Wildlife Society Bulletin 9999:1–8; 2015; DOI: 10.1002/wsb.595

Tools and Technology

Developing Nondestructive Techniques for Managing Conflicts Between Fisheries and Double-Crested Cormorant Colonies

YASUKO SUZUKI,[1] *Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, 104 Nash Hall, Corvallis, OR 97331, USA*

DANIEL D. ROBY, *United States Geological Survey-Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, 104 Nash Hall, Corvallis, OR 97331, USA*

DONALD E. LYONS, *Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, 104 Nash Hall, Corvallis, OR 97331, USA*

KAREN N. COURTOT,[2] *Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, 104 Nash Hall, Corvallis, OR 97331, USA*

KEN COLLIS, *Real Time Research, Incorporated, 52 SW Roosevelt Avenue, Bend, OR 97702, USA*

ABSTRACT Double-crested cormorants (*Phalacrocorax auritus*) have been identified as the source of significant mortality to juvenile salmonids (*Oncorhynchus* spp.) in the Columbia River Basin. Management plans for reducing the size of a large colony on East Sand Island (OR, USA) in the Columbia River estuary are currently being developed. We evaluated habitat enhancement and social attraction as nondestructive techniques for managing cormorant nesting colonies during 2004–2007. We tested these techniques on unoccupied plots adjacent to the East Sand Island cormorant colony. Cormorants quickly colonized these plots and successfully raised young. Cormorants also were attracted to nest and raised young on similar plots at 2 islands approximately 25 km from East Sand Island; 1 island had a history of successful cormorant nesting whereas the other was a site where cormorants had previously nested unsuccessfully. On a third island with no history of cormorant nesting or nesting attempts, these techniques were unsuccessful at attracting cormorants to nest. Our results suggest that some important factors influencing attraction of nesting cormorants using these techniques include history of cormorant nesting, disturbance, and presence of breeding cormorants nearby. These techniques may be effective in redistributing nesting cormorants away from areas where fish stocks of conservation concern are susceptible to predation, especially if sites with a recent history of cormorant nesting are available within their foraging or dispersal range.

KEY WORDS cormorant, habitat enhancement, *Phalacrocorax auritus*, predation, salmonids, social attraction.

The double-crested cormorant (*Phalacrocorax auritus*) population in western North America represents a distinct management unit. This population's size has been estimated to be <10% of what it was prior to European settlement (Wires and Cuthbert 2006), and about a 10th the size of the population of the species in interior-eastern North America (Adkins et al. 2014). East Sand Island (OR, USA) in the Columbia River estuary supports approximately 40% of the breeding pairs of the western North America population (Adkins et al. 2014), which includes approximately 31,200 breeding pairs and an average annual population growth rate of 3% (Adkins et al. 2014). If not for the rapid growth of the East Sand Island colony, the western population of double-crested cormorants would be approximately stable. This is in sharp contrast to the rapid growth and robust populations of the species in the interior and eastern North America, where the population size has reached approximately 340,000–350,000 breeding pairs, and is now the subject of widespread lethal control for its presumed impact on fisheries and other resources (Wires 2014).

In the Columbia River Basin, double-crested cormorants have been identified as the source of significant mortality to juvenile anadromous salmonids (*Oncorhynchus* spp.) listed under the U.S. Endangered Species Act (ESA; National Oceanic and Atmospheric Administration 2004). There is agreement among federal, state, and tribal resource management agencies that management is warranted to reduce the impact of East Sand Island double-crested cormorants in support of recovery of ESA-listed salmonid stocks (National Oceanic and Atmospheric Administration 2014).

Received: 12 August 2014; Accepted: 9 May 2015

[1]*E-mail: yasuko.suzuki@oregonstate.edu*
[2]*Present address: United States Geological Survey, Pacific Island Ecosystems Research Center, Kilauea Field Station, Hawaii National Park, HI 96718, USA.*

The Public Resource Depredation Order that was implemented by the U.S. Fish and Wildlife Service (USFWS) to limit the impact of the double-crested cormorant population in interior-eastern North America does not include the range of the western population (USFWS 2003), and no federal action to control the western population has been implemented. Consequently, this population remains protected under the Migratory Bird Treaty Act, and federal and state permits are required for lethal take. The impact of destructive control measures at the East Sand Island cormorant colony would be proportionately much greater than lethal control at any of the breeding colonies in interior-eastern North America. Therefore, studies that explore potential nondestructive management approaches are necessary.

Habitat enhancement and social attraction techniques to encourage seabirds to nest at suitable colony sites have been successfully used for restoration and management of breeding colonies of a variety of seabird species (Kress 1983; Roby et al. 2002, 2010; Jones and Kress 2012). We tested whether nesting habitat enhancement and social attraction techniques could be used to attract double-crested cormorants to nest at alternative colony sites and away from the East Sand Island colony. If these techniques proved successful, they could be employed to redistribute double-crested cormorants nesting at the East Sand Island colony to sites where the cormorant consumption of ESA-listed fish would be reduced. We sought to test nesting habitat enhancement and social attraction techniques at plots in 3 different settings: 1) in areas of East Sand Island where cormorants had not previously nested; 2) on other islands in the Columbia River estuary where cormorants had a prior history of nesting, either successful or unsuccessful attempts; and 3) on an island in the Columbia River estuary that appeared suitable for cormorant nesting, but where cormorant nesting had not previously been reported. We estimated chick survival rate (the average no. of young raised per breeding pair) in test plots as a measure of suitability of the alternative habitat. We also monitored disturbance caused by potential predators at and near test plots other than East Sand Island to evaluate whether disturbance negatively affected successful attraction of cormorants.

STUDY AREA

We first evaluated techniques to enhance nesting habitat and to socially attract nesting double-crested cormorants by creating plots adjacent (as close as within 5 m from the edge of the colony) to the cormorant colony on East Sand Island (46°15′46″N, 123°59′15″W) in 2004 and 2005. Double-crested cormorants that nested on East Sand Island built their nests almost entirely on the ground, with the exception of a small number of pairs that built their nests in low-lying trees or shrubs. The vast majority of cormorants at this colony nested on artificial rocky revetment, patches of accumulated driftwood and other floating debris, or on patches of vegetation such as beach–dune grass. In order to evaluate whether double-crested cormorants can be attracted to potential colony sites at islands other than East Sand Island, we also created test plots using nesting habitat enhancement and social attraction at 3 different locations within the Columbia River estuary: 1) a small rock island at the mouth of Trestle Bay (46°12′53″N, 123°58′44″W), 5 km south of East Sand Island (in 2005); 2) the downstream end of Rice Island (46°15′01″N, 123°43′05″W), 26 km up-river from East Sand Island (in 2006); and 3) the downstream end of Miller Sands Spit (46°14′46″N, 123°40′50″W), 30 km up-river from East Sand Island (in 2004–2007; Fig. 1).

Double-crested cormorants were known to have nested in Trestle Bay in the 1980s and early 1990s (Carter et al. 1995); however, there was no record of cormorants nesting on the rocky islet at the mouth of the bay where a test plot was set up. Double-crested cormorants formerly nested on the ground near the downstream end of Rice Island (>1,100 breeding pairs in 1997) until 2003. Unsuccessful nesting attempts by 10 pairs of double-crested cormorants on the ground at the downstream end of Miller Sands Spit were observed in 2001 (nests were abandoned prior to egg hatching).

METHODS

East Sand Island Test Plots

Nesting habitat enhancement and social attraction.—We created 2 test plots each in 2004 and 2005 in the interior of East Sand Island (Fig. 1) and adjacent to the existing cormorant colony to evaluate whether nesting habitat enhancement and social attraction techniques would induce cormorants to nest in areas where none had nested previously. To test social attraction techniques, we deployed 12 cormorant decoys (Mad River Decoys, Waitsfield, VT) in sitting and incubating postures and an audio system with 2 speakers that broadcasted cormorant vocalizations in each plot. Vocalizations of double-crested cormorants were digitally recorded from actively breeding birds during the incubation period at the East Sand Island colony (Alaska's Spirit Speaks, Fairbanks, AK) and broadcasted using solar-charged sound systems (Murremaid Music Boxes, South Bristol, ME).

During the 2004 breeding season, we tested 2 types of habitat enhancement techniques. We set up a 41-m^2 plot using pieces of driftwood that were moved to the plot to create structure similar to natural habitat used by nesting double-crested cormorants elsewhere on the island. We filled this driftwood plot with small woody debris to supply abundant nest-building material for prospecting cormorants. We also added a few dozen old cormorant nests from previous breeding seasons to the plot. We created the second test plot with a square array of 49 old truck tires laid out in a 99-m^2 area. We filled each tire with sand and topped it with a cormorant nest used in previous years. The 2 plots were approximately 20 m apart and separated by a gully and sparse cover of herbaceous vegetation. We removed all nesting habitat enhancement and social attraction materials before the following breeding season to evaluate whether nesting cormorants would be faithful to the same area in the subsequent year, despite the lack of nesting habitat enhancement and social attraction.

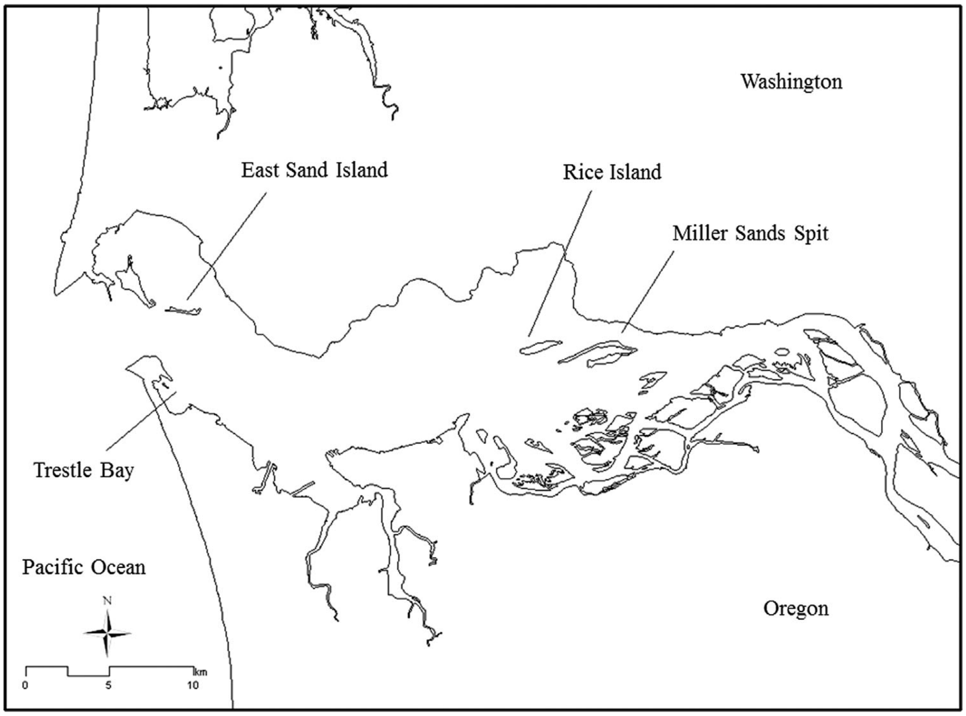

Figure 1. The Columbia River (Pacific Northwest, USA) estuary showing the location of islands where test plots for habitat enhancement and social attraction techniques for double-crested cormorants were created during 2004–2007.

During the 2005 breeding season, we tested whether cormorants could be induced to nest on artificial structures by constructing 2 wooden platforms measuring $5 \times 5\,m^2$ and elevated approximately 0.7 m above ground level, in 2 different areas of the East Sand Island colony where cormorants had not previously nested. We placed 36 old truck and car tires, each filled with sand and topped with a single cormorant nest, on each platform. The distance between the platforms was approximately 30 m, and the platforms were separated by a gully and sparse herbaceous vegetation.

Data collection and analysis.—Between onset of nest building (Apr) through chick-rearing (end of Jul), we monitored double-crested cormorant nesting activities in test plots on East Sand Island from a nearby elevated observation blind. Monitored nesting activities included number of active nests (breeding pairs), nest density (active nests/m^2), and chick survival rate (young raised per active nest; see below). We also monitored nest initiation in the test plots and in other areas of the colony to evaluate how quickly cormorants would be attracted to the test plots as compared with unmanipulated habitat. In order to evaluate differences in cormorant nesting activities associated with nesting habitat enhancement and social attraction, we monitored nests in test plots and control plots ($n = 20$–65 nests/plot in unmanipulated habitat in 3 different areas of the colony). We estimated chick survival rate as the average number of nestlings alive at 28 days posthatch/active nest; cormorant chicks in ground nests at East Sand Island were capable of leaving their nests after 28 days. We compared chick survival rate between test and control plots in each year during 2004 and 2005 using *t*-tests. We performed all statistical analyses using SAS 9.2 (SAS Institute, Inc., Cary, NC) and set α at 0.05.

Test Plots on Other Islands in the Columbia River Estuary

Nesting habitat enhancement and social attraction.—During 2004–2007, we created a test plot at the downstream end of Miller Sands Spit each year prior to the breeding season (Fig. 1); the test plot was located where a few double-crested cormorants had previously nested unsuccessfully in 2001. In 2004, we gathered driftwood into a 10×8-m^2 plot, and filled the plot with fine woody debris suitable as nest material that we had collected from the shoreline of the island. We placed 62 cormorant decoys and an audio system with 2 speakers that broadcasted cormorant vocalizations in the plot. In 2005, we created a smaller driftwood plot ($8 \times 5\,m^2$) with 24 cormorant decoys and 2 speakers in the same area of the island, but with 25 old tires filled with fine woody debris to simulate nesting material. In the subsequent 2 years (2006 and 2007), we repeated the test at the same site using larger numbers of decoys (40), tires (36), and speakers (4) placed in an even smaller plot ($4.5 \times 4.5\,m^2$).

In 2005, we created a test plot on top of a small rocky islet at the mouth of Trestle Bay (Fig. 1), which was an area with no prior history of cormorant nesting. The plot measured approximately $10 \times 20\,m^2$ in size, and we set it up with 26 cormorant decoys, 24 old car and truck tires, and an audio system with 2 speakers that broadcasted cormorant vocalizations. We filled the center of each tire with fine woody debris.

Finally in 2006, we created a test plot at the downstream end of Rice Island (Fig. 1), near where double-crested cormorants had nested as recently as 2003. In a test plot that measured $4.0 \times 4.3\ m^2$, we placed 36 old tires filled with fine woody debris, 40 cormorant decoys, and an audio system with 4 speakers that broadcasted recordings of cormorant vocalizations (Fig. 2). The plan was to remove the test plot after the 2006 breeding season, regardless of whether cormorants attempted to nest there or not. If the plot was used by nesting cormorants in 2006, removal of the habitat enhancement and social attraction after the 2006 breeding season would assess whether cormorants would nest at the same site in subsequent years without habitat enhancement and social attraction.

Data collection.—Because there was no observation blind on Miller Sands Spit or at the Trestle Bay site, we monitored the presence of cormorants on the test plots, plus any nesting activities on the plots, during boat-based and aerial surveys conducted 1–3 times/week from April through July, supplemented with land-based surveys at considerable distance from the plot to ensure that any potential nesting cormorants were not disturbed. In addition to routine surveys, we monitored the test plot and adjacent areas of Miller Sands Spit from Rice Island, located across the river channel and approximately 1 km from Miller Sands Spit, for the presence of cormorants and potential causes of disturbance to nesting cormorants, averaging 11 hr of observation each week from June through July in 2006.

At Rice Island, we monitored numbers of cormorants, nesting activities, and sources of disturbance (e.g., predators, human activities) to cormorants on or near the plot from a nearby observation blind during May–July. We recorded an average of 13 hr of observation each week. We counted any event that caused a flight response by cormorants as one disturbance event. We based chick survival rate at all sites on whether nestling presence was visually confirmed during either land- or boat-based surveys.

We conducted a single on-the-ground survey at each test plot during the chick-rearing period to count nest structures and numbers of nestlings. In order to minimize gull (*Larus* spp.) predation on cormorant eggs and nestlings while adult cormorants were away from their nests because of our presence at the plots, we conducted each on-the-ground survey at night. We conducted each on-the-ground count of nests and chicks when we estimated the oldest chicks to be about 28 days old. When nesting chronology was highly asynchronous within a plot, we postponed the single on-the-ground survey of nests and nestlings in an attempt to maximize the number of chicks old enough to be included in an estimate of chick survival rate. In these cases, we set up a fence made of fabric around the plot in order to catch and count any older chicks that could move away from their nests. Double-crested cormorant chicks on ground nests can return to their nests once the cause of disturbance leaves the site (previous observations by authors). Nests with eggs or chicks <2 weeks old were excluded from the estimates of chick survival rate because the fate of eggs and young chicks were unpredictable at such early stages of nesting.

This study was performed using protocols for animal care and use that were approved by the Institutional Animal Care and Use Committee at Oregon State University.

Figure 2. Test plot on Rice Island in the Columbia River (Pacific Northwest, USA) estuary, created in 2006, to attract double-crested cormorants using habitat enhancement and social attraction techniques.

RESULTS

Attracting Cormorants to Nest in New Areas Adjacent to the East Sand Island Colony

Double-crested cormorants were attracted to nest and successfully fledged young at all test plots on East Sand Island, regardless of the method of habitat enhancement. In each year of the study, the first observations of cormorants and the initiation of nesting behavior on the test plots were synchronous between plots, concurrent with early nesters outside the test plots, and within a week of when cormorants first settled on other parts of the colony. The nesting density of cormorants on each test plot was similar to or greater than colony-wide nesting densities (Table 1). After habitat enhancement and social attraction were removed from the 2 plots following the 2004 nesting season, cormorants did not nest in these 2 areas during 2005–2007.

There was no significant difference in mean chick survival rate between test and control plots in 2004 (test plot $\bar{x} = 2.3$ chicks/nest, $SE = 0.1$, $n = 43$; control plot $\bar{x} = 2.0$ chicks/nest, $SE = 0.1$, $n = 89$). In 2005, mean chick survival rate in the 2 test plots ($\bar{x} = 1.9$ chicks/nest, $SE = 0.1$, $n = 64$) was 36% greater than the control plots ($\bar{x} = 1.4$ chicks/nest, $SE = 0.1$, $n = 118$; $t = 3.7$, $P < 0.001$; Fig. 3).

Island with a Recent History of Cormorant Nesting

On the Rice Island test plot, we first observed prospecting cormorants and cormorants engaged in courtship display only 1 day after the completion of plot preparations. Thirty pairs of cormorants nested within the plot and 5 additional pairs nested immediately adjacent to the plot. The best estimate of chick survival rate for cormorants that nested in or adjacent to the Rice Island plot was 2.6 chicks/nest (older chicks were approx. 28 days posthatch).

Bald eagles (*Haliaeetus leucocephalus*) caused disturbances to double-crested cormorants nesting on the Rice Island test plot or roosting in the immediate vicinity at a rate of 0.1

Table 1. Breeding pairs of double-crested cormorants and nest density in each test plot for habitat enhancement and social attraction on East Sand Island, Oregon, USA, in 2004 and 2005. Colony-wide nest densities for each year are presented for reference.

Year	Habitat enhancement	Area (m^2)	No. of breeding pairs	Nest density (active nests/m^2)	Colony-wide nest density (active nests/m^2)
2004	Driftwood	41	94	2.3	0.7
	Tires on ground	99	162	1.6	
2005	Tires on platform 1	25	29	1.2	1.2
	Tires on platform 2	25	33	1.3	

disturbance events/daylight hour (total observation time was approx. 87 daylight hours). Up to 5 bald eagles were observed at one time on the beach adjacent to the test plot. Although recreational boaters were observed in the vicinity of Rice Island at a rate of 0.4 boats/daylight hour, no boats were observed close enough to the plot to visibly disturb cormorants nesting on the plot. During the subsequent nesting season (2007), after the habitat enhancement and social attraction had been removed from the plot, double-crested cormorants did not attempt to renest on Rice Island.

Island with No Prior History of Successful Cormorant Nesting

Cormorants were observed congregated on the beach immediately adjacent to the Miller Sands Spit test plot on several occasions, and also in the upland area near the plot on one occasion during the first year (2004); however, there was no evidence that cormorants attempted to nest on the plot. The first confirmation of cormorant nesting attempts in the test plot was recorded during the second year (2005), when cormorants were observed carrying nest material to the plot 24 days after completion of plot preparations. Subsequently, 21 partially or completely built cormorant nests and 6 cormorant eggs in 4 different nests were confirmed both within and immediately adjacent to the test plot. All of these cormorant nests failed prior to eggs hatching; presumably due to egg predation by glaucous-winged-western gulls (*L. glaucescens–occidentalis*), which nested in the vicinity of the plot.

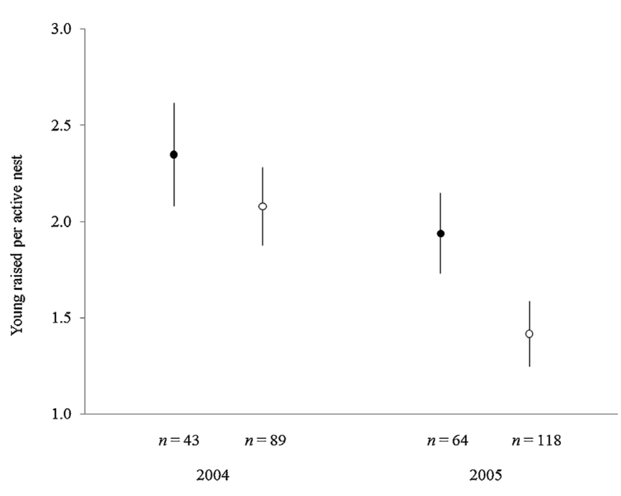

Figure 3. Chick survival rate (average no. of young raised per active nest, estimated at 28 days posthatch) of double-crested cormorants in 2 test plots and 3 control plots at East Sand Island, Oregon, USA, in 2004 and 2005. Dark circles and open circles represent test and control plots, respectively. Error bars represent 95% confidence intervals.

Double-crested cormorants successfully nested and fledged chicks on Miller Sands Spit during 2006 and 2007. Prospecting cormorants were first observed on the test plot 26 days and 28 days after completion of plot preparations in 2006 and 2007, respectively. Forty-one breeding pairs nested in the plot or immediately adjacent to the plot in 2006, with an average of 2.2 chicks/nest (oldest chicks were approx. 28 days posthatch). In 2007, we counted 90 active nests in and around the test plot, with an average of 1.7 chicks/nest (oldest chicks were approx. 40 days posthatch).

Eagles disturbed nesting cormorants on Miller Sands Spit at a similar rate to that measured at the Rice Island plot in 2006 (approx. 0.1 disturbance events/daylight hour; total observation time for the Miller Sands Spit plot approx. 79 daylight hours). Recreational boaters were observed in the area at a rate of 0.5 boats/daylight hour. Some boats drove along the shore immediately below the test plot and disturbed cormorants on-near the test plot at a rate of 0.04 disturbance events/daylight hour.

Island with No Prior History of Cormorant Nesting

No double-crested cormorants were observed on or in the immediate vicinity of the rocky islet at the mouth of Trestle Bay during the 2005 nesting season. Cormorants were seen in the Trestle Bay area during all surveys in 2005 ($n = 16$) except one; however, the majority of cormorants observed in the area were in subadult plumage. Bald eagles (up to 4 eagles/survey) and/or recreational boaters were present in the Trestle Bay area during most surveys.

DISCUSSION

Nesting habitat enhancement and social attraction techniques attracted double-crested cormorants to nest at sites where nesting was not currently taking place. Artificial platforms have been successfully used as habitat enhancement to restore arboreal nesting habitat for double-crested cormorants (Meier 1981, Matteson et al. 1999, Wires 2014). The combination of habitat enhancement and social attraction also has been used to attract tree-nesting double-crested cormorants to ground nests (Feldmann 2011) and to restore a colony of Brandt's cormorants (*P. penicillatus*; McChesney et al. 2004, 2005). In both studies, however, social attraction techniques did not succeed in inducing cormorants to nest at the intended locations. In our study, cormorants were enticed to nest and successfully raised young adjacent to the large colony on East Sand Island in areas that were not previously occupied by nesting birds. Cormorants also nested and successfully raised young on similar plots at 2 islands approximately 25 km from East Sand Island; one island had a history of successful cormorant nesting 3 years prior and the other was a site where cormorants had attempted to nest but were unsuccessful 5 years prior.

On East Sand Island, cormorant nest initiation in test plots was simultaneous with nest initiation in unmanipulated sections of the colony (i.e., control plots). This, along with the observed similarities in nesting density between test and control plots, indicates that habitat enhancement and social attraction provided a set of cues that prospecting adult cormorants found equally attractive. Furthermore, similarities in chick survival rate among plots on the East Sand Island colony suggest that cormorants did not experience substantial differences in the quality of nesting habitats. The simultaneous occupancy by cormorants at both driftwood and tire plots in the first year of the study, and of the newly built platforms in the second year of the study, indicates that double-crested cormorants can readily adapt to nesting on manipulated habitat and artificial structures. The absence of any cormorant nesting attempts at the site of former plots where habitat enhancement and social attraction had been removed after 1 year suggests that those methods need to be maintained longer for double-crested cormorants to develop fidelity to the sites. Although the number of years that habitat enhancement and social attraction must be sustained after the establishment of a new colony was not examined in this study, long-term restoration projects of other seabird species used social attraction techniques for $\geq$9 years (Kress and Nettleship 1988, Parker et al. 2007). Removing or modifying the structure (e.g., piles of driftwood, nesting material) that support nesting cormorants could serve as a potential management technique for dissuading cormorants from nesting, especially if colonies have not been well-established, as was the case with the test plots in this study.

The response of double-crested cormorants to habitat enhancement and social attraction at 3 separate islands in the Columbia River estuary where cormorants were not currently nesting varied from an immediate response to no response at all. A key factor was the previous history of double-crested cormorant nesting or nesting attempts on the islands. The island with the most recent history of successful cormorant nesting displayed the most rapid response to habitat enhancement and social attraction, whereas no response was observed on the island without a previous history of cormorant nesting or nesting attempts. No effort to discourage cormorants from nesting on East Sand Island was made concurrent with attempts to attract cormorants to nest at these other islands within the Columbia River estuary. Active dissuasion of cormorants at East Sand Island, paired with habitat enhancement and social attraction at these other islands, may amplify the response of cormorants to these techniques.

If cormorants have never historically nested at a site, or have previously nested but the colony was abandoned, the factors responsible should be identified and thoroughly evaluated (Kress 1998, Schlossberg and Ward 2004, Ahlering et al. 2010). This study documented the sensitivity of nesting double-crested cormorants to disturbance by predators and humans, which is consistent with previous studies (Henny et al. 1989, Carter et al. 1995, Chatwin et al. 2002, Adkins et al. 2014). Bald eagles have been observed harassing and depredating adult and juvenile double-crested cormorants at colonies in the Columbia River estuary, and the associated disturbance to nesting cormorants has resulted in the loss of large numbers of cormorant eggs to predation by glaucous-winged-western gulls (Adkins and Roby 2010). In addition to factors we evaluated in this study, the presence of other bird species should be considered in selection of a site because cormorants tend to colonize sites where other colonial waterbirds are nesting (Bregnballe and Gregersen 1997, Wires and Cuthbert 2010).

As an extension of our effort to evaluate the nondestructive techniques tested in this study, we also created 2 additional plots designed to attract nesting double-crested cormorants to sites outside the Columbia River estuary by using old tires and fine woody debris as habitat enhancement, plus decoys and audio playback systems as social attraction during 2007–2009 (Roby et al. 2008, 2010; Collis et al. 2009). Neither of these efforts at using habitat enhancement and social attraction to either 1) establish a new cormorant colony, or 2) expand an existing arboreal colony succeeded during a 3-year trial period. The first attempt was probably unsuccessful because of the lack of a previous history of cormorant nesting in the area, the presence of bald eagles in the vicinity of the test plot, and the long distance to a large source colony (approx. 250 km from East Sand Island; Jones and Kress 2012). The lack of success with the second attempt was likely the presence of unoccupied potential nest trees nearby that provided preferred nesting sites. Without a substantial increase in the local or regional population during the study period, there was probably no incentive for cormorants to seek new nesting sites, especially when ample nesting habitat at current colonies was available.

This study addressed the question of whether cormorants will use artificial colonies, but determining where these colonies should be placed is also important. Cormorants from the East Sand Island colony may prospect for nesting sites hundreds of kilometers from the Columbia River estuary because postbreeding double-crested cormorants from East Sand Island disperse as far as 530 km from the colony (Courtot et al. 2012). Based on maximum foraging distances of double-crested cormorants reported by previous studies (Neuman et al. 1997, Anderson et al. 2004, Coleman et al. 2005), alternative colony sites should be $\geq$50 km from sites where fish species of special concern are susceptible to cormorant predation. Testing habitat enhancement and social attraction at former colony sites within the post-breeding dispersal range of the East Sand Island colony would be the next logical step for evaluating these nondestructive management techniques. If these techniques are applied at former colony sites concurrent with dissuasion at an existing colony experiencing conflicts with fish of conservation concern, this may be effective in relocating nesting cormorants to sites at substantially greater distances than the sites tested in this study.

ACKNOWLEDGMENTS

This study was funded by the U.S. Army Corps of Engineers (USACE) Portland District and the Bonneville Power Administration (BPA). We especially thank G. Dorsey and P. Schmidt (USACE Portland District) and J. Skidmore (BPA) for their support. We are grateful to U.S. Fish and Wildlife Service and the Oregon Department of Fish and Wildlife for their assistance and support. We are very thankful to many people in our research team for their valuable help: J. Adkins, D. Battaglia, B. Cramer, B. Courtot, A. Evans, N. Hostetter, L. Kerr, P. Loschl, and many field technicians and interns. K. Dugger provided valuable comments that improved earlier drafts of this manuscript. We also thank A. Pearse, L. Wires, J. Gervais, and an anonymous reviewer for providing insightful comments that improved the manuscript. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

LITERATURE CITED

Adkins, J. Y., and D. D. Roby. 2010. A status assessment of the double-crested cormorant (*Phalacrocorax auritus*) in western North America: 1998–2009. Unpublished report to the U.S. Army Corps of Engineers. U.S. Geological Survey, Corvallis, Oregon, USA.

Adkins, J. Y., D. D. Roby, D. E. Lyons, K. N. Courtot, K. Collis, H. R. Carter, W. D. Shuford, and P. J. Capitolo. 2014. Recent population size, trends, and limiting factors for the double-crested cormorant in western North America. Journal of Wildlife Management 78:1131–1142.

Ahlering, M. A., D. Arlt, M. G. Betts, R. J. Fletcher, J. J. Nocera, and M. P. Ward. 2010. Research needs and recommendations for the use of conspecific-attraction methods in the conservation of migratory songbirds. Condor 112:252–264.

Anderson, C. D., D. D. Roby, and K. Collis. 2004. Foraging patterns of male and female double-crested cormorants nesting in the Columbia River estuary. Canadian Journal of Zoology 82:541–554.

Bregnballe, T., and J. Gregersen. 1997. Changes in growth of the breeding population of cormorants *Phalacrocorax carbo sinensis* in Denmark. Supplementi alle Ricerche di Biologia della Selvagggina 26:31–46.

Carter, H. R., A. L. Sowls, M. S. Rodway, U. W. Wilson, R. W. Lowe, G. J. McChesney, F. Gress, and D. W. Anderson. 1995. Population size, trends, and conservation problems of the double-crested cormorant on the Pacific Coast of North America. Colonial Waterbirds 18:189–215.

Chatwin, T. A., M. H. Mather, and T. D. Giesbrecht. 2002. Changes in pelagic and double-crested cormorant nesting populations in the Strait of Georgia, British Columbia. Northwestern Naturalist 83:109–117.

Coleman J. T. H., M. E. Richmond, L. G. Rudstam, and P. M. Mattison. 2005. Foraging location and site fidelity of the double-crested cormorant on Oneida Lake, New York. Waterbirds 28:498–510.

Collis, K., D. D. Roby, D. E. Lyons, Y. Suzuki, J. Y. Adkins, L. Reinalda, N. Hostetter, L. Adrean, M. Bockes, P. Loschl, D. Battaglia, T. Marcella, B. Cramer, A. Evans, M. Hawbecker, M. Carper, J. Sheggeby, and S. Sebring. 2009. Research, monitoring, and evaluation of avian predation on salmonid smolts in the lower and mid-Columbia River. 2008 Final Season Summary to the Bonneville Power Administration and the U.S. Army Corps of Engineers, Portland, Oregon, USA. www.birdresearchnw.org Accessed 17 Aug 2015.

Courtot, K. N., D. D. Roby, J. Y. Adkins, D. E. Lyons, D. T. King, and R. S. Larsen. 2012. Colony connectivity of Pacific Coast double-crested cormorants based on post-breeding dispersal from the region's largest colony. Journal of Wildlife Management 76:1462–1471.

Feldmann, I. 2011. Double-crested cormorant management at Tommy Thompson Park: a conspecific attraction experiment and egg-oiling modeling scenarios. Thesis, York University, Toronto, Ontario, Canada.

Henny, C. J., L. J. Blus, S. P. Thompson, and U. W. Wilson. 1989. Environmental contaminants, human disturbance and nesting of double-crested cormorants in northwestern Washington. Colonial Waterbirds 12:198–206.

Jones, H. P., and S. W. Kress. 2012. A review of the world's active seabird restoration projects. Journal of Wildlife Management 76:2–9.

Kress, S. W. 1983. The use of decoys, sound recordings, and gull control for re-establishing a tern colony in Maine. Colonial Waterbirds 6:185–196.

Kress, S. W. 1998. Applying research for effective management: case studies in seabird restoration. Pages 141–154 *in* J. M. Marzluff and R. Sallabanks, editors. Avian conservation: research and management. Island Press, Washington, D.C., USA.

Kress, S. W., and D. N. Nettleship. 1988. Re-establishment of Atlantic puffins (*Fratercula arctica*) at a former breeding site in the Gulf of Maine. Journal of Field Ornithology 59:161–170.

Matteson, S. W., P. W. Rasmussen, K. L. Stromborg, T. I. Meier, J. Van Stappen, and E. C. Nelson. 1999. Changes in the status, distribution, and management of double-crested cormorants in Wisconsin. Pages 27–45 *in* M. E. Tobin, technical coordinator. Symposium on double-crested cormorants: population status and management issues in the Midwest. U. S. Department of Agriculture, Animal and Plant Health Inspection Service Technical Bulletin 1879, Washington, D.C., USA.

McChesney, G. J., N. M. Jones, T. B. Poitras, K. J. Vickers, L. E. Eigner, H. R. Carter, R. T. Golightly, S. W. Kress, M. W. Parker, K. Studnicki, P. J. Capitolo, and J. N. Hall. 2005. Restoration of common murre colonies in central California: annual report 2004. U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Newark, California, USA.

McChesney, G. J., A. H. Robinson, J. S. Koepke, H. A. Knechtel, N. M. Jones, C. M. Caurant, T. B. Poitras, R. T. Golightly, H. R. Carter, S. W. Kress, and J. Stankiewizc. 2004. Restoration of common murre colonies in central California: annual report 2003. U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Newark, California, USA.

Meier, T. 1981. Artificial nesting structures for the double-crested cormorant. Wisconsin Department of Natural Resources Technical Bulletin 126, Madison, USA.

National Oceanic and Atmospheric Administration. 2004. Biological opinion for consultation on remand for operation of the Columbia River Power System and 19 Bureau of Reclamation Projects in the Columbia River Basin. National Oceanic and Atmospheric Administration Fisheries, Portland, Oregon, USA.

National Oceanic and Atmospheric Administration. 2014. Endangered Species Act section 7(a)(2) supplemental biological opinion for consultation on remand for operation of the Columbia River Power System. National Oceanic and Atmospheric Administration Fisheries, Portland, Oregon, USA.

Neuman, J., D. L. Pearl, P. J. Ewins, R. Black, D. V. Weseloh, M. Pike, and K. Karwowski. 1997. Spatial and temporal variation in the diet of double-crested cormorants (*Phalacrocorax auritus*) breeding on the lower Great Lakes in the early 1990s. Canadian Journal of Fisheries and Aquatic Sciences 54:1569–1584.

Parker, M. W., S. W. Kress, R. T. Golightly, H. R. Carter, E. B. Parsons, S. E. Schubel, J. A. Boyce, G. J. McChesney, and S. M. Wisely. 2007. Assessment of social attraction techniques used to restore a common murre colony in central California. Waterbirds 30:17–28.

Roby, D. D., K. Collis, J. Y. Adkins, M. Correll, K. Courtot, B. Cramer, N. Hostetter, P. Loschl, D. E. Lyons, T. Marcella, Y. Suzuki, J. Tennyson, A. Evans, M. Hawbecker, J. Sheggeby, and S. Sebring. 2010. Research, monitoring, and evaluation of avian predation on salmonid smolts in the lower and mid-Columbia River. Final 2009 Annual Report to the Bonneville Power Administration and the U.S. Army Corps of Engineers, Portland, Oregon, USA. www.birdresearchnw.org Accessed 17 Aug 2015.

Roby, D. D., K. Collis, D. E. Lyons, D. P. Craig, J. Y. Adkins, A. M. Myers, and R. M. Suryan. 2002. Effects of colony relocation on diet and productivity of Caspian terns. Journal of Wildlife Management 66:662–673.

Roby, D. D., K. Collis, D. E. Lyons, Y. Suzuki, J. Y. Adkins, L. Reinalda, N. Hostetter, L. Adrean, A. Evans, M. Hawbecker, and S. Sebring. 2008. Research, monitoring, and evaluation of avian predation on salmonid smolts in the lower and mid-Columbia River. 2007 Final Season Summary to Bonneville Power Administration and U.S. Army Corps of Engineers, Portland, Oregon, USA. www.birdresearchnw.org Accessed 17 Aug 2015.

Schlossberg, S. R., and M. P. Ward. 2004. Using conspecific attraction to conserve endangered birds. Endangered Species Update 21:132–138.

U.S. Fish and Wildlife Service. 2003. Final environmental impact statement: double-crested cormorant management in the United States. U.S. Department of Interior Fish and Wildlife Service in cooperation with U.S. Department of Agriculture APHIS Wildlife Services, Washington, D.C., USA.

Wires, L. R. 2014. The double-crested cormorant, plight of a feathered pariah. Yale University Press, New Haven, Connecticut, USA.

Wires, L. R., and F. J. Cuthbert. 2006. Historic populations of the double-crested cormorant (*Phalacrocorax auritus*): implications for conservation and management in the 21st Century. Waterbirds 29:9–37.

Wires, L. R., and F. J. Cuthbert 2010. Characteristics of double-crested cormorant colonies in the U.S. Great Lakes Island Landscape. Journal of Great Lakes Research 36:232–241.

Associate Editor: Pearse.