U.S. Army Corps of Engineers – Portland District

Implementation and Effects of Double-crested Cormorant Dissuasion Research at East Sand Island, Columbia River Estuary: 2008-2012

Technical Memorandum

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This Technical Memorandum provides a summary of the research activities related to testing the feasibility of several techniques for dissuading double-crested cormorants (*Phalacrocorax auritus*) from nesting on parts of their breeding colony on East Sand Island. These studies were conducted during 2008-2012. Descriptions of each dissuasion method, the efficacy of each dissuasion method (i.e., effects on breeding double-crested cormorants), and the effects of each dissuasion method on non-target waterbird species are included. A feasibility assessment is provided for each dissuasion method that was tested. Standards used to evaluate the feasibility of the different dissuasion methods include: (1) effectiveness at dissuading double-crested cormorants from nesting, (2) degree of disturbance to non-target species, (3) expense, and (4) ease of implementing the dissuasion method. Table 1 compares the cost estimates for each dissuasion method by year. An appendix describing the history of scientific collection of double-crested cormorants related to research at East Sand Island and elsewhere in the Columbia River estuary during 1997-2012 is also provided.

Year: 2008

Dissuasion Methods Tested: We investigated two techniques for discouraging nesting by double-crested cormorants on parts of their breeding colony at East Sand Island during the 2008 nesting season: (1) human disturbance on a discrete portion of the breeding colony, prior to the onset of egg-laying by cormorants, and (2) hazing with a green laser on cormorants that were roosting on beaches adjacent to the breeding colony.

Isolated human disturbance was tested as a potential method for discouraging nesting by double-crested cormorant on East Sand Island. Prior to the initiation of breeding, a visual barrier (a fence of black plastic fabric, 1.5-m tall) was erected to isolate a small section of the cormorant breeding colony at the eastern-most end of the colony. An above-ground tunnel was built prior to the nesting season to allow researcher access to this treatment area of the colony without detection by nesting cormorants. On multiple occasions during the week preceding the expected date of the first cormorant egg, a single researcher emerged from the tunnel onto the treatment section of the cormorant colony, flushing cormorants from the area. The researcher remained in view of the cormorants for a short period, initially less than three minutes, before withdrawing into the tunnel. During these disturbances, additional researchers situated at three different vantage points observed the reaction of the cormorants and recorded the number of cormorants affected (including any non-target individuals) and the duration of absence of cormorants from the treatment area. Because this was a pilot study, the length and frequency of the disturbances was varied in order to achieve the desired effect. All human disturbances in the treatment area ceased as soon as egg-laying was initiated.

We tested the efficacy of a green laser (LEM50 laser torch) for dispersing double-crested cormorants from roosting locations along the shore of East Sand Island. Because the laser was acquired in the first week of May, after double-crested cormorants had initiated egg-laying; testing of the laser for hazing cormorants was restricted to roosting individuals and flocks encountered off-colony. Researchers attempted to haze roosting cormorants daily and to vary the time of day, weather, distance to target birds, and light conditions under which the laser was tested. We recorded the response of target individuals and flocks. Tests that resulted in a flushing response by some or all of the target cormorants were considered successful.

Effects of Dissuasion Methods on Double-crested Cormorants: We initiated human disturbance just prior to egg-laying in the treatment area. Consequently, disturbances began after many cormorants within the treatment area had well-established pair bonds and were defending nest territories. A total of six human disturbances were carried out over three days prior to the observation of eggs within the dissuasion treatment area and the cessation of hazing.

During the late pre-laying period, short duration human disturbance (< 5 minutes) successfully flushed cormorants from the treatment area; however, cormorants re-landed in the treatment area within two minutes after the disturbance ended. Human disturbance was most effective at keeping cormorants off of the treatment part of the colony when sustained for extended periods of time and repeated frequently. Disturbances lasting longer than 10 minutes kept cormorants out of the treatment area for greater than 10 minutes. Additionally, when disturbances were repeated immediately after cormorants returned to the treatment area, the length of time the birds remained off of the treatment part of the colony increased. These results suggest that to preclude egg-laying by cormorants during the late pre-laying stage, the magnitude of disturbance (i.e., duration and/or frequency) would need to be much higher than was employed in this pilot study; (i.e., > 15 minutes/day or > 2 events/day). Presumably, initiating disturbance earlier in the pre-laying period would also be more effective at discouraging cormorant nesting.

The use of a fence as a visual barrier was successful at limiting the portion of the colony affected by human disturbance. Cormorants west of the visual barrier were successfully screened from the researcher during disturbance events, but individuals did react at times to the alarm behavioral response of cormorants on the east side of the visual barrier (those in the treatment area with an unobstructed view of the researcher). Occasionally, cormorants < 5 m to the west of the visual barrier flushed when target cormorants flushed due to social facilitation. Within the treatment area, cormorants in view of the researcher consistently flushed.

Seventeen tests using the green laser were completed in 2008, of which five were successful in causing some or all of the target cormorants to flush. All successful tests were completed early or late in the day; three at 2100 or later, and two at 0840 and 0845. All successful tests were conducted at a distance of 55 m or less from the roosting cormorants; four successful tests were at a distance of 30 m or less. During the test from 55 m, half of the target cormorants flushed, while the other half ran to the water. Cloud cover during successful tests was 40% or more. Three unsuccessful tests were repeated successfully at closer range (distances of 40 to 80 m). The remaining nine tests, all with no apparent effect on the target cormorants, were conducted between 0920 and 1846 under varying light conditions and distances.

Effects of Dissuasion Methods on Other Colonial Waterbird Species: Effects on non-target species were not monitored in 2008. Based on the timing of the human disturbance method and the area of the colony that was targeted, however, disturbance to non-target species would likely have been minimal. Based on the nature of the green laser treatment (i.e., targeting individuals or small groups of double-crested cormorants roosting off-colony), the effects of this dissuasion method on non-target species was likely minimal or absent.

Feasibility of Dissuasion Methods: Both of the disturbance measures tested in 2008 were effective at flushing cormorants, however, each was initiated too late in the nesting cycle to determine efficacy to deter nest initiation and egg-laying. The effect of human disturbance was likely limited because cormorants had already established a moderate to high level of commitment to nesting territories and pair bonds. Short duration (< 5 minutes) human disturbances were not effective at keeping cormorants off of the colony for periods that were likely to inhibit nest initiation. However, we cannot be certain that short disturbances would not have been effective if initiated earlier in the nesting cycle. Future efforts to apply human disturbance to deter egg-laying on a portion of the double-crested cormorant colony should be initiated earlier in the breeding cycle, before pair bonds and nest territories have been established.

The green laser was most effective in low light conditions, as described by the manufacturer. All successful tests were conducted early or late in the day under a minimum of 40% cloud cover. Under the conditions tested, the laser appeared to be most effective at short range (< 60 m) relative to its potential range (≥ 2 km). Preliminary field tests of the green laser conducted early in the day under low light at a site in the Willamette Valley confirmed that the unit is capable of flushing ducks (Anatidae) from wetland areas at a distance of 500 m (P. Loschl, pers. comm.). Based on these results and the results of the human disturbance tests, any attempt to use the green laser to deter egg-laying should be (1) initiated early in the breeding cycle, before pair bonds and nest territories have been established, (2) carried out during low light conditions before 0830 and after 2100 each day, at a minimum, and (3) employed for as long as necessary to clear the treatment area of any prospecting cormorants.

Year: 2009

Dissuasion Methods Tested: We repeated tests of the efficacy of two active nest dissuasion techniques, human disturbance and hazing with a green laser, and added tests of a third technique in the form of habitat modification. This prospective habitat modification technique consisted of covering a discrete area previously used by nesting cormorants with pond liner.

Human disturbance methods used in 2009 were modified from those used in 2008. Prior to the initiation of cormorant nesting, an observation blind was built at the terminus of an above-ground tunnel, allowing researchers to access the colony without disturbance to nesting cormorants. The blind was constructed with one east-facing and one west-facing window, allowing views of the nesting colony in either direction. A visual barrier (a fence of black plastic fabric, 1.5-m tall) was erected in front of the blind, effectively isolating a small section of the double-crested cormorant colony at the eastern-most tip. Beginning in mid-April, researchers entered the blind each day to disturb double-crested cormorants that were initiating nesting in the eastern-most section of the colony (treatment area). Prior to each disturbance, the number of cormorants that occupied the treatment area near the blind was recorded and photos were taken to evaluate the effects of the disturbance on cormorants in both the treatment and non-treatment areas. Before, during, and immediately following the disturbance the behavior of all cormorants was noted, both in the treatment and non-treatment areas.

The treatment area was disturbed when a researcher exited the blind through a hatch and emerged onto the cormorant colony. Upon entering the colony, the researcher noted the time, the number of birds disturbed, and their initial reaction to the disturbance. The researcher remained on the colony for five minutes and then re-entered the blind. In order to quantify the effectiveness of human disturbance, researchers noted the length of time the treatment area was abandoned by cormorants, as well as the time elapsed until 50% and 100% of the cormorants returned to the treatment area. Five minutes after the first cormorant returned to the treatment area, a researcher entered the treatment area again as described above. In each successive emergence onto the treatment area, the researcher increased the time spent on-colony. This repeated procedure was terminated for the day once cormorants did not return to the treatment area for over one hour. Researchers remained in the blind to conduct post-treatment observations in order to determine the most effective temporal and visual dissuasion methods. In an attempt to keep cormorants from nesting in the treatment area, protocols were altered to focus on techniques that were determined to be most effective. Over the course of the study, the daily frequency and temporal intensity of the disturbances increased in response to the apparent habituation of cormorants to the dissuasion methods. Disturbances ceased as soon as egg-laying was detected in the treatment area.

In addition to human disturbance, we again tested the efficacy of a green laser (LEM50 laser torch) as an active dissuasion technique to deter double-crested cormorants from nesting at select locations on the East Sand Island colony. Prior to the initiation of cormorant nesting, a second observation blind (separate from the blind constructed for testing the human disturbance technique mentioned above) was built at the terminus of an above-ground tunnel, which allowed researchers access to the designated hazing area without detection by nesting cormorants. The blind was constructed with a single large window made of one-way glass. Under the window was a 3-inch by 6-inch slot that allowed operation of the green laser from within the blind. For laser hazing, we targeted an area where approximately 110 double-crested cormorant nests were counted in 2008. This treatment area was selected adjacent to other nesting cormorants so that the effectiveness of the laser to dissuade selected individuals could be tested. Beginning in mid-April, researchers entered the blind twice daily (one hour prior to sunrise and one hour prior to civil twilight) to conduct laser dissuasion sessions. Upon entering, researchers would record the number of cormorants in the area and note their behavior using a Bushnell Night Vision 26-4050 – Monocular 4 x 50, when necessary.

Thirty minutes prior to sunrise and 30 minutes prior to civil twilight, researchers directed the laser at the feet of the targeted birds with a back and forth sweeping motion until the maximum number of birds in the targeted area was flushed. The researcher recorded the amount of time the laser was directed on the colony, the number of targeted and non-targeted birds that were disturbed, and the initial reaction of the birds. The researcher recorded the time elapsed before the first bird returned, when 50% of the birds had returned, and when 100% of the birds had returned. Five minutes after the first bird returned, the laser was swept across the target area again. This process was repeated until the area remained free of birds for one hour (or, in the case of the pre-sunrise dissuasion, until daylight prevented the laser from effectively dissuading birds from the area). Laser treatments ceased as soon as evidence of egg-laying was detected in the treatment area.

We also tested the feasibility of a passive method to dissuade cormorants from nesting in a specific section of the colony. We covered an area of the rock rip-rap that protects the south shore of East Sand Island, approximately 80 square meters, with rubber pond liner material in an attempt to dissuade cormorants from nesting by eliminating the substrate structure that cormorants seem to prefer for nest-building. Using two 45-mm thick strips of pond liner, we were able to “smooth out” a section of the rip-rap previously used by nesting cormorants. We removed nesting structures and small pieces of driftwood by hand and used a chainsaw to trim larger pieces of driftwood. Large gaps between rocks were filled in to make the area as level as possible before attaching the pond liner. The two sheets of liner were laid down one on top of the other. Sections of 2”x 4”s were placed above and below the edge of the two sheets and screwed together using 3-inch wood screws. A 6-inch deep trench was dug along the northern edge of the pond liner, where the liner was draped down onto the sandy area of the colony, and buried to secure it. The remaining three edges were secured using 10-inch spikes and washers hammered through the material into larger logs wedged into rocks. When possible, the logs were set flush with the edge of the pond liner to discourage cormorants from nesting on these undulations. In an effort to further stabilize the pond liner and to prevent gaps that the wind could lift, large rocks were piled along the edges. Additional 10-inch spikes and washers were driven into other areas of the pond liner to insure it was held down securely. Once in place, the pond liner effectively smoothed out the rocky area that was previously prime cormorant nesting habitat. The habitat modification was completed in early April, before cormorants arrived on the colony.

Effects of Dissuasion Methods: The human disturbance experiment proved to be an effective method of delaying, but not preventing, cormorants from nesting in the treatment area and caused little apparent disturbance to cormorants nesting in non-treatment areas. The time invested in dissuading birds from nesting in the treatment area appeared to be the limiting factor that eventually resulted in egg-laying in the treatment area. Although the efforts to disturb nesting cormorants in the treatment area were conducted daily, there was evidence of habituation to the disturbance by cormorants using the treatment area. Access to the blind was limited by the tides (i.e., researchers could not enter or leave the blind during high tide without disturbing large numbers of nesting cormorants and roosting California brown pelicans (*Pelecanus occidentalis*). This constraint prevented us from disturbing nesting cormorants in the treatment area frequently enough to prevent the onset of egg-laying.

After each disturbance, displaced cormorants circled overhead between one and four times before landing in the water or landing to roost further west on East Sand Island. The length of time that cormorants took to return to the treatment area after the researcher re-entered the blind was not associated with the length of time the researcher remained on the treatment area (5-30 minutes). The disturbance to cormorants nesting in non-treatment areas was minimal. Most disturbances to non-treatment areas were recorded in the initial weeks of the treatment, when cormorants were just beginning to prospect in the surrounding areas. As nesting progressed and birds became more committed to nest sites, the number of cormorants that flushed from non-treatment areas declined. Cormorants nesting within 10 m of the blind on the west side (non-treatment area) were observed to have eggs in early May (compared to mid-May in the treatment area). This chronology was consistent with the nesting chronology of the rest of the double-crested cormorant colony.

The green laser was effective at flushing cormorants from the targeted areas when used in low light conditions (primarily at dusk); its effectiveness decreased considerably as light levels increased after sunrise, until the laser failed to flush any cormorants. When employed in the evening, it was necessary to direct the laser at the targeted area three to six times in order to successfully flush cormorants from the area. All 14 night-time disturbances using the green laser were successful at keeping birds off the treatment area for longer than one hour. It was noted that on at least two occasions the treatment area remained free of birds until the following morning. Although moderately successful in flushing cormorants, none of the 13 morning disturbances using the green laser were successful at keeping birds off the targeted area for more than one hour. Thus, while the laser was effective at disturbing birds in low light conditions, on average there were 14 h and 20 min of daylight per day when the birds were not disturbed. The experiment was terminated in late April, when a cormorant egg was observed in the treatment area, seven days after the first cormorant egg was observed elsewhere on the colony.

The area of rip-rap covered by pond liner remained free of nesting cormorants for the entire 2009 breeding season. The pond liner was compromised, however, when a wind storm lifted the southern edge and folded it over on itself, exposing approximately 20 m^2 of rip-rap. The pond liner was quickly re-secured by researchers who entered the colony, and stayed in place for the remainder of the nesting season. It was common for gulls (*Larus* spp.), Canada geese (*Branta canadensis*), and cormorants to roost on the pond liner, but no nesting by any species was observed on the pond liner. Cormorants nested against the edges of the pond liner, and on some anchoring logs. The lack of nesting structure (e.g., rock and coarse woody debris) was apparently the most important factor inhibiting cormorants from nesting on the pond liner. The pond liner billowed during south winds and became slippery when wet, factors that may have contributed to deterring nesting by cormorants. Cormorants were seen slipping and falling on the pond liner during wet conditions.

Effects of Dissuasion Methods on Other Colonial Waterbird Species: Small numbers of Brandt's cormorants (*P. penicillatus*; i.e., ≤ 25 individuals) roosted in and adjacent to the human disturbance treatment area. Disturbances to Brandt's cormorants were recorded during 15 double-crested cormorant hazing events; a maximum of 20 Brandt's cormorants were disturbed at any one time. California brown pelicans also roosted adjacent to the treatment area during the active hazing period, with up to 800 brown pelicans observed roosting on the rip-rap and beaches both east and west of the visual barrier. Four disturbance events to brown pelicans were recorded during double-crested cormorant hazing events, and a maximum of 500 brown pelicans were flushed following the largest disturbance event.

No non-target species were disturbed as a result of testing the green laser dissuasion method.

The pond liner prevented all species from nesting in the area of deployment. In previous years, however, only double-crested cormorants had been observed nesting in the pond liner treatment area.

Feasibility of Dissuasion Methods: Both of the active disturbance techniques tested were effective at flushing cormorants, but ultimately failed to prevent nesting in the treatment areas. Human disturbance appeared to be an effective option for deterring cormorants from nesting on part of the colony, if frequency and intensity of disturbances could be increased. Although time and resources might limit this method as a cost-effective management strategy for selective dissuasion of nesting cormorants, cost per unit area dissuaded would be expected to decrease as the treatment area for dissuasion is increased. As expected, the green laser was most effective in low light conditions, but proved completely ineffective during daylight. While the green laser may be effective in dissuading nesting cormorants on East Sand Island if coupled with other methods of dissuasion, it was ineffective when used alone because hazing during low light conditions was not sufficient to deter egg-laying by cormorants. The passive habitat modification technique using pond liner was successful at deterring cormorants from nesting in a small area of the cormorant colony throughout the 2009 breeding season. See the 2010 Feasibility of Dissuasion Methods section for an evaluation of the feasibility of the pond liner method.

Year: 2010

Dissuasion Methods Tested: The pond liner dissuasion technique was tested again on a larger area of the double-crested cormorant colony. Using the original dissuasion area from 2009, the 2010 pond liner treatment was expanded to the west to encompass 315 square meters of the rip-rap nesting habitat.

The pond liner was installed using the same methods as in 2009. Installation was completed in early April, before cormorants arrived on the island to nest.

Effects of Dissuasion Methods: The area of rip-rap covered by pond liner remained free of nesting cormorants for the entire 2010 breeding season. The pond liner was compromised, however, when a wind-storm lifted large sections of the pond liner, leaving several areas of rip-rap exposed. This did not compromise the efficacy of the remaining pond liner in dissuading cormorants from nesting. Using data on double-crested cormorant nesting density in 2010, approximately 348 nests were excluded from the 2010 pond liner dissuasion area, compared to 80 nests in 2009.

Effects of Dissuasion Methods on Other Colonial Waterbird Species: The pond liner prevented all species from nesting in the area of deployment. In previous years, however, only double-crested cormorants had been observed nesting in the treatment area.

Feasibility of Dissuasion Methods: Although the use of pond liner to dissuade double-crested cormorants from nesting in a small area of the East Sand Island cormorant colony was effective in both 2009 and 2010, several issues should be considered before large scale deployment of this method is considered for reducing the numbers of double-crested cormorants nesting at this colony. High cost, difficulty of deployment, and durability are all problems with this method. Scaling up the method, we estimate a cost of over $27,000 per acre for pond liner material alone, based on the advertised price ($3,150) for a large (50' x 100') sheet of pond liner. Logistically, an important consideration for this method is the weight of the pond liner. One roll of pond liner, measuring 20 m x 5 m, weighs over 100 kg, making transport and installation difficult. The 50' x 100' sheets noted above weigh 1,550 lbs. each. In addition, wind action lifted and compromised the integrity of the pond liner in both years, suggesting that the material used would not provide long-term dissuasion of the entire area covered without monitoring and maintenance. Tidal and wave action along the rip-rap habitat pose additional risks for any pond liner that used to dissuade nesting along the southern edge of the cormorant colony. Due to the harsh environment on East Sand Island, the pond liner can be damaged or shifted during the nesting season, allowing cormorants to build nests in the gaps. Also, pond liner should be removed at the conclusion of the breeding season to avoid damage or loss during winter storms, adding to transport challenges. Thus, methods of transport would need to be dramatically improved before large-scale use of pond liner for dissuasion of nesting cormorants on East Sand Island would be practical. Finally, this technique would require covering more than 5 ha of potential cormorant nesting habitat in order to be effective at limiting the numbers of cormorants nesting on the existing colony at East Sand Island.

Year: 2011

Dissuasion Methods Tested: We tested the feasibility of dissuading double-crested cormorants from nesting on a portion of the East Sand Island cormorant colony where approximately 15% of the breeding pairs nested in 2010. A 2.4-m high by 65-m long privacy fence was erected across the cormorant colony and an attempt was made to prevent cormorants from nesting on the east side of the fence, while minimizing the disturbance to cormorants nesting west of the visual barrier. Several techniques for dissuading cormorants from nesting on the east side of the privacy fence were investigated, including human disturbance, destruction of cormorant nest structures, and experimentation with a moving coyote (*Canis latrans*) effigy (artificial coyote on a zip-line). Reflective polyester tape was also evaluated as a method to dissuade cormorants from nesting in or near three small trees (< 2 m height) on the East Sand Island colony.

The dissuasion treatment area was located at the eastern end of the double-crested cormorant breeding colony on East Sand Island, and had been occupied by nesting cormorants for several years. Nesting substrate was a mix of rocky terrain (rip-rap), woody debris, open sandy areas, and vegetated areas characterized by herbaceous vegetation with scattered small shrubs. In 2010, approximately 1,500 double-crested cormorant nests were located in the 2011 dissuasion treatment area.

In addition to the privacy fence, an observation blind and above-ground tunnel system were constructed to provide researchers access to an enclosed researcher camp without disturbing nesting cormorants outside of the dissuasion treatment area. The enclosed camp concealed all researcher activity from cormorants within the treatment area, as well as those cormorants nesting west of the privacy fence, and provided an elevated vantage point for observations on either side of the privacy fence. To augment the effectiveness of dissuasion efforts, all cormorant nest structures that were constructed in the treatment area prior to the start of hazing were destroyed by scattering the nesting material.

Cormorants were first observed in the treatment area on 23 April and hazing efforts began on 29 April. The dissuasion area was observed every half hour from civil twilight in the morning to civil twilight in the evening during each day. During each observation, researchers counted the number of cormorants in the treatment area and recorded breeding behaviors (i.e., courtship display, nest building, copulation). Researchers flushed cormorants from the treatment area when (1) any double-crested cormorant exhibited a breeding behavior, (2) congregations of 50 or more loafing cormorants were observed in the treatment area, or (3) cormorants were present in the treatment area at civil twilight in the evening, in order to prevent overnight roosting in the treatment area. If no hazing occurred for two hours, the frequency of observations was reduced to every hour. To minimize disturbance to other wildlife, researchers remained on the treatment area until cormorants were dispersed and then immediately returned to base camp. Following dissuasion activities, researchers remained in the blind to conduct post-dissuasion observations to determine the effectiveness of hazing activities and to assess disturbance to cormorants nesting west of the fence. At least one researcher was stationed at the camp from 28 April until 12 May, when cormorant dissuasion activities ceased.

To evaluate the effectiveness of dissuasion efforts and to determine whether hazed double-crested cormorants left East Sand Island, we captured and marked 91 double-crested cormorants in the dissuasion treatment area during 26 - 28 April, shortly after their arrival on this part of the colony. All 91 cormorants were banded with a federal numbered metal leg band on one leg and a field-readable plastic leg band engraved with a unique alphanumeric code on the other. Of the 91 banded cormorants, 60 were also tagged with a VHF radio transmitter.

Researchers scanned for marked cormorants from observation blinds daily during the active hazing period (28 April - 12 May), and then several times per week once dissuasion activities ceased. Weekly scans were conducted until 15 July, 12 weeks after all marked cormorants were released. Scans were frequently conducted at dusk when cormorants were most likely to be on East Sand Island and within detection range.

We also tested the feasibility of using reflective polyester tape to dissuade cormorants from nesting in or near three small trees on the East Sand Island cormorant colony. Several strands of tape were attached and haphazardly draped throughout the branches of each tree. The tape was left loose to create both a reflective visual and audible deterrent as it moved in the wind. Each tree was marked with approximately 6-8 strands of tape. All trees were within 50 m of an observation blind and were monitored daily to document any nesting attempts in or near the trees.

Effects of Dissuasion Methods: The human disturbance treatment, in concert with a large visual barrier and destruction of nest structures, was an effective method of preventing cormorants from nesting in the dissuasion treatment area. These methods also caused little apparent disturbance to cormorants nesting west of the privacy fence. For example, double-crested cormorants established nests just to the west of the privacy fence and successfully raised young within 10 m of the privacy fence.

Counts of double-crested cormorants east of the privacy fence decreased sharply after hazing began. After one week of hazing, counts of more than 2,000 cormorants in the dissuasion area prior to hazing dropped to less than 100 cormorants. Nest initiation by double-crested cormorants ceased within two weeks of the initiation of active hazing. An average of five (range: 1 - 9) hazing incursions occurred each day, with the number dependent upon the return and subsequent behavior of cormorants in the treatment area after a hazing incursion. Researchers continued daily monitoring of the treatment area for two additional weeks to confirm that no further nest initiation occurred, but did not flush any additional cormorants.

In the four weeks following the initiation of hazing activities, 80 - 93% of the cormorants outfitted with detectable transmitters (i.e., functioning transmitters; excluding those with active mortality signals) were detected daily on East Sand Island outside the treatment area. During this same four-week time period, more than 90% of all detectable cormorants were identified in every week. During the 12-week study period, 30 radio-tagged cormorants (50%) were detected at least once in 10 or more weeks, 17 or 28% were detected at least once in 5 or more weeks (includes two failed transmitters), 11 or 18% were detected in four or fewer weeks (includes five failed transmitters), and two or 3% were never detected post-release.

Two incidents of widespread cormorant nest failure may have contributed to irregular detections of radio-tagged cormorants on the East Sand Island cormorant colony. Bald eagle disturbance and subsequent gull predation on cormorant eggs caused a large portion of the cormorant colony to abandon their nests on 22 May, and again on 23 June. Many cormorants that were regularly detected during the first four weeks post-release presumably left East Sand Island following these disturbances. The lowest proportion of detected cormorants occurred on 25 June following the second nest failure event, when only 34% of detectable radio-tagged cormorants were detected on East Sand Island. During that week, ca. 57% of detectable radio-tagged cormorants were detected at least once; the only week with a lower percent detected was the final week of the study period, when ca. 53% of active transmitters were detected.

Detections of radio-tagged cormorants and re-sightings of color-banded cormorants from the dissuasion area suggest that cormorants displaced from the dissuasion treatment area were widely dispersed across the remainder of the breeding colony. Of the 91 double-crested cormorants captured and banded in the treatment area prior to hazing efforts, 26 or 29% were later re-sighted on East Sand Island, nine of which were confirmed to have at least re-nested on East Sand Island outside the treatment area in 2011. No marked cormorants were observed away from East Sand Island during the 2011 breeding season, nor were any radio-tagged individuals detected during the two aerial surveys of other double-crested cormorant colonies in the Columbia River estuary and Grays Harbor.

The use of reflective polyester tape in trees on East Sand Island was not successful in preventing or delaying cormorants from nesting in or under those trees. Within two days most of the tape had began to deteriorate or was ripped from branches during high wind events. While some reflective material remained in the trees, cormorants initiated and successfully nested both in and under the trees with polyester tape.

Effects of Dissuasion Methods on Other Colonial Waterbird Species: Brandt's cormorants established nests within 5 m of the privacy fence on the west side of the fence and successfully raised young at those nests. Small numbers of California brown pelicans roosted in the dissuasion treatment area during active cormorant hazing and at no time during the feasibility study period were more than 100 pelicans flushed. Shortly after hazing activities were concluded, several hundred brown pelicans were observed using the treatment area and the adjacent rip-rap as a nighttime roost. Several hundred glaucous-winged/western gulls also nested in the treatment area, and quickly became habituated to our hazing activities. Observations suggested that nesting chronology of gulls in the dissuasion area was similar to those nesting elsewhere on East Sand Island.

Feasibility of Dissuasion Methods: Since 2008 we have tested several techniques to discourage nesting by double-crested cormorants: human disturbance (2008-2009, 2011), destruction of nest structures prior to egg-laying (2011), pond liner installation (2009-2010), laser hazing (2008-2009), and reflective tape (2011). Of these techniques, only human disturbance in concert with nest destruction and a large visual barrier has been a feasible means to prevent cormorant nesting in a pre-determined treatment area of the East Sand Island cormorant colony. Detections of radio-tagged cormorants and observations of banded cormorants displaced from the dissuasion treatment area suggested that the vast majority of cormorants hazed in the treatment area relocated west of the visual barrier and resumed nest initiation activities in 2011. A portion of the marked cormorants did appear to leave East Sand Island for one or more weeks during the breeding season; however, the timing of departure suggests that temporary colony abandonment was associated with bald eagle disturbance and subsequent cormorant nesting failure. Human disturbance is a viable option for effectively preventing cormorant nesting on part of the colony, but requires significant infrastructure and labor-intensive hazing and monitoring on a daily basis.

Year: 2012

Dissuasion Methods Tested: We repeated and expanded efforts to test the feasibility of dissuading double-crested cormorants from nesting on a portion of their breeding colony on East Sand Island. In 2011, double-crested cormorants were dissuaded from nesting in 15% of the area used by nesting double-crested cormorants in 2010. The dissuasion area was increased in 2012 to 62% of the area used by nesting cormorants in 2010. A privacy fence (2.4 m high by 25 m long) was erected across the cormorant colony and an attempt was made to prevent cormorants from nesting to the east of the fence, while minimizing the disturbance to cormorants nesting to the west of the fence. Two techniques to dissuade cormorants from nesting on the east side of the privacy fence were investigated in concert: human disturbance and destruction of existing cormorant nests (i.e., scattering of sticks used to form nests using rakes or other implements).

The dissuasion treatment area was located on the eastern half of the double-crested cormorant breeding colony on East Sand Island; this area had been occupied by nesting cormorants for several years. Nesting substrate was a mix of rocky terrain (rip-rap), woody debris, open sandy areas, and vegetated areas characterized by herbaceous vegetation with scattered small shrubs. In 2011, approximately 8,400 double-crested cormorant nests were located in the 2012 treatment area. The treatment area encompassed approximately 6.5 acres, and the linear distance from the privacy fence east to where the eastern-most cormorants nested in 2010 was ca. 650 m.

In addition to the privacy fence, a camp, two observation blinds, and an above-ground tunnel system were constructed to provide researchers access to the area without disturbing nesting cormorants outside of the dissuasion treatment area. The camp concealed all routine non-hazing researcher activity from cormorants within the dissuasion area, as well as those cormorants nesting west of the privacy fence, and the blinds provided an elevated vantage point for observations of either side of the privacy fence.

Cormorants were first observed in the dissuasion treatment area on 16 April and hazing efforts began on 28 April. The treatment area was scanned every half hour from dawn to dusk during each day. During each scan, researchers counted the number of cormorants present in the treatment area and recorded breeding behaviors (i.e., courtship display, nest building, copulation). Researchers flushed cormorants from the dissuasion area when (1) double-crested cormorants exhibited breeding behaviors, (2) aggregations of 100 or more loafing cormorants were observed in the dissuasion area, or (3) cormorants were present in the dissuasion area prior to civil twilight in the evening; the latter was in order to prevent overnight roosting in the treatment area. If no hazing occurred for two hours, the frequency of scans was reduced to every hour. To minimize disturbance to other birds in the treatment area (i.e., roosting brown pelicans and nesting glaucous-winged/western gulls) researchers only remained visible on the cormorant colony until cormorants had dispersed and then immediately returned to camp. Following dissuasion activities, researchers remained in the blind to conduct post-dissuasion observations to determine the effectiveness of hazing activities, enumerate any disturbance to brown pelicans, and assess disturbance to cormorants nesting in the non-treatment area to the west of the fence. At least one researcher was stationed at the camp from 20 April until 12 June, when daily cormorant dissuasion activities ceased for the season.

To evaluate where displaced double-crested cormorants might prospect for alternative nest sites if they left the East Sand Island colony, we captured and marked 149 adult double-crested cormorants in the treatment area during 20 - 28 April, shortly after their arrival on that part of the colony. All captured double-crested cormorants were banded with a federal numbered metal leg band on one leg and a field-readable plastic leg band engraved with a unique alphanumeric code on the other. Of the 149 banded double-crested cormorants, 12 were fitted with satellite transmitters and 126 were fitted with VHF radio transmitters.

The satellite tags were programmed to collect nighttime roost locations every other night for ca. 50 days, and then once a week for the remainder of their expected battery life of 14 months. The tags transmitted nighttime roost location data to the ARGOS satellite network and data were later retrieved from the website of CLS America, Inc.

During several aerial surveys over Washington, Oregon, and northern California, we actively searched for VHF radio-tagged cormorants that might have left the Columbia River estuary. Surveys (n = 12) were conducted between 29 April and 11 July along the Washington Coast (n = 2 surveys), along the Oregon Coast (n = 2), along the lower Columbia River (n = 5), in the Salish Sea/Puget Sound region (n = 3), over the Columbia Plateau (n = 2), and over much of interior Oregon/northeastern California (n = 2). Surveys specifically targeted current and historical double-crested cormorant nesting colonies. We also conducted opportunistic road- and boat-based surveys of several cormorant colonies and roost locations along the northern Oregon coast and lower Columbia River. Finally, weekly scans were conducted at two double-crested cormorant colonies in the Columbia Plateau region, one on Foundation Island and the other at North Potholes Reserve.

In addition to efforts to locate tagged cormorants away from East Sand Island, we regularly scanned for VHF-tagged cormorants at the East Sand Island colony to identify what portion of tagged cormorants remained at the colony. Researchers scanned for banded and VHF-tagged cormorants from observation blinds daily during the active hazing period (28 April - 12 June), and then several times per week once daily dissuasion activities had ceased. Scans were regularly conducted at dusk when cormorants were most likely to be roosting on East Sand Island, and therefore within detection range of the VHF receivers. To supplement this VHF scanning effort at East Sand Island, we also conducted regular observations from blinds throughout the colony to identify color-banded cormorants that remained at the East Sand Island colony and lacked VHF radio tags (e.g., the satellite tagged cormorants, cormorants captured in the dissuasion area but not tagged [n = 11], or cormorants with failed/shed VHF or satellite tags).

Effects of Dissuasion Methods: The human disturbance treatment, in concert with a large visual barrier and destruction of nest structures, was effective at preventing cormorants from nesting in the dissuasion treatment area, which consisted of 62% of the area used by nesting cormorants in 2010. Up to 4,500 cormorants were observed in the treatment area prior to hazing, and a maximum of 2,400 individuals were observed in the treatment area once hazing began. An average of five (range = 1-19) hazing incursions were conducted in the treatment area each day, with the number dependent upon the return rate and subsequent behavior of cormorants in the treatment area. While cormorants continued to prospect and initiate nests in the treatment area throughout the study period, only four cormorant eggs were known to have been laid in the treatment area (three were consumed by gulls and one was collected under permit).

The necessary hazing period was substantially longer in 2012 (28 April – 12 June) than in 2011 (29 April – 12 May). Several factors may have contributed to a greater need for continued hazing in 2012, including (1) a greater number of cormorants displaced from the treatment area, (2) greater site fidelity to nesting areas that had been in use for a longer period, and (3) large scale nest failure in the far western portion of the colony in 2012 due to disturbance and depredation by bald eagles and fewer preferred nesting opportunities west of the 2012 dissuasion fence.

Dissuasion activities caused little or no disturbance to cormorants nesting west of the privacy fence. Double-crested cormorants established nests within 1 m of the privacy fence on the west side of the fence and successfully raised young at those nests.

Based on detections of satellite-tagged and VHF radio-tagged cormorants that had been captured in the treatment area, many displaced cormorants conducted dispersal trips of one to several weeks following capture and/or large-scale nest failure on the western end of the East Sand Island cormorant colony. Immediately following deployment of satellite tags and VHF radio tags on double-crested cormorants captured in the treatment area, some of the tagged cormorants left the Columbia River estuary (defined as from the mouth of the river [Rkm 0] upriver to Puget Island; Rkm 74.5). In the first three weeks following capture and tagging, 6 of 11 (55%) satellite-tagged double-crested cormorants were detected outside the Columbia River estuary. Also, 27 of 126 (21%) VHF radio-tagged double-crested cormorants were detected outside the estuary during aerial and ground-based telemetry surveys. Most of the tagged cormorants that left the estuary, however, had returned to the estuary within a month and were regularly detected there during the remainder of the breeding season. In total, satellite-tagged double-crested cormorants visited 21 sites outside the Columbia River estuary in three primary regions: the Lower Columbia River, Coastal Washington, and Coastal British Columbia. Similarly, detections of VHF radio-tagged cormorants outside the Columbia River estuary documented the use of 11 sites in the same three regions. Tagged cormorants visited active cormorant breeding colonies in the Columbia River estuary (Astoria-Megler Bridge, channel markers), lower Columbia River (Troutdale transmission towers), coastal Washington (Grays Harbor channel markers, Snohomish River pilings), and coastal British Columbia (Second Narrows Bridge transmission tower). Of note, two VHF-tagged double-crested cormorants relocated to the cormorant colony on the Astoria-Megler Bridge and were regularly detected there throughout the breeding season. No confirmed detections of satellite- or radio-tagged cormorants came from inland sites east of Bonneville Dam or coastal sites south of Cannon Beach, OR.

Effects of Dissuasion Methods on Other Colonial Waterbird Species: Brandt's cormorants established nests within 1 m of the privacy fence on the west side of the fence and successfully raised young at those nests. California brown pelicans roosted in and adjacent to the treatment area throughout the active hazing period for cormorants, with up to 1,500 brown pelicans observed roosting in the treatment area at times. Brown pelicans were disturbed during 22 cormorant hazing events; a maximum of 450 individual brown pelicans were flushed in the largest single disturbance event. Several hundred glaucous-winged/western gulls also nested and raised young in the cormorant treatment area.

Feasibility of Dissuasion Methods: Human hazing, in concert with nest destruction and a large visual barrier, proved to be a feasible method of preventing double-crested cormorants from nesting in a pre-determined area of the East Sand Island cormorant colony. Preventing cormorants from nesting in 62% of their former nesting area was achieved, with little impact to cormorants nesting west of the visual barrier. Compared to the pilot study conducted in 2011, however, cormorant dissuasion activities across a much large area in 2012 required significant additional effort. Cormorants continued to initiate nests in the treatment area for up to eight weeks following the onset of hazing, compared to less than three weeks in 2011. The extended period of prospecting by cormorants could have been due to several factors, including a greater number of cormorants displaced from the treatment area, greater site fidelity to nesting areas that had been in use for a longer period, and large scale nest failure in the far western portion of the colony in 2012 due to disturbance and depredation by bald eagles and fewer preferred nesting opportunities west of the 2012 privacy fence. Human disturbance remains a viable option for effectively preventing cormorants from nesting on a portion of the East Sand Island colony, but requires significant infrastructure, labor-intensive hazing, and daily monitoring of the area for extended periods during the nesting season.

Tracking studies of satellite-tagged and radio-tagged double-crested cormorants, plus observations of banded cormorants displaced from the treatment area, suggest that for some cormorants, capture and hazing and/or nest failure were sufficient to induce dispersal from East Sand Island during the cormorant nest initiation period. A large proportion of tagged double-crested cormorants left East Sand Island immediately following tagging, and explored areas of the Lower Columbia River, Coastal Washington, and Coastal British Columbia on these dispersal trips. We identified 21 specific sites where cormorants may aggregate in these regions during prospecting trips. In addition, we did not observe cormorants exploring the Columbia Plateau region or the Oregon Coast (with the exception of one bird detected during one day near Cannon Beach).

Despite dispersal trips outside of the Columbia River estuary by at least 33 tagged cormorants, we found no evidence of permanent emigration from the estuary. The only evidence of permanent emigration from East Sand Island was the persistent detection of two VHF radio-tagged cormorants on the Astoria-Megler Bridge. The general pattern of aborted dispersal trips and subsequent high return rates to East Sand Island suggests that cormorants may display high colony site fidelity if resource managers decide to permanently reduce available cormorant nesting habitat in the future. High colony site fidelity may be a result of prolonged nesting history at the site (many individual cormorants having nested at East Sand Island their entire lives), social facilitation by this very large colony, and/or the lack of suitable nesting opportunities elsewhere. To induce prolonged prospecting or permanent emigration from the Columbia River estuary, it may be necessary to further restrict nesting habitat on East Sand Island and prevent greater use of alternative nesting sites within the estuary (e.g., the Astoria-Megler Bridge).

Table 1. Estimated costs of various dissuasion methods for nesting double-crested cormorants that were tested during 2008-2012.[1]

Year	Dissuasion Method	Materials Cost	Personnel Cost	Total Cost	Notes
2008	Human Disturbance	$130	$2,580	$2,710	
	Green Laser	$0	$800	$800	Laser was used on a trial basis at no cost
2009	Human Disturbance	$1,130	$4,870	$6,000	
	Green Laser	$6,260	$4,340	$10,600	
	Pond Liner (80 m^2)	$980	$1,940	$2,920	Monitored during regular data collection, no additional cost
2010	Pond Liner (315 m^2)	$2,680	$1,940	$4,620	Monitored during regular data collection, no additional cost
2011	Human Disturbance	$8,960	$27,890	$36,850	Used previously constructed observation blind; total does not include USACE direct costs
	Destruction of Nests	$80	$610	$690	
	Coyote Effigy	$50	$340	$390	
	Mylar Tape	$140	$40	$180	
2012	Human Disturbance	$1,540	$38,030	$39,570	Reused camp infrastructure from 2011; total does not include USACE direct costs
	Destruction of Nests	$0	$1,070	$1,070	Reused tools from 2011

[1]Shared project costs (e.g., housing, transportation) are not included in the estimates.

Appendix. History of scientific collection related to double-crested cormorant research in the Columbia River estuary during 1997-2012.

Year	State	County	Location	Species	# Lethally Collected	# Viable Eggs Collected	Purpose
1997	OR	Clatsop	Rice & East Sand islands, Channel Markers	double-crested cormorant	88		Diet study
1998	OR	Clatsop	Rice & East Sand islands, Channel Markers	double-crested cormorant	206		Diet study
1998	OR	Clatsop	East Sand Island	Brandt's cormorant	3		Incidental take related to diet study
1999	OR	Clatsop	East Sand Island	double-crested cormorant	101		Diet study
2000	OR	Clatsop	East Sand Island	double-crested cormorant	93		Diet study
2001	OR	Clatsop	East Sand Island	double-crested cormorant	91		Diet study
2001	OR	Clatsop	East Sand Island	Brandt's cormorant	1		Incidental take related to diet study
2001	OR	Clatsop		pelagic cormorant	3		Incidental take related to diet study
2002	OR	Clatsop	East Sand Island	double-crested cormorant	180		Diet and contaminants studies
2002	OR	Grays Harbor		double-crested cormorant	20		Contaminants study
2003	OR	Clatsop	Rice & East Sand islands	double-crested cormorant	154		Diet study, doubly-labeled water study
2004	OR	Clatsop	East Sand Island	double-crested cormorant	161		Diet study
2005	OR	Clatsop	East Sand Island	double-crested cormorant	157		Diet study
2005	OR	Clatsop	East Sand Island	Brandt's cormorant	1		Incidental take related to diet study
2006	OR	Clatsop	East Sand Island	double-crested cormorant	162		Diet study
2006	OR	Clatsop	East Sand Island	Brandt's cormorant	2		Incidental take related to diet study
2007	OR	Clatsop	East Sand Island	double-crested cormorant	147		Diet study
2007	OR	Clatsop	East Sand Island	Brandt's cormorant	1		Incidental take related to diet study
2008	OR	Clatsop	East Sand Island	double-crested cormorant	163		Diet study, 1 PTT deployment-related death
2008	OR	Clatsop	East Sand Island	Brandt's cormorant	1		Incidental take related to diet study
2009	OR	Clatsop	East Sand Island	double-crested cormorant	150	30	Diet study, eggs collected for contaminants study
2009	OR	Clatsop	East Sand Island	Brandt's cormorant	1		Incidental take related to diet study
2010	OR	Clatsop	East Sand Island	double-crested cormorant	175		Diet study
2011	OR	Clatsop	East Sand Island	double-crested cormorant	154		Diet study
2011	OR	Clatsop	East Sand Island	Brandt's cormorant	2		Incidental take related to diet study
2012	OR	Clatsop	East Sand Island	double-crested cormorant	169	1	Diet study, egg collected as part of hazing experiment