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Double-Crested Cormorants: Too Much of a Good Thing?

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For centuries, people have viewed double-crested cormorants *Phalacrocorax auritus* negatively, and human persecution coupled with environmental contamination severely reduced numbers of cormorants throughout North America. Shifts in paradigms for management of our natural resources resulted in reductions in environmental contaminants and regulatory protection of cormorants, allowing for an amazing population resurgence of this adaptable fish-eating bird. However, for cormorants, as with some other native wildlife species the populations of which have rebounded due to conservation efforts, there have been cormorant–societal conflicts with respect to commercial and natural resources such as aquaculture and sport fisheries. Increasing resource conflicts caused cormorants to be a priority with agencies responsible for their management, resulting in development of policy to facilitate addressing stakeholder concerns. Subsequent research and management in regard to cormorant issues have been subject to considerable challenges and debate. In this feature, we discuss the primary resource damage issues associated with cormorants, management efforts and outcomes, what we have learned, and the future with regard to cormorant management.

RISE OF THE CORMORANT

The double-crested cormorant *Phalacrocorax auritus* is a large, long-lived, fish-eating, native colonial water bird (Figure 1) and the most numerous and widely distributed species of the six North American cormorants (Dorr et al. 2014). The cormorant's widespread distribution and history provide some insight into how it is perceived. Human persecution up to the early 1900s, coupled with environmental contamination through the early 1970s, severely reduced numbers of cormorants throughout North America (Taylor and Dorr 2003). Reduction of environmental contaminants, regulatory protection, and adaptability to anthropogenic environmental changes (e.g., creation of reservoirs, fish introductions) facilitated an astonishing population resurgence of cormorants (Dorr et al. 2014). In the Great Lakes alone, cormorants rebounded from around 200 nesting pairs in the early 1970s to 115,000 in 2000 (Taylor and Dorr 2003). However, for cormorants, as with some other native wildlife species the populations of which have rebounded due to conservation efforts, there have been conflicts with respect to natural resources and society (Carey et al. 2012).

THE ISSUES

For centuries, people have viewed cormorants negatively. The use of the word "cormorant" in classical literature represented greed and gluttony (Taylor and Dorr 2003). Yet to some, cormorants remain esthetically pleasing, a representative of wildness and remarkable adaptability. Resource professionals have long recognized the ecological value of all wildlife, and cormorants are no exception. However, resource professionals also recognize

Figure 1. Nesting double-crested cormorants. Photo credit: D. Tommy King, USAD-WS, National Wildlife Research Center.

that some wildlife, particularly abundant wildlife, can have negative interactions with other wildlife and society. There is a host of real and perceived cormorant conflicts with various natural resource stakeholder groups; however, four categories of impacts drive most of the issues and management associated with cormorants: impacts to fisheries, aquaculture, co-nesting species, and insular habitat (see Dorr et al. 2014).

In the United States, nearly all bird species are protected by the Migratory Bird Treaty Act, the oversight of which is a responsibility of the U.S. Fish and Wildlife Service (USFWS). Increasing resource conflicts in the early 1990s caused cormorants to be a management priority with the USFWS. The USFWS, in cooperation with U.S. Department of Agriculture Animal and Plant Health Inspection Service Wildlife Services (USDA-WS), developed, after years of National Environmental Policy Act review, new policies for addressing the aforementioned cormorant issues. The result was the issuance of the Aquaculture Depredation Order (AQDO) in 1998, and the Public Resource Depredation Order (PRDO) in 2003 (collectively DOs), affecting 13 and 24 states, respectively. The DOs enhanced the flexibility of aquaculturists and management agencies to deal with local cormorant issues, including lethal control, while ensuring the long-term sustainability of cormorant populations through USFWS review (Hanisch et al. 2011; Dorr et al. 2014).

MANAGEMENT AND COLLABORATION

The AQDO of 1998 eliminated the requirement that producers obtain individual permits and enabled fish farmers in 13 states to shoot cormorants that are foraging at their farms (Glahn et al. 2000). The AQDO did not restrict the number of cormorants that may be shot; however, farmers were still required to report the numbers of cormorants killed to the USFWS. The AQDO was modified on renewal in 2003, expanding the depredation order to allow lethal shooting by USDA-WS or their designated agents for reinforcing dispersal strategies at cormorant night roosts in aquaculture-producing areas (Glahn et al. 2000).

The PRDO allowed authorized agencies to reduce cormorants locally through culling and egg oiling or nest destruction of up to 10% each year. Take beyond 10% of a breeding colony was permitted with advance notice of management methods, goals, and expected impacts to cormorants and nontarget species and if the USFWS found no threat to sustainability of cormorants. Considerable cormorant management efforts have occurred under the DOs. Early on, it was recognized by managing agencies that research and monitoring associated with management activities would be desirable, not just to document damage but also to provide feedback on management effects and whether management goals are met. So what has been done and what have we learned?

Fisheries

Various state and federal agencies and some federally recognized Native American tribes have managed cormorants under the PRDO since its inception in a variety of locations across the eastern and central United States. One of the first locations to receive management under the PRDO was the Les Cheneaux Islands (LCI) of northern Lake Huron. The LCI is a 26-island archipelago and was home to an important recreational Yellow Perch *Perca flavescens* fishery but was also colonized by more than 11,000 nesting cormorants on five of the smaller uninhabited islands.

Research in the LCI in the 1990s documented predation by cormorants on Yellow Perch but concluded that it was not sufficient to diminish the Yellow Perch population or fishery (Belyea et al. 1999). The majority of predation on Yellow Perch was documented to occur in mid-April to mid-May and, to a lesser degree, in mid-August to early October, corresponding with the prechick and postfledging period of the cormorant breeding season (Belyea et al. 1999). During the late spring and summer, cormorant consumption was primarily nonsport fish species like the invasive Alewife *Alosa pseudoharengus* (Belyea et al. 1999). Belyea et al. (1999) estimated that seasonal consumption of Yellow Perch numerically was between 270,000 and 720,000 in 1995. Belyea et al. (1999) also documented that cormorants primarily fed on young Yellow Perch (ages 1–3), concluding that the lack of direct competition with angler-caught age-classes was further evidence that there was no impact requiring management action (Belyea et al. 1999). However, by 2000 the Yellow Perch population and recreational fishery collapsed and further investigation concluded that cormorants were a significant source of mortality contributing to that collapse (Fielder 2004, 2008). These differing research results underscored some of the initial challenges in pursuing cormorant management, those being how to assess fisheries impacts and what constitutes actionable evidence.

While Belyea et al. (1999) documented that more nongame prey species were consumed by cormorants than Yellow Perch, the significance of the impacts can be assessed only with respect to Yellow Perch population demographics. Subsequent studies in the LCI have utilized different population assessment methods than diet studies to illustrate possible cormorant impacts. Fielder (2008) concluded that cohort-specific mortality rates are an effective method to document cormorant impacts and their significance. Using this method, Fielder (2008) documented total annual mortality rates on Yellow Perch as great as 85% while the LCI fishery was in collapse, leaving only natural mortality sources such as predation as limiting mortality factors.

Assessing total annual mortality when natural mortality of the youngest age-classes is the leading cause of mortality is challenging (Diana et al. 2006). Total annual mortality rates in fisheries are often assessed with catch curves (estimating the slope of the declining age structure from a population sample). If mortality varies by age and is concentrated on recruits, collections may result in flattened age structures for catch curves, resulting in an underestimated total mortality rate (see Miranda and Bettoli 2007 for a review). For this reason, Fielder (2008) hypothesized that Belyea et al. (1999) may have underestimated total annual mortality rates caused by predation of cormorants on Yellow Perch. In addition, Alewives declined in Lake Huron (Riley and Roseman 2013) shortly after the Belyea et al. (1999) study, possibly causing increased cormorant predation on Yellow Perch, resulting in a phenomenon known as prey-partner loss, leading to further decline (Brodie et al. 2014).

In 2003, following years of fisheries monitoring, research, review of management alternatives, and public comment, the Michigan Department of Natural Resources and USDA-WS partnered in an effort to manage the cormorant and sport fishery issues in the LCI. The research was conducted in an adaptive framework with premanagement modeling conducted to evaluate effects of management on cormorant numbers and the a priori selection of fishery and Yellow Perch population metrics to evaluate management outcomes. Throughout, annual monitoring provided feedback to guide agencies on whether management effectively reduced cormorant numbers and foraging and if the Yellow Perch fishery responded, given the underlying hypothesis that cormorants are a limiting mortality source (Fielder 2010; Dorr et al. 2012b).

Cormorant management using egg oiling and lethal control of adults on breeding colonies was implemented in 2004. Management resulted in a 90% decline in nesting numbers within 6 years and reduced foraging in the LCI. All monitored Yellow Perch population and fishery metrics trended in the direction expected, given that cormorants are an influential mortality source. Significantly, cohort-based mortality rates of Yellow Perch declined during management to their lowest levels since 1996 and the Yellow Perch population increased (Fielder 2010). In the Les Cheneaux Islands case study, control activities implemented under the provisions of the PRDO were successful in releasing the Yellow Perch population from the deleterious effects of cormorant predation. Management led to recovery of most fish population and fishery metrics in the LCI (Fielder 2010) but has done little to stem the debate surrounding cormorant management or research to document impacts to fisheries (Diana 2010; Fielder 2010; Wires 2014).

There are clearly many challenges to assessing cormorant impacts to fisheries. These challenges are not confined to North America, as similar issues have been observed in Europe with cormorant species and fisheries (see Cowx 2003 for a review). The tendency for cormorant predation to mimic recruitment declines (poor reproductive success) is often given as a competing hypothesis to cormorant-caused declines of a fish population. A number of researchers have documented this reduced recruitment effect of cormorant predation on Yellow Perch (O'Gorman and Burnett 2001; Fielder 2008, 2010), Walleye *Sander vitreus* (Rudstam et al. 2004; Dorr et al. 2010; Coleman et al. 2016), and Smallmouth Bass *Micropterus dolomieu* (Lantry et al. 2002), with some describing the phenomena as a mortality bottleneck prior to recruitment (Figure 2). This predation effect may reflect foraging cormorants being tied to a breeding colony (central place foraging) for extended periods. This foraging behavior is described as Ashmole's halo, a term derived from Philip Ashmole's seminal paper on the subject (Ashmole 1963). Ashmole's halo describes a general theory of regulation of breeding populations of colonial waterbirds based on the energetic relationship between their reduction of prey within a given radius of a breeding colony and the increased energetic demand associated with having to forage farther from a colony to find prey as colony size increases (Ashmole 1963; Birt et al. 1987; Lewis et al. 2001). Ashmole's halo, in effect, provides a colonial water bird–specific mechanism for Holling's (1959) foundational type-III density-dependent predator–prey response.

Cormorants tend to consume younger age-groups of a sport fish population (likely due to abundance and preferred prey size) before moving on to older ages or switching to other prey species. Schultz et al. (2013) hypothesized that this type-III functional re-

sponse of cormorants to multiple prey contributed in part to declines of percids in Leech Lake, Minnesota. While such cormorant predation may occur prior to recruitment to a fishery, it likely still comes at life stages beyond where mortality is largely compensatory and is therefore additive, to some degree, on total mortality (Rudstam et al. 2004). If this relationship is correct, then cormorant predation mimicking recruitment declines can lead to misinterpretation of predation impacts that will not be revealed until later investigations (Fielder 2008) or will require elaborate modeling exercises (Rudstam et al. 2004). Ultimately, it may require age-structured quantitative stock assessment methods such as statistical catch at age models to disentangle the relative sources of age-specific mortality rates. Such approaches, however, require long-term, data-rich assessments that do not typically exist in most locations.

Classic predator–prey theory (Townsend et al. 2003) has often been interpreted to mean that a predator will never be solely responsible for the collapse of a prey population, expecting instead compensation in predator abundance to declining prey abundance. Where this thinking breaks down, however, is when ecosystems have changed in a way that favor predators or disadvantage prey or when the prey are not the primary prey. If predator abundance is tied principally to a highly abundant prey (e.g., Alewives or Round Gobies *Neogobius melanostomus*), then their functional response to a secondary prey such as Yellow Perch becomes decoupled and predation can then greatly reduce or even eliminate a prey population. Hilborn and Walters (1992) described this effect as a predator threshold resulting in dispensatory prey mortality with declining prey abundance due to consistent predation from a predator population sustained by other prey resources. As such, predation can result in the extirpation of a prey species in those systems (Drost and McCluskey 1992; Wittmer et al. 2005). This predator threshold effect may be compounded in the case of central place foragers like breeding cormorants, which must forage within an area bounded by physiological demands, regardless of prey density.

Addressed less often when examining potential fishery impacts of cormorants are secondary effects such as competition for prey resources in prey-limited situations. Cormorants often consume prey fish species that are also the principle prey for species of recreational or commercial importance. Profound changes in the food webs of Lakes Huron and Michigan have resulted in reduced pelagic prey resources and shifts to more benthic prey species (Claramunt et al. 2012; Riley and Roseman 2013), posing possible limitations to, for example, the recreationally popular Pacific salmon fishery. As fishery managers alter stocking and management to try to maintain predator–prey balance, there is awareness by some that cormorants are among a suite of predators competing for limited prey (Dobiesz et al. 2005).

Comprehensive studies evaluating cormorant impacts to fisheries are limited owing to the cost and complexity necessary to draw reliable conclusions (Dorr et al. 2012b). However, in studies where cormorant control has been implemented and fisheries outcomes evaluated, fishery improvements have been observed (Fielder 2010; Dorr et al. 2012b; Schultz et al. 2013; Johnson et al. 2015; Coleman et al. 2016). The strength of evidence varies for each study and in many cases is complicated by other contributing factors. However, combined, these studies provide substantial evidence that cormorants can impact local fisheries and management can improve fish populations and fishing opportunities. Even with existing research, further study would be beneficial regarding issues such as predator thresholds, trophic effects, and competition for prey in prey-limited situations (Ridgway and Fielder 2013).
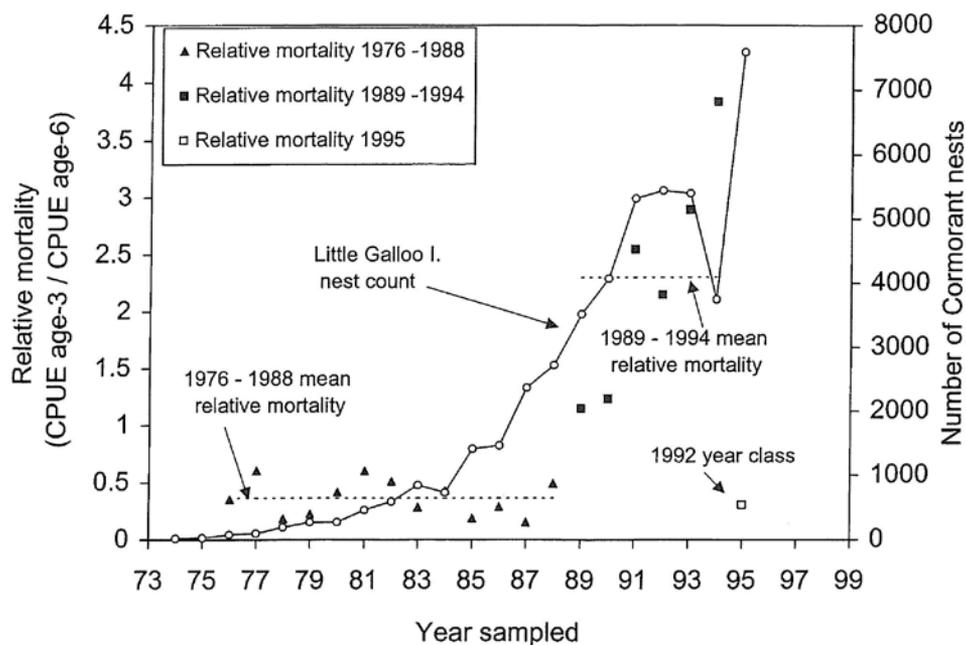

Figure 2. Relative mortality of Smallmouth Bass recruits from eastern Lake Ontario relative to double-crested cormorant abundance. The relative mortality of Smallmouth Bass from the eastern basin of Lake Ontario between ages 3 and 6 (triangles: 1976–1988; squares: 1988–1995) and the number of cormorant nests on Little Galloo Island (circles) versus year. Relative mortality is equivalent to the catch per unit effort (CPUE) of age-3 Smallmouth Bass divided by the CPUE of age-6 Smallmouth Bass within the same cohort 3 years later. Relative mortalities are plotted for the year in which the age-3 Smallmouth Bass were sampled. Dotted lines represent estimates of the means of relative mortality data for years 1976 to 1988 and 1989 to 1994 and are extended to cover each time interval. Reprinted with permission from Lantry et al. (2002, Figure 3).

Catfish Aquaculture

Commercial production of catfish *Ictalurus* spp. is one of the largest aquaculture industries in North America (Dorr and Engle 2015). Due to favorable geologic, climatic, and socioeconomic factors, much of this catfish production occurs in the southeastern United States and the southern end of the Mississippi flyway, a major migratory route for birds, including cormorants (Dorr et al. 2012a). During winter, more than 60,000 cormorants may be in the primary aquaculture-producing regions on any given day. Cormorant depredation at catfish farms has been extensively studied (see Dorr et al. 2014). Direct predation impacts due to cormorants in western Mississippi alone were estimated at US$5.6 to $12.0 million annually (Dorr et al. 2012a). While these estimates of regional impacts are important to the industry, individual farmers experience losses at the pond level. Trying to estimate impacts at the farm and pond level have proved challenging for a host of reasons (Dorr et al. 2012a).

Research has shown an average of about 16 cormorants per day feeding on a 6-ha pond over the winter (October–March) could cause a 22% decline in biomass at harvest and negative return to the producer, even in the presence of buffer prey and accounting for compensatory growth of surviving catfish (Glahn and Dorr 2002). However, this study was conducted in a single-batch production system, whereas most commercial catfish production occurs in multibatch production systems. In multibatch production, different sizes of catfish are present in ponds after the first year of production. Faster growing catfish are selectively harvested for sale (food fish) using a large mesh seine, and stocker size fingerlings (15–20 cm) are then stocked to replace fish harvested, plus any losses incurred (Tucker et al. 2004). This production system is largely driven by the need to provide continuous production to processors throughout the year (Tucker et al. 2004). Production can continue for years without the need to drain and refill ponds. An unintended outcome of this production system is that catfish of a consumable size for cormorants are available in most food fish production ponds, which make up the majority of total ponds (Dorr et al. 2012a).

Dorr and Engle (2015) evaluated declines in catfish production based on simulated levels of cormorant predation on only stocker size fingerlings in a multibatch system. This research evaluated a multibatch scenario in which about 50% of the harvestable catfish had been removed and replaced and at a specific stock density (25,000 head/ha). The sale price needed to break even increased with increasing predation on fingerlings up to a maximum of 14.3 more cents per kg, largely due to reductions in biomass at harvest (Figure 3). Of interest, due to compensatory growth of catfish, as their density decreased the largest incremental losses occurred at lower predation levels. Compensatory mortality (e.g., mortality due to disease) was not a factor in loss estimates, as reduced catfish density due to predation did not increase survival of the remaining fish (Dorr and Engle 2015).

The research by Dorr and Engle (2015) represents a stocking rate that is at the upper end for the industry range and reflected the findings of Glahn et al. (2002) that higher stocking densities may mitigate cormorant-caused losses. Lower stocking densities and varying proportions of stocked versus harvested catfish could alter losses at harvest due to cormorant predation. It is likely that these pond-level loss estimates due solely to depredation are conservative, as they do not account for lower stocking densities, disease transmission by cormorants, or multiplicative losses through the economy to processors and retail markets.

So what has worked to limit losses? An enormous range of nonlethal management tools have been used to limit cormorant predation. Pyrotechnics, propane canons, effigies, overhead wires, changes in culture practices, and even lasers have all been tried with mixed success. Even when multiple techniques are used in an integrated program, cormorants can become habituated to nonlethal methods relatively quickly. The most effective tools to date have been on-farm nonlethal harassment and lethal shooting from a vehicle and night roost nonlethal harassment and lethal shooting conducted primarily by producers and USDA-WS (Dorr et al. 2012a).

The USDA-WS roost harassment efforts (Figure 4) mainly occur in the aquaculture-producing areas of Mississippi and Alabama. The Mississippi program was designed to shift cormorants from night roosts near aquaculture to roosts along the Mississippi River where there is a more natural foraging habitat (Glahn et al. 2000; Dorr et al. 2012a). In Alabama, these programs are designed to shift cormorants away from aquaculture farms, with some roosts serving as unmanaged refugia. These programs have been shown to be successful in reducing cormorant foraging on nearby farms and industry in the region. Mott et al. (1998) evaluated coordinated dispersal of roosting cormorants in MS and found that cormorants did shift their roosting activity to locations along the Mississippi River and subsequently reduced cormorant numbers in the vicinity of catfish ponds by approximately 70% compared to nonharassment periods (Mott et al. 1998). Regionally, a 10% annual shift of wintering cormorants to Mississippi River roosts was estimated to reduce regional losses by $0.6 to $1.2 million (Dorr et al. 2012a). This and other research has provided biologically based and aquaculture-specific management
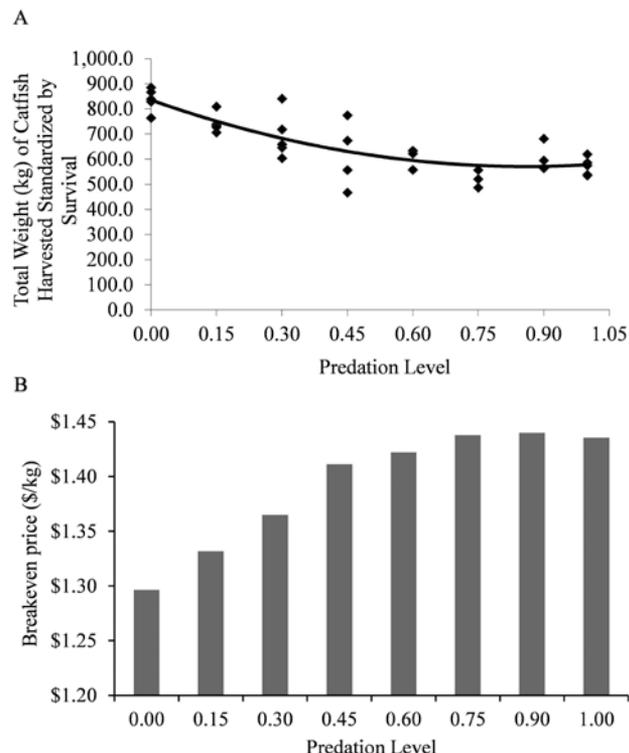

Figure 3. (A) Nonlinear trend (R^2 = 0.68) in overall weight of catfish harvested and standardized for pond-specific survival to simulate various levels of double-crested cormorant predation. (B) Estimated breakeven price of Channel Catfish *Ictalurus punctatus* harvest (US$/kg) above total production cost specific to losses associated with varying levels of simulated double-crested cormorant predation. Reprinted with permission from Dorr and Engle (2015, Figures 2 and 4).

that has been effective; however, challenges remain in refining management methods and economic loss estimates.

Although the night roost harassment and shooting program continue to be used, they have changed substantially. Agency budget and logistic limitations have been further exacerbated by increases over time in the wintering population and number of known roost sites in the aquaculture-producing regions (Glahn et al. 2000). Other factors may have changed the nature of cormorant depredation and therefore loss estimates. The hectares of aquaculture in production, particularly in Mississippi, have declined by 60% from a peak in the mid-2000s. There have also been changes in culture practices, such as split-pond culture where fish are concentrated in a smaller area potentially reducing predation and facilitating dispersal (Dorr et al. 2016). These changes have raised questions regarding cormorant impacts. For example, are there now more cormorants on fewer ha of aquaculture, or is it unchanged or even reduced? Do cormorants have the same distribution, and can harassment programs still shift them to areas along the Mississippi River? Previous research has clearly shown that cormorants can impact aquaculture and that management can reduce those impacts. However, the nature of those impacts should be revisited with respect to changes in the industry and culture practices.

Habitat and Co-Nesting Species

Cormorants have caused extensive damage to vegetation where they nest due to excessive guano, associated soil chemistry changes, and physical destruction (Hebert et al. 2014; Ayers et al. 2015; Lafferty et al. 2016; Figure 5).These impacts can be relatively rapid (tree mortality in 3–10 years). Changes in soil have been shown to affect plant species composition, resulting in reduced number of species and opportunity for exotic, inva-

sive plants (Ayers et al. 2015), as well as impacts to arthropod communities (Craig et al. 2012). Hebert et al. (2014) documented significant damage to trees on forested islands associated with cormorant nesting and that vegetation damage can negatively impact co-nesting avian species that are obligate tree nesters. These impacts are not relegated to the cormorant's northern breeding grounds, as Lafferty et al. (2016) documented significant impacts to trees and soils on southern breeding colonies. As the vegetation dies, the adaptable cormorant will often continue to nest on downed trees or the ground leading to open areas free of almost all vegetation. Conflicts occur when there are impacts to sensitive habitats and vegetation, including diminished nesting habitat for other birds. In some cases, cormorants may directly compete for limited nesting space (e.g., Figure 6). However, some species that nest in open areas (e.g., American white pelican Pelecanus erythrorhynchos) may benefit from cormorant-caused habitat change.

A number of cormorant management efforts have been conducted in the United States and Canada to address these vegetation and co-nesting species issues. One example is West Sister Island, Lake Erie, Ohio, where the Ohio Department of Natural Resources (ODNR), USDA-WS, and USFWS Ottawa National Wildlife Refuge have collaborated to manage cormorants to reduce damage to native vegetation and wildlife, including rare species. A sharp decline in numbers of nesting wading birds, particularly great blue herons Ardea herodias, coincided with increases in cormorants and damage to nesting habitat. A strategy incorporating monitoring programs with integrated wildlife damage management, including no-entry zones, habitat modification, and culling, was developed and implemented in 2006. With annual culling, cormorant nesting pairs have declined from a peak in 2005, fluctuating at or just above target levels of 1,500–2,000 since 2007. Overall, there has been a sustained positive veg-

Figure 4. Double-crested cormorants dispersed from a night roost in Mississippi. Photo credit: USDA-WS, National Wildlife Research Center.

Figure 5. (A) Impacts of double-crested cormorants on Young Island, Lake Champlain, Vermont, in 1996. (B) Young Island in 2015, after several years of cormorant and gull control and habitat remediation (note planted trees in background). Photo credits: John Gobielle, Vermont Game and Fish.

etation response to cormorant management, and numbers of nesting pairs of wading bird species have been stable at or near management goals (ODNR 2013).

There are a few other examples of management of cormorants to protect insular habitats, primarily in the Great Lakes. Hebert et al. (2014) documented decline in forest cover on three islands in western Lake Erie, Ontario, Canada, ranging from 47% to 85%. Cormorant control to reduce numbers, including culling, on one of the islands (Middle Sister Island) reduced cormorant nesting densities, and vegetation has begun to recover, whereas vegetation on the other two islands without management has continued to decline (Hebert et al. 2014). Management of cormorants at Tommy Thompson Park, Toronto, Canada, by the Toronto and Region Conservation Authority (TRCA) was undertaken in 2008 on four island peninsulas within the park due to severe declines in forested habitat and co-nesting species (TRCA 2016). The TRCA has taken a largely nonlethal approach of attempting to decoy cormorants from tree to ground nests coupled with intensive pre- and post-nesting harassment and active nest and egg removal from remaining forested areas (TRCA 2016). Cormorant numbers have declined by 56% as of 2015 on a managed forested peninsula. Overall numbers of nesting cormorants continued to increase through 2013, with much of this increase due to successful shifting to ground nesting at other locations (TRCA 2016). However, remaining trees on the managed peninsula still indicate severe impacts relative to a control site, and black-crowned night-herons have continued to decline. Continued research and monitoring will be necessary to determine if less intrusive methods can mitigate impacts.

Cormorant damage to habitat and relatedly co-nesting species may be the most visible and easily documented of the issues associated with these abundant birds. However, managing cormorants to reduce those impacts can be incredibly challenging. Trying to balance the needs of the species and habitat involved presents a complex mix of potential methods and outcomes. The preceding examples are a few of several ongoing management efforts geared toward addressing cormorant impacts to insular habitat and co-nesting species and represent a portion of the range of integrated and adaptive wildlife damage management techniques used.

MANAGING ABUNDANT WILDLIFE

Natural resource managers are given the very difficult task of maintaining as much remaining diversity and ecological integrity as possible while meeting multiple societal uses of those resources. At times, this mandate has meant controlling abundant wildlife to benefit wildlife and habitats that are rare or to benefit human uses. When this management is in the form of control or culling, it has created a philosophical dilemma for some natural resource professionals. Zwart (2008) framed two largely competing philosophies among natural resource professionals, with the "governance view of nature" consistent with an interventionist approach for either rare or overabundant wildlife and the compet-

Figure 6. Double-crested cormorants competing with a herring gull *Larus argentatus* for its nest site. Photo credit: Brian S. Dorr, USDA-WS, National Wildlife Research Center.

ing "rationalist view" or "romantic view" in which nature naturally reflects harmony and human intervention is nearly always a perturbation to that harmony (Ridgway and Fielder 2013). Ultimately, the decision to invoke cormorant management for the benefit of other species or habitats is a matter of policy and law to be sorted out by agency managers and their constituencies. In none of the preceding examples have cormorants been extirpated from an area by management, but many are killed. Given this, agency collaboration and adaptive management frameworks can help reduce the risk of unexpected outcomes and inform and refine management efforts.

OUTLOOK

A recent lawsuit regarding the DOs has put a hold on further management under these authorities. However, cormorants remain very abundant in North America. It is unlikely that cormorant-related conflicts and the call and need for management will end in the near future. Much has been learned about cormorant management, affected resources, and management outcomes since the DOs were originally implemented. This information can be used to update and refine cormorant management for the future.

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