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The Direction of Research and Management of Double-crested Cormorants Heading into the 2000s: Symposium Overview and Future Information Needs

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Abstract.—An overview is provided of a symposium on the direction of research and management of Double-crested Cormorants (*Phalacrocorax auritus*) heading into the 2000s. The current symposium built on previous efforts and described a number of focus areas of informational need, including cormorant impacts on natural resources, demographics of cormorants, assessment of control efforts, assessment of fish consumption and bioenergetics, and cormorant spatial ecology and influences on movements. The cormorant symposium highlighted a shift in research focus relative to earlier symposia, from evaluating potential impacts on commercial and natural resources to evaluating management actions in attaining desired goals. In addition, the symposium addressed the pressing need to obtain baseline information on cormorant population demographics. The shift reflects a response to increasing management efforts and intensity in North America and the need to understand the effects and effectiveness of increased cormorant control at several spatial scales. The symposium furthered communication and the sharing of information on cormorant issues in North America. However, uncertainty regarding impacts to cormorants associated with policy changes and management actions and outcomes presents significant future challenges. *Received* 26 July 2012, *accepted* 26 August 2012.

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In North America, the population of Double-crested Cormorants (*Phalacrocorax auritus*; hereafter cormorants) has increased substantially since the late 1970s, particularly in the eastern United States and Canada including the Great Lakes (Hatch and Weseloh 1999; Wires and Cuthbert 2006). Given that in 1972 the cormorant was added to the list of protected birds in the U.S. Migratory Bird Treaty Act (23 U.S.T. 260 1972; Trapp *et al.* 1995), this population resurgence can be considered a conservation success story (Taylor and Dorr 2003; Wires and Cuthbert 2006). However, as with some other conservation success stories (e.g. White-tailed Deer, *Odocoileus virginianus*), there have been both positive and negative aspects to population recovery from a human perspective (Conover 2002). With the cormorant's long history of negative perception by humans (Jackson and Jackson 1995; Taylor and Dorr 2003), it was perhaps inevitable that the increase in cormorant numbers would lead to increased concern over real and perceived damages associated with cormorants. While there was increasing evidence that at the current population size cormorants can impact commercial and natural resources (Shieldcastle and Martin 1999; Rudstam *et al.* 2004; Hebert *et al.* 2005; Fielder 2010), the significance of resource damages and the need and intensity of management to address potential impacts are often complex and ambiguous. The uncertainty was the driving force for this symposium on the direction of research and management of Double-crested Cormorants in the 2000s.

Several North American symposia have focused on cormorant research, conservation and management issues. Two of the most prominent of these were "The Double-crested Cormorant: Biology, Conservation and Management" held in 1992 and published in 1995 (Nettleship and Duffy 1995), and the symposium on "Double-crested Cormorants: Population Status and Management Issues in the Midwest" held in 1997 and published in 1999 (Tobin 1999). The general consensus of these symposia was that more data were needed to inform management decisions regarding this often controversial species. Interestingly, these findings are similar to those involving the Great Cormorant (*Phalacrocorax carbo*) in Europe, and several other species elsewhere, highlighting the fact that cormorant conflict with humans is geographically very widespread (Doucette *et al.* 2011). Thus, the insights generated from considering collective bodies of work on cormorants have the potential to inform management plans not only in North America, but also worldwide.

The current symposium attempted to build on previous efforts and described a number of focus areas of informational need highlighted from previous symposia. Covering all potential research topics was beyond the scope of this one-day symposium; however, a number of needs were addressed. Chief among the needs were a better understanding of: (1) cormorant impacts on natural resources including fisheries, co-nesting bird species, and vegetation; (2) demographics of cormorants, particularly as they relate to population modeling efforts; (3) assessment of effectiveness of control efforts; (4) assessment of fish consumption and bioenergetics of cormorants; and (5) migration ecology, local and seasonal movements, and potential management effects on movements of cormorants. The research in this symposium covered aspects of all of the topics listed above with some topics being covered by several articles. We provide an overview by primary topic covered for research presented at the symposium, as well as general conclusions and areas of future research need.

Overview

Impacts on Natural Resources

Craig *et al.* (this issue) examined the effects of cormorants and co-occurring colonial waterbird species on their nesting habitats by observing plant and arthropod community structure as well as soil and leaf litter characteristics. Existing literature has highlighted impacts of nesting cormorants to vegetation (e.g. Weseloh and Ewins 1994; Weseloh and Collier 1995; Wires *et al.* 2001), but information on impacts to soil and soil animal communities are less well known. Craig *et al.* (this issue) found that plant species richness and total plant cover were reduced in cormorant colonies, and that the arthropod community shifted from primarily plant feeders to carrion and dung feeders relative to reference areas. In addition, these ecological impacts were related to colony size and history, with older, larger cormorant colonies being more affected than those that were more recently established or comprised long-legged wading bird species.

Koh *et al.* (this issue) assessed the physical attributes of individual trees to determine whether forest damage increased with cormorant nesting densities on Middle Island in Lake Erie, Canada. Sampling stations with high numbers of cormorant nests were significantly related to lower crown densities, more transparent foliage and greater branch damage than stations with fewer cormorant nests. The authors reported extensive defoliation of mature trees and reduced canopy coverage with several damage indices indicating worsening trends over the study period (2004-2006). Koh *et al.* (this issue) showed that cormorants can affect the stability and trajectory of ecosystems and vegetation communities and how rapidly these changes can occur in response to increases in bird numbers.

Craig *et al.* (this issue) and Koh *et al.* (this issue) provide useful information with regard to vegetation impacts, which are often a consideration when implementing cormorant management, but little published information is currently available (see Kolb *et al.* 2010; Boutin *et al.* 2011). Interestingly Koh *et al.* (this issue) suggest that findings from this study (and other research) could be used in developing carrying capacity models for Middle Island to determine the number of nests that can be supported while maintaining the island's ecological integrity. The research by both Craig *et al.* (this issue) and Koh *et al.* (this issue) could prove beneficial in furthering such modeling efforts which would be a valuable tool with regard to cormorant management and policy.

Population Demographics

Compared to many other bird species the population dynamics of cormorants are poorly known. The lack of knowledge was recognized in earlier symposia (Erwin 1995) and presents an important current challenge with respect to changing cormorant management paradigms and policies. With the advent of the Aquaculture and Public Resource Depredation Orders in the United States (USDI/FWS 2003), the need to model the potential cumulative effects of increasing local management efforts has only increased. A considerable amount of research effort has been expended on this subject in this symposium driven at least in part by regulatory factors.

Seamans *et al.* (this issue) used band recovery models to test several hypotheses, including the effects of the depredation orders and disease epizootics on annual survival of cormorants in the Great Lakes from 1979 to 2006. The authors indicated no apparent trend in annual survival of second-year and older cormorants, whereas hatch-year cormorants showed a density-dependent declining trend with a small additive effect due to management activities. These findings provide valuable data on annual survival of cormorants at a large spatial scale (i.e. Great Lakes of the U.S. and Canada) and potential cumulative effects of management on hatch-year cormorants.

Stromborg *et al.* (this issue) took a different approach in focusing their analyses of band recovery data on survival patterns of cormorants from selected Wisconsin colonies from 1988 to 2006. The authors found that mortality rates, both natural and anthropogenic, of cormorants from these colonies appear to have risen as the population has grown and control activities in the southern U.S. have increased. However, their results indicated considerably lower adult survival than reported by Seamans *et al.* (this issue). The authors also modeled the effects of 90% reproductive control (simulating egg-oiling) and found that simulated colony breeding numbers decreased by 27 to 30% per year. These data can be used by managers directly if the modeled rates of population reduction suit management objectives. However, field validation of models would be a very useful addition to information in this area (as in Smith *et al.* 2008).

Seefelt (this issue) examined short-term, annual population changes and distribution patterns of cormorants in the Beaver Archipelago of northern Lake Michigan between 2000 and 2007, and compared these data to decadal trends for the Great Lakes as a whole. The primary insights were that the long-term trends in the cormorant population are likely captured with decadal surveys, but the dynamic nature of local and cormorant metapopulations was not. Seefelt's (this issue) conclusions are also supported by the differences in survival and response to management seen by Stromborg *et al.* (this issue) as compared to the larger-scale analyses by Seamans *et al.* (this issue). These findings highlight the importance of scale in evaluating cormorant population or colony demographics.

Evaluation of Control Efforts

DeVault *et al.* (this issue) provide a history and review of management efforts to reduce negative impacts of cormorants in central New York, and particularly on Oneida Lake. The authors conclude that management has been successful in reducing cormorant use of Oneida Lake, and that management has not significantly impacted breeding terns. They also indicate that there has been an apparent recovery of certain sportfish populations, which may be attributed to cormorant management. The authors acknowledge some limitations of management activities, especially the fact that harassed cormorants dispersed to other locations where additional conflict may arise. The authors also recognize the need for continued research and monitoring in conjunction with management in an adaptive framework. The financial return from cormorant control efforts on Oneida Lake is of particular interest as a means of evaluating control efforts because of their intensity and high cost. Recent modeling efforts have indicated potentially good economic value to cormorant reduction in the area (Shwiff *et al.* 2009); however, the validity of assumptions in the financial models has not been thoroughly tested.

Farquhar *et al.* (this issue) describe a long-term (since 1999) cormorant control program in the eastern basin of Lake Ontario to mitigate cormorant impacts on fish communities and co-nesting colonial waterbird species. Similar to DeVault *et al.* (this issue), they document a decline in cormorant numbers and fish consumption due to management, and provide evidence of increased abundance of a sportfish species. The authors also show that the diversity and numbers of co-occurring waterbirds have either increased or have not been impacted negatively by management. Also, Farquhar *et al.* (this issue) discuss that targeted colony reduction goals have been reached and that the control program is moving into a phase of maintaining current cormorant colony size. The situation is likely to become more common where cormorant control has been implemented and when management programs reach their targeted goals. However, of note, the underlying factors affecting cormorant population success in both Oneida Lake and eastern Lake Ontario (DeVault *et al.* this issue; Farquhar *et al.* this issue), and thereby productivity, remain uncertain. Thus, without addressing the cause of the original cormorant population increase in these areas, long-term control will likely be required to maintain management objectives.

McGregor and Davis (this issue) conducted an interesting evaluation of the cost effectiveness of egg-oiling as opposed to culling for reducing fish consumption by cormorants. They reported that egg-oiling was more cost effective on the basis of control costs per ton of fish predation prevented. The finding contrasts the commonly-held view that culling is a generally more cost effective means of cormorant control. The authors do acknowledge that a host of factors such as colony size, duration of control, public perception and start-up costs could affect the evaluation of culling or egg-oiling cost effectiveness. An additional uncertainty is the economic return on egg-oiling activities at various sites, similar to issues addressed by Shwiff *et al.* (2009). The fish spared from predation by management of cormorants may not be those that provide direct economic return from fisheries. Therefore, it is difficult to determine whether the funds spent on egg-oiling really produce a significant return on investment, and whether tons of fish saved per dollar spent is the best metric for evaluating management practices.

Quinn *et al.* (this issue) evaluated the use of a tethered eagle to displace roosting cormorants. The authors report that the non-lethal technique was effective on cormorants during this short-term study, and that there was a residual effect of several days after the eagle was removed. However, dispersal was localized and cormorants did move to another nearby island, indicating that this technique is limited to certain management scenarios. In this specific case the objective was to move cormorants away from local residential properties, which was accomplished. Such local movements, however, would not reduce fisheries conflicts or mitigate other management issues occurring at larger geographic scales. Nevertheless, as a non-lethal alternative, the technique of using a tethered raptor certainly holds promise.

Assessing Fish Consumption and Bioenergetics

Analyses of cormorant chick diet, feeding rates, and adult foraging directions by Andrews *et al.* (this issue) provide useful information on cormorant foraging and breeding ecology at a large (>6,000 pairs), unmanaged colony. The authors found that cormorants from this colony fed few sportfish to chicks, and approximately 20% of adults foraged over ten km from the colony. The authors also noted a possible density-dependent decline in productivity, suggesting that the colony may be approaching carrying capacity. Baseline information on diet and foraging ecology from an unmanaged colony can help inform decisions regarding cormorant impacts to fisheries, and identify important changes that result from management activities. Studies of cormorants that are not already under the influence of management programs are often difficult to find, making this information a valuable resource.

Göktepe *et al.* (this issue) compare two bioenergetics models of cormorant fish consumption: Madenjian and Gabrey's (1995) model and Niche Mapper™. Both models showed similar results in estimating daily food consumption by cormorants; however, sensitivity analyses varied in parameters of importance to each model. The authors indicate that while the Madenjian and Gabrey (1995) method is simpler and provides greater generality with fewer parameters, the Niche Mapper™ approach provides the capability of extrapolation to new sites where observational data might not be available. The increased input parameters in Niche Mapper™ may also allow for more nuanced explanations of experimental observations.

Coleman *et al.* (this issue), examined the prevalence of an invasive fish species; the Round Goby *(Apollonia melanostomus)*, in the diet of cormorants on the Upper Niagara River over a four-year period. The authors found that Round Goby were consumed throughout the breeding season (May-August) and contributed from 38% to 85% of the biomass in cormorant diet. In addition, the authors indicated that cormorants may show selection for larger Round Gobies, which may have caused significant declines in average length of gobies between and within seasons. Coleman *et al.* (this issue) suggest that cormorant predation may keep Round Goby populations in check near colony sites however the effects of this predation are uncertain. While Round Gobies do compete with native species including sport fish (Johnson *et al.* 2005), they also may serve as a buffer species with respect to cormorant predation on sport and commercial fish species (Coleman *et al.* this issue).

The diet studies reported in this symposium report little consumption of recreationally or commercially valuable fish species. As with the majority of cormorant diet studies, the studies reported here are focused primarily during nesting and chick rearing (May-August) and do not include consumption outside these periods, including migration. Diana *et al.* (2006) reported that 87% of the consumption of Yellow Perch (*Perca flavescens*) and Northern Pike (*Esox Lucius*) by cormorants occurred prior to May 15 and after September 1, in the Les Cheneaux Islands, Michigan. In addition, Dorr *et al.* (2010b) reported significant impacts to sportfisheries in early spring (April-May) caused by migrating cormorants in Michigan. Cormorant diet studies limited to the May-August time periods may miss important spatial and temporal differences in diet composition and potential influences on fish populations including sportfish.

Migration Ecology and Local and Seasonal Movements

Dorr *et al.* (this issue) conducted a two-year satellite telemetry study of summer and migrational movements of satellite-marked cormorants from Little Galloo Island (LGI) in eastern Lake Ontario, New York, which is managed by egg-oiling. They found that egg-oiling was successful in reducing recruitment within breeding seasons, and within-breeding-season re-nesting attempts by cormorants in this study were limited and likely unsuccessful. The study also showed that most (75%) cormorants captured at LGI migrated east of the Appalachian Mountains, and their winter range extended from southeastern Louisiana, along the coast of the Gulf of Mexico, to the southern portion of the Atlantic coast. The authors encouraged further research on between year fidelity of breeding cormorants to their colonies, particularly as it relates to potential management effects.

King *et al.* (this issue) provided two papers: one on winter and summer home ranges and the other describing migration patterns of cormorants marked with satellite transmitters in the primary catfish aquaculture region of the southeastern U.S. They found that mean 95% home range size and 50% core use areas of marked cormorants wintering in the southeastern U.S. were 17,490 ± 1,986 km^2 and 1,550 ± 265 km^2, respectively. The authors also found that winter home range size was not affected by the density of aquaculture facilities in the southeastern U.S., nor by the age class or body mass of marked cormorants. These findings differ from analyses of satellite-marked cormorants reported by Scherr *et al.* (2010), who found that the 95% home range for cormorants wintering in aquaculture regions was significantly larger than those wintering outside such regions. The mean home ranges reported by King *et al.* (this issue) were also much larger than those reported by Scherr *et al.* (2010) in aquaculture and non-aquaculture regions, respectively. The reason for these differences is unclear but may be related to among other factors, differences in analytical methods of King *et al.* (this issue) and Scherr *et al.* (2010) (adaptive kernel home range estimator vs. minimum convex polygon, respectively) or capture effects (captured on wintering vs. breeding grounds, respectively). Regardless, further research may be needed to better understand cormorant movements on their wintering grounds.

Summer home range and core use areas of marked cormorants reported by King *et al.* (this issue) were also on average much larger than the means reported by Dorr *et al.* (this issue) and Guillaumet *et al.* (2011). The differences between these studies may be due to small sample sizes for some home range estimates, differences in methods of home range estimation, marking techniques (e.g. backpacks vs. implants), changes in transmitter technology, and effects of capture and marking on post-release movements. The differences in reported home ranges highlight the difficulties associated with home range estimation for highly mobile species such as cormorants. Nevertheless, it is clear from these studies that cormorants show high individual variability in movements and can move over very large distances within seasons (separate from migration), illustrating part of the major challenge in their management.

In their second paper, King *et al.* (this issue), reported that during spring, cormorants captured in Alabama migrated east of the Mississippi River and primarily west of the Appalachian Mountains. Cormorants from Arkansas, Louisiana and Mississippi migrated north along the Mississippi River Valley, the Missouri River Valley and/or the Ohio River Valley. Departure for spring migration occurred between 26 March and 12 May, with adult cormorants departing earlier for spring migration than immature cormorants. Mean duration of migration was only twelve days with marked cormorants traveling an average of 70 km per day. The average departure date for fall migration was 1 October, which was within the range reported by Dorr *et al.* (this issue). However, Dorr *et al.* (this issue) did report earlier departure dates for some of their marked cormorants from a managed colony.

Conclusions

The one-day symposium on the direction of research and management of Double-crested Cormorants heading into the 2000s covered a broad range of topics on cormorant biology, ecology and management. Although the range of topics was diverse, it also highlighted advances in research and changes in research and management focus from earlier symposia. The 1992 cormorant symposia focused on basic biology and ecology, and management issues were concentrated on cormorant interactions with the aquaculture industry in the southeastern U.S. (Nisbett 1995). While the 1997 cormorant symposium also covered some basic aspects of cormorant ecology, there was also a decided shift in focus to management issues on the breeding grounds, particularly fisheries issues, as well as aquaculture (Cuthbert 1999). The current symposium was even more focused on cormorant conflicts on the breeding grounds. However, consistent with previous symposia has been a continued focus on unanswered questions regarding cormorant biology and ecology, particularly population demography.

The symposium provided much needed information on cormorant population demographics at scales ranging from specific colonies (Seefelt this issue; Stromborg *et al.*

this issue) to the entire Great Lakes (Seamans *et al.* this issue; Seefelt this issue). As regulatory changes and increased management have occurred, particularly on the breeding grounds, there has been a greater need for agencies responsible for cormorant management to have demographic data necessary to evaluate and model the cumulative impacts of management activities. The research provided in this symposium provides useful information with regard to cormorant management, but also highlights the difficulties of translating management trends and population monitoring from colony specific to regional populations of cormorants (e.g. the entire Great Lakes). The view that local management may have cumulative effects on a regional cormorant population is a significant paradigm shift since the 1997 symposium, when limited control efforts where considered unlikely to have population level effects (Siegel-Causey 1999).

Related to the issue of population demographics was research on cormorant migration, and local and seasonal movements using satellite-marked cormorants. This research provided some of the first detailed information on home range size and movements of cormorants on the wintering and breeding grounds, particularly in the aquaculture regions of the southeastern U.S. The research also highlights that cormorants marked on their wintering grounds return to broadly distributed sites on the breeding grounds. Guillaumet *et al.* (2011) reported evidence for existence of a migratory divide in cormorants marked with satellite transmitters in the Great Lakes region of the U.S. and Canada. The movement data presented in this symposium lend further evidence of this migratory divide between cormorants breeding in the western versus eastern portion of the Great Lakes region, and their proportional use of the Mississippi and Atlantic flyways. Similar to Guillaumet *et al.* (2011), research presented in this symposium indicated considerable variability in home range sizes among individual marked cormorants on the breeding grounds.

The largest numbers of papers in this symposium were related to cormorant management and evaluation of management efforts. Clearly, as local management efforts have increased to address various human-cormorant conflicts, evaluation of those management efforts has become ever more critical. The symposium papers provide overviews of management efforts that include egg-oiling and culling of breeding cormorants, and harassment of breeding and migrating cormorants, including the novel non-lethal technique of the use of a tethered eagle to disperse cormorants. The papers highlight the need, challenges and cost to carry out management within an adaptive framework that incorporates management, research and monitoring. However, all authors indicated that further research and monitoring is necessary to fully address the possible range of techniques and tools and management efficacy.

Related to management was the evaluation of fish consumption and bioenergetics of cormorants. Although much work has been done in the area of cormorant diet and bioenergetics (e.g. Ridgway 2010; Seefelt and Gillingham 2008), the papers here approached specific issues of consumption during chick rearing, comparison of models estimating consumption and potential impacts regarding consumption of the invasive Round Goby. A growing number of cormorant control programs have been put in place to address issues associated with fisheries conflicts (e.g. Dorr *et al.* 2010a,b; Fielder 2010). Given that this management often involves culling and reproductive control of cormorants, the ability to accurately assess both fisheries impacts and the efficacy of management actions hinges on the best available data and models. As with previous symposia, cormorant impacts to vegetation and soil communities have received less effort than research on impacts to fisheries resources. However, information from this symposium highlights the relationship between colony history, density and impacts to vegetation and soil communities and how this information may be used to inform management and policy.

Future Information Needs

A significant change in this cormorant symposium as compared to previous symposia has been a shift in research focus. The shift has encompassed a clear move from evaluating potential impacts on commercial and natural resources, and methods for mitigating those impacts, to evaluation of management actions in attaining desired goals. In addition, the importance of obtaining baseline information on cormorant population demographics with respect to increasing management efforts and intensity has clearly been recognized. This shift reflects recent liberalization in regulation and policies, at least in the U.S., regarding cormorant control. However, the term "shift" reflects the fact that these changes in research and management focus are ongoing and considerable knowledge gaps still exist.

An important factor driving much current research and management is determining the effects and effectiveness of increased cormorant control locally and at meta-population and population levels. Similarly, uncertainty associated with policy changes, management actions, and desired outcomes and how to deal with that uncertainty, present significant future challenges. These challenges are no less important in that policy and regulation at times may be contradictory to regional and even continental conservation plans for waterbird management including cormorants (Wires and Cuthbert 2006). Regardless, whether focused on control or conservation, policies and plans are closely linked to the status of the cormorant population (Wires and Cuthbert 2006).

Given increased management activities, a means of estimating cumulative impacts of management and ways to assess how lethal and reproductive control may affect cormorant populations are critical. Development of population models such as potential biological removal models (Runge *et al.* 2009) could provide important information on cumulative impacts of management and provide guidelines for future policy, particularly in light of limited demographic data. As our knowledge of cormorant demographics increases other modeling efforts such as age-structured and spatially explicit models can be developed that can enhance our understanding of cormorant populations and inform cormorant management and conservation. For example, Guillaumet *et al.* (2011) indicated some segregation within the Interior population of cormorants with respect to wintering and breeding grounds and migratory movements. Our understanding of how this segregation could affect evaluation of cumulative management effects is poorly developed. Given this information, is regional monitoring on the wintering and breeding grounds important for evaluating effects of more intensive management? Further regional and population level monitoring and research on spatial ecology in cormorants would be beneficial for informing management.

Although this symposium provided new information regarding evaluation of management programs, considerable effort in this regard is still needed. Information indicating that cormorants can in some cases impact sport fisheries (Rudstam *et al.* 2004; Fielder 2008), cause vegetation damage (Hebert *et al.* 2005; Boutin *et al.* 2011) and impact co-nesting species (Somers *et al.* 2007) is increasing. However, management to achieve specific goals to mitigate damage is relatively recent in the U.S. and Canada and data on their effectiveness are limited. With regard to evaluation of management to reduce impacts on fisheries some new information has been published (Fielder 2010; Dorr *et al.* 2012) suggesting that at least in some cases, short-term management goals can be achieved. However, many questions remain, including whether fishery improvements are sustainable in an ecological context, what is the context for when management works and when it does not, and can this information be used to evaluate where cormorants may have impacts or not?

Information with respect to attainment of management goals in other situations such as mitigation and restoration of vegetation and mitigating impacts to co-nesting species is poorly documented. This symposium provided information on cormorant impacts to vegetation and soil communities and possible management implications but questions remain. Can island vegetation be restored, and if so, how? Is there a carrying capacity for nesting cormorants where ecological integrity of island vegetation can be maintained? Similarly, some information on the effects of cormorant management on co-nesting species was presented in this symposium, but more is needed. For example, if management actions cause more damage to co-nesting species than cormorants themselves, then management would not be warranted. If management simply moves cormorants to other locations where they remain an issue, is management effective?

Evaluating cormorant management can also provide useful information with respect to informing adaptive management and structured decision making as means of reducing risk associated with outcomes of management decisions. More research needs to be done identifying and evaluating the economic and social outcomes of management. For example, what is the cost: benefit ratio associated with management, and is it positive? What are societal views on management and management success, for all involved constituents? As local management moves from programs to reduce cormorant numbers to local maintenance of cormorant numbers, how will that affect management methods? Lastly, what management methods may be most effective in meeting objectives in the most ecologically sound way?

Much of the research on cormorants in the U.S. and Canada has focused on the Great Lakes region. However, cormorants breed in the southeastern U.S. and the prairie pothole region and lakes throughout the northern U.S. and Canada. Little is known about cormorants or their numbers in these regions or where they migrate or winter. Monitoring programs that include these regions would be a good start to provide baseline information on these populations. Also, the symposium provided little information on cormorant impacts to aquaculture, particularly catfish aquaculture. However, the aquaculture industry in the U.S. has been changing rapidly over the past decade, and new issues may evolve. In addition, aquaculture continues to grow internationally, and lessons learned in North America may be useful in other countries.

As is often the case, this symposium identified as many or more information needs as it addressed. However, meeting the challenge of these needs is a necessity in order to provide science-based solutions to cormorant conservation and management. The symposium furthered communication and the sharing of information on cormorant issues in North America to help meet these challenges.

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