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Modeling the economic impacts of double-crested cormorant damage to a recreational fishery

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Abstract: The double-crested cormorant (*Phalacrocorax auritus*) has undergone a significant range expansion in the Great Lakes area of the United States since the 1970s, negatively impacting native fish populations and sport fisheries. Effective management of wildlife requires policies and practices that quantify their economic impacts, which is often complicated by multiplier effects in the regional economy. This analysis estimates the potential direct and regional economic impacts of the cormorant to a recreational fishery. We estimated that the potential economic loss was on average $5 million to $66 million annually, as well as 66 to 929 job-years in the region annually over a 20-year period (1990 to 2009). This approach to calculating the economic impacts of wildlife damage can be applied to other wildlife to provide the most accurate estimate of total economic impacts.

Key words: double-crested cormorant, economic impact, human–wildlife conflicts, input-output modeling, New York, *Phalacrocorax auritus*, recreational fishery, tourism, wildlife damage management

Double-crested cormorants (*Phalacrocorax auritus*) are large, fish-eating, colonial-nesting waterbirds native to the United States and Canada. Their population size has undergone dramatic fluctuations over the past century (Hatch 1995, Weseloh and Ewins 1994). The first documented nesting record for double-crested cormorants in the Great Lakes was in 1913 on the western end of Lake Superior, and from there cormorants spread eastward to colonize the other Great Lakes (Weseloh et al. 1995, Wires and Cuthbert 2006). By the early 1950s, double-crested cormorants were common throughout much of the Great Lakes, although their numbers declined significantly from the 1950s through the mid-1970s due to contamination from agricultural pesticides (e.g., DDT) that damaged their eggs (Hatch and Weseloh 1999). By 1973, breeding cormorants had disappeared completely from lakes Michigan and Superior and were scarce elsewhere in the Great Lakes.

From 1973 through 1991, the double-crested cormorant population began increasing throughout the Great Lakes ecosystem, doubling their population size every 3 years (Hatch 1995). The interior population of cormorants, including the Great Lakes states and provinces, increased from 32,000 breeding pairs in the 1970s to >226,000 pairs in the 1990s (Wires and Cuthbert 2006). Stronger government regulations eventually eliminated the use of the pesticide DDT in the United States. A concurrent increase in food availability for wintering cormorants at catfish aquaculture facilities in the southeastern United States likely contributed to the population increases of cormorants in the Great Lakes region (Hatch and Weseloh 1999, Glahn et al. 1999).

The presence of double-crested cormorants in the Great Lakes region has resulted in the displacement of some bird species (Jarvie et al. 1999, Shieldcastle and Martin 1999), reduced wildlife habitat (Lemmon et al. 1994, Hebert et al. 2011), suppressed production of fish species in some areas (Rudstam et al. 2004), and affected angler perception regarding potential catch rate in some watersheds. In this study, we examined the potential reduction in economic activity

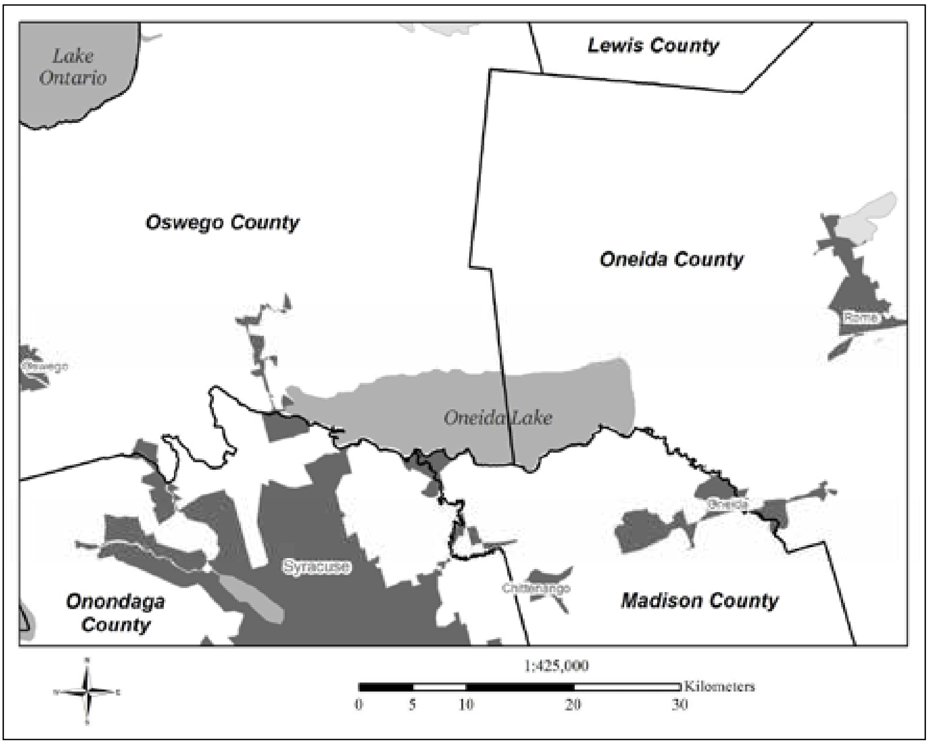

Figure 1. Oneida Lake and the 4 adjacent counties: Oswego, Oneida, Madison, and Onondaga, in central New York state.

created by the double-crested cormorant at a recreational fishery at Oneida Lake, located within the Lake Ontario watershed (Figure 1), as a case study to quantify both direct and indirect economic impacts using an input-output (IO) model.

The Oneida Lake Region is comprised of the 4 New York counties that surround Oneida Lake (i.e., Oneida, Oswego, Madison, and Onondaga counties). The economic composition of the counties is very different. The city of Syracuse, New York, located in Onondaga County, gives this county the largest human population and the most overall economic activity. Oneida County is generally second in most demographic and economic categories, and Madison County is consistently the smallest county in most categories. Focusing on those businesses that are directly surrounding the lake (e.g., marinas, boat launches, convenience stores, restaurants, hotels, cabins, campgrounds, and campsites), a slightly different picture of the Oneida Lake Region emerges. Oneida County has the most hotels (Onondaga County has the most hotel rooms), cabins, campgrounds, and campsites, while Oswego County has the most convenience stores and restaurants (Oswego County Tourism Bureau 2008). Madison County leads the region in the number of marinas (Madison County Tourism Bureau 2008). Those businesses that are directly related to angler tourism in the region are the most impacted by reduced angler expenditures.

Recreational fishing is an important socio-economic activity in upstate New York, especially at Oneida Lake (Connelly and Brown 1991). The Oneida Lake Region provides an ideal study location, because of the data availability on fish populations, angler license sales, angler spending, and cormorant populations (Rudstam et al. 2004, Shwiff et al. 2008, VanDeValk et al. 2008). Researchers have identified double-crested cormorants as the primary contributor to declines in walleye (*Sander vitreus*) and yellow perch (*Perca flavescens*) populations at Oneida Lake (Rudstam et al. 2004, VanDeValk et al. 2008). Other possible influences on the walleye and perch populations, including the

Figure 2. Nesting cormorants.

arrival of zebra mussels (*Dreissena polymorpha*) at Oneida Lake in 1991, have been considered, but cormorant predation remains the most likely cause of decreased fish populations (Rudstam et al. 2004, VanDeValk et al. 2002, Zhu et al. 2006).

Nesting cormorants were first documented on Oneida Lake in 1984 (Claypoole 1988; Figure 2). By 1990, there were 62 nesting pairs, and by 1997, the population had grown to 269 nesting pairs, with approximately 2,700 individuals present on the lake during fall migration (Claypoole 2009). As populations of cormorants have increased, so has fish consumption and, thus, conflicts with recreational anglers who compete for the same fish cormorants consume. In 2003, the presence of cormorants at the lake prompted the >4,000-member Oneida Lake Association to produce its semi-annual bulletin containing articles with such alarmist titles as "Cormorant Emergency Action Alert," "Aquatic Killing Fields of Oneida Lake Fish" and "An Economic Armageddon" (Oneida Lake Association Inc. 2011). Anglers are sensitive to perceived catch rate at sport fisheries (Johnson and Carpenter 1994). While Johnson and Carpenter (1994) suggested that fish consumption by cormorants potentially decreased catch rates at the lake, thereby influencing angler visitation to Oneida Lake, it is also possible that the most significant factor affecting nonresident angler tourism to the lake was the negative press generated as a response to the presence of cormorants. Evaluation of these effects separately was outside the scope of this analysis.

The evaluation of the economic impact of wildlife has been measured in a variety of ways (e.g., hunting, crop damage, and viewing). Positive economic impacts of wildlife often are measured as the benefit to the economy resulting from revenue gained through wildlife viewing (Duffield 1992, Upneja et al. 2001). For example, the presence of wolves (*Canis lupus*) in Yellowstone National Park has increased park visitation related to wolf viewing, positively impacting local businesses (U.S. Fish Wildlife and Service 1994, Duffield et al. 2008, Smith 2011). One common measure of the negative economic impact of wildlife is the amount of damage caused by wildlife (Hueth et al. 1997, Jones 2004, MacMillan et al. 2004, Gebhardt et al. 2011). For example, as wildlife consume or damage crops, the level of impact can be quantified beyond the direct impact to the producer, as crop losses extend to affect the regional economy (Anderson et al. 2013). Evaluation of wildlife-caused damage through its effect upon tourism has been used to measure the potential economic impact of invasive species (Loomis and Richardson 2001, Shwiff et al. 2010).

In this analysis, the direct economic impact of cormorants in the Oneida Lake Region is measured as the value of the diminished nonresident angler tourism to the region (Fisher et al. 2008). This study focuses on nonresident (of New York state) angler tourism as the appropriate measure of cormorant impacts, because, unlike resident anglers, nonresidents provide an influx of funds that would not otherwise be present in the region (Shwiff et al. 2008). We provide a step-by-step analysis of the methodology used to estimate the economic impacts of cormorants to this region. Results from this study quantify some of the measurable cormorant effects to the region and provide information to policy makers and others to determine the need for cormorant management in the Oneida Lake Region.

Methods

This model integrates the biological impacts of increased double-crested cormorant populations on Oneida Lake with the economic impacts in the Oneida Lake Region, specifically, reduced angler spending. This methodology draws on work by Hirsch and Leitch (1996), who developed a framework for the estimation of economic impacts from 3 species of invasive knapweed (*Centaurea diffusa, C. maculosa*, and *Acroptilon repens*) in the state of Montana. Cormorants have been directly linked to the decline in perch and walleye populations, likely impacting angler tourism (Rudstam et al. 2004, VanDeValk et al. 2002). Other potential causes for decreases in nonresident angler tourism were considered, including fishing license price increases in New York and a national trend of decreasing recreational license sales (Connelly and Brown 2009, U. S. Fish and Wildlife Service 2008). Both of these potential impacts proved unlikely, as price increases did not impact nonresident sales historically and nonresident fishing license sales slowly increased nationally over the study period. Data on cormorant populations were collected by USDA Wildlife Services and the Oneida Lake Association (Oneida Lake Association Inc. 2011, Wildlife Services, unpublished data, 2008).

The inclusion of Oswego County, which borders the 2 most fished lakes in the state, Ontario and Oneida lakes, complicates the estimate of impacts to anglers. While the proximity of the lakes to each other likely means that both were impacted by cormorants, this study focuses only on Oneida Lake and, therefore, incorporates only those anglers who would have fished at Oneida but purchased their fishing license in Oswego County. To avoid counting anglers who purchased licenses in Oswego County but did not fish in Oneida Lake, we relied on information of angler license sales and angler days at each location provided in the New York state angler survey from 1996 and 2007. These data indicated that in 1996 Lake Ontario had approximately 6.8 times the number of anglers as Oneida Lake. However, these data were not available for 2007; further complication results from the fact that the number of angler days at Oneida Lake was only half the number at Lake Ontario. Additionally, interpretation of these data from the survey is not straightforward due to the manner in which the questions were asked. The data may indicate that some anglers who purchased licenses in Oswego County to fish in Lake Ontario were also likely fishing Oneida Lake. It was impossible to derive the exact number of anglers who purchased licenses in Oswego County and who fished in either lake or both lakes. We, therefore, constructed a range of low, medium, and high estimates. The low estimate was derived from omitting anglers who purchased licenses in Oswego County and including only angler license sales in the other 3 counties. The medium estimate relied on the information from 1996 survey and assumed that only 14% of the anglers in Oswego County fished in Oneida Lake, plus all of the anglers from the other 3 counties. The high range was constructed by incorporating 50% of the anglers from Oswego County (determined by the ratio of angler days for each lake) and all of the anglers from the other 3 counties. This information was then incorporated into an input-output model to quantify the total economic impact to the Oneida Lake Region.

Nonresident anglers

To assess the potential loss of nonresident angler tourism, nonresident fishing license sales data within the Oneida Lake Region from 1965 to 2009 were collected from the New York State Department of Environmental Conservation (2013; Figure 3). Nonresidents who intended to fish at Oneida Lake and purchased a nonresident fishing license in a county outside the Oneida Lake Region were not counted because they were unidentifiable. The nonresident anglers who visit the Oneida Lake Region create numerous benefits to the regional economy through spending. The monetary value of nonresident anglers to the region includes both the direct monetary expenditures (i.e., purchase of lodging, food, gas) and the economic activity created from those inputs. When determining the direct loss associated with fewer nonresident anglers, assumptions regarding angler spending were made based on New York state angler surveys conducted in 1996 and 2007 (Connelly et al. 1997, Connelly and Brown 2009). The variables considered included type of license (i.e., 1-, 5-, 7-day, and annual) and daily expenditures (e.g.,

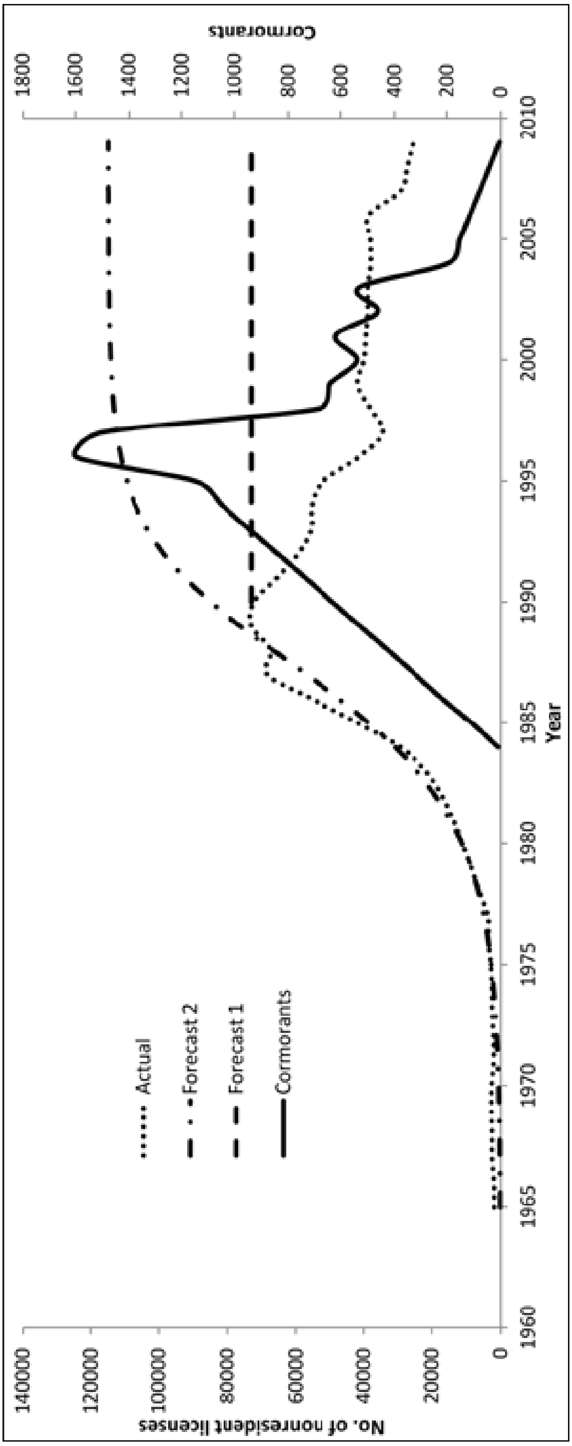

Figure 3. The actual and forecasted numbers of nonresident fishing licenses, with actual cormorant population.

food, gas, supplies, and lodging). Each nonresident angler's expenditures vary depending on how long the person visits the area. All nonresident angler expenditure information was adjusted to 2013 dollars and determined to be approximately $187 daily for individuals who stayed in a hotel and motel and $127 for individuals who camped (Connelly et al. 1997). Only individuals who purchased a 5-day, 7-day, or annual license were allocated lodging expenses. Nonresidents purchasing a 1-day license were allocated expenditures of $107 per day (Connelly et al. 1997, Connelly and Brown 2009).

Calculation

Estimating the economic impact of cormorant presence on nonresident angler numbers in the Oneida Lake Region was challenging. Our estimate was based on the assumption that real or perceived impacts of cormorants in the region played a role in the decline in the total number of nonresident licenses sold in the Oneida Lake Region. Fewer nonresident licenses sold resulted in fewer angler spending days. To determine the hypothetical number of fishing licenses lost, we estimated the number of licenses that would have been sold in the absence of cormorant impacts from 1990 to 2009. To do this, 2 forecasting techniques were used (Figure 3). Forecast 1 simply fixed the level of fishing licenses for the period from 1990 to 2009 at the 1989 level. This forecast was used as a baseline estimate; however, it resembles the trend in the national nonresident fishing license sales from 1990 to 2009, which had a moderate, almost static, average change (1%) over the time period.

The second forecast relied on a discrete logistic growth model to match the "pre-cormorant" nonresident license data. The discrete logistic growth model is often used in biology to model the growth of populations.

It assumes that growth rate is proportional to both the current population of the species and the carrying capacity of that species. Growth is slow when the population is small, increases as the population grows, but, then, decreases as the population nears its carrying capacity. This model seemed appropriate for our purposes because there are a finite number of people who would wish to buy nonresident fishing licenses (the carrying capacity, C) and the early growth characteristics of the model roughly matched the data.

The equation governing the number of licenses (L) at time k is

$$L(k+1) = L(k)\left[1 + r\left(1 - \frac{L(k)}{C}\right)\right] \quad ,$$

where r is the growth rate.

Nonresident license data from 1965 through 1989 (pre-cormorant impacts) were used to calculate the parameters of the model. We originally fixed the modeled number of licenses in 1965, L(0), to be equal to the actual number of licenses in 1965, but lower errors were observed when a different value for L(0) was used. We, thus, estimated 3 parameters: L(0), r, and C. Our goal in choosing values for these parameters was to minimize the absolute error of the approximation, defined as

$$\text{Error} = \sum_{k=0}^{24} |L_{Estimated}(k) - L_{Actual}(k)|$$

The set of parameters L(0) = 150, C = 115,000, and $r = 0.34$ returned the lowest error (Figure 3).

All calculations of the potential direct cormorant damage were derived from the difference between the forecasted numbers of licenses sold in the absence of cormorants and the actual number sold annually, as well as the portion of licenses lost from cormorant presence (e.g., low, medium, high). This information was then combined with information regarding both the type of licenses sold and angler expenditures to determine the direct economic impact of these lost anglers. All dollar values were adjusted to 2013 dollars.

Input-output model

We developed an input-output (IO) model for the Oneida Lake region using the IMPLAN® software model (Minnesota IMPLAN® Group, Stillwater, Minn.). The counties in the Oneida Lake Region were used to build the IO model for the data year 2009; then, we adjusted to 2013 dollars. Deterministic economic IO modeling is an accepted methodology for estimating the indirect and induced economic impacts on an economy using complex mathematical models that simulate the linkages within a specified regional economy based on the most current economic and demographic data available (Weiler et al. 2002, Shwiff et al. 2010).

IMPLAN creates a mathematical representation of the regional economy that contains the linkages among economic sectors (e.g., agricultural, retail, service, manufacturing, and industrial). This model allows the estimation of the total economic impact from cormorant damage to fisheries within the Oneida Lake Region economy. For example, if the presence of cormorants results in reduced angler spending at local restaurants, the restaurant owner receives less revenue from sales (the direct effect) and, as a result, will reduce the amount of supplies, services, and labor purchased. These direct changes (reductions) cause the businesses that are responsible for supplying food products, beverages, labor, and restaurant supplies to also receive less income for the sales (the indirect effect). Lastly, workers in the restaurants and other supplying industries have less income, which reduces overall household income (the induced effect). These secondary impacts (e.g., indirect and induced effects) that reduce the amount of supplies, services, and labor necessary in the region, can be calculated by IMPLAN as they ripple through the regional economy.

In calculating this final demand change, the lost spending patterns were applied to the economic sectors that were most appropriate, as fewer nonresident anglers visited the Oneida Lake Region (U.S. Census Bureau 2007). Most of the economic stimulation from nonresident anglers that was lost would have impacted commodities in the services sector and were, therefore, incorporated into the model as final demand reductions in the services sector. The estimated impact of cormorants to nonresident angler tourism presented earlier, along with the value of each nonresident angler in terms of estimated spending on commodities during

Table 1. Estimated average annual economic impacts in the Oneida Lake Region (1990 to 2009).

	Forecast 1 fixed		Forecast 2 logistic	
Forecasted totals	Jobs	Revenue*	Jobs	Revenue*
Low	66	$4.70	152	$10.80
Medium	159	$11.30	369	$26.20
High	399	$28.20	929	$65.80

*Million, 2013 US$.

their stay in the Oneida Lake Region, represents the initial final demand change to the IMPLAN model. The total impact was a combination of the direct, indirect, and induced impacts that provide the comprehensive impact to revenue and jobs in the region as a result of the initial final demand changes.

Results

Results were reported using 2 specific measures of the economic impact. The first was a measure of revenue lost in the Oneida Lake Region and was calculated by the value-added component in the IO model. Viewing revenue from the value-added perspective can be defined as a reflection of the excess of the value of the reporting entity's outputs in the form of goods and services that it creates over the costs of its inputs in the form of materials and services that it purchases from other entities. The second measure was simply the number of job-years (i.e., 1 job for 1 year) estimated to be lost due to the cormorant impacts in a variety of sectors, not soley the sector in which the impact was initiated.

The results over the 20-year period from 1990 to 2009 indicate that potential cormorant-induced reductions in angler visitation to the Oneida Lake Region resulted in average annual losses in 2013 dollars ranging from $5 million to $65 million (Table 1). Additionally, this loss of revenue caused on average 66 to 929 job-years to be lost in the region annually. These are significant impacts felt over this period and, while predominately concentrated to businesses surrounding the lake, these effects were not limited only to this area, but were felt by the entire Oneida Lake Region.

Discussion

The choice of forecasting technique and the number of Oswego anglers attributed to the analysis played a role in the determination of the overall economic impact. Nonresident angler data exhibited an upward trend to the start of the forecast period (1989), and while the forecasting methods incorporated this trend, we did not assume that it would continue *ad infinitum*. All forecasting techniques have limitations. Therefore, both estimations of future potential trends in the data were projected to provide a range of possible future scenarios to minimize the uncertainty surrounding the projection of overall results.

Many factors contribute to the attractiveness of Oneida Lake as a nonresident fishing destination, including fish populations, weather, angler income, accessibility, press, and publications related to the lake. Research on walleye and perch populations suggested that cormorant predation contributed to their decline; however, it is difficult to determine to what extent anglers were aware of this or how this impacted fishing success. Anglers may have become aware of potential cormorant effects on fish populations, as the Oneida Lake Association and local news organizations, which generated negative press regarding potential angler success at the lake. Therefore, it was necessary to estimate hypothetically a range of decreased angler activity. Future estimates could be enhanced by conducting surveys of nonresident anglers within New York regarding their perception of cormorant impact to fisheries.

Two factors were not explicitly included in this analysis. First, the impacts of Bass Pro tournaments and other similar events were not incorporated; yet, it may have helped to offset some of the negative tourism impacts as estimated. If the tournaments increased the number of nonresident anglers that purchased fishing licenses in the Oneida Lake Region, then some of the impacts were implicitly captured. However, data on the number of individuals that visited the lake to watch the tournament and spent money in the region were not captured or incorporated into the analysis. Calculation of these impacts was outside the scope of this analysis.

Secondly, a federal-state cooperative management program was initiated by USDA-APHIS-Wildlife Services and the New York State Department of Environmental Conservation in 1998 to decrease cormorant impacts to Oneida Lake (Chipman et al. 2000). From 1998 through 2003, management efforts were focused on nonlethal harassment of migrating cormorants during August and September (Coleman 2008). From 2004 to 2009, cormorants were managed at Oneida Lake using pyrotechnics, egg oiling, nest removal, and limited lethal removal to reduce cormorant impacts to fish populations in the lake (DeVault et al. 2012). As such, the cormorant management at Oneida Lake was primarily a nonlethal program. From 2004 through 2007, the average number of cormorants on Oneida Lake from ice-out (when the ice melts and the lake is free of ice) in April until September 30 (based on weekly boat surveys of the entire lake) was 225, 154, 129, and 103, each year, respectively (USDA Wildlife Services, unpublished data, 2008). Cormorant management and subsequent population decreases are known to positively affect sport fish populations (Rudstam et al. 2004; Dorr et al. 2010*a*, *b*, 2012). Therefore, it is likely that the reduction in cormorant numbers on Oneida Lake resulted in smaller negative impacts to sport fish. If management increased the number of nonresident anglers who purchased fishing licenses in the Oneida Lake Region, then some of the impacts were implicitly captured; however, calculating the impacts to angler populations of reduced cormorants at Oneida Lake was outside the scope of this study and will be incorporated into future research.

There were 2 limitations to the present study. First, this type of modeling technique can be used only if the damage caused by wildlife is to an established sector in the IO model. This can limit the types of impacts evaluated by this technique. Secondly, the simulated economic impacts projected by IO models suffer from the general weaknesses of deterministic models. This is a static model in that the economic impact of damage by wildlife results in a unidirectional immediate change in all other sectors affected by this loss. This may not be the case in a more dynamic model setting. This analysis was made more dynamic by estimating a range of impacts at different levels of projected damage (Weiler et al. 2002).

Management implications

Tighter budgets and increased fiscal scrutiny have created limited resources to mitigate wildlife damage, increasing the need to use these resources efficiently by employing management strategies that will provide the biggest return on investment. This study has illustrated the value of IO models to assess wildlife impacts on regional economies and provides a general framework that can be used to identify, assemble, and measure the components needed to determine the regional impact of wildlife damage management efforts. Modeling impacts in this way can translate management efforts into regional (e.g., local, state) impacts on revenue and jobs, expanding the general public's perception of management benefits. The range of revenue and job loss in this study provides the foundation from which wildlife managers begin the discussion surrounding the benefits associated with managing cormorants at Oneida Lake. While the range of estimated impacts is large, so is the associated range of beliefs in the region surrounding the actual impacts of cormorant damage. Many individuals in the region will acknowledge that there is some effect, but think that it is minimal, while others (often those who are directly impacted by the decrease in anglers) believe the impact to be severe. By projecting a range of impacts, wildlife managers can engage individuals at opposite ends of the spectrum in the discussion of return on investment of wildlife management. Typically, with those individuals who perceive that wildlife damage and benefits of management are at the lower bounds of the range, the discussion is focused on the level of damage reduction that must be achieved to simply justify implementation of the wildlife damage management program. In contrast, with individuals who believe that damage and benefits are more realistically represented by the upper bound of the range, the discussion is centered on how much revenue and how many jobs will return to the area once management reduces the number of offending animals in the region.

Our method takes advantage of a situation where wildlife damage occurs in established economic sectors, thereby providing the input into predictive IO models. Using these models increases the robustness and accuracy of estimated economic impacts of wildlife by allowing the determination of the multiplier effects created throughout the economy. This technique is not limited to calculating the impacts of piscivorous birds and can, by extension, be applied to other nuisance wildlife species, proving useful in planning and management situations that require accurate assessment of wildlife damage.

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