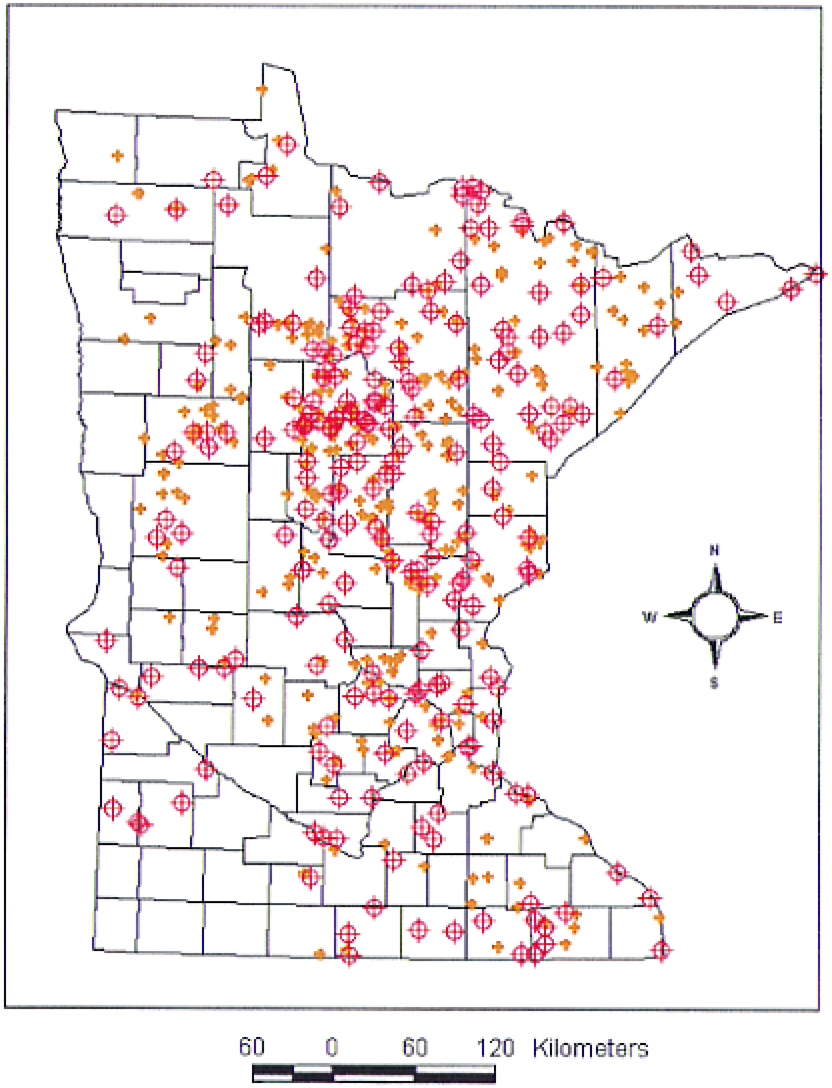


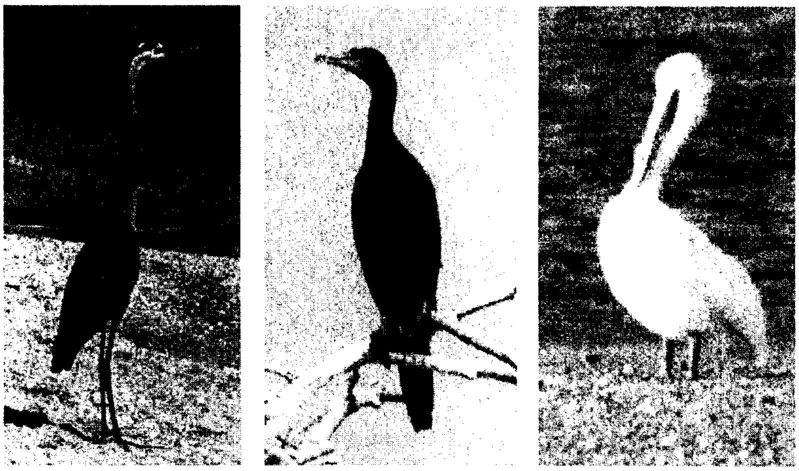
Figure 30. Great Blue Heron nesting distribution (colonies), 1977-2002.

⊕ Active heron nest site
+ Inactive heron nest site

APPENDIX 1. MINNESOTA FISH FARM–BIRD PREDATION SURVEY & LETTER

MINNESOTA FISH FARM – BIRD PREDATION SURVEY (2002)

A study to document bird predation on Minnesota fish farms



Your help on this study is greatly appreciated!

Please return your completed questionnaire in the enclosed envelope. The envelope is self-addressed and no postage is required. Thanks!

A survey conducted by the Department of Fisheries, Wildlife and Conservation Biology at the University of Minnesota

Funded by Minnesota Sea Grant

(I) Characterization of fish production operations

A) Type of fish production operation

1) In what types of fish production are you involved? (✓ all that apply):

(a) ____ Bait Fish Production (fish grown for use as bait)

____ Fathead minnow
____ White sucker
____ Golden Shiners
____ Other Shiners (emerald, spottail, common, etc.)
____ Chubs (creek, redtail)
____ Dace
____ Other – please list____________________________

(b) ____ Food Fish Production (fish grown for human consumption)

____ Bluegill sunfish
____ Brook trout
____ Rainbow trout
____ Tilapia
____ Walleye
____ Yellow perch
____ Other -- please list____________________________

(c) ____ Forage Fish Production (fish grown as forage for other cultured fish such as walleye)

____ Fathead minnow
____ Other

(d) ____ Fry or Fingerling Production

____ Walleye
____ Largemouth bass
____ Smallmouth bass
____ Crappies
____ Bluegill sunfish
____ Muskellunge
____ Northern pike
____ Yellow perch
____ Rainbow trout
____ Brook trout
____ Brown trout
____ Other -- please list____________________________

(e) ____ Other type of fish production – Please describe

____

2) Please estimate % of total production contributed to your fish farm by each of the following:
   1) ____% Bait Fish Production
   2) ____% Food Fish Production
   3) ____% Fry or Fingerling Production
   4) ____% Other Production – Describe ____________________
   ----
   100 % Total

3) What proportion of your personal income is derived from your aquaculture operation:
   (a) ____ ≥ 50%
   (b) ____ < 50%

B) Pond types, sizes, stocking densities and distribution

In this section we ask questions on stocking densities because studies done on catfish losses show that stocking density affects likelihood and severity of bird predation. These data will help describe characteristics at ponds of varying appeal to fish-eating birds, increase our understanding of factors driving interactions between birds and ponds, and help us evaluate management options.

4) Please list the number of NATURAL ponds or lakes you use in each of the following size ranges.
- (a) ____ ≤ 5 acres
- (b) ____ 6 – 20 acres
- (c) ____ 21 – 40 acres
- (d) ____ 41 – 60 acres
- (e) ____ > 60 acres
- (f) ____ can't answer…skip to question 5

5) *If you could not answer question 4,* please provide:
- (b) number of NATURAL ponds used _______
- (c) average size in acres of NATURAL ponds/lakes used ________.

6) Please list the number of MAN-MADE ponds/ lakes you use in each of the following size ranges
- (a) ____ ≤ 1 acre
- (b) ____ 2 – 4 acres
- (c) ____ 5 – 7 acres
- (d) ____ 8 – 10 acres
- *(f)* ____ > 10 acres
- *(g)* ____can't answer…skip to question 7

7) *If you could not answer question 6,* please provide:
- a) Number of MAN-MADE ponds used_________
- b) Average size in acres of MAN-MADE ponds/lakes used ______.

8) In a typical year, how many ponds do you stock with:
- (a) fry____
- (b) fingerlings____
- (c) adults_____

9) Please list each species (top 4) and the average number of each stage you stock per acre:

Species stocked	**# fry / acre**	**# fingerlings / acre**	**# adults / acre**

10) Which factor most strongly influences your decisions for stocking densities? (check one)

_____Pond Acreage
_____Feed levels at time of planting
_____Water and pond conditions (i.e., water depth relation to b water depth prior year; farming practices planned around pond; product left in lake from previous year).
_____Other (please be specific)___________________________

11) Please list the counties where your ponds are located and put a ✓ next to the counties where the majority of your ponds are located.

(II)Problem scale – the extent of problems with fish-eating birds relative to other sources of loss.

***A) Losses due to bird predation* (Please check one box)**

1) Have you experienced losses due to fish-eating birds?
- ☐ yes
- ☐ no

2) To what extent do you categorize losses to fish-eating birds as a problem?
- ☐ not at all
- ☐ slight
- ☐ moderate
- ☐ severe

3) Do you experience losses due to bird predation each year?
- ☐ yes
- ☐ no

4) If you answered yes to question 2, are the losses you experience:
- ☐ at the same ponds each year
- ☐ at different ponds each year

5) Which months of the year do you experience losses to bird predation? (check all that apply)

☐April	☐ Aug
☐May	☐Sept.
☐June	☐Oct.
☐July	☐Nov.

6) When do the greatest concentrations of fish-eating birds occur on your ponds? (check all that apply)

☐April	☐ Aug
☐May	☐Sept.
☐June	☐Oct.
☐July	☐Nov.

7) At what time do you experience greatest losses from bird predation? (check all that apply)

☐April	☐ Aug.
☐May	☐Sept.
☐June	☐Oct.
☐July	☐Nov.

8) To what extent do you feel the following fish-eating bird species are problems for your business?

(a) *Double-crested Cormorant*:

- ☐ not at all
- ☐ slight
- ☐ moderate
- ☐ severe

(b) *American White Pelican*:

- ☐ not at all
- ☐ slight
- ☐ moderate
- ☐ severe

(c) *Great Blue Heron*:

- ☐ not at all
- ☐ slight
- ☐ moderate
- ☐ severe

(d) *Other*:

Please list species ___________________

- ☐ slight
- ☐ moderate
- ☐ severe

9) Are you aware of any large breeding colonies, night or day roosts, or bird refuges within 5 miles of your ponds (large = several hundred birds)?

- ☐ yes
- ☐ no

B. Losses to other sources

The impact of bird predation within the context of other mortality factors helps document the scale of the problem caused by birds. Additionally mortality factors may be related. For instance, at ponds in the southern U.S. where catfish farmers are having problems disease, there appear to be more birds present.

10) To what extent do you categorize loss to predators other than birds as a problem?

- ☐ not at all
- ☐ slight
- ☐ moderate
- ☐ severe

11) To what extent do you categorize loss to disease as a problem?

- ☐ not at all
- ☐ slight
- ☐ moderate
- ☐ severe

12) To what extent do you categorize loss to hauling/ holding stress as a problem?

- ☐ not at all
- ☐ slight
- ☐ moderate
- ☐ severe

13) To what extent do you categorize loss to low dissolved oxygen in ponds/lakes as a problem?

- ☐ not at all
- ☐ slight
- ☐ moderate
- ☐ severe

14) To what extent do you categorize loss to fluctuating temperature in ponds/lakes as a problem?

- ☐ not at all
- ☐ slight
- ☐ moderate
- ☐ severe

15) At what time do you experience the greatest losses from:
(✓ all that apply)

(a) *Predators other than birds:*

☐April	☐Aug.
☐May	☐Sept.
☐June	☐Oct.
☐July	☐Nov.

☐Other months ______________________

(b) *Disease:*

☐April	☐
☐May	☐
☐June	☐
☐July	☐

☐Other months ______________________

(c) *Hauling and holding stress:*

☐April	☐Aug.
☐May	☐ Sept.
☐June	☐ Oct.
☐July	☐ Nov.

☐Other months ______________________

(d) *Low dissolved oxygen in ponds/lakes:*

☐April	☐Aug.
☐May	☐Sept.
☐June	☐Oct.
☐July	☐Nov.

☐Other months ______________________

(e) *Fluctuating temperatures*:

☐April ☐Aug.
☐May ☐Sept.
☐June ☐Oct.
☐July ☐Nov.
☐Other months ______________________________

16) Can you estimate approximate % loss you experience yearly to each of the following? (Please provide % loss for each factor.)
- (a) ____ % lost to fish-eating birds
- (b) ____ % lost to predators other than birds
- (c) ____ % lost to hauling and holding stress
- (d) ____ % lost to disease
- (e) ____ % lost to low dissolved oxygen in ponds/lakes
- (f) ____ % lost due to water temperature change

17) What is the maximum % you could lose to fish-eating birds as an acceptable cost of doing business? (Please ✓ one.)
- (a) ☐ 0
- (b) ☐ 1 – 5%
- (c) ☐ 6 –10%
- (d) ☐ 11 – 20%
- (e) ☐ 21 – 30%
- (f) ☐ Other (please fill in amount) __________%

(III) Effectiveness and acceptability of management practices

1) In the table below, please place a ✓in front of all strategies you have employed to minimize losses to bird predation. Rate effectiveness (0 = Not effective; 1 = Slightly effective; 2 = Moderately effective; 3 = Very effective) and costliness (1 = Minimal; 2 = Moderately expensive; 3 = Cost prohibitive) of each strategy based on your experience or knowledge of the method. If you are unfamiliar with the method do not rate.

		Not Effective		Very Effective			Costliness		
	Exclusion devices: physical/functional barriers	0	1	2	3		1	2	3
	Netting								
	Overhead wires								
	Floating ropes								
	Other Flight Inhibitors								
	Underwater exclusion devices								
	Non-lethal harassment at facilities								
	Human harassment with pyrotechnics								
	Simulated human harassment (scarecrows, noisemakers, cannons)								
	Other harassment (distress calls, sirens, electronically generated noises; reflectors; eyespot balloons, raptor silhouettes)								
	Alteration of aquaculture practices								
	Decrease fish densities								
	Pond dyes								
	Water turbulence								
	Alter stocking practices								
	Lethal control at facilities								
	Shooting to reinforce non-lethal harassment								
	Shooting by itself to kill individuals (not as reinforcement for non-lethal harassment)								
	Other (please describe):								

2) Of the strategies listed in the above table, please list those you currently employ to minimize losses to birds.

3) In 1998, the US Fish and Wildlife Service established a depredation order to allow those engaged in commercial aquaculture to shoot cormorants without a federal permit at freshwater aquaculture premises in 13 states, including Minnesota. How effective do you feel this order has been at helping you to reduce losses to cormorants at your ponds?

- ☐ not at all
- ☐ slightly effective
- ☐ moderately effective
- ☐ very effective

4) Please estimate % of yearly earnings spent on efforts to minimize losses to bird predation.
- ☐ 0
- ☐ 1 - 10%
- ☐ 11 – 20%
- ☐ 21 – 30%
- ☐ over 30%

5) What % of yearly earnings are you willing to spend on efforts to minimize losses to bird predation:
- ☐ 0
- ☐ 1 – 5%
- ☐ 6 – 10%
- ☐ 11 – 15%
- ☐ 16 – 20%
- ☐ over 20%.

6) Which do you consider the most acceptable strategies for minimizing losses? (Please check one box for each strategy below)

a) Reduce losses through mechanical farm / pond improvements (e.g., netting, ropes, wires)
- ☐ not acceptable
- ☐ slightly acceptable
- ☐ moderately acceptable
- ☐ acceptable

b) Reduce losses through government compensation
- ☐ not acceptable
- ☐ slightly acceptable
- ☐ moderately acceptable
- ☐ acceptable

c) Reduce losses through non-lethal actions aimed at dispersing birds
- ☐ not acceptable
- ☐ slightly acceptable
- ☐ moderately acceptable
- ☐ acceptable

d) Reduce losses through lethal control of birds at ponds

- ☐ not acceptable
- ☐ slightly acceptable
- ☐ moderately acceptable
- ☐ acceptable

e) Reduce losses through lethal control of birds away from ponds

- ☐ not acceptable
- ☐ slightly acceptable
- ☐ moderately acceptable
- ☐ acceptable

7) place a ✓ to indicate the extent of responsibility you feel individual producers and government agencies have for managing losses due to birds.

Producers / Agencies	**Amount of Responsability**			
	None	**Slight**	**Moderate**	**Full**
Private fish farmer				
Federal Government[1]				
State Government[2]				

[1]US Fish and Wildlife Service, USDA / Wildlife Services
[2]MN Department Natural Resources

THANK YOU!

May we contact you for additional information?

☐ yes ☐ no

Name: ______________________________

Phone (   ) ________________________

Address: ____________________________

City: ________________________________

State: _______________________________

Zip code: ____________________________

This information will be used only for future contact; all information supplied in survey is confidential

Aug 22, 2002

To: Minnesota Fish Producer

From: Linda Wires
Francesca Cuthbert
David Fulton

Subject: Survey to determine bird caused fish losses in MN fish ponds

We are a group of researchers at the University of Minnesota in the Department of Fisheries, Wildlife and Conservation Biology who have developed the project: **Fish-eating bird predation at aquaculture facilities in Minnesota: bridging the information gap.** The goal of this project is to integrate information on the biology of fish-eating birds (especially cormorants, pelicans and herons) in MN with information on fish farm operations as a first step towards reducing losses at fish farms caused by fish-eating bird predation. This project is important because even though fish farmers report large losses due to bird predation, little effort has been made to understand the conflict between fish-eating birds and fish farms in this state. Therefore, we are writing to ask for your help.

In the first part of our project, funded by a grant from MN Sea Grant, we have three objectives:

1) Characterize fish production operations in Minnesota
2) Document scale of problems MN fish farmers experience with fish-eating birds
3) Obtain your opinion on effectiveness of management practices aimed at reducing losses.

To accomplish these objectives, we have developed the enclosed fish farmer survey, which has been sent to all licensed aquaculturalists in the state. Response to the survey is voluntary and confidential. A final report submitted to MN Sea Grant will summarize the information, and be available to the public and wildlife managers. No individual producers or farms will be identified, but we will include a map showing counties with farming operations. Later, you may be contacted to provide (voluntarily) more information on your operation and / or problems you've experienced with fish-eating birds.

Your participation in the survey is extremely important to accurately document problems and develop appropriate management strategies. Without these data it will not be possible to make good management decisions and develop practices to reduce or eliminate losses to birds. Please complete the survey to the best of your ability and send it back to us in the enclosed self-addressed envelope as soon as possible. We will distribute a fact sheet and our recommendations for management strategies in Fall 2002.

APPENDIX 2: ADDITIONAL SURVEY DATA

Section 1: Characterization of fish production operations

Fish farm production types. Fifty recipients provided information on the type of fish production they engaged in (Figure i). Producers frequently raised a variety of fish species for an average of 1.46 industries (e.g., baitfish, food fish, fry and fingerling fish). The most common combined production types were baitfish and fry and fingerling production (47% of combined businesses were these two types; 68% of all combinations included these two types). Baitfish production accounted for 80% or more of fish production for the majority of producers (62%). White suckers and shiners (golden and other species) were the main species produced by baitfish producers (Figure ii). Production of fry and fingerling fish for stocking in sport fish lakes accounted for 70% or more of the businesses of 26% of producers. Production of food fish often occurred in conjunction with another fish production type; only 10% of producers identified this production type as accounting for 50% or more of their businesses. With the exception of bullheads, all species produced by food fish producers were also produced by baitfish producers. Walleye, sunfish species and yellow perch were the most commonly produced species by producers who identified food fish or fry and fingerling fish production as their primary production (Figure iii(a)), and by producers overall for sale in these industries (Figure iii(b)).

Personal Income. Forty-eight (89%) recipients provided information on percent of personal income provided by their fish production business. For the majority of producers (74%), their fish production business provided >50% of their annual income.

Pond types. Fifty-three recipients (98%) provided information on pond type utilized (natural and/or artificial) (Figure iv). Producers used many more natural than artificial ponds (Figure v). Of those using natural or a combination of natural and artificial ponds, 88% provided information on the number of natural ponds they used; on average producers each used 33.3 natural ponds. By contrast, 91% of producers using artificial or a combination of natural and artificial ponds provided information on the number of artificial ponds they used; on average these producers each used 6.4 artificial ponds. Of the 21 producers using only natural ponds, 90% provided information on the type of production for which they raised fish. With the exception of one producer, aquaculturalists using only natural ponds were exclusively or almost exclusively baitfish producers. Conversely, only one individual producer using all artificial ponds reported baitfish production as the main focus of his business. Producers using only artificial ponds more frequently produced food fish and or and fry and fingerling fish.

Pond sizes. Fish producers reported they use natural ponds in 5 size categories; the greatest number of ponds was in the 21-40 acre and 6-20 acre size categories (Figure vi). Artificial ponds were reported in 5 size categories; nearly 90% were in the ≤1-acre category (Figure vii).

Fish species stocked. Forty-six producers (85%) reported stocking 11 species or groups of species in ponds. The most commonly stocked species was white sucker, reported by 59% of producers, followed by walleye, reported by 35% of producers (Figure viii).

Life stage and number of ponds stocked. Forty-nine producers reported the number of ponds and the life stages they stocked. Most producers (86%) reported stocking fry (Figure ix). Producers stocking fry stocked on average 18 ponds; those stocking fingerlings stocked on average 6 ponds while those stocking adults stocked on average 4 ponds (Figure x).

Stocking densities. We obtained limited information on stocking densities. For white suckers, the most commonly stocked species, only seven producers (26% of those stocking this species) provided information on the numbers they stocked. The average number of white sucker fry stocked reported by these producers was 49,500/acre; the range per acre was 8,000–120,000 fish. For walleye, 13 producers (81% of those stocking this species) provided information on the numbers they stocked. The average number of walleye fry stocked reported by these producers was 19,000/acre; the range per acre was 2,500–80,000 fish. Too few data were obtained to summarize for other life stages or species. Water and pond condition was the factor most frequently identified as influencing stocking decisions (Figure xi).

Section 2. Loss to fish-eating birds

Producers experience loss to several fish-eating bird species. Producers experiencing loss to fish-eating birds usually had problems with more than one avian species. The average number of avian species reported to cause loss was three; 22% of producers reported loss due to four or more species. The most common triple association reported at ponds was AWPE, DCCO and GBHE (57%). Cormorants and pelicans were the most frequently reported pair; of the 49 respondents reporting losses, 67% were experiencing some degree of loss to both these species together. Losses to pelicans were almost always reported in combination with losses to cormorants (94%); only 6% of producers reporting loss to pelicans were not experiencing loss to cormorants. While GBHE were often reported with these species, they were reported with other species (e.g., kingfishers, egrets) more frequently than were cormorants and pelicans.

Nearby large associations of fish eating birds. Forty-one percent of producers had knowledge of nearby (≤5 miles or 8 km) large breeding colonies (several hundred birds), night or day roosts, and or refuges, while 49% had no knowledge of large associations.

Frequency of loss to birds. Forty-nine producers reported on frequency of loss to fish-eating birds: 96% reported yearly losses.

Specific and/or general pond loss to birds. Forty-seven producers stated whether loss occurred at the same or at different ponds: 49% reported loss occurred at the same ponds each year, 30% reported loss at different ponds, and 21% reported that loss occurred in both categories.

Figure i. Number of producers in each production type.

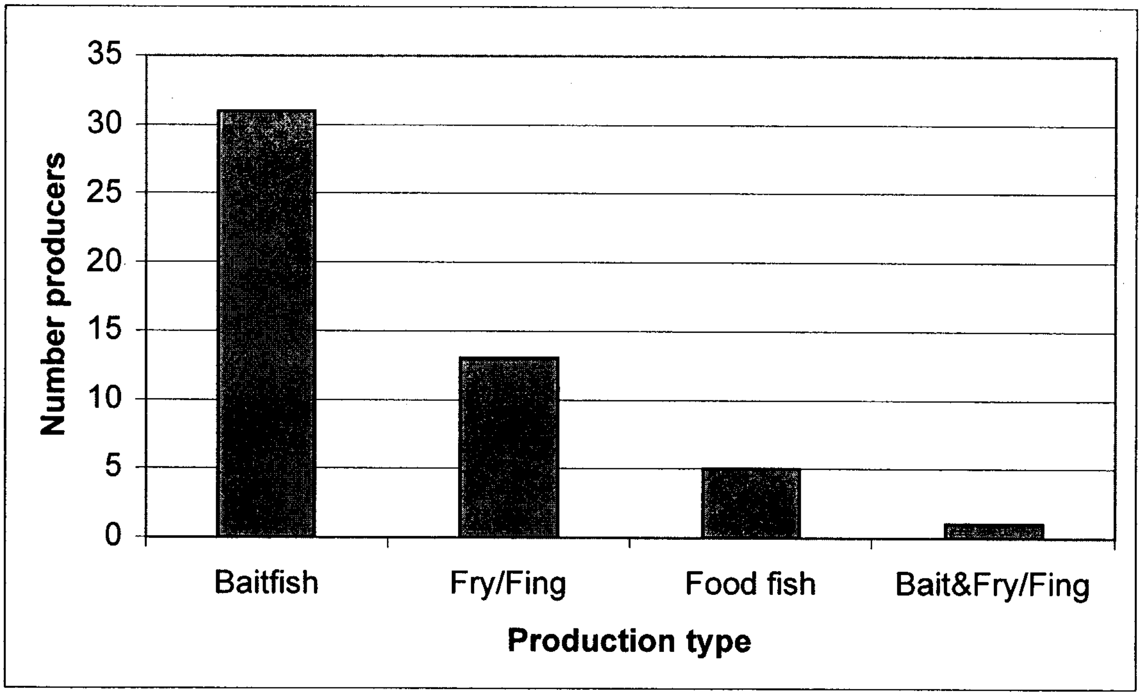


Figure ii. Fish species produced by baitfish farmers.

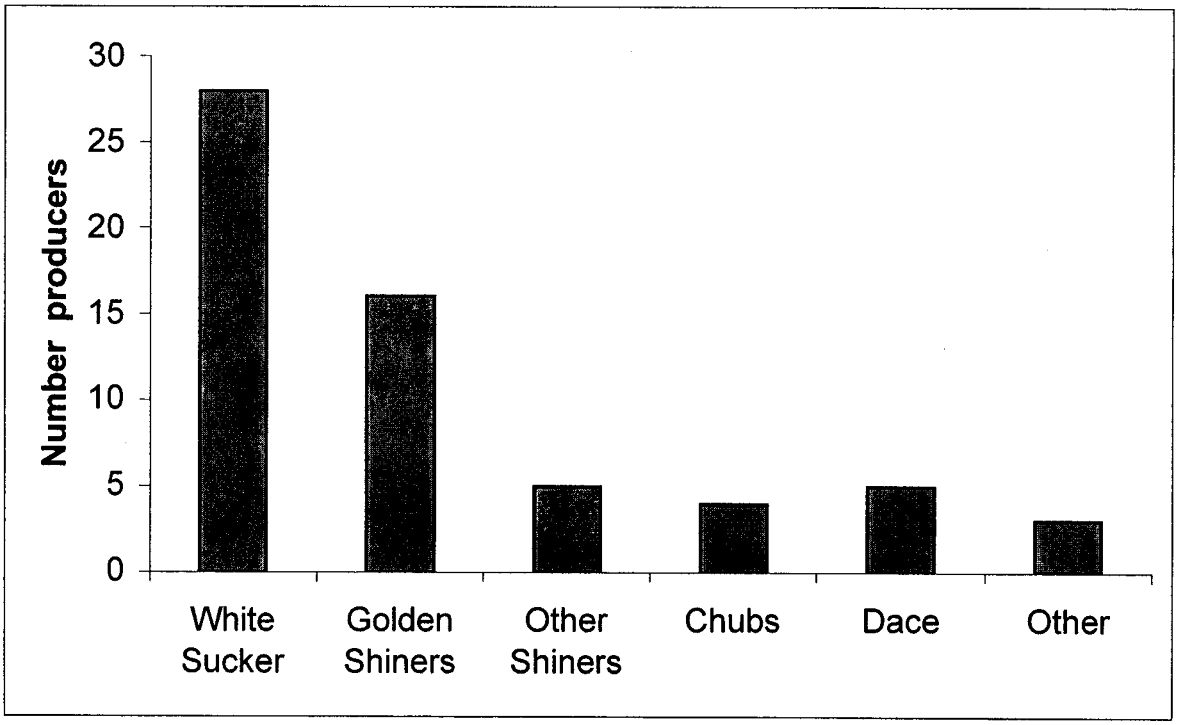


Figure iii(a). Fish species produced by food fish and fry and fingerling producers.

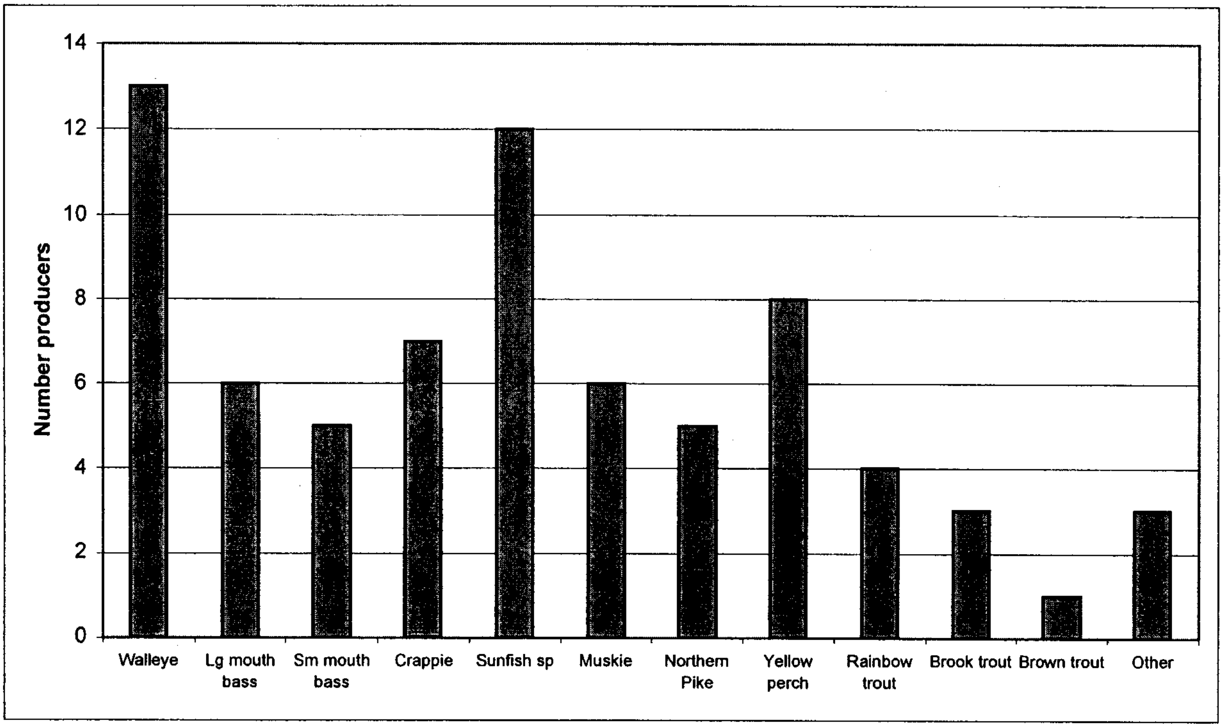


Figure iii(b). Fish species produced for sale in food and fingerling industries.

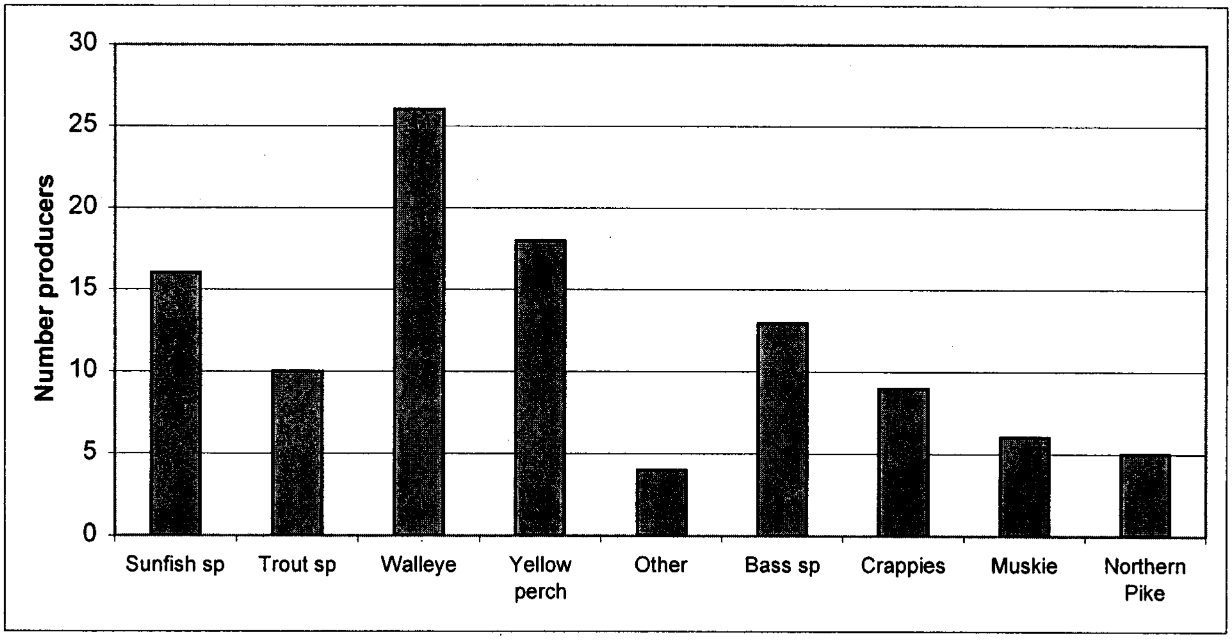


Figure iv. Pond types used by fish farmers.

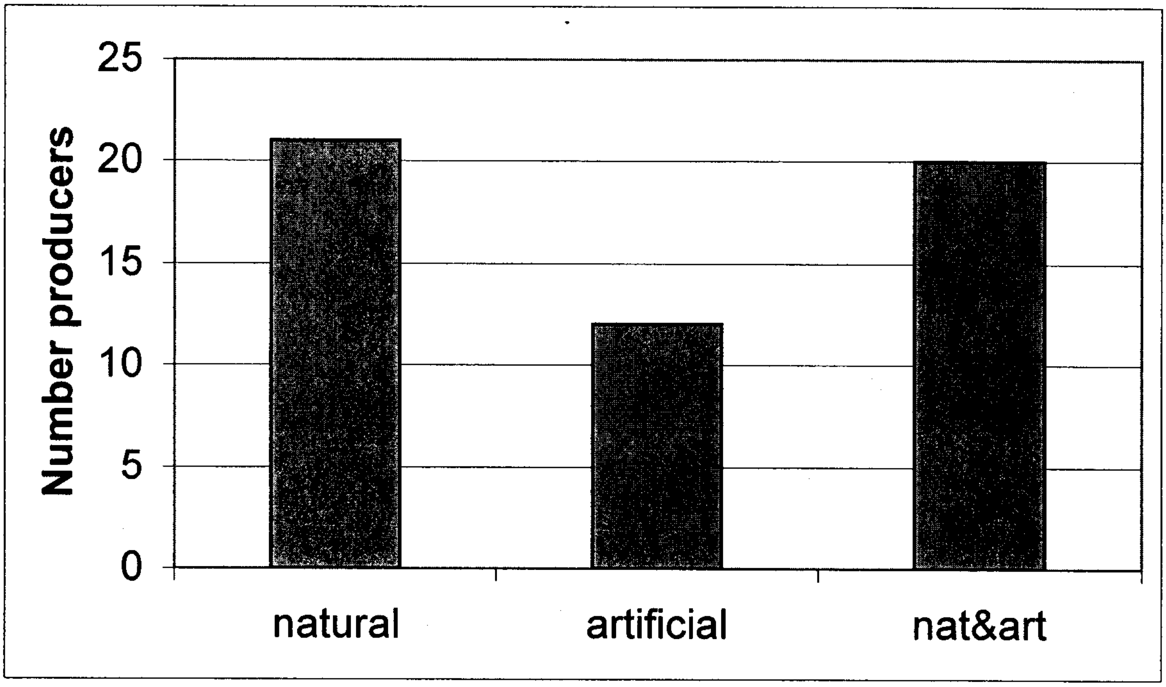


Figure v. Average number of each pond type used by fish farmers.

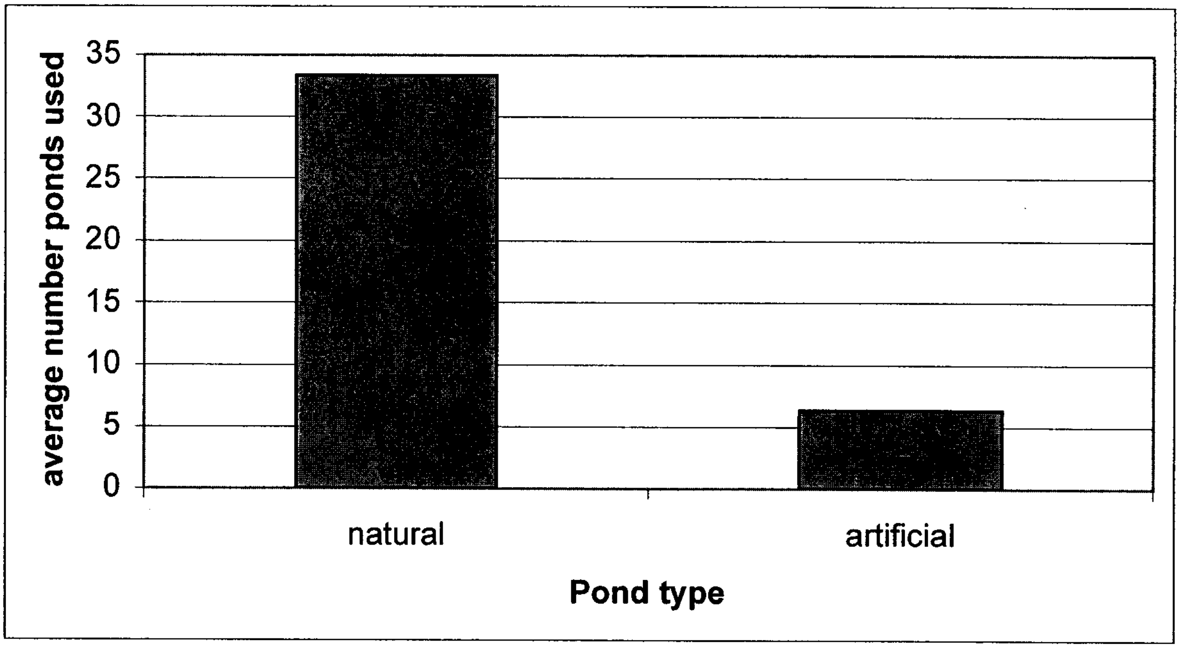


Figure vi. Size of natural ponds used.

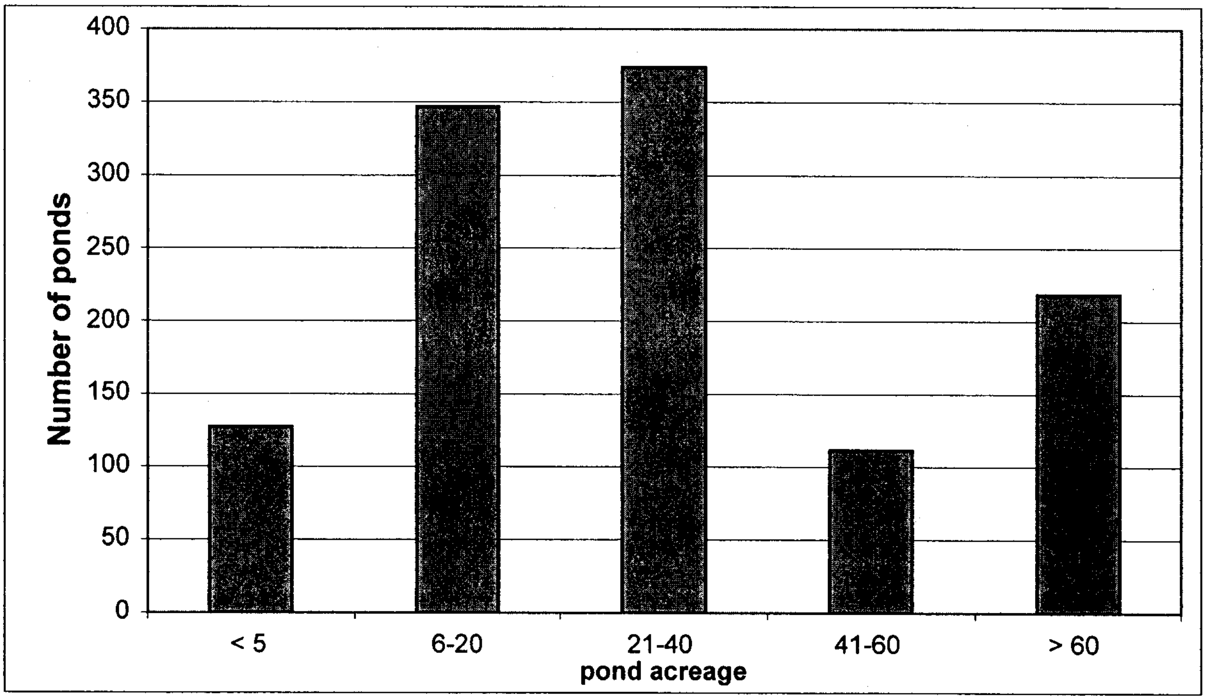


Figure vii. Size of artificial ponds used.

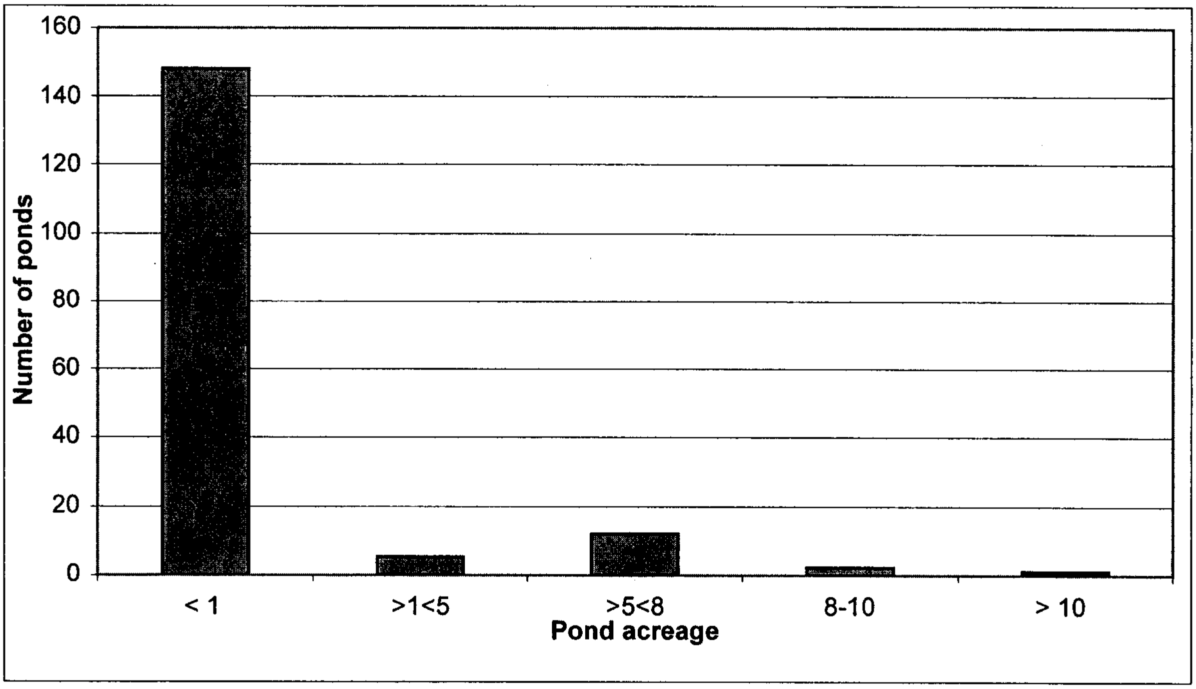


Figure viii. Fish species spocked by Minnesota fish producers.

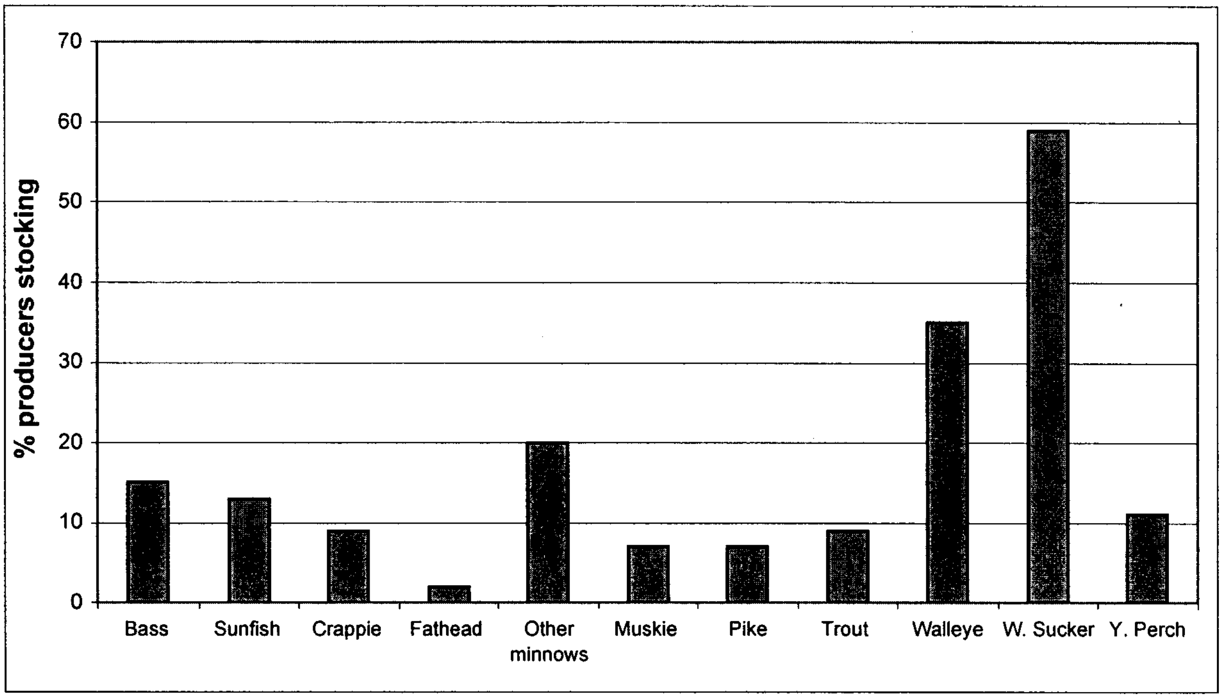


Figure ix. Percent producers stocking each life stage.

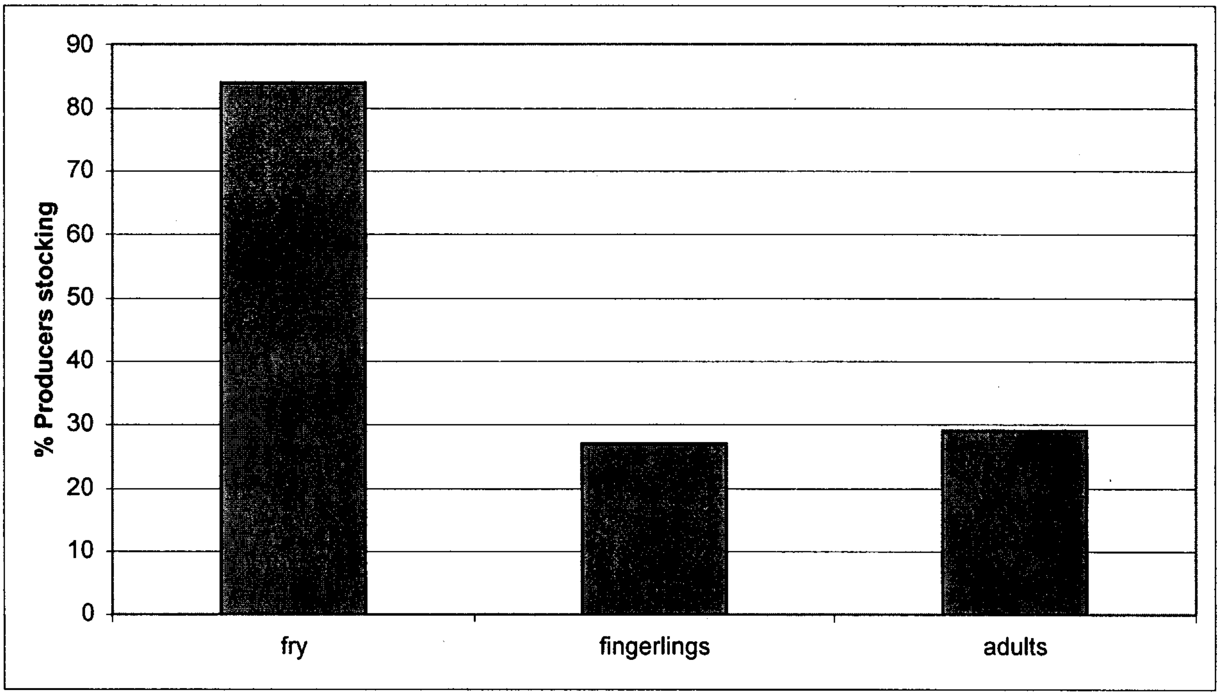


Figure x. Average number of ponds per producer stocked with each life stage.

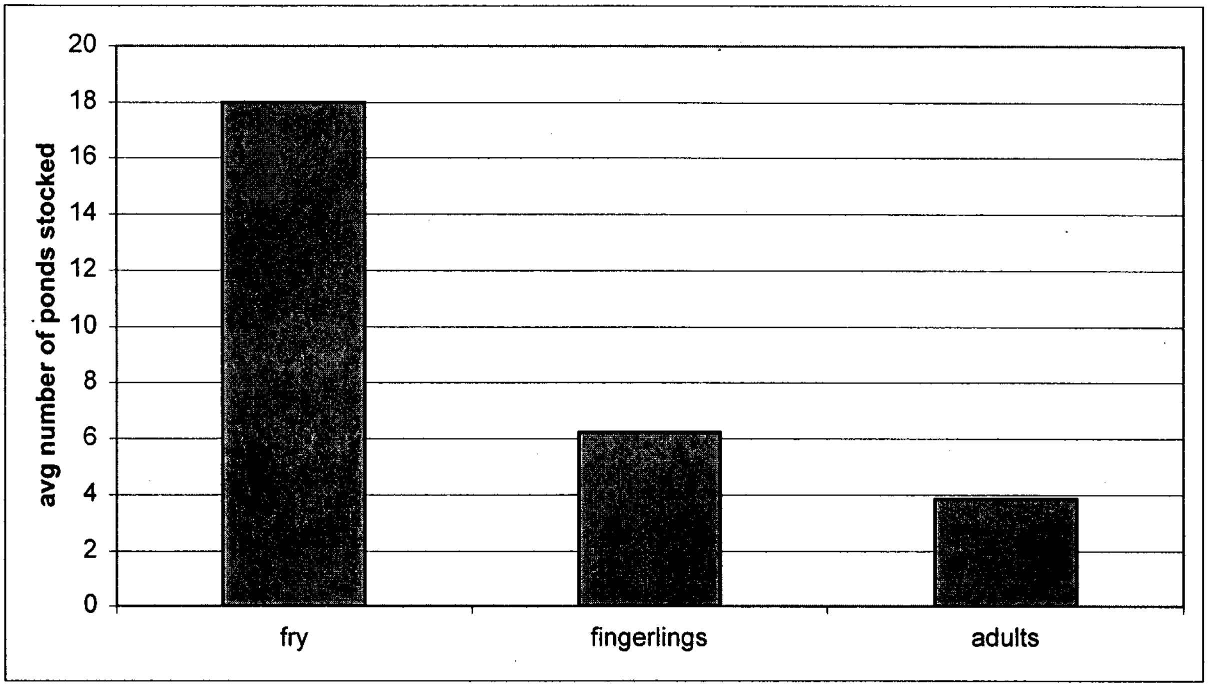
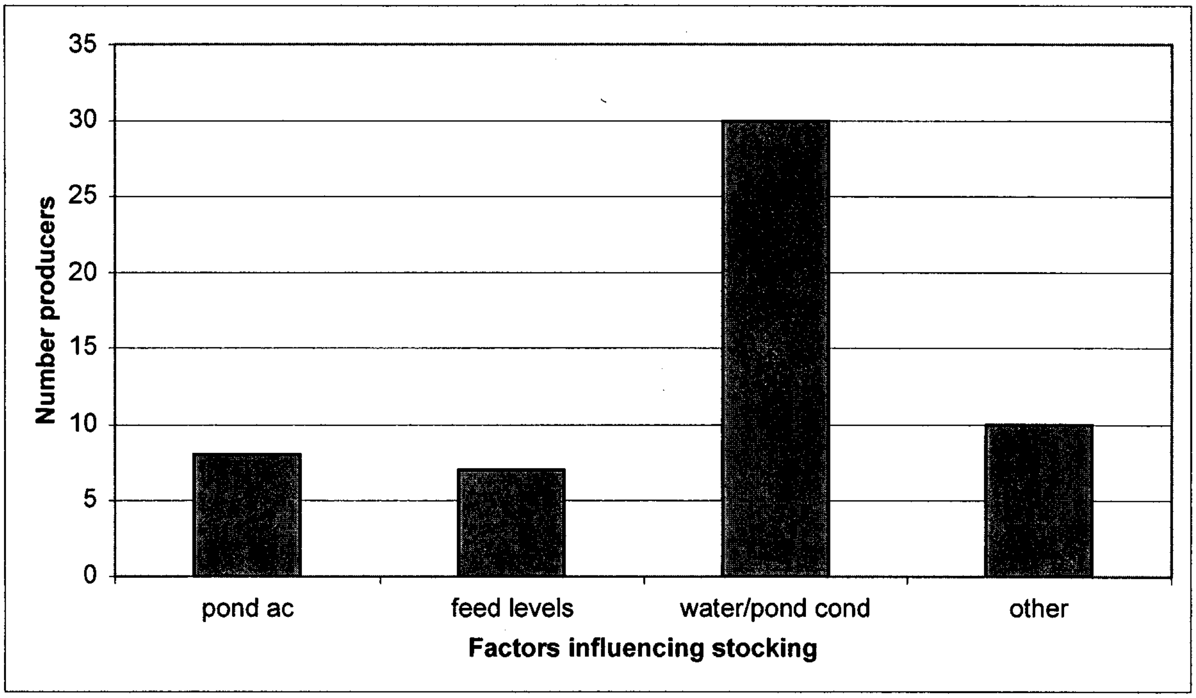


Figure xi. Factors influencing stocking density decisions.



APPENDIX 3: MIGRATION DATES FOR CORMORANTS AND PELICANS

Cormorants

In the 1990s, early southerly spring arrival dates were recorded in Hennepin and Rice counties during the first week of March. Early northerly spring arrival dates were usually reported the last week of March and first week of April in Otter Tail, Grant and Pennington counties; in 1994, one report occurred as early as Mar 16 in St. Louis County. Late northerly fall dates were reported during the last week of November in Duluth, Otter Tail, Beltrami and Lake counties. Late southerly fall dates were reported in Washington, Carver, Ramsey, Goodhue, Kandiyohi, and Dakota counties in the last week of November (The Loon, 1990-2001).

Pelicans

In the 1990s, early southerly spring arrival dates were recorded in Renville, Nicollet, Pope, Rock, Lac Qui Parle, Faribault, and Jackson counties in the last week of March. An exceptionally early date of March 7 was recorded in Wabasha in 1991 (The Loon, 1990-2001). Early northerly spring arrival dates were usually recorded in the last week of March and first week of April (Jansen 1992). In the 1990s, late northern arrival dates were recorded in St. Louis and Otter Tail counties in the second and third weeks of November. Late southern dates were recorded in Goodhue, Dakota, Murray, and Washington counties during the last week of November (The Loon 1990-2001).