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A Disconnect between Science and Management for Double-crested Cormorants (*Phalacrocorax auritus*) in Northern Lake Michigan, USA, 2000-2016

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Abstract.—In 2000, studies began on the Double-crested Cormorant (*Phalacrocorax auritus*) in the Beaver Archipelago, Lake Michigan, Michigan, USA, and have continued through the present. Research was conducted to determine whether Double-crested Cormorants were preying on smallmouth bass (*Micropterus dolomieu*) and causing a decline in this fishery. Breeding Double-crested Cormorant population estimates were recorded to document population dynamics before management and throughout the intensive control program, initiated in 2007. Research included studies using telemetry, raft surveys, banding, game cameras, and development of several bioenergetics models. In addition, co-nesting species were monitored to investigate impacts of Double-crested Cormorant control on non-target species. Results indicated that Double-crested Cormorants do not negatively impact smallmouth bass populations, co-nesters or other components of the system. However, control measures were initiated and continued through 2015; litigation ended control activities in 2016. Research suggested that control led to abandonment by Double-crested Cormorants of traditional colony sites, a switch from ground to tree nesting, and impacts on co-nesting species. This review demonstrates a significant disconnect between science-based knowledge and chosen management practices. Although court rulings ceased Double-crested Cormorant control, this disconnect should be addressed and remedied; science-based knowledge should be emphasized in any future management. *Received 23 July 2017, accepted 9 August 2017.*

Key words.—bass, Caspian Tern, co-nesting species, Double-crested Cormorant, Lake Michigan, management, *Phalacrocorax auritus*, round goby.

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Double-crested Cormorants (*Phalacrocorax auritus*; hereafter, cormorants) have been intensely managed in Michigan under a Public Resource Depredation Order (PRDO) (U.S. Fish and Wildlife Service 2003) due to perceived conflicts; this order was subsequently renewed in 2009 and 2014 (U.S. Fish and Wildlife Service 2009, 2014). Under this rule, the Michigan Department of Natural Resources (DNR) released a report outlining planned cormorant management activities (Rustem *et al.* 2005). Although both the depredation order and the Michigan DNR report state that cormorant management should be guided by science and done where cormorants are negatively impacting other resources, the control measures appear to be largely driven by sociopolitical motivations (Wires 2014).

This work summarizes a long-term, intensive study on breeding cormorants in the Beaver Archipelago of northern Lake Michigan, Michigan, USA, that began in 2000, and examines the extent to which research supported and correlated with the intensive management actions pursued. This review includes not only previously published cormorant research, but also publications on the smallmouth bass (*Micropterus dolomieu*; hereafter, bass) fishery in the same study area. Although historical data are included, this work focuses primarily on studies completed between 2000 and 2016. Recent observations and research undertaken during cormorant control measures are included to describe the unintended impacts of intensive management on habitat and co-nesting species.

Study Area and Cormorant Population Changes

The Beaver Archipelago of northern Lake Michigan, Michigan, USA, consists of about 10 main islands and numerous smaller islands, depending on fluctuating water levels (Fig. 1). Between 2000 and 2016, seven of these islands, including Gull Island, Hat Island, Hog Island, Pismire Island, Trout Island, Whiskey Island, and an unnamed island referred to as Southeast Garden Island,

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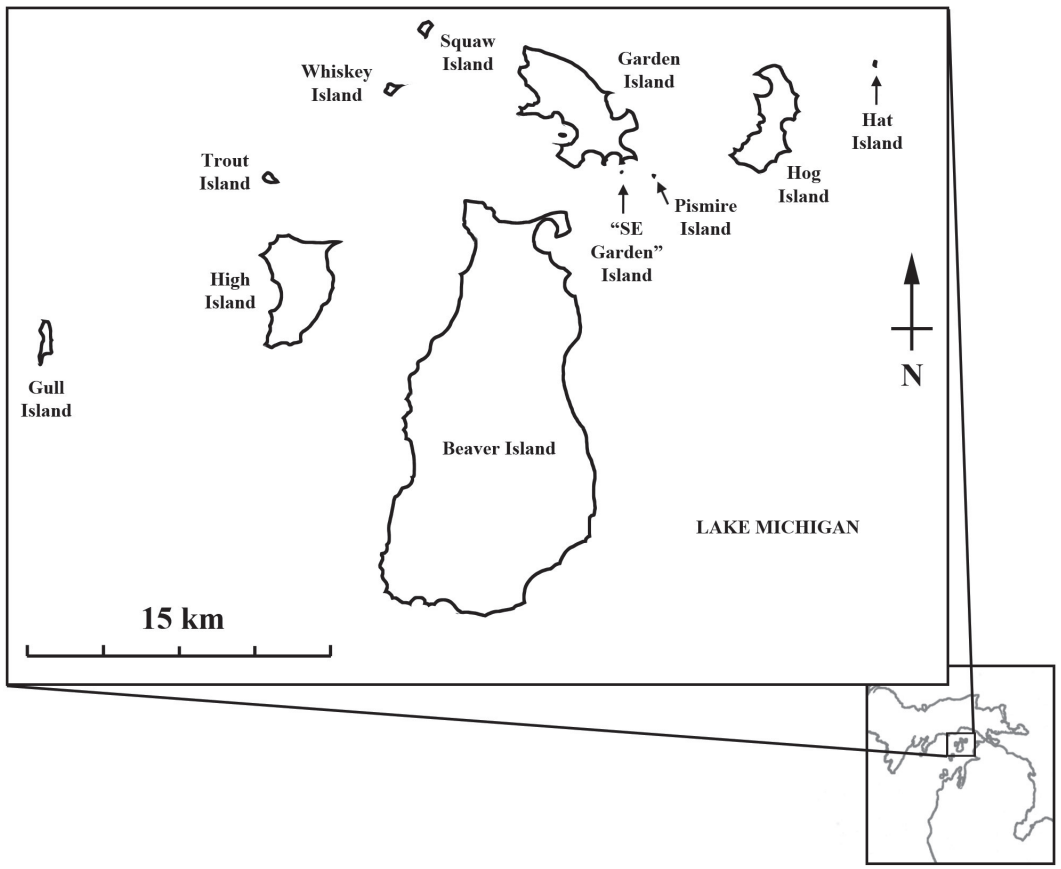


Figure 1. Map of the Beaver Archipelago, northern Lake Michigan, Michigan, USA.

supported cormorant colonies. Because of the large number of breeding cormorants in the Beaver Archipelago (Cuthbert *et al.* 2010) combined with their fish-eating habits, it was believed that cormorants were adversely impacting bass, an important local sport fishery. In the Beaver Archipelago, important bass habitat includes bays and harbors of Beaver Island, Garden Island and Hog Island (Kaemingk *et al.* 2012). Because cormorants were observed near bass habitat, direct predation on bass by cormorants was suspected. Studies in eastern Lake Ontario had reported impacts on bass via cormorant predation where cormorants and bass shared habitats (Johnson *et al.* 2003). In addition to cormorant studies, a bass population study that took place 1969-1972, 1975, 1977, and 1984 was reinitiated in 2000-2008 (Kaemingk *et al.* 2012) and has continued through the present (T. L. Galarowicz, pers. commun.). Both research programs indicate that cormorants have not negatively impacted bass populations in the archipelago (Seefelt and Gillingham 2006, 2008; Kaemingk *et al.* 2012).

The number of cormorants breeding in the archipelago increased between 1984 and 2007 (Table 1). The size of the breeding cormorant population peaked in 1997, with a total of 11,709 breeding pairs nesting at six colonies (Cuthbert *et al.* 2010). The population showed an overall decline between 2000 and 2006, but spiked again during the next decadal census in 2007, with a total of 11,423 pairs nesting at three colonies (Seefelt 2012). By 2016, the number of breeding pairs declined to 1,965 in the archipelago (N. E. Seefelt, unpubl. data).

One colony, Hat Island, has been a consistent cormorant breeding colony location in the archipelago since 1984 (Ludwig

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Table 1. Population estimates of breeding Double-crested Cormorants in the Beaver Archipelago, northern Lake Michigan, Michigan, USA, by colony. Sources of nest count data: 1984, Ludwig 1984; 1989, Scharf and Shugart 1998; 1997, Cuthbert *et al.* 2010; 2006 and 2007, Seefelt 2012; and 2016, N. E. Seefelt, unpubl. data.

Year	Grape	Gull	Hat	Pismire	Southeast Garden	Timms	Whiskey	Total
1984	0	139	54	57	0	0	0	250
1989	291	260	294	35	0	0	0	880
1997	3,509	1,887	4,617	383	0	753	560	11,709
2006	0	2,464	5,776	512	148	0	0	8,900
2007	0	2,821	7,942	660	0	0	0	11,423
2016	0	158	1,565	0	0	0	142	1,965

1984) and has been monitored yearly since 2000 (Seefelt 2012; Fig. 2). Hat Island has remained an important breeding site for cormorants, while several other sites in the archipelago have been abandoned (Seefelt 2012). Hat Island has also become the focus of more intensive study due to its importance to other breeding waterbirds and because it is part of the Michigan Islands National Wildlife Refuge (NWR) overseen by Seney NWR, Michigan, USA. The population of breeding cormorants on Hat Island has declined since 2007, when it peaked at almost 8,000 pairs; in 2016, only 1,565 nests were documented (Fig. 2). The reasons for this decline are complicated, as the invasion of the round goby (*Neogobias melanostomus*; hereafter, goby) has changed the forage base and fish community dramatically in Lake Michigan (Madenjian *et al.* 2010). Additionally, the intensive cormorant control measures in the archipelago likely played a large role in the population decline.

CORMORANT AND BASS RESEARCH

Diet studies on cormorants were initiated in 2000 to determine if cormorants were directly impacting bass by consuming them; these diet studies have continued through the present. Over the years, cormorants have consumed primarily non-native forage fish. In the early years of the project, alewife (*Alosa pseudoharengus*) was the most abundant and important prey species taken by cormorants

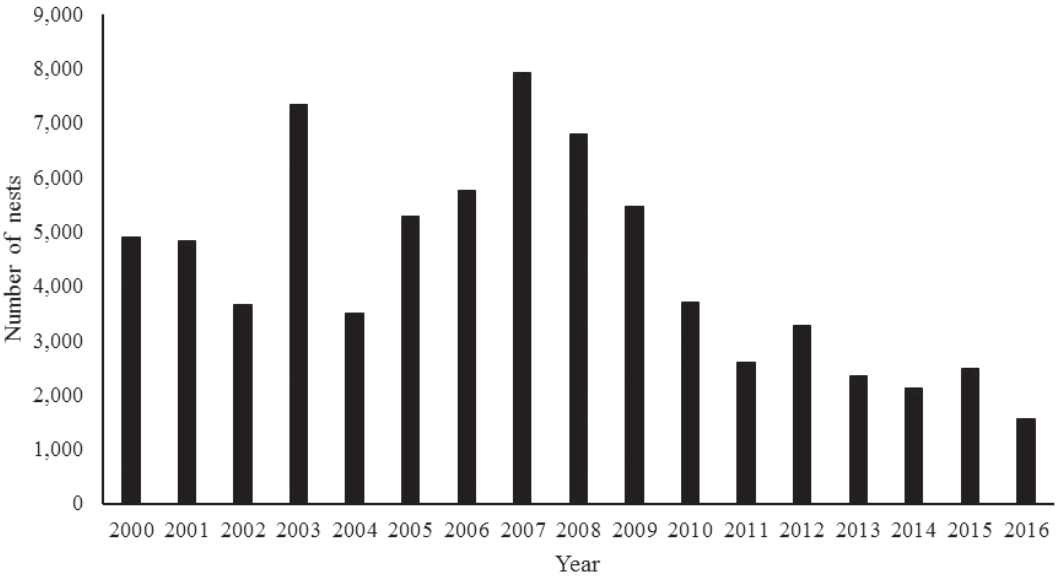


Figure 2. The Double-crested Cormorant breeding population size, 2000-2016, on Hat Island in the Beaver Archipelago, northern Lake Michigan, Michigan, USA. Control measures began in 2007 with off-shore shooting and continued through 2015. In 2010, control also included egg-oiling and killing birds on the island.

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(Seefelt 2005; Seefelt and Gillingham 2008). More recently, goby became the most abundant and important prey species for breeding cormorants (VanGuilder and Seefelt 2013; Table 2). Additionally, this change in diet may have impacted the abundance of breeding cormorants in the archipelago. Alewife is an energetically rich prey source (Cummins and Wuycheck 1971) while goby is comparably poor (VanGuilder and Seefelt 2013). More food is required from hatching to fledging when a cormorant chick is fed goby compared to alewife (Table 3). As the frequency of chick feeding is not dependent on the type of prey (meaning adults do not feed chicks more often when less energetic prey are fed to chicks), fewer chicks survive to fledge on a goby rich diet (VanGuilder and Seefelt 2013). The availability of alewife has been linked to cormorant reproductive output (Hatch and Weseloh 1999); this has been supported by studies in the Beaver Archipelago (Seefelt 2005; Seefelt and Gillingham 2008; VanGuilder and Seefelt 2013).

Although bass are a dominant species in the Beaver Archipelago (Kaemingk *et al.* 2012), forage fish, or prey base, are still the most abundant species in the study area (Madenjian *et al.* 2004, 2010). To assess the potential for cormorant predation on bass, cormorant behavioral studies using rafting (groups of foraging cormorants) locations and VHF (Very High Frequency) radiotelemetry were implemented. In 2003, cormorant foraging locations determined by both raft and telemetry locations indicated that birds foraged in open water areas with dramatic changes in depth and not typically in the island bays considered to be bass habitat (Seefelt and Gillingham 2006; Fig. 3A). Rafting and telemetry studies in 2010 documented that cormorants still foraged in the same locations; however, the foraging range had expanded most likely due to the abundance of goby, use of Whiskey Island as a colony site (unmanaged in 2010), and cormorant control activities in the archipelago (Tucker and Seefelt 2014; Fig. 3B). During the same time period, bass telemetry studies and tag studies documented that bass move to areas outside of the archipelago (Kaemingk *et al.* 2011); therefore, it is possible that bass may occur transiently in cormorant foraging areas. However, the long term bass population studies indicate that neither cormorants or other ecological changes (e.g., declining primary productivity, introduction of nonnative species) negatively impacted the bass population because both bass condition and growth rate improved compared to historical data (Kaemingk *et al.* 2012). Other factors, including angling during the bass spawning season, may have had a greater impact on the bass population (Philipp *et al.* 1997; Kaemingk *et al.* 2011).

CORMORANT CONTROL ACTIONS AND OUTCOMES

Despite the many studies indicating that cormorant diet in recent decades was largely nonnative forage fish and that cormorants have not negatively impacted the bass population in the Beaver Archipelago, cormo-

Table 2. The proportions of prey species found in the Double-crested Cormorant diet in 2000 (Seefelt and Gillingham 2008) and 2010 (VanGuilder and Seefelt 2013) in the Beaver Archipelago, northern Lake Michigan, Michigan, USA. Other prey species include nine-spine stickleback (*Pungitius pungitius*), johnny darter (*Etheostoma nigrum*), and trout-perch (*Percopsis osmiscomaycus*).

	Proportion	
Species	2000	2010
Alewife (*Alosa pseudoharengus*)	0.54	0.29
Round Goby (*Apollonia melanostomus*)	0.00	0.67
Brook stickleback (*Culaea inconstans*)	0.01	< 0.01
Crayfish (*Orconectes* spp.)	0.24	< 0.01
White Sucker (*Catostomous commersonii*)	0.11	0.04
Sculpin (*Cottus* spp.)	0.06	0.00
Other	0.04	0.00

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Table 3. Modeled amount of food consumed (g) for the mean Double-crested Cormorant chick mass (g) at each sampling session in 2010 in the Beaver Archipelago, northern Lake Michigan, Michigan, USA. The biomass of prey consumed in 2000 (Seefelt and Gillingham 2008) for each corresponding chick mass and the difference between the two years is also listed for comparison (VanGuilder and Seefelt 2013).

	Food (g) Consumed/Chick		
Chick Mass (g)	2000	2010	Difference (g)
40	18.00	20.36	2.36
85	33.00	35.97	2.97
315	84.50	99.70	15.20
780	170.50	201.33	30.83
953	199.00	255.30	56.30
1,000	206.50	264.09	57.59
1,250	245.50	289.99	44.49
1,330	258.00	330.51	72.51
1,610	299.00	352.94	53.94
1,710	313.00	369.60	56.60
1,849	333.00	426.62	93.62

rant control measures were implemented in 2007, specifically to protect bass. The peer-reviewed cormorant and bass research in the Beaver Archipelago was largely ignored to justify continued cormorant management actions due to unsubstantiated claims that cormorants were eating bass (Wires 2014) in the hopes of restoring the bass population to "historical levels" (U.S. Department of Agriculture 2011). However, over a 10-year period, just one bass was found in cormorant diet samples (Seefelt 2005; VanGuilder and Seefelt 2013). Additionally, cormorant control was implemented because cormo-

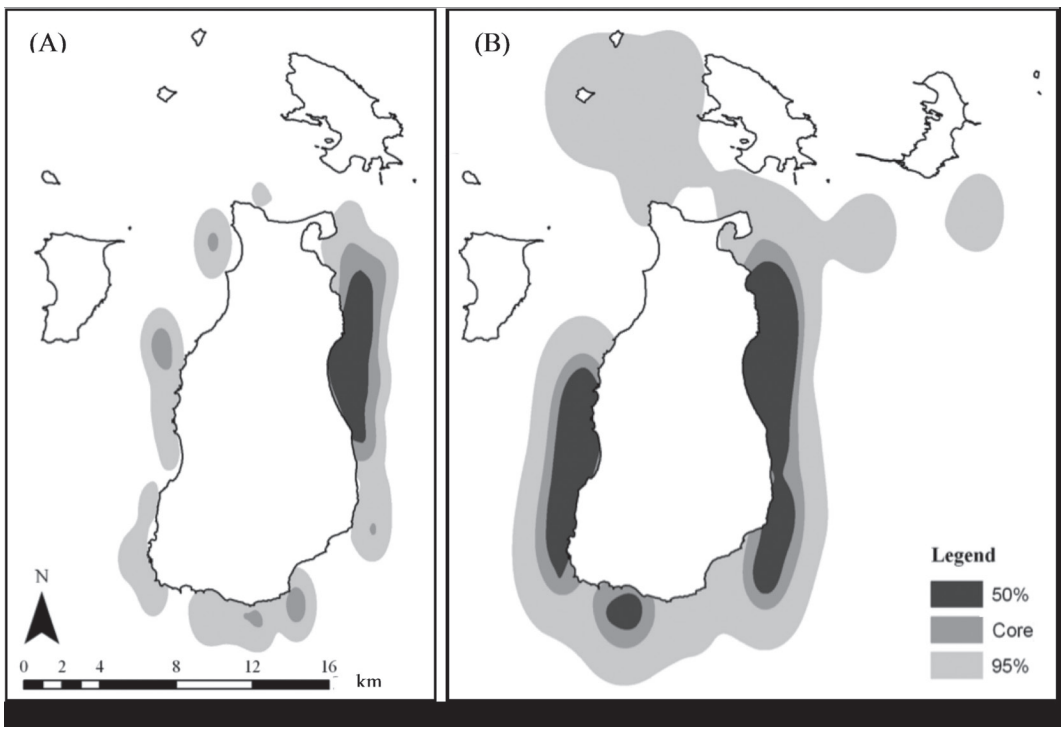


Figure 3. Double-crested Cormorant rafting location volume contours from (A) 2003 and (B) 2010, as determined by using a fixed kernel density estimator (Tucker and Seefelt 2014).

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rants could have been competing with bass for the forage fish, and thus reducing bass survivorship and growth (U.S. Department of Agriculture 2011). However, the relative abundance, mortality rates and recruitment of bass had not changed significantly from historical levels in the presence of the increased cormorant population; bass condition and growth rates actually increased in the archipelago while cormorants were present (Kaemingk *et al.* 2012).

Between 2007 and 2012, the breeding cormorant population in the Beaver Archipelago was reduced by 58% (Wires 2014). In 2012, 38% (n = 9,626) of individuals shot in Michigan were killed in the Beaver Archipelago (U.S. Department of Agriculture 2012). An additional 1,839 and 1,485 birds were shot in 2013 and 2014, respectively (U.S. Department of Agriculture 2013, 2014). Up to 60% of the birds taken each year between 2007 and 2014 in the Beaver Archipelago were removed from Gull Island (U.S. Department of Agriculture 2013, 2014; Wires 2014), which is spatially separated from the main archipelago (and prime bass habitat) by 18 km (Fig. 1). Thus, cormorant control in the archipelago was not likely to benefit the bass fishery, as telemetry studies found birds typically fly shorter distances (2.5 km) to forage (Seefelt and Gillingham 2006). Overall, the management actions have been successful at removing cormorants and reducing the breeding population in the archipelago, which has declined almost 83% from 11,423 pairs in 2007 (Seefelt 2012) to 1,965 pairs in 2016 (N. E. Seefelt, unpubl. data).

Cormorant management under the PRDO also appears to have had negative impacts on island habitats and co-nesting species. On Gull Island, cormorants responded to management by changing their nesting location on the island (Seefelt 2012; U.S. Department of Agriculture 2013). Historically, cormorants nested at both the north and south ends of the island, primarily on the ground or on trees blown over in storms (Seefelt 2005). In 2007, in addition to shooting birds on their nests, all ground nests were oiled on Gull Island (Wires 2014) while only 15% of the breeding pairs nested in trees (Seefelt 2012). Oiling was successful in eliminating breeding success at these ground nests and, in subsequent years, the birds responded by tree nesting at new locations on the west side of the island (U.S. Department of Agriculture 2013). Shooting of cormorants on tree nests continued through 2015 and became the primary mechanism of control on Gull Island as eggs in tree nests could not be reached to be oiled (U.S. Department of Agriculture 2013). Additionally, both Great Blue Herons (*Ardea herodias*) and Black-crowned Night-herons (*Nycticora nycticorax*) that nested near and among the cormorants prior to control efforts in 2007 (Seefelt 2012) declined as management actions continued (N. E. Seefelt, unpubl. data).

Because Caspian Terns (*Hydroprogne caspia*), a species listed as threatened in Michigan, nested on Hat Island, cormorant management (2007-2015) was restricted to shooting cormorants at least 500 m away from the island, except in 2010. In 2010, eggs were oiled and cormorants were shot on this island (VanGuilder and Seefelt 2013; Wires 2014). A small portion of the cormorant colony nearest the Caspian Tern colony was left un-oiled; these cormorants and the nearby Caspian Terns were studied concurrently during the breeding season (VanGuilder and Seefelt 2013). Remote game cameras, VHF radiotelemetry, chick banding and colony visits indicated that the remaining cormorants had little reproductive success (VanGuilder and Seefelt 2013; Tucker and Seefelt 2014). Telemetry indicated that cormorants that originally attempted to nest on Hat Island visited but did not nest on Whiskey Island (Tucker and Seefelt 2014), an unmanaged colony where cormorants nested successfully in 2010 (VanGuilder and Seefelt 2013). A change in colony location and/or nest site can be a consequence of cormorant control (Strickland *et al.* 2011). Photos indicated that remaining Hat Island cormorants were also subject to predation by Bald Eagle (*Haliaeetus leucocephalus*) after control efforts as the breeding season continued (VanGuilder and Seefelt 2013). Cormorants

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finally abandoned Hat Island and left the archipelago by early July in 2010 (VanGuilder and Seefelt 2013; Tucker and Seefelt 2014), while in prior years (2000-2007) cormorants remained in the archipelago until August and September (Seefelt 2005, 2012; Seefelt and Gillingham 2006). Additionally, Caspian Terns and Herring Gulls (*Larus argentatus*) left Hat Island during July in 2010; these co-nesting species are typically observed in August on Hat Island (N. E. Seefelt, unpubl. data).

DISCUSSION

The depredation order allowed the Michigan DNR to authorize cormorant control activities throughout the State. Objectives of cormorant management in Michigan included maintaining a viable cormorant breeding population distributed across the State, minimizing adverse impacts on fisheries, managing on a site-by-site basis, and supporting research and monitoring while evaluating cormorant control actions (U.S. Department of Agriculture 2011). Specifically, management decisions were to be based on the best available science, especially relative to fisheries, using an adaptive management approach (U.S. Department of Agriculture 2011). However, management decisions continued to ignore peer-reviewed science and repeatedly pursued reduced cormorant numbers across Michigan. In the Beaver Archipelago, up to 50% of the breeding population could be removed each year until a threshold of 3,000 nesting pairs was achieved under this management plan (U.S. Department of Agriculture 2011; Michigan Department of Natural Resources 2016). How this threshold of 3,000 pairs was set is unclear as only the bass population objectives are discussed in reference to cormorant management goals in the archipelago (U.S. Department of Agriculture 2011). Furthermore, the claim that management actions would be implemented on a "local basis" when adverse cormorant impacts were established (Rustem *et al.* 2005) was ignored as almost all breeding cormorant colonies in Michigan were impacted under the depredation order (Michigan Department of Natural Resources 2016). Assumptions, unsubstantiated claims and/or misconceptions should have no role in informing management decisions. Moreover, in areas where scientific evidence exists indicating that cormorants are not adversely impacting other resources, cormorants should not be managed.

In 2014, the PRDO was extended for an additional 5 years through 2019; this extension was deemed necessary to protect resources from cormorant damage, and reiterated that cormorant management should be science-based and adaptive (U.S. Fish and Wildlife Service 2014). However, to qualify as adaptive, management must be informed by monitoring cormorants, habitat, co-nesting species and fisheries, as well as other important ecological parameters that may affect resource status (Wires 2014). Without this monitoring, it may be impossible to determine if management is having the desired effects. Nevertheless, funding for monitoring activities was very limited in the Beaver Archipelago, while funding for cormorant control was readily available each year. A more holistic approach to document the relationships among other species and the impact of non-native species (e.g., goby) could have provided a clearer picture on whether anything should have been managed in the archipelago. Cormorant predation on invasive gobies in the archipelago may have benefited some native fish populations by possibly controlling the expanding goby population. Furthermore, because the consumption of gobies may have limited cormorant reproductive success (VanGuilder and Seefelt 2013), cormorant numbers may be reduced in the region without extensive control actions.

In 2016, the Michigan DNR released plans to continue statewide control of cormorants under the extended PRDO. Although nest counts in the Beaver Archipelago from 2015 indicated that the number of breeding pairs fell below the established threshold, all accessible nests would be oiled and 1,000 birds would be shot during the post-fledging period to offset productivity of tree-nesting cormorants and cormorants nesting on Hat

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Island (Michigan Department of Natural Resources 2016). These management plans were suspended, but not due to the most recent nest counts or any research efforts in the archipelago. In May 2016, a ruling was released vacating the extension of the PRDO (Case 1:14-cv-01807-JBD) as the U.S. Fish and Wildlife Service issued the extension in violation of policy; a new environmental assessment needed to be completed prior to any extension of the PRDO. In October 2016, the U.S. Fish and Wildlife Service dropped the appeal to this decision (USCA Case #16-5224 Documents #1643011 & #1643695). With this action, permits to control cormorants will again be issued on a site-by-site basis and require documentation of damage. Although the removal of the PRDO is a victory for cormorants and those who defend the birds, and science did play a role in the final decision, the central issue that science was ignored in pursuance of cormorant management must still be addressed. There must be a re-examination of adaptive management as practiced by agencies managing cormorants under the PRDO. This should include how management is implemented and acknowledgment that decisions made were centered on socio-political motivations and not scientific evidence. Simply, adaptive management must be supported by and correlated with science. The disconnect between science and management decisions in this case is the essential lesson that must be recognized.

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