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A Science-Based Initiative to Manage Double-Crested Cormorant Damage to Southern Aquaculture

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Executive Summary

Aquaculture has expanded rapidly in the Southern United States during the past two decades, especially the cultivation of catfish, crawfish, and bait fish. These fish usually are cultivated on farms with extensive systems of large shallow ponds that are highly susceptible to predation by birds. Double-crested cormorants (*Phalacrocorax auritus*), American white pelicans (*Pelecanus erythrorhynchos*), wading birds (*e.g., Ardea alba, Ardea herodius*), and scaup (*Aythya* spp.) are among the birds most frequently implicated. Well-documented problems associated with cormorant predation on catfish farms have coincided with the increase of this industry and the rapid growth of cormorant breeding populations on northern breeding grounds. From 1995 to 1998, the number of cormorants spending the winter in the catfish production region of Mississippi has more than doubled and now exceeds 60,000 birds. Also in 1998, cormorants were discovered breeding in Mississippi and Arkansas for the first time in decades. Without human intervention, breeding populations in the Great Lakes will likely continue to increase, resulting in more habitat destruction, competition with other colonial waterbirds, competition with sport fishermen, and depredations on southern aquaculture farms.

The nature and expansiveness of southern aquaculture and the continued growth of cormorant populations limit options for managing depredations on aquaculture farms. Most efforts rely on devices designed to frighten them from ponds and roosts, although the effectiveness of this strategy is limited and, due to expanding habitat utilization by cormorants, is becoming increasingly difficult to implement. In the long-term, further research may lead to the development of barriers, new fish-culturing practices, or other techniques that may help alleviate problems in certain situations. However, no such strategies seem promising at this time and may be limited in the future by the rapid proliferation of this species. In the short term, lethal control strategies under the current cormorant depredation order may need to be implemented to their fullest extent at aquaculture facilities and may need to be expanded to roosting sites to reinforce harassment strategies. Authority should also be pursued to manage southern breeding colonies at levels compatible with aquaculture to forestall future depredation problems. However, such localized population control efforts are unlikely to affect continental or flyway populations, and problems are likely to grow as long as the interior population grows. Managers should consider managing cormorant populations on a flyway basis, which will require setting biologically and socially acceptable population goals

and evaluating management options for achieving these goals. Construction of a realistic, deterministic population model for cormorants would facilitate these ends. Increased dialog among public agencies and private organizations concerned about the management and conservation of cormorants is critical to the development of a realistic and effective plan for managing the depredations caused by this species.

Introduction

The U. S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services (USDA-WS) program provides national leadership in managing conflicts between wildlife and humans. USDA-WS strives to facilitate interagency discussions, understanding, cooperation, and planning to enhance professional responses to public demands for assistance in managing adverse impacts caused by wildlife (Acord 1995).

Populations of double-crested cormorants (*Phalacrocorax auritus*) have irrupted during the past two decades and are of increasing concern to commercial aquaculturists in the Southern United States, commercial and sport fishermen on the Great Lakes and in the Northeastern United States, and conservationists worried about habitat destruction and impacts to other waterbirds. In response to these concerns, this document was prepared for the Eastern Regional Office of USDA-WS based, in part, on a previous planning document that was a collaborative effort of the following current and former USDA-WS personnel: Keith Andrews, Jerry Belant, Travis Carpenter, Pete Poulos, David Reinhold, P. G. Ross, and Charles "Bo" Sloan. It has been reviewed by USDA-WS State Directors and circulated for review to wildlife and fisheries administrators in the following states: Alabama, Arkansas, Connecticut, Florida, Georgia, Kentucky, Louisiana, Maine, Michigan, Minnesota, Mississippi, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Vermont, and Wisconsin.

The objectives of this document are: 1) provide an overview of double-crested cormorant conflicts with southern aquaculture and concerns with cormorants elsewhere; 2) review the effectiveness and limitations of current strategies to alleviate conflicts; 3) identify research needs and management actions: and 4) develop a systematic plan to meet research needs and set a course of action.

This document is reflective of contemporary social and economic values and addresses both prevention and correction of problems associated with cormorants. From a research perspective we attempt to define what information is needed to formulate sound management decisions. It is intended to facilitate thought, discussion, and partnerships among wildlife and fishery biologists, aquaculturists, conservationists, and the public regarding how these conflicts can be prevented or minimized.

Authorities

Various governmental agencies and private individuals share responsibility for managing wildlife damage problems, depending on the type of problem species involved and where the problems occur. The U.S. Fish and Wildlife Service (USDI-FWS) is the primary governmental agency responsible for managing migratory birds and federally threatened and endangered species. State agencies manage most other wildlife species and share in the management of migratory birds. State and federal wildlife management agencies often share responsibilities with other state and federal agriculture, land management, and health agencies. Private organizations and wildlife damage control businesses may receive authority from governmental agencies to directly manage specific wildlife problems.

The USDI-FWS has statutory authority for enforcing the Migratory Bird Treaty Act (16 U.S.C. 703-712) and thus for managing cormorant populations. However, the agency exercises this authority in consultation with other federal, state, and provincial agencies. Under the Animal Damage Control Act of March 2, 1931, as amended (7 U.S.C. 426-426c; 46 Stat. 1468), the USDA-WS program is responsible for protecting American agriculture and other resources from damage caused by wildlife, including cormorants.

USDA-WS may implement localized depredation abatement actions, but must consult with USDI-FWS and state agencies to implement more far-reaching management actions.

As part of their authority to manage cormorant populations, the USDI-FWS previously issued depredation permits that allowed individual aquaculture producers to shoot cormorants that were causing or about to cause damage on their farms. USDA-WS assisted in this process by certifying that cormorants were in fact causing damage and that nonlethal means were insufficient to reduce damages. In March 1998, the USDI-FWS issued a Standing Depredation Order (50 CFR, Part 21, Section 21.47) that eliminated the requirement that producers obtain individual permits and enabled fish farmers in 13 states to shoot double-crested cormorants that are committing or about to commit damage at their farms. Some states still require individual permits. The present cormorant depredation order does not restrict the number of cormorants that may be shot nor the methods that may be used to bring birds within shooting range. Under these provisions, farmers must keep a log of the numbers of cormorants killed each month and make these logs available to wildlife enforcement officials.

Southern Aquaculture

Aquaculture is the intensive commercial propagation of various fish, crawfish (crayfish) (*Procambarus clarkii*, *P. acutus*), or shrimp (Family Pennaeidae). Southern aquaculture is devoted primarily to the culture of catfish (*Ictaluridae)*, bait fish (C*yprinidae)*, and crawfish in large (> 2 ha) shallow (< 2 m) ponds and is located primarily in the states of Alabama, Arkansas, Louisiana, and Mississippi. Most production of channel catfish (*Ictalurus punctatus*) is concentrated in Mississippi, which has more than 41,000 ha of ponds and is responsible for 70 percent of the domestic commercial production. Arkansas ranks second, with over 9,000 ha of catfish ponds. Alabama and Louisiana rank third and fourth, respectively. More than 90 percent of all catfish production in the United

States occurs in these four states (USDA 1998). Arkansas raises approximately 80 percent of all cultured bait fish in the United States, having almost 12,000 ha in production (Collins 1995). Almost all crawfish are produced in Louisiana, which has more than 40,000 ha of ponds in production (Avery and Lutz 1996).

Although southern aquaculture farms vary greatly in size, a typical Mississippi catfish farm has 20 ponds, each containing about 6 surface hectares of water. Because of the size of bait fish and crawfish and multi-batch cropping systems with catfish, almost all ponds are vulnerable to predation. Both bait fish and catfish ponds are stocked at extremely high densities ranging from 5,000 to 150,000 fish/ha with catfish and
123,000 to almost 500,000 fish/ha with bait fish. Such crowding make fish highly susceptible to bird predation, particularly by cormorants.

Southern aquaculture production has seen phenomenal growth in the past 30 years, due mostly to the expansion of the catfish industry. In both Mississippi and Arkansas, the first crops were raised in a few ponds in the early 1960s. The industry expanded in the delta region of Mississippi from the mid-1970s through the 1980s, when the acreage increased almost tenfold. In the early 1990s this growth slowed due to low market prices but resumed again in 1996 when acreage increased by 4 percent in both Mississippi and Arkansas (USDA 1996). Continued increases were observed in 1997 (USDA 1997) in the four major production states. The additional acreage in recent times has come from expansion of existing farms in the delta region of Mississippi and rapid expansion of catfish farming in areas such as east Mississippi. Crawfish production has also increased. Between 1960 and 1996, commercial crawfish acreage in Louisiana increased from 800 ha to 45,000 ha (J. Avery, Louisiana Coop. Ext. Service. Pers. Commun.). Overall, aquaculture is the fastest growing agricultural enterprise in the United States (Van Gorder 1992) and by the year 2000, is predicted to account for $59 billion, or 40 percent of the world's fish production (Price and Nickum 1995).

Cormorant Demography and Biology

Historical trends reveal several factors affecting the fluctuation in cormorant populations. Cormorant populations were suppressed during the early 1900s due to egg collecting for human food and nest destruction by fishermen who considered the cormorant to be a competitor (Lewis 1929, Hatch 1984, Dolbeer 1990, Chapdelaine and Bédard 1995). From the 1920s through mid-1940s, population increases throughout the Great Lakes, New England, and Canada (Baillie 1947, Fargo and Van Tyne 1927, Hatch 1984, Postupalsky 1978) were probably due to newly-created reservoirs that killed trees and created new islands for nesting (Markhan and Brechtel 1978).

Cormorants are highly susceptible to pollutants bioaccumulated by prey fish species, and pesticide-related bill deformities continue to occur (Fox et al. 1991, Ludwig et al. 1996). From the mid-1940s through the early 1970s, human persecution, human competition for fish resources, but most importantly widespread use of environmental contaminants (e.g., organo-chlorine compounds) led to a decline of cormorant populations (Noble and Elliott 1986, Craven and Lev 1987, Ludwig et al. 1989, Dolbeer 1990, Weseloh et al. 1995). During this period, the Great Lakes cormorant population as a whole suffered a reduction in excess of 80 percent (Postupalsky 1978) due to eggshell thinning and reproductive failure attributed to pesticide deposition (e.g., DDT/DDE) (Postupalsky 1978, Weseloh et al. 1983, Weseloh et al. 1995). In addition, between 1944 and 1952, the USDI-FWS incorporated cormorant egg-spraying into a herring gull (*Larus argentatus*) reduction effort in New England, primarily targeting cormorant colonies in Maine (Gross 1952). A cormorant control program was initiated on Lake Winnipegosis, Manitoba, in 1945 that reduced the colony from 9,862 to 4,656 nests by 1951 (McLeod and Bondar 1953).

Protected status was granted to cormorants in the United States by the Migratory Bird Treaty Act in 1972. That event, combined with DDT use restrictions implemented in the mid-1970s, contributed to the resurgence of cormorant populations (Bishop *et al*. 1992, Ludwig 1984, Noble and Elliott 1986, Tyson et al. 1999). A dramatic increase in food availability (e.g., alewife [*Alosa pseudoharengus*]), particularly in the Great Lakes, has also aided this recovery (Hobson et al. 1989, Price and Weseloh 1986, Weseloh et al. 1995). An annual increase in cormorant breeding pairs has been reported for the following areas: southern New England (20 percent), the Canadian lower Great Lakes (about 40 percent from 1976-1990), and the entire Great Lakes (29 percent from 1970-1991) (Hatch 1984, Blokpoel and Tessier 1991, Weseloh et al. 1995). Cormorants also began to colonize areas south of their traditional range (Post and Seals 1991). Overall, the cormorant nesting population in the Great Lakes increased from 89 nesting pairs in 1970 to about 93,000 pairs in 1997 (Tyson *et al.* 1999). Between 1986 and 1989, recently established breeding populations in South Carolina increased 310 percent from 60 nesting pair to 186 nesting pairs (Post and Seals 1991). Concurrent with the rapid growth of cormorant populations in North America, great cormorant (*Phalacrocorax carbo)* populations in Europe experienced a similarly dramatic resurgence largely due to increased protection and restrictions on persistent pesticides (Veldkamp 1997). The similar life history and conflicts caused by great cormorants provide insight into management issues with double-crested cormorants.

Most double-crested cormorants that affect southern aquaculture breed in the Northern United States and Canada (Dolbeer 1991), although flocks of cormorants have been observed in the delta region of Mississippi during the summer and small breeding colonies have recently been documented in Mississippi (Reinhold et al. 1998) and Arkansas (Thurmond Booth, Wildlife Services, Pers. Commun.). Up to 70 percent of cormorants banded at nesting colonies from Saskatchewan through the Great Lakes prior to 1988 were recovered in the lower Mississippi River Valley (Dolbeer 1991). This breeding area encompasses most of what is referred to as the "interior population," that makes up 61 percent of the total North American breeding population, recently estimated between 1 and 2 million birds (Hatch 1995, Tyson *et al*. 1999). Past band recovery analyses reveal no apparent "focal point" of breeding birds that conflict with southern aquaculture (Dolbeer 1991), but it seems clear that the conflict involves birds associated with the Mississippi flyway. A more up-to-date analysis of band recoveries is needed to begin to understand current movements along this flyway.

Increased winter survival of juveniles due to a higher forage base provided by catfish may have contributed to this growth (Duffy 1995, Vermeer and Rankin 1984, Weseloh and Ewins 1994). A recent study has confirmed that premigratory cormorants from the delta region of Mississippi are in better body condition than cormorants from non-aquacultural areas (Glahn et al. 1999). Cormorant mortality has been estimated at 50 to 70 percent during the first year after hatching and 15 to 25 percent annually thereafter (Hickey 1952, Palmer 1962, van de Veen 1973). Price and Weseloh (1986) suggest a pre-breeding mortality (up to age 3) of 70 percent in stable populations and 31 percent in expanding populations; van de Veen (1973) reports survival to breeding age as 30 percent in the stable western population.

Historically, human activities have been the primary cause of cormorant population fluctuations, including the current population resurgence. Most notable has been the rise and fall of persistent pesticides in the environment, the protection afforded the species, and the recent increase of the food base on the wintering grounds provided by southern aquaculture. Although it is impossible to accurately predict future trends in cormorant populations, there is little evidence that populations will decline markedly without human intervention. Density-dependent factors could lead to eventual stabilization of the population, albeit at a high level. This has been demonstrated, in part, through population modeling of the great cormorant populations in Europe (Bregenballe et al. 1997). In North America, density dependent factors might limit the size of some individual breeding colonies, but available breeding habitat for further colonization remains abundant (Hatch and Weseloh 1998). Prey can become depleted for individual cormorant breeding colonies (Birt et al. 1987; Hatch and Weseloh 1998), but range-wide reduction in the availability of prey is unlikely. Although epizootic diseases may help regulate localized populations, additional research is needed to clarify the potential for diseases to limit population growth throughout the entire range. Recent outbreaks of Newcastle's disease (avian paramyxovirus) may have slowed the growth of some established breeding colonies (Hatch 1995); however, no viable cultures were isolated from exposed birds (M. Avery, NWRC, per. commun.) even though more than half of the wintering birds examined in a recent ongoing study had been exposed to this disease organism.

Cormorant - Human Conflicts and Values

Conflict With Southern Aquaculture

The increasing conflict between cormorants and southern aquaculture has been chronicled through population trends of wintering cormorants in areas of intensive aquaculture. With the expansion of Mississippi aquaculture in the 1980s came a corresponding increase in the number of cormorants spending the winter in this region (Glahn and Stickley 1995). Prior to 1980, few cormorants remained there for the winter (Glahn and Stickley 1995). However, during the 1980s, the number of cormorants recorded during Christmas bird counts increased dramatically (Glahn and Stickley 1995, Jackson and Jackson 1995). Since 1990, mid-winter counts of this species doubled from approximately 30,000 birds in 1990, when USDA-WS biologists began conducting roosts censuses, to 67,000 birds in 1998 (Glahn et al. 2000). These counts have remained approximately at 1998 levels through 2000 (USDA-WS files). Less is known about wintering cormorants in other aquaculture production areas, but recent midwinter counts suggest populations of approximately 10,000 birds inhabit the rapidly expanding aquaculture region of East Mississippi and West Alabama. In the catfish production region of Arkansas, surveys in February 2000 revealed 50,000 cormorants roosting in several different roost sites (M. Hoy, USDA-WS, Pers. Commun.). Despite the value of these counts as indices to potential conflicts, little is known about overall cormorant populations that might utilize southern aquaculture production areas over time. However, banding records indicate approximately 120,000 birds were moving through the lower Mississippi valley in 1989 (Dolbeer 1990). Considering the increased breeding populations since that time, this number may have more than doubled.

Cormorants traditionally arrive on their wintering grounds in November and depart by mid-April (Aderman and Hill 1995). However, appreciable numbers now arrive in September and do not depart until late April or early May (Reinhold and Sloan in press), thus extending the period of depredations. These wintering birds congregate at night in bald cypress (*Taxodium distichum*) or tupelo gum (*Nyssa aquatica*) trees that are typically over water in oxbow lakes or other naturally occurring wetlands associated with river drainages (Aderman and Hill 1995, Glahn et al. 1996). From a dynamic number of active night roost sites, cormorants travel only a mean distance of 16 km to forage on catfish ponds (King et al. 1995). Thus, depredations are temporarily highly concentrated on ponds in close proximity to active roost sites, but shifts in roosting activity (King 1996) cause depredations to be a widespread problem.

The impact of cormorant foraging activity on the catfish industry has been well documented but their impact on bait fish and crawfish remains unclear. Most catfish producers in the Southern United States perceive cormorants as threats to their livelihood (Stickley and Andrews 1989, Wywialowski 1999). In a 1996 national survey of catfish producers, depredations by cormorants were the most commonly cited wildlife problem. Losses due to cormorants were cited by 77 percent of Mississippi producers, 66 percent of Arkansas producers, and 50 percent of Alabama producers. The main problems reported were cormorants feeding on catfish, injuring catfish, and disturbing feeding patterns. Losses reported from all depredating species approximated 4 percent of catfish sales, or a 16 to 33 percent loss of profits (Wywialowski 1999).

Observational studies of cormorants foraging at catfish ponds were the first concrete evidence of their potential to impact catfish production. The smaller subspecies of Florida cormorants were observed feeding at a fingerling catfish pond at an estimated a consumption rate of 19 fingerlings/bird/day, or approximately 304 g/bird/day (Schramm et al. 1984). Hodges (1989) only rarely observed cormorants on catfish ponds but concluded that they pose the greatest threat to catfish farmers because of their gregarious behavior and ability to dive for fish. It has been calculated that 30 cormorants feeding throughout the day would consume half of the fingerling population in an 8-ha pond in 167 days (Stickley et al. 1992). In a recent study, captive cormorants consumed 516 to 608 g, or about 10 catfish, per day (Glahn unpubl. data). These findings are consistent with previous bioenergetic projections for these birds (Glahn and Brugger 1995) and based on replacement costs indicate that one cormorant subsisting exclusively on catfish would remove about $1 worth of fingerlings per day.

Food habits studies have also documented the prevalence of catfish in the diet of cormorants on their winter range. A 3-year study found that approximately half of the cormorant diet (wt/wt) in the delta region of Mississippi was composed of channel catfish (Glahn et al. 1995). Most of the remaining diet was gizzard shad (*Dorosoma cepedianum*). Catfish were most often consumed during the spring months in areas with the highest concentration of fish farms. Catfish consumed in this study averaged 16 cm in length, equivalent to the average size fingerlings stocked by producers.

For the winters of 1989-90 and 1990-91, a bioenergetics model estimated cormorant-related production losses on catfish farms in the delta region of Mississippi at 18 to 20 million fingerlings per winter, or approximately 4 percent of the available fingerling-class during the November to April study periods (Glahn and Brugger 1995). The annual cost of replacing these fingerlings was estimated at approximately $2 million. Cormorant populations in the delta region of Mississippi have more than doubled since this study, and the annual impact of cormorants on the catfish industry in the Mississippi delta may now exceed $5 million (Glahn et al. 2000). Based on the estimated value of these fish at harvest, actual production losses might be 10 times greater, but more study was needed to assess whether losses due to predation are additive or compensatory as related to density-dependent growth and mortality of catfish. To partially address these questions one study (QA-634, in progress) is examining catfish production at harvest with and without cormorant predation simulating average cormorant numbers seen foraging by Stickley et al. (1992) on catfish ponds (i.e., 30 cormorants foraging on a 6 ha pond for 100 days). Also to simulate field conditions, an ample supply of buffer prey was provided along with catfish fingerlings stocked at 12,355 fish/ha (5,000 fish/ac). Preliminary results suggest that despite the buffer prey reducing depredation on catfish by an estimated 33 percent, catfish population declines due to cormorant predation at harvest ranged from 26 to 33 percent where catastrophic disease problems did not occur. Because of density-dependant compensatory growth, actual biomass production loss ranged from 19 to 21 percent. Considering this 20 percent loss in production, losses at a commercial pond scale would be $10,500 or 5 times the value of the fingerlings lost. Because of small profit margins in the catfish industry, some agricultural economists suggest that a 20 percent loss in production would result in a 100 percent loss in profits (C. Engle University of Arkansas, Pers. Commun.).

Other Cormorant Conflicts

Controversy surrounding cormorants has polarized people (Shetterly 1986) whose views range from those who wish to declare cormorants a nuisance species in need of control (Arkansas Senate Bill 345 [1993], Arkansas Senate Concurrent Resolution 12 [1995], Bayer 1989, Oklahoma Senate Bill 362 [1991]) to those who feel that cormorant populations are causing no problems and have the right to recover to the fullest extent (Duffy 1995). Historically, animosity towards cormorants has been based on their perceived impact on fisheries (Lewis 1929, Mendall 1934, 1936) and has generated extended periods of intense persecution by commercial fishing interests (Baillie 1947, Craven and Lev 1987, Ludwig 1984, Omand 1947, Postupalsky 1978), at times leading to sanctioned efforts to reduce cormorant populations (Hatch 1995). Both sanctioned and unsanctioned reduction efforts have occurred at breeding colonies during the most recent build up of populations (Ewins and Weseloh 1994, USDI-FWS 1998). These efforts have largely been justified by impacts on fisheries but have also been spurred by a growing concern about cormorant impacts on unique insular habitats and on other colonial nesting birds (Bèdard et al. 1995). These latter concerns have recently lead natural resource managers in both the United States (Garland et al. 1998) and Canada (St. Martin and Loftus 2000) to express concern and either call for action or definitive studies to defend a control program. Consistent with these views, conservationists developing the North American Colonial Waterbird Conservation Plan have referred to cormorants as "pests." Below, we briefly review the literature concerning these other cormorant conflicts.

Research to clarify the impact of cormorants on sport or commercial fisheries has yielded mixed results. Most studies, principally in the Great Lakes region, indicate that cormorants feed primarily on abundant small forage fish in these ecosystems, namely alewife and shad (Lewis 1929, Mendall 1936, Omand 1947, Craven and Lev 1987, Ludwig et al. 1989, Weseloh et al. 1995). More recent and detailed studies on Lake Erie (Bur et al. 1999) and Lake Ontario (Ross and Johnson 1999) concluded that cormorants usually did not have a significant impact on either game fish or their forage base. However, cormorants on Lake Champlain consumed primarily yellow perch, a preferred sport fish in Vermont (Garland et al. 1998).

Cormorants can have a direct impact on fisheries during stocking, such as when trout or salmon are released into rivers (Blackwell et al. 1997, Derby and Lovvorn 1997, Meister and Gramlich 1967, Ross and Johnson 1999). Cormorants can also reduce sports fisheries where forage prey such as alewife are less numerous. During a series of intensive investigations on the Eastern Basin of Lake Ontario (Schneider et al. 1998), cormorants shifted their diet to smallmouth bass when alewife and other prey species populations were low. Although smallmouth composed only a small percentage of the cormorant diet, specific age classes important to this fishery (primarily 3- to 5-year old fish) may have been significantly reduced.

The resurgence in the interior cormorant population has spurred growing concern that migrating cormorants might adversely affect sport and commercial fisheries along the Upper Mississippi River, but limited data suggest that cormorants foraging in such areas take mainly gizzard shad (Kirsch 1995). Little scientific information is available on cormorant food habits on natural waters (e.g., rivers, lakes and reservoirs) in the Southern United States. Results of a study in Texas (Campo et al. 1993) indicated that most cormorants fishing in natural waters took mainly shad and sunfishes. Nonetheless, the researchers acknowledged that cormorants could have an impact on sport fish in some locations. Another study (Glahn et al. 1998) reported that cormorants foraging at lakes during winter in Mississippi and Alabama took mostly shad and sunfish, but recommended more in-depth studies of cormorant impact in southern waters.

Based on a review of the literature and a survey of state agencies, Trapp et al. (1999) concluded that cormorants have only a minor impact on sport fish populations except in highly localized situations. This view may summarize the situation best as of now, but further research is needed to clarify this issue in areas where cormorants are concentrated.

The impact of nesting cormorants on habitat and other colonial waterbirds is well documented in localized areas. Cormorants strip leaves, break branches, and deposit guano that ultimately kills the trees. The resulting habitat destruction is highly visible (Weseloh and Ewins 1994, Bédard et al. 1995, Jarvie et al. 1999, Shieldcastle and Martin 1999).

Habitat destruction, combined with competition for nest sites, impacts black-crowned night herons (*Nycticorax nycticorax*) and other heron and egret species (Jarvie et al. 1999, Shieldcastle and Martin 1999). Although these impacts seem localized at present, they are clearly density dependent and likely to be an increasing problem as cormorant populations continue to expand.

Benefits Associated With Cormorants

The double-crested cormorant is a native species that is of intrinsic as well as esthetic value to humans. Cormorants are potential indicator species for environmental contaminants (Noble and Elliott 1986, Fox et al. 1991, Ludwig et al. 1995). Some aquaculture producers believe that cormorants are beneficial when they feed on undesirable fish such as gizzard shad (*Dorosoma cepedianum*) and sunfish (*Lepomis sp.*) that infest commercial ponds. Cormorants can increase species diversity on natural waters and reservoirs and may stabilize the relationship between predatory fish and their prey. Bird watchers enjoy viewing cormorants in their natural setting (Bédard et al. 1995, Mendall 1936, Vermeer 1970). Most aquaculturists recognize that some depredation is natural and to some degree is a cost of business (Thompson et al. 1995), but the threshold for acceptable depredation losses may have long since been exceeded.

Alleviating Depredations on Southern Aquaculture

Alleviating problems caused by or related to the presence of wildlife is integral to the field of wildlife management (Berryman 1992, Leopold 1933, The Wildlife Society 1992). Responsible wildlife managers balance the needs of humans and wildlife, foster tolerance toward wildlife, and advocate cost-effective and environmentally acceptable remedial solutions that reduce the implementation of environmentally or legally unacceptable actions by those experiencing the problem.

The utility of any damage management strategy depends on the costs of deploying the strategy relative to the anticipated reduction in damage. Environmental, biological, social, physical, and legal considerations also influence the selection and application of management strategies (Owens and Slate 1991, Slate et al. 1992, USDA 1994). Because each damage situation is unique, appropriate management actions must be determined on an individual basis.

Numerous factors determine which methods are most environmentally sound, socially acceptable, and cost-effective. Is the population of the problem wildlife rare or abundant? Is it stable, increasing, or decreasing? What are the behavioral traits of the wildlife? Is the proposed management strategy legal and feasible? What are the potential impacts on other wildlife species? Are weather or local conditions likely to influence effectiveness? Is the method likely to affect soil, water, or air quality? What are public perceptions toward the method? Are resource managers and the public likely to accept the human and nontarget risks associated with the method?

Alleviating wildlife damage entails employing one or a combination of three strategies: 1) managing the resource being impacted; 2) physically separating the wildlife from the resource; or 3) managing the wildlife responsible for, or associated with, the damage (USDA 1994). Below we describe these strategies in more detail relative to catfish production and discuss research needs.

Resource Management

Managing a resource to reduce wildlife conflicts usually involves modifying cultural practices (e.g., animal husbandry or crop selection), altering the habitat to reduce its attractiveness to wildlife, or adjusting human behavior. In the case of aquaculture production, the objective would be to reduce the vulnerability of fish to predation by cormorants.

Pond size and location - Smaller ponds would facilitate the installment and maintenance of bird exclusion structures, as well as improved management of fish diseases and water quality. However, production is typically reduced and levee maintenance costs are typically increased when smaller ponds are used. Pond construction costs, a major determinant of economic success in the industry, also increase as pond size decreases (Tucker and Robinson 1990). Changing pond depth probably would have no effect on cormorant foraging efficiency as the birds dive to depths >20 m (Palmer 1962, Knopf and Kennedy 1981). Locating fingerling ponds or other ponds that are especially susceptible to predation near areas with human activity (e.g., warehouses, processing plants) or where they are easily accessible facilitates harassing birds and reduces susceptibility to predation (Mott and Boyd 1995).

Cultural practices - Catfish ponds are managed either as multiple-cropping systems, which contain two or more size classes of fish and are selectively harvested over a period of years, or single-batch systems, which contain only one year class of fish and are completely harvested before restocking. All multi-crop ponds contain a fish size class that is vulnerable to predation by birds and must be protected. The vulnerability of single-crop ponds to predation varies depending on the size of fish. Thus, farms with the single-crop system usually have fewer ponds with vulnerable fish. The multi-cropping system was adopted by most catfish farmers to meet the needs of processors but has a number of disadvantages when compared to the single-batch system (Tucker and Robinson 1990). Although the industry is large enough now to assure year-round supplies of fish using single-batch culture (Tucker and Robinson 1990), most farmers continue to use the multi-batch culture so they can harvest fish throughout the year and improve their cash flow.

Other modifications in fish stocking regimens have the potential to limit predation by cormorants. Barlow and Bock (1984), Brugger (1995), Glahn et al. (1995), and Mott and Boyd (1995) suggest that modifying stocking rates, size-class of fish stocked, or stocking times can reduce resource losses to birds. Reduced stocking rates might reduce the foraging success of cormorants and, in turn, reduce the attractiveness of catfish ponds (Mott and Boyd 1995). Conversely, the current industry trend is to use higher stocking rates that might compensate producers for production losses due to predation and other causes. Research is needed to determine optimal stocking rates with respect to bird predation that maintains acceptable profit margins. Delaying transfer of fingerlings into food-fish ponds would shorten the period when producers would need to protect these fish and allow more concentrated bird-control efforts at fewer fingerling ponds. By delaying restocking from late winter until mid-April, producers would miss the peak period of cormorant depredation (Glahn et al. 1995). However, delaying stocking is not consistent with the multi-batch cropping system and may increase the risk of stress-related mortality from disease due to water temperature changes. Also, because these fish are not expected to grow during the winter (Tucker and Robinson 1990), fall and winter stocking might not be cost-effective because it increases the period of exposure to cormorant predation in food-fish ponds.

Other cultural practices to reduce cormorant predation might include the use of buffer prey and pond water dyes to reduce the visibility of fish to the cormorant (Mott and Boyd 1995). In studying the predation by cormorants on catfish ponds, Stickley et al. (1992) noticed that cormorants fed heavily on shad, which are more easily manipulated than catfish for swallowing. However, preliminary results of controlled captive cormorant studies suggest that over time, cormorants had no real preference for a more readily manipulated buffer prey (i.e. golden shiners) despite this prey having some desired effect in reducing overall production losses (Glahn unpubl. data). Even if preferred buffer prey could be identified, use of buffer prey to reduce damage on catfish remains controversial because of the possibility that more abundant prey will attract more cormorants to these ponds (Mott and Boyd 1995). Along similar lines, some authors (Mott and Boyd 1995, Erwin 1995) suggest the use of developing alternative foraging sites stocked with preferred buffer prey. However, even if such ponds could be developed, they would quickly be depleted by increasingly large cormorant populations exploiting these areas in southern aquaculture regions. Although pond dyes have never been evaluated, the natural turbidity (Secchi disk readings <40 cm) of most catfish ponds would probably limit the utility of dyes for reducing the ability of cormorants to pursue and capture prey.

Exclusion Techniques

Exclusion, the physical separation of wildlife from the resource, usually entails erecting fences, nets, or other barriers. Although total separation might not be practical, various barrier techniques may serve to limit cormorant access to ponds or the fish in these ponds (Littauer et al. 1997).

Complete enclosure - Supported netting is the only completely effective method of excluding cormorants from ponds but is physically and economically impractical for large (>5 ha) catfish and bait fish ponds. Littauer et al. (1997) estimated that it would cost approximately $1 million to enclose a 40-ha farm. Furthermore, the levees on most catfish farms are not wide enough to accommodate support systems and vehicle access. Complete exclusion might be cost-effective and prudent for high-value fish like trout or ornamental fish in smaller ponds and raceways; however, complete exclusion of extensive (>50,000 ha) aquaculture production areas is impractical and may negatively impact other waterbirds that currently use these wetlands.

Partial enclosure - Plastic or wire grids suspended over ponds can deter cormorant flocks from landing or taking off but do not exclude cormorants from highly attractive aquaculture ponds (Barlow and Bock 1984, Moerbeek et al. 1987). Although some research continues with the use of overhead wires in Arkansas, May and Bodenchuk (1992) concluded that an overhead wire grid structure over a 3.7-ha pond was impractical under current catfish culture practices. Materials ($404 per ha; $163/ac) and labor (15.5 person-days) costs were lower than full net-coverage, but the structural durability and functional design were not adequate for protecting large ponds. As with complete enclosure, benefit to cost ratio for using many partial enclosures may not justify their use. However, Keller (1999a) found that overhead wires, in conjunction with harassment efforts, might be cost-effective for protecting smaller (0.2 to 2.5 ha) ponds from great cormorants in Germany where the state of Bavaria subsidized 40 percent of the costs. Overhead wires can exclude and injure other nontarget waterbirds (Mott and Boyd 1995), but marking wires with flagging material can minimize this risk.

Floating and underwater grids - Floating ropes can hamper cormorants from landing and taking off from ponds, depending on the prevailing wind direction. Mott et al. (1995) partially protected 2 catfish ponds from cormorant flocks (total of 10.6 ha; 26.17 ac) for 3 and 8 weeks, respectively. The ropes cost $97/ha ($39/ac) and took 57 hours to install and subsequently disassemble on the 2 ponds. Although floating ropes have practical advantages over overhead wires, they are similarly limited in effectiveness and would be less likely to deter cormorants in situations where few alternatives existed. Underwater barriers or baffle systems could theoretically interfere with cormorants' pursuit of fish (Barlow and Bock 1984), but studies using submerged nets as fish refugia to deter cormorant predation suggested no significant effects on predation rates (Gottfried 1998). Because of repeated harvesting with the multi-batch cropping system, most underwater barriers would have to be repeatedly removed and reinstalled, adding to overall costs of such systems.

Localized Cormorant Management

Management of cormorants at or near the site of damage currently includes harassment techniques and lethal removal of birds. These techniques do not presently appear to reduce regional populations (Glahn et al. 1996, Glahn et al. 2000, Mott et al. 1998).

CORMORANT HARASSMENT

At Aquaculture Facilities - Scare devices consist of auditory or visual stimuli intended to move or deter cormorants from a target site (Booth 1994, Draulans 1987, Littauer 1990a, Littauer 1990b, Mott and Boyd 1995). This category of harassment includes human activities, vehicles (truck, all-terrain vehicle, boat), propane exploders, pyrotechnics (exploding or whistling projectiles), cormorant distress calls, alarm units, sirens, and effigies (stationary or inflatable). Single devices or a combination of methods has thus far proven to alleviate depredation only temporarily (Draulans 1987, Moerbeek et al. 1987, Mott and Boyd 1995, Rodgers 1994). The typical practice is to patrol pond levees in a vehicle throughout daylight hours and shoot pyrotechnics or shotguns at birds. Human effigies have been used to augment this strategy (Stickley unpub. data). Altogether, 245 fish producers surveyed in the delta region of Mississippi by Stickley and Andrews (1989) claimed annual expenditures of $2.1 million to harass all species of fish-eating birds. The cost-effectiveness of these efforts has not been determined. The expansive size of most catfish farms limits the effectiveness of harassment techniques (Reinhold and Sloan 1999). Because simultaneous harassment of all ponds is difficult on large farms, birds simply move to other ponds, resulting in no net decrease in predation. Even when birds can be dispersed from farms, they often return as soon as harassment ceases or simply move to other farms (Reinhold and Sloan 1999).

Winter Roost Harassment - Coordinated and simultaneous harassment of cormorants can disperse them from night roosts and reduce damage at nearby catfish farms (Mott et al. 1992, Hess 1994). Electronic noise generators, amplified recordings of cormorant alarm calls, propane gas exploders, pyrotechnics, and firecrackers can be used. During a 3-year study, Mott et al. (1998) evaluated a coordinated roost dispersal program of cormorants at all known roost sites in the delta region of Mississippi and observed fewer cormorants at catfish ponds near harassed roosts. Harassed cormorants temporarily shifted their roosting activity from the intensively farmed east-central delta to sites along the Mississippi River, where they foraged primarily on shad.

Despite the partial success of this program, several factors limit its usefulness as a long-term solution to aquaculture predation problems. Roost harassment must be conducted on a regular basis to have a sustained effect (Mott et al. 1998) because harassed cormorants usually establish new roosts at the nearest suitable location, then return to previous roosting sites when harassment ceases. In 1993, when the roost dispersal program was initiated in the delta region of Mississippi, there were 48 known cormorant roosts in this region. That number increased to 75 by 1999 (Glahn et al. 2000). If this number continues to increase, there eventually may not be enough producers to simultaneously harass cormorants at occupied roosts in the delta region of Mississippi.

Another problem encountered with the roost dispersal program is that hunters increasingly express concerns about unintended effects of harassment on waterfowl (Mott et al. 1998). Although the use of low-power laser devices for dispersing cormorants may help alleviate these concerns (Glahn et al. unpub. data), an increasing number of hunting clubs and refuges are restricting cormorant harassment. Cormorant populations have increased at these sites to 15,000 birds (D. Reinhold, USDA-WS, pers. commun.), negating efforts to move cormorants out of the protected area. Repeated harassment with non-lethal frightening devices may become less effective as birds become accustomed to them. A recent study (Glahn in press) indicates that shooting cormorants in roosts is as effective as dispersing them with pyrotechnics and may not result in habituation. However, lethal control at roosts is not authorized under current regulations.

LETHAL CONTROL

Shooting a limited number of cormorants reinforces non-lethal harassment (EIFAC 1988, Hess 1994, Littauer 1990b, Mastrangelo et al. 1995, Rodgers 1988 and 1994, Tucker and Robinson 1990, USDA [Vol.2, J-12; Vol. 3, P-32] 1994). This strategy can be part of an integrated damage management plan implemented at farms when non-lethal methods are ineffective (Mastrangelo et al. 1995). The USDI-FWS depredation order for the double-crested cormorant (50 CFR Part 21) allows for localized control of cormorant populations at aquaculture facilities (USDI-FWS 1998). However, most fish farmers can shoot only a small percentage of the cormorants feeding in their ponds (Hess 1994). Similarly, if shooting in roosts were restricted to daylight hours, only a small percentage of roosting birds would be killed (Glahn in press). Hess (1994) investigated the feasibility and potential impact of allowing farmers to shoot an unlimited number of cormorants on their farms. The producers at two facilities (1,920 ha) in the delta region of Mississippi spent more than 3,000 person-hours trying to shoot cormorants, yet killed only 290 birds, as the birds quickly learned to avoid the hunters. Glahn (in press) observed the same response when attempting to shoot cormorants in roosts, resulting in less than 5 percent of the roosting population killed before the roost dispersed. Waterfowl exhibit similar behavior during the hunting season (Owens 1977). The cormorant depredation order allows fish farmers to implement strategies similar to those used by waterfowl hunters, such as using decoys, blinds, and camouflage clothing (USDI-FWS 1998). Employing such tactics might enable farmers to reduce the number of birds on their farms significantly without affecting continental or flyway populations. Under the old permit system, catfish farmers reported taking an average of only 42 cormorants per year, and the total number reported shot in any one year never exceeded 68 percent of the authorized take (Mastrangelo et al. 1995). Assuming an average take of 42 cormorants per catfish farm, the USDI-FWS predicted a total annual take of 92,400 cormorants under the depredation order (USDI-FWS 1998). However, Glahn et al. (2000) found that the take under the depredation order might exceed the reported take under the former depredation permit system and recommended more extensive monitoring of the number of cormorants taken under the depredation order. However, even doubling the take would represent only a small percentage of the annual recruitment, conservatively estimated at 612,000 cormorants per year (USDI-FWS 1998).

Flyway Management

Localized management efforts help to reduce cormorant depredations on southern aquaculture farms but have little effect on the flyway population (Belant et al. In press, Glahn et al. 2000, Mott et al. 1998). The objective of flyway management would be to help alleviate localized conflicts by managing the "interior" population of cormorants. Van Eerden et al. (1995) noted that local conflicts between human interests and great cormorants (*P. carbo*) in Europe seemed impossible to mitigate without managing the entire continental population. For instance, large-scale sanctioned shooting of great cormorants in Germany resulted in no reduction of the observed wintering population (Keller 1999b). This seems to parallel the lack of population decline of birds wintering in the delta region of Mississippi despite the large take of cormorants under the depredation order (Glahn et al. 2000). To some degree, the same difficulty has been observed in attempting to control breeding populations with egg oiling (Gross 1952, McLeod and Bondar 1953). However, combining egg oiling and culling has been effective in controlling populations on a localized basis (Bedard et al. 1999). Thus, effective manage ment of cormorants for reducing depredation to southern aquaculture will likely require more intensive control (culling) on the wintering grounds, control on the breeding grounds, or a combination of both. In addition, preventing new breeding colonies from being established might be an effective way of controlling populations (Bregenballe et al. (1997). A recently initiated satellite telemetry study (QA- 742) will provide insight on where control may be best implemented but not the extent of control needed. For instance, if cormorants wintering in southern aquaculture regions have a strong fidelity for these foraging areas but come from a wide breeding area, then control might be best implemented on the wintering area, i.e. culling at winter roosts. Conversely, control on the breeding grounds may be important if most cormorants come from a rather narrow breeding range. However, science-based management of cormorants will require a thorough knowledge of population and density-dependant parameters that can be incorporated into a population dynamics model for determining the type and extent of control needed to reduce cormorant conflicts.

Most wildlife management plans include species-specific population goals, plans for meeting those goals (e.g., hunting regulations, habitat management plans), guidelines for gathering information on important variables (e.g., population changes, natality, and mortality rates), and criteria for evaluating the effectiveness of the plan (Williams and Nichols 1990, Nichols et al. 1995). As with waterfowl and other species, management of cormorants should be based on the ecology of the species on both the breeding and wintering grounds as well as on biologically realistic and socially acceptable population goals.

Cormorant Life History - Double-crested cormorants are considered seabirds but are well adapted to life away from maritime regions. Like other Pelecaniformes, cormorants are relatively long-lived (Johnsgard 1993), an important consideration when deciding how to manage this species. Populations of long-lived species tend to be regulated by the mortality of juveniles, rather than by that of adults (Hickey 1952, Johnsgard 1993). Because cormorants are long-lived and mortality is highest among juveniles, management relying on egg-oiling and other reproductive control measures will likely be less effective and take longer to achieve the desired result (see also Bédard et al. 1995, 1999; Dolbeer 1998). Unlike most seabirds, cormorants have a relatively high annual reproductive rate of two to three fledglings per year (Price and Weseloh 1986, Weseloh and Ewins 1994, Weseloh et al. 1995). Birds usually reach sexual maturity and breed 3 years after hatching, although some breed during their second year (Palmer 1962, Weseloh and Ewins 1994, Weseloh et al. 1995). In addition, cormorants have several adaptations that help them avoid density-dependent mortality and maintain their population at or near the environmental carrying capacity (Johnsgard 1993). Based on great cormorant population modeling, these density dependant factors would tend to buffer the impact of management actions, but most management actions alone or in combination would lead to stabilization below the environmental carrying capacity (Bregnballe et al. 1997). In contrast to information available to generate population models for the great cormorant in Europe, very little information is available concerning the demographics of the double-crested cormorant (Erwin 1995, Bédard et al. 1995, 1999).

Setting Population Goals - Wildlife managers must have a clearly defined population goal and guidelines by which to meet that goal based on their understanding of the population status and dynamics of a species (even if limited) in order to justify and defend lethal or reproductive control measures (Dolbeer 1998). Precedence for such action is seen in the sustained increases in populations of herring (*Larus argentatus*) and lesser black-backed gulls (*L. fuscus*) which prompted wildlife managers in Britain to cull populations to reduce habitat damage and impacts on other colonial waterbirds (Duncan 1978, Wanless and Langslow 1983, Wanless et al. 1996). Also, biologists successfully implemented a 5-year plan in 1989 to reduce numbers in a breeding colony of cormorants whose excreta was destroying unique insular habitats in the St. Lawrence Estuary (Bédard et al. 1995, 1999). In both Britain and the St. Lawrence Estuary, decisions to remove birds and the population goals established were assessed relative to reducing species-specific damage, while maintaining biodiversity within the ecosystem.

Despite the marked increase in cormorant numbers in the United States and Canada since 1970 and a population now estimated at more than 1 million birds (Tyson et al. 1999), natural limits on further increase and peak population size cannot be accurately predicted. Nonetheless, such population increases on the breeding grounds will likely result in increased depredations at aquaculture facilities and other conflicts in the Southern United States, given recent band recovery analysis and satellite telemetry linking cormorants wintering in Louisiana, Mississippi, Alabama, and Arkansas with breeding populations in the Great Lakes. Although there are increasing concerns about the unchecked growth of cormorant populations, there is no consensus on the biological and social carrying capacities for cormorants on either the breeding or the wintering grounds. Although population goals in southern aquaculture regions are difficult to ascertain, studies that determine the economic threshold of cormorant predation may be an important step in helping define socially acceptable goals. In addition, projections of the extent of control needed from population modeling, coupled with a knowledge of the logistics for accomplishing these control efforts, may provide insight into setting biologically realistic population goals.

Evaluating Management Options - Public sentiment has and will continue to spark debate about the lethal management of wildlife populations. Increasing public awareness and input on natural resource management issues demands that wildlife managers investigate thoroughly all options and stand ready to communicate and defend their decisions. The path of least resistance may be to base strategies on natural population regulatory mechanisms (e.g., limitations on breeding space, fluctuations in the prey base, or disease). However, such expediency will likely maintain the status quo and may even lead to increased in conflicts between cormorant and human activities for an extended period of time. For example, Bregnballe et al. (1997) predicted from population modeling that rapidly increasing great cormorant populations in 1995 would further increase from 108,700 birds to approximately 600,000 before stabilizing 14 years later and that most of this growth would occur during the last 5 years before stabilization. A variety of management scenarios can be evaluated and management decisions justified (given current knowledge of the species' population dynamics) by using population models that project the effects of various options relative to a range of realistic population variables (Bregnballe et al. 1997, see Crouse et al. 1987, Williams and Nichols 1990, Bédard et al. 1995, Nichols et al. 1995, Wanless et al. 1996, Schmutz et al. 1997). For example, Bregnballe et al. (1997) used modeling to explore the efficiency of various control options for great cormorant populations and found that all strategies alone or in combination lead to stabilization of the population at lower levels. However, culling adults and preventing formation of new colonies were the most efficient means of stabilizing the population. With better demographic information, population modeling will help guide the planning process with double-crested cormorants.

Models that have already been used successfully to plan the culling of cormorant colonies in the St. Lawrence Estuary (Bédard et al. 1995, 1999), to evaluate the growth rate of the cormorant population on Lake Ontario (Price and Weseloh 1986), and to evaluate the effectiveness of lethal versus reproductive control measures (Dolbeer 1998) provide a basis for developing future plans to manage cormorant populations. Even with the limited demographic data available for cormorants, initial age-classified matrix models (Caswell 1989, McDonald and Caswell 1993) can be developed that will aid assessment of cormorant population growth thus far, and guide future management decisions.

Assessing Results - Population models are most useful for developing testable hypotheses; confirmation of model predictions must still be obtained from the field. Censuses of managed populations should be conducted during and after control programs are implemented to judge effectiveness and prevent excessive losses (Duncan 1978, Wanless and Langslow 1983, Bédard et al. 1995, 1999, Wanless et al. 1996). Estimates of population indices following a management program provide the data necessary to refine management models important in predicting future population trends (see Wanless et al. 1996). For example, further monitoring of population trends and annual take under the depredation order could provide insight into culling adults as a regional management technique that might, if expanded, accommodate flyway-based objectives. Ultimately, the results of management programs should be assessed from the standpoint of resource economics (Werner in press) and reducing the costs or enhancing the effectiveness of other control strategies (Mott et al. 1998).

Conclusions

Southern aquaculture, primarily devoted to the cultivation of catfish, crawfish, and bait fish, involves the extensive use of large shallow ponds that are highly susceptible to predation by cormorants. Previous research has clearly documented the resulting impact on the catfish industry. This problem has been exacerbated in recent years by the doubling of wintering cormorant populations in catfish production areas of Mississippi from 1995 to 1999. Future increases in cormorant wintering populations combined with growth of southern breeding populations will likely intensify the problem. Current damage abatement measures are of limited effectiveness and are becoming increasingly difficult to implement. Continued research is needed to evaluate cultural and barrier strategies to reduce depredations at aquaculture farms. Methods should also be explored for improving the implementation of the current standing depredation order for reducing local populations on aquaculture farms as well as expanding the depredation order for reinforcing harassment strategies at roosts. Authority should be sought to implement control of localized populations at southern breeding colonies, as needed, to forestall future depredation problems and population growth.

Further, managers should continue to explore the factors ultimately affecting the growth of the cormorant population within the Mississippi flyway and management options necessary to meet preset population goals. We suggest that these investigations include the development of a goal-oriented population model to guide management decisions. Given suitable population models to guide its implementation, we suggest that cormorant populations be managed on a flyway basis, as part of an integrated strategy to reduce their conflicts to southern aquaculture, as well as elsewhere.

Without human intervention, cormorant populations are likely to continue to grow and create increasing problems with southern aquaculture facilities, fisheries, and other colonial nesting species. Dialogue among public agencies and private organizations concerned about the conservation and management of cormorants would facilitate the development of realistic population goals that would ensure the continued well being of this species while mitigating the negative impacts associated with unbridled population growth.

Recommendations