Final Annual Report: Double-crested Cormorant Monitoring on East Sand Island, 2017

IDIQ CONTRACT NO. W912EF-14-0004 (ORDER NO. DT02)

Submitted To: U.S. Army Corps of Engineers – Portland District

Submitted By: RTR/BLE (JV)
1000 S.W. Emkay Drive
Bend, Oregon 97702

Title: Double-crested Cormorant Monitoring on East Sand Island, 2017

Authors: Aaron Turecek[1, 2], James Tennyson[2], Ken Collis[2], and Bradley Cramer[2]

[1] Project Manager and Principal Investigator

[2] Real Time Research, Inc.
1000 S.W. Emkay Dr.
Bend, OR 97702

Project Duration: March 23, 2017 to February 15, 2018

Final Submitted: February 16, 2018

TABLE OF CONTENTS

EXECUTIVE SUMMARY

To reduce avian predation on juvenile salmonids in the Columbia River estuary, the U.S. Army Corps of Engineers (Corps) is continuing to implement the Double-crested Cormorant Management Plan to Reduce Predation on Juvenile Salmonids in the Columbia River Estuary, which consists of measures designed to reduce the size of the double-crested cormorant (DCCO; *Phalacrocorax auritus*) colony at East Sand Island (ESI).

The purpose of this project was to provide the Corps with information needed to implement, monitor, evaluate, and adaptively manage the Double-crested Cormorant Management Plan during the 2017 breeding season. The objectives of this study were to (1) repair and modify existing infrastructure on the DCCO colony on ESI used for monitoring and implementation of the management plan, including removal of materials that may serve as a hazard to nesting birds and (2) conduct surveys to enumerate and monitor DCCO and Brandt's cormorants (BRAC; *P. penicillatus*) on ESI without disrupting nesting or roosting birds.

The cormorant colony was visited weekly to determine colony status, and enumerate DCCO and BRAC nests and individuals. Colony visits consisted of on-island surveys and boat-based surveys. Autonomous cameras deployed on the colony were monitored daily to broadly assess colony status (i.e., presence or absence of cormorants) and inform decisions regarding other monitoring needs throughout the season. High-resolution aerial photography was collected concurrently with on-colony monitoring by researchers when cormorants occupied the colony site for breeding. The high-resolution aerial photography was orthorectified and analyzed to enumerate cormorant individuals and active nests. Image-derived counts were classified by species based on field observations made during ground-based monitoring.

Pre-breeding season colony preparations on the DCCO colony was completed on 11 April, prior to DCCO arrival. Monitoring occurred from 16 April–13 October, with 13 aerial survey flights and 23 colony monitoring surveys conducted. DCCO began loafing in large numbers on the north beaches of ESI on 17 April. DCCO began sporadic attempts at occupying the colony area during early to mid-May, and finally established a continuous presence on the colony for seven days from 13–19 May. A second week-long period of continuous presence on the colony was observed on 30 May, before cormorants dispersed from ESI on 5 June.

Successful DCCO and BRAC nesting did eventually occur on ESI on the far west jetty and the adjacent upland east of the jetty beginning in mid-July, and cormorants remained on colony until the end of monitoring (13 October). Peak DCCO nesting occurred on 26 July, with 544 breeding pairs (95% CI = 512 – 576 breeding pairs), approximately 94% fewer than the peak colony count from 2016. The DCCO colony area was 0.26 acres. Nest density was 0.5 nests/m^2, approximately 50% lower than nest density prior to management. By 13 October no cormorants were observed incubating eggs, and chicks of both species had been mobile for several weeks. DCCO and BRAC breeding success was likely low.

Based on our experience monitoring the DCCO colony in 2017, combined with our past ESI DCCO monitoring projects (1997-2014), we offer the following recommendations for monitoring during future DCCO breeding seasons:

- Contract award at least 6 weeks prior to DCCO arrival at ESI (typically late March or early April) is essential to ensure adequate time for project planning and infrastructure maintenance
- Deploy several additional autonomous camera systems on the colony to provide remote monitoring of the entire colony (including views of the west jetty, beaches, and tidal flats)
- Conduct aerial mapping flights with a combination of traditional manned, fixed-wing mapping systems and small unmanned aerial systems
- Include DCCO monitoring throughout the Columbia River Estuary to achieve comprehensive estuary-wide monitoring as part of a single project
- Include a regional monitoring component to assess DCCO use of historical colonies (i.e. the coast of Washington and Puget Sound) to help assess where cormorants displaced from ESI and the Columbia River Estuary might be going

INTRODUCTION

The number of double-crested cormorants (DCCO; *Phalacrocorax auritus*) nesting on East Sand Island in the Columbia River estuary has increased dramatically in the last two decades; this growth in colony size appears to have been largely at the expense of other colonies in the region, especially along the coast of Washington and British Columbia (Adkins et al. 2014). During the period 1997-2013 the DCCO colony on East Sand Island increased nearly three-fold to ca. 14,900 breeding pairs, the largest known breeding colony for the species in western North America (Adkins et al. 2014, BRNW 2005-2014). Although juvenile salmonids represented ca. 18% of the diet for DCCOs (% biomass) compared to ca. 35% of the diet for Caspian terns (CATE; *Hydroprogne caspia*; % prey items) nesting on East Sand Island in 2010-2012, estimated smolt consumption by DCCOs was about four times greater than that of CATEs during this same time (i.e., ca. 20 million vs. ca. 5 million smolts consumed by DCCOs and CATEs, respectively; BRNW 2013). The large numbers of smolts consumed by the DCCOs nesting at the East Sand Island colony are due to both the historically larger size of the DCCO colony (number of breeding pairs) and the greater per bird food requirements of DCCOs relative to CATEs (BRNW 2013). The DCCO colony on East Sand Island has experienced high nesting success (average of 1.8 young raised/breeding pair per year during 1997-2012; BRNW 2013), perhaps contributing to increases in colony size and the recent level of impact of the DCCO colony on smolt survival. Resource management agencies decided that management of the large colony of DCCOs on East Sand Island to reduce losses of ESA-listed juvenile salmonids in the Columbia River estuary is warranted.

As a component of a comprehensive strategy for salmonid recovery in the Columbia Basin, a management plan was developed to reduce the impacts of DCCOs breeding on East Sand Island (ESI), in the Columbia River Estuary, on the survival of juvenile salmonids listed under the Endangered Species Act (ESA; USACE 2015; NOAA 2017). The management plan entitled "Double-crested Cormorant Management Plan to Reduce Predation on Juvenile Salmonids in the Columbia River Estuary" was released in 2015 and calls for the reduction of the size of the ESI DCCO colony through lethal strategies (i.e., culling and egg oiling) and habitat modifications (USACE 2015).

PROJECT OBJECTIVES

The impetus for this project was to provide the U.S. Army Corps of Engineers (Corps) with information needed to implement, monitor, evaluate, and adaptively manage the DCCO management plan in the Columbia River estuary during the 2017 breeding season. Specifically, the objectives of this study were to (1) repair and modify existing infrastructure on the DCCO colony on ESI used for monitoring and implementation of the management plan, including removal of materials that may serve as a hazard to nesting birds and (2) conduct surveys to enumerate and monitor DCCO and Brandt's cormorants (BRAC; *P. penicillatus*) on ESI without disrupting nesting or roosting birds.

Study Area

East Sand Island is located near the mouth of the Columbia River, in the Columbia River estuary (*Figure 1*). The island is home to breeding colonies of DCCOs, BRACs, CATEs, glaucous-winged/western gulls (*Larus glaucescens/occidentalis*), ring-billed gulls (*L. delawarensis*), and roosting California brown pelicans (*Pelecanus occidentalis californicus*). DCCOs utilize the western portion of the island for nesting, primarily on bare substrate, rip-rap revetment, and amongst large woody debris deposited on the island during winter storms. The DCCO nesting area on ESI was the focus of our monitoring efforts in 2017.

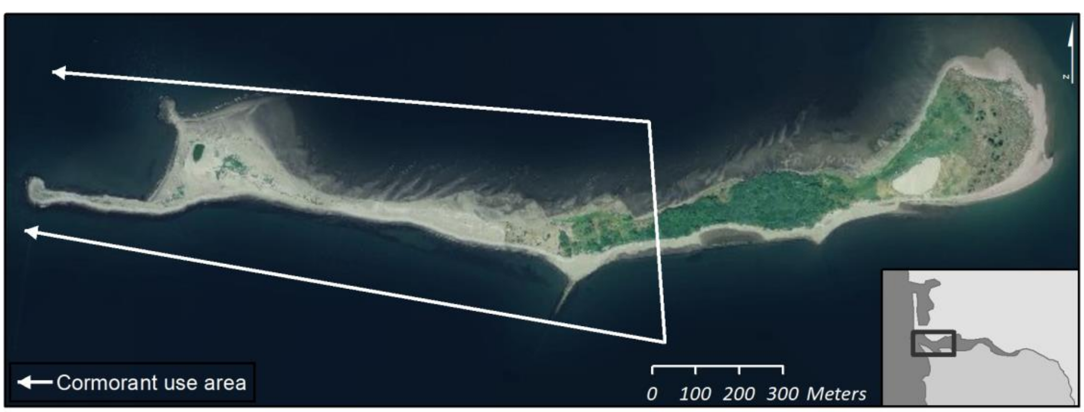

Figure 1. Area utilized by DCCO for nesting 1997 - 2017. Nesting typically occurs on bare substrate, rip-rap revetment, and amongst large woody debris. In 2017, DCCO nests were confined to the western-most upland area, adjacent to the jetty on the extreme west end of the island.

METHODS & ANALYSIS

SITE PREPARATION AND MAINTENANCE

To facilitate the monitoring of DCCO and BRAC nesting on ESI, an infrastructure of tunnels, blinds and visual barriers had been constructed (see *Figure 2*) as part of monitoring efforts in previous years. Prior to the arrival of the cormorants to ESI in 2017, all damaged infrastructure was repaired and/or replaced (as needed) to ensure safe breeding conditions and successful monitoring activities on the colony. Following the breeding season derelict infrastructure materials and marine debris were removed from the island.

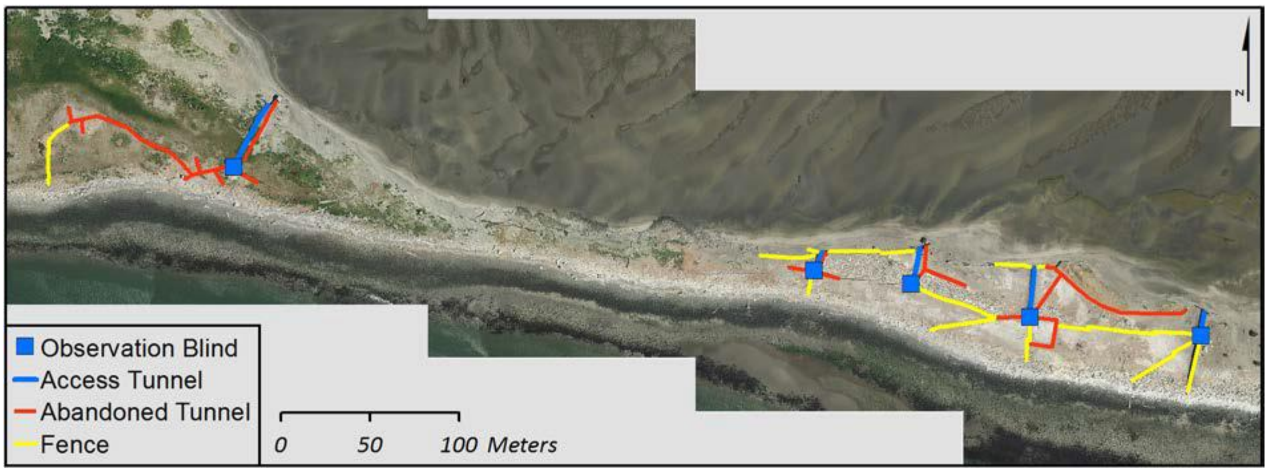

Figure 2. Schematic of the infrastructure on the East Sand Island cormorant colony.

DOUBLE-CRESTED CORMORANT COLONY MONITORING

DCCO monitoring activities on ESI were conducted with an emphasis on acquiring comprehensive enumerations and metrics for the colony, while minimizing the potential to inadvertently cause disturbances to the colony. Our monitoring methods were comprised of, (1) ground-based surveys of the colony conducted by researchers, (2) aerial mapping flights conducted simultaneous to the ground-based surveys, and (3) real-time monitoring by autonomous cameras deployed at various locations throughout the colony.

Ground-based surveys and aerial mapping were planned to be conducted on a weekly basis for 15 weeks throughout the anticipated 2017 cormorant breeding season (mid-April through mid-August; *Figure 3* and *Table 1*). However, the cormorants were unsuccessful in establishing a colony on ESI during the typical initiation period and proceeded to intermittently attend the colony area for several months before finally establishing a colony in mid-July. The frequency and timing of aerial imagery acquisition was modified throughout the breeding season to adapt our resources and efforts to most effectively monitor the colony for the duration of the greatly protracted DCCO breeding season in 2017 (*Figure 3* and *Table 1*). Following the failure of initial nesting attempts in May/June, ground-based monitoring was conducted weekly to assess conditions and to record cormorant breeding status, but aerial mapping flights were conducted only during periods of sustained cormorant attendance on the colony (i.e., continuous presence on the colony, including overnight roosting). Weekly aerial surveys were resumed when the colony ultimately became established in mid-July. A schedule of surveys completed during this study is summarized in *Table 1.*

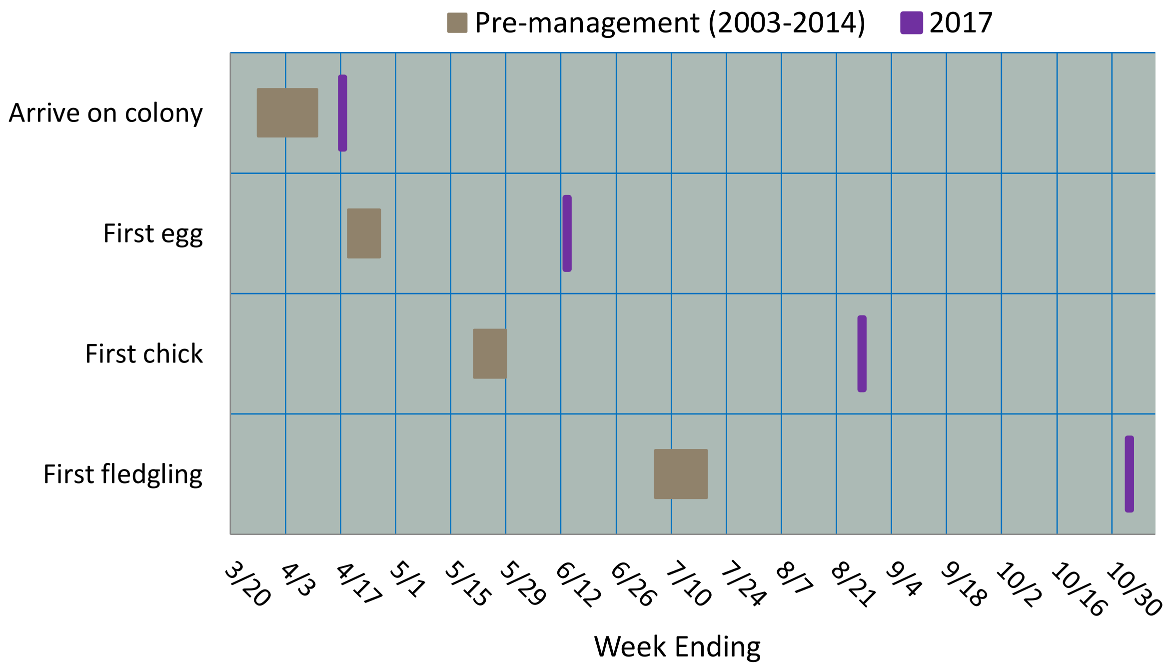

Figure 3. DCCO nesting chronology on ESI in 2017 compared to the nesting chronology for the 2003 – 2014 breeding seasons (pre-management).

Table 1. Ground-based surveys and aerial mapping flights conducted on the ESI DCCO colony in 2017.

Week	Ground Survey		Aerial Survey	
	On-island	Boat-based	Fixed-wing	UAS
16-Apr	√	-	√	-
23-Apr	√	-	√	-
30-Apr	√	√	-	-
7-May	√	-	-	-
14-May	√	√	√	-
21-May	√	√	-	-
28-May	√	√	-	-
4-Jun	√	√	√	-
11-Jun	√	-	√	-
18-Jun	√	-	-	-
25-Jun	√	-	-	-
2-Jul	-	-	-	-
9-Jul	-	-	-	-
16-Jul	√	√	-	-
23-Jul	-	√	√	-
30-Jul	√	-	-	-
6-Aug	√	-	-	-
13-Aug	√	-	√	-
20-Aug	√	-	√	-
27-Aug	√	-	-	-
3-Sep	√	-	√	-
10-Sep	√	-	√	√
17-Sep	√	-	-	-
24-Sep	√	-	-	-
1-Oct	√	-	-	√
8-Oct	√	-	-	√
Totals	23	7	10	3

Ground-based surveys

Ground-based monitoring of the ESI cormorant colony area was achieved via on-island and boat-based surveys conducted by a two-person research team lead by a senior wildlife biologist with over a decade of experience studying DCCOs throughout the Columbia River Basin. Monitoring activities were conducted in accordance with a “no disturbance” standard to eliminate the potential for researchers inadvertently impacting cormorant breeding activities. On-island monitoring was conducted from four observation blinds in the central portion of the habitat area and the observation tower on the western end of the island (see *Figure 2* above). Observation blinds were accessed via tunnels that obscured the researchers from view by birds attending the colony. On several occasions researchers did not access all or any of the observation blinds due to concern that approaching the tunnels would potentially disturb cormorants loafing on the tidal flats on the north side of the island. Boat-based monitoring was conducted along the southern rip-rap revetment and western jetty to provide observations of areas obscured from view from the observation blinds, as well as to monitor the central colony when the blinds were inaccessible. Ground- and boat-based surveys were conducted 23 times between mid-April and October (see *Table 1* above).

Researchers used spotting scopes and binoculars to observe cormorants during surveys. Data collected included: (1) date and time; (2) survey location; (3) cormorant behavior (i.e., courtship displays, nest construction, incubation, chick rearing); (4) counts of cormorants (i.e. adults and attended nests); (5) site conditions; and (6) evidence of predators and other sources of colony disturbance. Researchers delineated colony boundaries by species (DCCO or BRAC) on mobile GIS tablets with the most recent orthoimagery displayed as the on-screen background. To aid the delineation process, the monitors correlated on-colony structures (e.g., tires, woody debris) and painted reference markers (installed during pre-season colony preparation in 2017) that were visible from the blind/boat and in the orthoimagery. The mobile GIS species delineations were used to help classify the cormorant features extracted from the aerial imagery (i.e. differentiating between DCCO and BRAC, as well as assigning nesting status). Three observation plots were established in the central colony area that were intended to monitor nesting chronology (i.e., pre-egg laying, egg-laying, chick-rearing, and fledging periods) throughout the study; however, cormorants did not establish a colony in this area in 2017. Methods for cormorant mapping, species differentiation, and nesting status are detailed below.

Aerial mapping surveys

During periods of cormorant attendance on the colony, 13 aerial mapping flights were conducted to acquire high-resolution vertical imagery of the colony (see *Table 1* above). Aerial surveys were conducted by both traditional manned, fixed-wing, aerial mapping systems, and unmanned aircraft systems (UAS). Imagery was orthorectified and mosaicked to achieve 1.5-2 cm ground sample distance (GSD) mosaics of the cormorant colony. Aerial surveys were coordinated with ground-based surveys so that researchers could monitor colony status during image acquisition to ensure that resulting imagery captured a stable snapshot of the colony. Orthomosaics were imported into a GIS platform and processed to digitize individual cormorants and attended nests on the colony. Methods for cormorant mapping, species differentiation, and nesting status classification are detailed below.

Autonomous camera monitoring

Three autonomous cameras were deployed on the central colony area to provide real-time imagery of the cormorant colony throughout the breeding season. The cameras recorded still images on a one-hour cycle, and uploaded the photos to a cloud-based data portal via cellular modem. Photos of the colony were monitored daily to assess the colony status, track colony attendance, and help determine optimal timing for ground-based and aerial mapping surveys.

Image analysis and enumerations

The orthophotography acquired during the aerial mapping surveys was synthesized with GIS data collected during the weekly ground-based surveys. Imagery and data were then used to generate counts and delineations of DCCOs and BRACs on ESI following each aerial mapping survey (see below for more detail). Count metrics included the number of adult cormorants and the number of attended cormorant nests, by species (DCCO and BRAC). *Figure 4* shows an example of cormorants mapped on an aerial image.

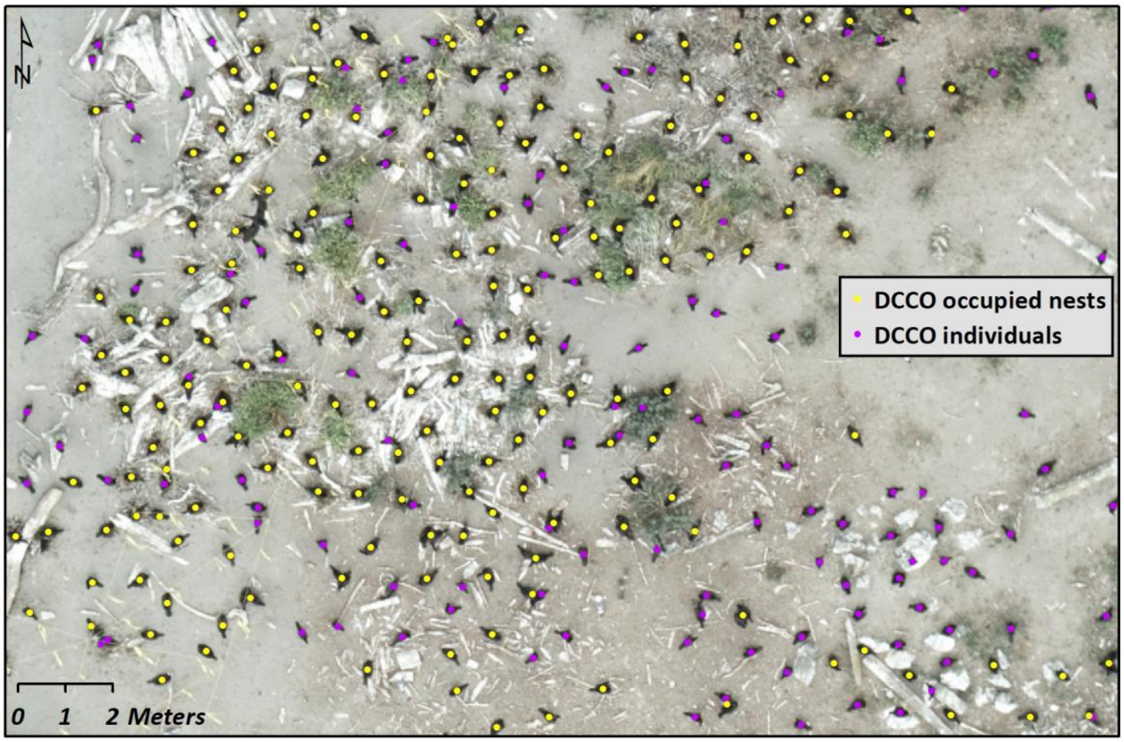

Figure 4. Counts of double-crested cormorants on nests (yellow dots) and individuals (purple dots) interpreted from aerial photographs and ground-based surveys of the East Sand Island colony in 2017.

Aerial imagery was orthorectified and mosaiced to a single image covering the entire cormorant colony area, with a GSD of 1.5 - 2 cm based on the image acquisition method (i.e. manned fixed wing or UAS), and then imported into a GIS platform for analysis. A processing mask was manually created to exclude all areas of the orthomosaic outside the area used by cormorants. An automated image classification process (unsupervised classification) was applied to the imagery (excluding all masked regions from the classification process). This automated classification isolated candidate groups of pixels that share the spectral signature of a cormorant. The resulting cormorant "candidates" were then run through an automated series of filters to isolate occurrences of groups of pixels that are of similar size and shape as a cormorant. The output from this automated classification process was a draft GIS point file depicting all cormorants (both DCCOs and BRACs, both nesting and loafing).

The draft GIS point file resulting from the previous step was manually audited to add cormorants that were not captured (false negatives), and to remove false positives. The resulting point file represents all cormorants, without distinction between species or nesting status. The next step assigned a species class to each point (i.e. DCCO or BRAC) by overlaying the cormorant points with the colony boundaries that were delineated in ground-based surveys.

The second to last stage of the process is to differentiate nesting birds from loafing birds. All points outside the colony boundaries were classified as loafing birds. An automated process was run to compare the points within the colony boundaries with nests from the previous flights/imagery. Points that shared approximate location (~ 0.2 meters) with previously identified nests were automatically classified as nests. Following this process, a manual audit was performed to verify the nest/loafing classification step. In situations where multiple birds were associated with a single nest, one bird was classified as "nesting" and the other(s) were classified as "loafing".

Finally, in addition to the 2-D analysis described above, points were imported into a soft-copy photogrammetry system and overlaid on 3-D stereo models to audit points. In some cases, this was helpful for differentiating nest composition to aid in assigning species (DCCO or BRAC). It is important to note, however, that 3-D analysis was not reliable for identifying nests during early nest initiation, when the peak nest counts occurred in 2017. *Figure 5* depicts the GIS and remote sensing workflow used to generate cormorant counts.

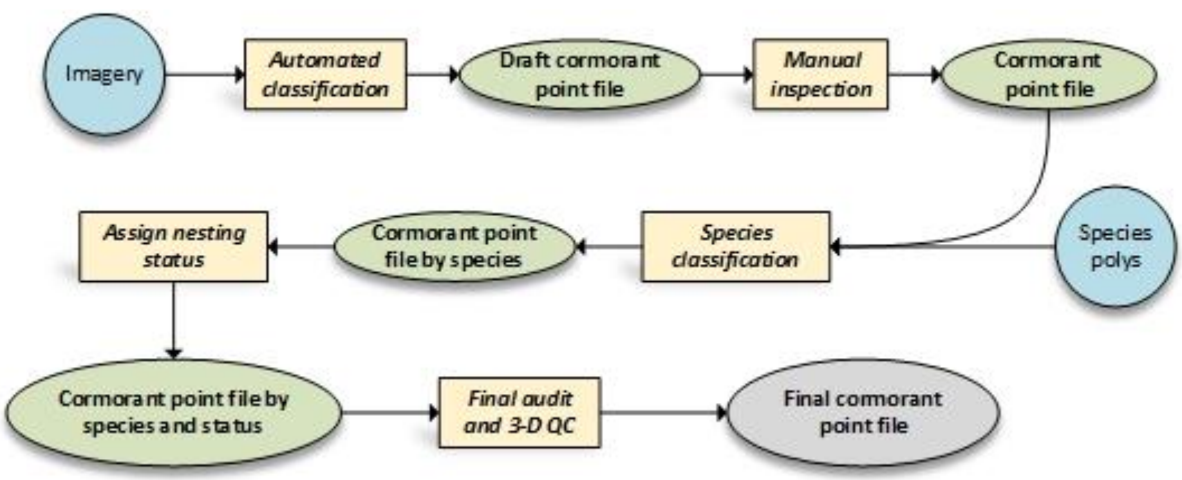

Figure 5. Step-wise process used to enumerate the number of nesting double-crested and Brandt's cormorants on East Sand Island each week during the 2017 breeding season.

Colony size estimates were generated from the imagery collected by each aerial mapping survey, and reported to the Corps during the season. Following the breeding season, the imagery for the highest DCCO nest count from the season was then re-counted, including the final 3-D audit, by two additional analysts to acquire three DCCO nest counts for the peak nest count. The three peak nest counts were used to estimate the colony size (number of attended nests or number of breeding pairs) and the 95% Confidence Interval (CI) for the estimate. This method for estimating colony size in 2017 is comparable to the methods used to estimate the DCCO colony size in 1997 – 2014 (BRNW 2015).

The area occupied by DCCO nests was derived by generating polygons around clusters of proximate nests (within 3 meters) that were digitized for the peak nest count. Resulting aggregated polygons were buffered by 1 meter to achieve the estimated colony area. Nest density was derived by dividing the number of nests within the colony area by the colony area. Nests that were not aggregated into nest area polygons were excluded from the nest density calculation.

RESULTS & DISCUSSION

SITE PREPARATION AND MAINTENANCE

Prior to the arrival of the cormorants to ESI in 2017, all damaged infrastructure was repaired and/or replaced (as needed) to ensure successful monitoring activities on the colony in 2017. Infrastructure modifications and repairs included replacing portions of two access tunnels, construction of several hundred meters of silt fence, and removal of hundreds of meters of derelict silt fences and damaged tunnels to prevent potential entrapment of cormorants. Following the breeding season, three abandoned monitoring structures were dismantled and removed from ESI, along with 115 tires and 10,750 lbs (4.9 metric tons) of derelict infrastructure material and marine debris that was spread throughout the west end of the island. *Figure 6* shows one of many stockpiles of debris that were removed from ESI in October 2017.

Figure 6. Stockpile of derelict infrastructure materials and marine debris awaiting removal from East Sand Island. In all, nearly 5 metric tons of material were removed from the island in 2017.

DOUBLE-CRESTED CORMORANT COLONY MONITORING

Nesting chronology

Cormorants began loafing on the beaches of ESI in the second week of April, and started sporadic attempts to establish a colony on the eastern end of the former colony area on 17 April (*Figure 7* and *Figure 8*). Throughout early colonization attempts, late April – early June, large numbers of cormorants (6,000 -7,000 observed on 10 May) used the western portion of the island for staging/loafing. Cormorants were not successful in establishing a colony on the eastern end of the former colony, although they did have two brief periods of attendance, one in mid-May, and another in early-June, each for approximately one week (*Figure 8*). During the two early periods of attendance, the cormorants were unable to establish a colony due in large part to frequent disturbances by bald eagles (*Haliaeetus leucocephalus*; *Table 2*). Researchers recorded 87 disturbances by bald eagles that mostly occurred during the early nest initiation attempts in mid-May to mid-June (*Table 2*). The disturbances resulted in partial or complete flushes of cormorants from this portion of the colony at rates ranging from 1.25 to 3.91 disturbances per hour (*Table 2*). Results from a previous study suggests that disturbance rates of >15 minutes/day or >2 events/day may delay or prevent cormorant nesting (BRNW 2013b). Cormorants responded to these disturbance events by dispersing to nearby beaches and tidal flats or by rafting together, usually in Baker Bay. The cormorants dispersed for good from the eastern portion of the colony on 5 June and no sustained colony attendance was recorded in this portion of the colony for the remainder of the 2017 breeding season.

Table 2. Bald Eagle disturbance rates in 2017.

Date	*Max Count of Bald Eagles*	*Disturbance Events*	*Hours of Observation*	*Disturbance Rate (per hr)*
28 April	6	1	2.0	0.50
30 April	6	2	2.0	1.00
10 May	20	17	6.0	2.83
17 May	18	15	4.3	3.49
22 May	17	11	6.0	1.83
26 May	12	5	2.0	2.50
30 May	12	9	2.3	3.91
5 June	15	15	6.4	2.33
13 June	12	5	4.0	1.25
19 June	15	5	3.0	1.67
26 June	12	1	2.8	0.36
21 July	6	1	4.0	0.25
26 July	0	0	2.0	0
2 August	0	0	2.0	0
9 August	1	0	2.0	0
19 August	0	0	2.5	0
25 August	0	0	4.0	0
1 September	0	0	2.0	0
5 September	0	0	1.5	0
13 September	0	0	4.0	0
20 September	0	0	1.0	0
3 October	0	0	2.0	0
13 October	0	0	3.3	0

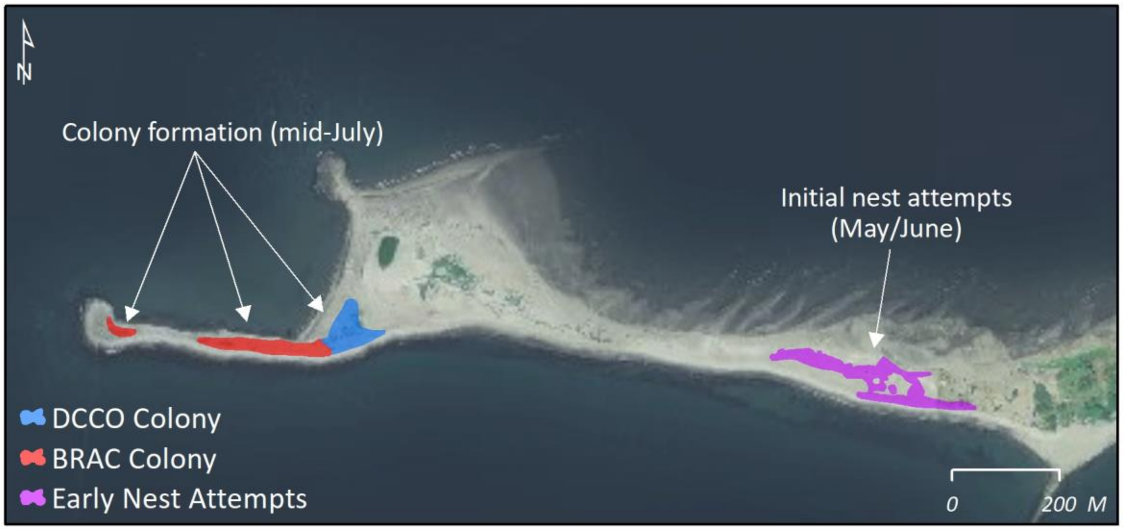

Figure 7. Cormorant nesting habitat use on East Sand Island in 2017. Early attempts to establish nests were focused in the eastern portion of the historical colony area, shown in purple. The double-crested and Brandt's cormorants did eventually establish colonies in mid-July, shown in blue and red, respectively.

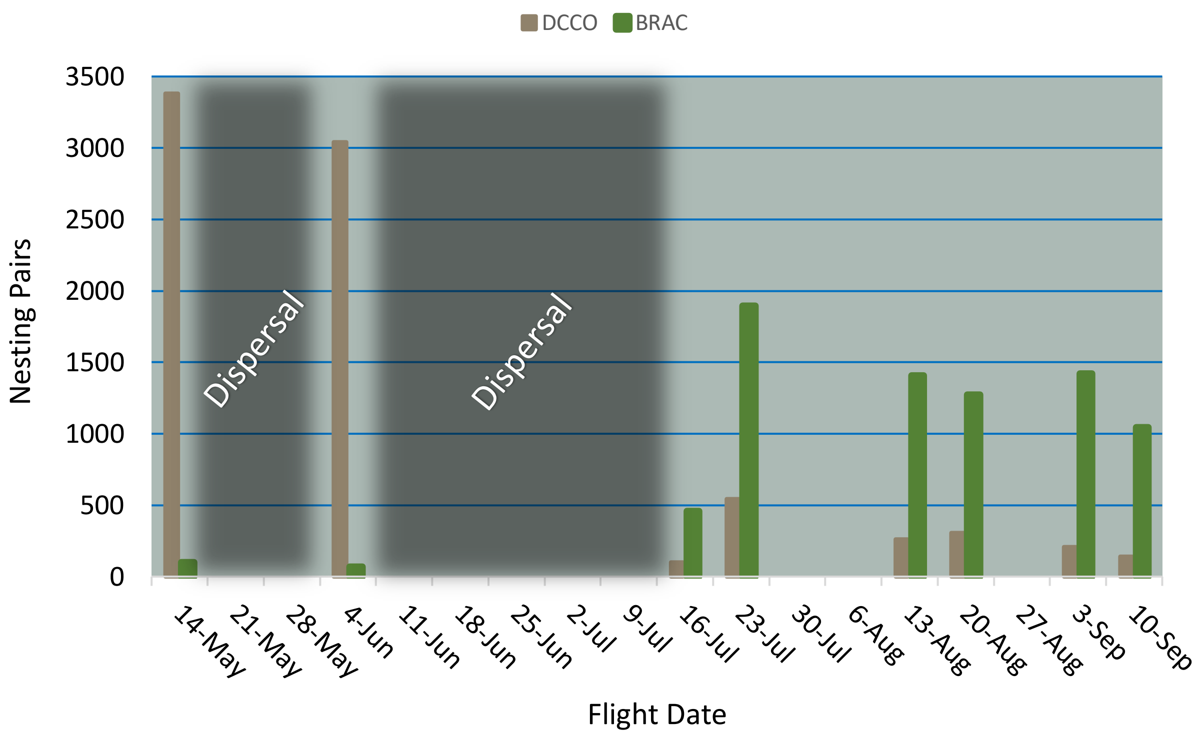

Figure 8. Colony counts derived from aerial photography during the cormorant breeding season on ESI in 2017.

Following dispersal from the eastern portion of the colony in early June (see *Figure 8* above), the cormorants continued to loaf on the north beach and tidal flats for over a month before finally establishing colonies on the west jetty and the adjacent upland area east of the jetty (*Figure 7*). Although DCCOs arrived on ESI in 2017 (17 April) soon after the historical range of arrivals seen prior to management (27 March – 11 April), colony formation in 2017 occurred nearly three months later (see *Figure 3* above). Following the late initiation in 2017, observations of the first DCCO egg (13 June), first DCCO chick (27 August), and first DCCO fledgling (3 November) all occurred 2-3 months after observations of these nest chronology events observed prior to management (BRNW 2015, see *Figure 3* above).

Attendance and colony size

DCCOs and BRACs established colonies on ESI in mid-July of 2017, approximately three months later than was observed in 1997 – 2016 (BRNW 2015, DSA 2015, AQEA 2017). The DCCO colony was located on an upland area adjacent to the west jetty, while the BRAC colony was established on the west jetty (see *Figure 7* above). The peak nest count for the DCCO colony was derived from the imagery acquired on the 26 July aerial mapping survey, with 544 nesting pairs (95% CI = 512 – 576 breeding pairs), approximately 94% fewer than the peak colony count from 2016. Over the past 21 years, the DCCO colony on ESI grew to a peak size of nearly 15,000 breeding pairs in 2013, and has been trending downward from 2014 to 2016, with a precipitous drop in 2017 (*Figure 9*).

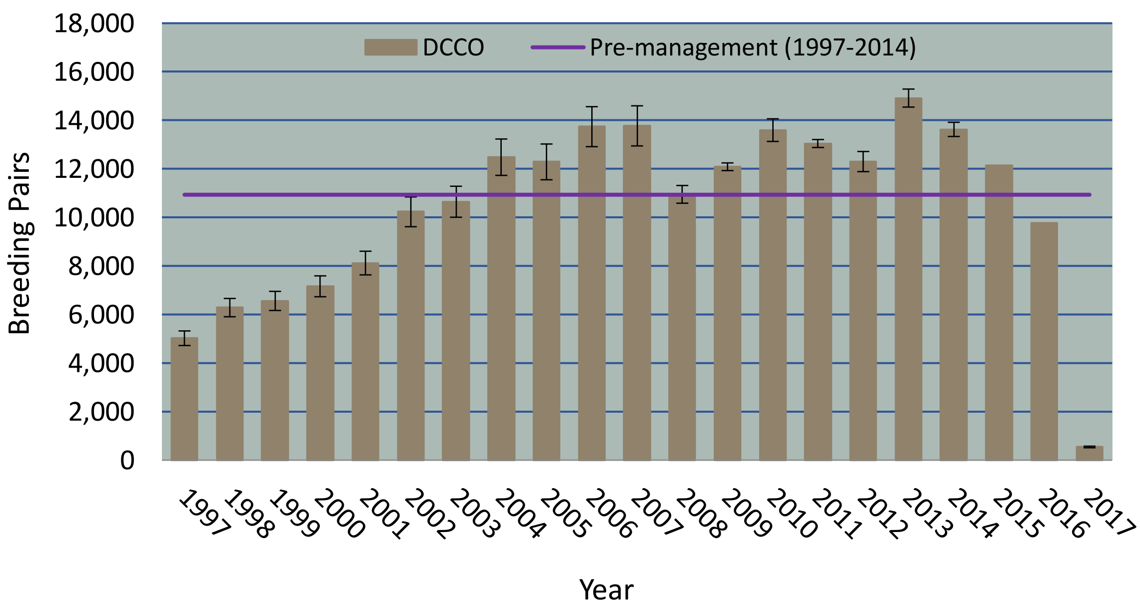

Figure 9. Size of the double-crested cormorant breeding colony (number of breeding pairs) on East Sand Island during the 1997-2017 breeding seasons (BRNW 2015, DSA 2015, AQEA 2017). Errors bars represent 95% confidence intervals 1997-2014 & 2017. The purple line represents the average colony size prior to management activities (1997-2014).

The peak nest count for the BRAC colony on ESI in 2017 was also derived from the imagery acquired on the 26 July aerial mapping survey, with 1,893 breeding pairs. The size of the BRAC colony in 2017 is generally in line with the size of the BRAC colonies observed on ESI in recent years (BRNW 2015, DSA 2015, AQEA 2017; *Figure 10*). BRACs first nested on ESI in this mixed-species colony in 2006, and numbers increased each year through 2012, when 1,680 breeding pairs were counted, with no trend in colony size observed in the years following (*Figure 10*).

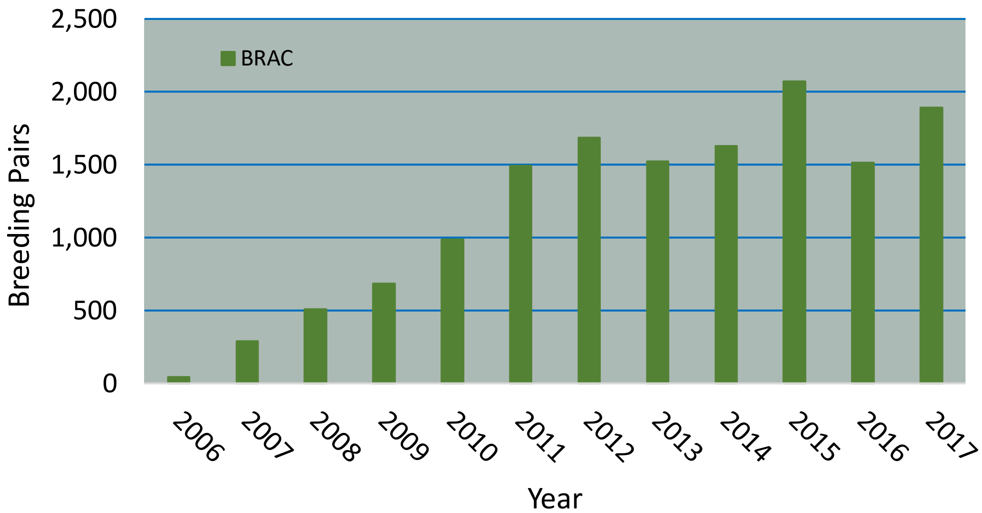

Figure 10. Size of the Brandt's cormorant breeding colony (number of breeding pairs) on East Sand Island during the 2006-2017 breeding seasons (BRNW 2015, DSA 2015, AQEA 2017).

Nest area and density

In 2017, DCCO colony area was 1,033 m² (0.26 acres), and nest density was 0.5 nests/m² (2,042 nests/acre), approximately 50% lower than nest densities observed on ESI prior to management (*Table 3*).

Table 3. Double-crested cormorant nest density on East Sand Island. Data for 2017 is for DCCO only; data for 2008, 2010-2014 (pre-management) is for DCCO and BRAC combined (BRNW unpublished data).

	2008	2010	2011	2012	2013	2014	2017
Nests	11,313	13,388	13,437	14,024	16,207	15,097	540
Nests in colony area	11,305	13,364	13,407	14,003	16,202	15,082	521
Colony area (m2)	11,706	13,277	13,589	13,332	13,233	13,617	1,033
Colony area (acre)	2.89	3.28	3.36	3.29	3.27	3.36	0.26
Nest density (# nest/m)	1.0	1.0	1.0	1.1	1.2	1.1	0.5
Nest density (# nest/ac)	3,908	4,073	3,993	4,251	4,955	4,482	2,042

Nesting success

Productivity data were not acquired as part of this study; however, our qualitative observations indicate that DCCO and BRAC breeding success was likely low. The observation plots established in the eastern portion of the cormorant colony were not used for nesting by cormorants in 2017, eliminating our ability to estimate breeding success. The first fledglings occurred following our final monitoring survey on 13 October. Our researchers were on-island for related work on 3 November and observed an unusually large number of dead DCCO and BRAC fledglings, as well as approximately 50 BRAC fledglings and 1 DCCO fledgling that were still alive, but appeared to be in poor condition. The absence of adults on the island may have indicated that the fledglings that remained on-colony in early November had been abandoned by their parents, perhaps due to poor foraging conditions in the estuary (see below). Nevertheless, cormorants were successful in fledging some chicks from ESI in 2017, but due to late fledging of chicks a low survival rate is expected (Leger and McNeil 1987).

CONCLUSIONS

There were likely several inter-related factors adversely impacting DCCO colony initiation and productivity at ESI in 2017, including: (1) bald eagle disturbance/predation, especially during early nest initiation in late April through early June; (2) high river discharge that affected the availability and composition of forage fish in the estuary; and (3) potential carry-over effects from the 2016 breeding season.

Early attempts to initiate nesting on the eastern end of the colony likely failed at least in part due to pervasive bald eagle disturbance. Bald eagles would flush the colony by flying low over the colony and/or landing on the colony. Once the colony flushed, eagles would move through the colony on foot inspecting nests looking for eggs to eat. In addition to nest predation, eagles were also observed actively predating on adult cormorants. Research suggests that rates of disturbance like those observed on ESI in 2017 can cause colony-wide nesting failure and abandonment (Carter et al. 1995, Hatch and Weseloh 1999, Windels 2012, Adkins et al. 2014).

High sustained river discharge during the spring resulting from heavy precipitation/runoff and increased spill at mainstem Columbia River dams, can cause a decrease in marine forage fish availability in the Columbia River estuary, and a decrease in estuary residence times for juvenile salmonids (Weitkamp et. al. 2012). *Figure 11* shows the average monthly discharge rate for the Columbia River in 2017 relative to the rates during the same months from 2007 – 2016. The discharge rates in 2017 were significantly higher than the average rates for the same months in 2007 – 2016. Research has shown that potential low prey availability can be a limiting factor in reproductive success in seabirds (Satterthwaite et al. 2012). Lack of prey resources can also lead to an increase in pressure from predators (i.e., bald eagles; Collar et al. 2017).

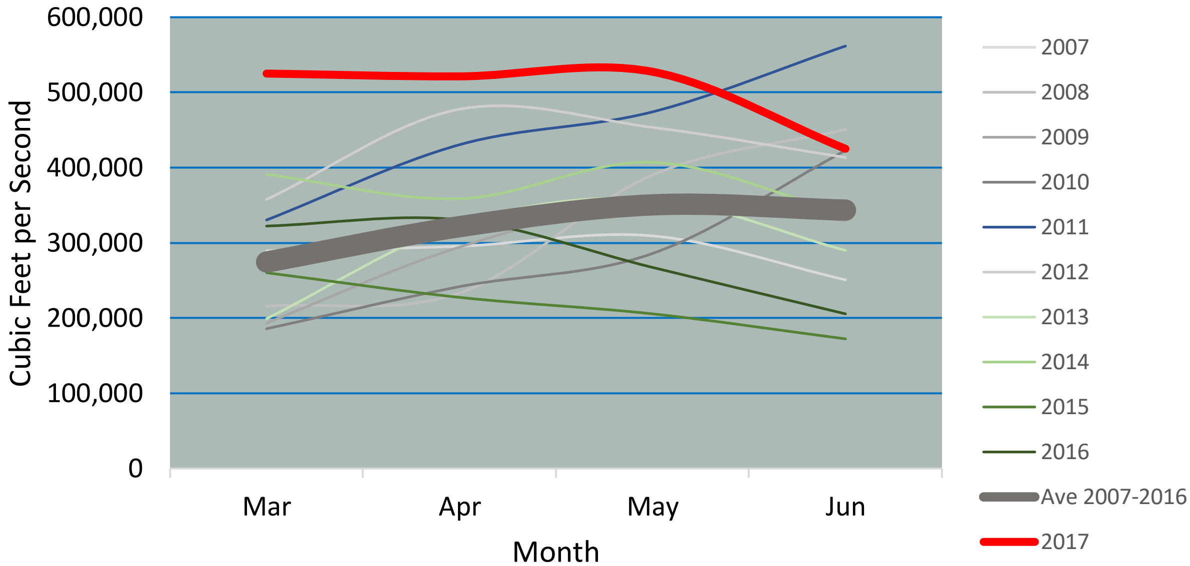

Figure 11. Columbia River discharge recorded at USGS Site #14246900 (Port Westward). Discharge data was downloaded from the U.S. Geological survey website (http:// waterdata.usgs.gov).

In 2016 the DCCO colony on ESI failed in mid-May and did not re-establish until late-June. The first fledged chick in 2016 was observed in late September (AQEA 2017), several months later than typical (see *Figure 3* above). It is known that late breeding and late departure from breeding colonies can introduce carry-over effects to seabird populations (Fayette et. al. 2016) in the following breeding season. Carry-over effects include delayed arrival to breeding sites and reduced fitness, both of which can impact nesting success and productivity. The combination of potential carry-over effects from the abnormally late nesting period in 2016 may have negatively affected cormorant nesting success and productivity in 2017. Given that the 2016 and 2017 breeding seasons have some similarities (i.e., repeated nesting attempts, late nesting, and late departure from breeding site) there is potential to see carry-over effects in the 2018 breeding season on ESI.

RECOMMENDATIONS

We offer the following recommendations for monitoring during future DCCO breeding seasons:

- Contract award at least 6 weeks prior to DCCO arrival at ESI (typically late March or early April) is essential to ensure adequate time for project planning and infrastructure maintenance
- Deploy several additional autonomous camera systems on the colony to provide remote monitoring of the entire colony (including views of the west jetty, beaches, and tidal flats)
- Conduct aerial mapping flights with a combination of traditional manned, fixed-wing mapping systems and small unmanned aerial systems

- Combine all the DCCO monitoring in the Columbia River Estuary (including at ESI) to ensure comprehensive estuary-wide monitoring
- Include a regional monitoring component to assess DCCO use of historical colonies (i.e. the coast of Washington and Puget Sound)

LITERATURE CITED

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. The Journal of Wildlife Management DOI:10.1002/jwmg.737.

AQEA (Anchor QEA). 2017. Double-crested Cormorant (DCCO) Monitoring Report: Avian Predation Program Monitoring. 2016 Draft Technical Report submitted to the U.S. Army Corps of Engineers in partial fulfillment of IDIQ contract # W912EF-14-D-0004.

BRNW (Bird Research Northwest). 2005. Caspian Tern Research on the Lower Columbia River: 2004 Final Report. Submitted to the Bonneville Power Administration and the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2006. Caspian Tern Research on the Lower Columbia River, 2005 Final Report. Submitted to the Bonneville Power Administration and the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2007. Caspian Tern Research on the Lower Columbia River, 2006 Final Report. Submitted to the Bonneville Power Administration and the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2008. Caspian Tern Research on the Lower Columbia River, 2007 Final Report. Submitted to the Bonneville Power Administration and the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2009. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2008 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2010. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2009 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2011. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2010 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2012. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2011 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2013. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2012 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2013b. Implementation and Effects of Double-crested Cormorant Dissuasion Research at East Sand Island, Columbia River Estuary: 2008-2012. Technical memorandum submitted to the U.S. Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2014. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2013 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, the U.S Army Corps of Engineers – Portland District, and the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2015. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2014 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, the U.S Army Corps of Engineers – Portland District, and the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2016. Avian Predation on Juvenile Salmonids: Evaluation of the Caspian Tern Management Plan in the Columbia River Estuary, 2015 Final Report. Submitted to the Bonneville Power Administration. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2017. Avian Predation on Juvenile Salmonids: Evaluation of the Caspian Tern Management Plan in the Columbia River Estuary, 2016 Final Report. Submitted to the Bonneville Power Administration. Available on-line at www.birdresearchnw.org.

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.

Collar, S., D.D. Roby, and D.E. Lyons. 2017. Top-down and bottom-up interactions influence fledging success at North America's largest colony of Caspian terns (*Hydroprogne caspia*) Estuaries and Coasts DOI:10.1007/s12237-017-0238-x.

DSA (David Smith and Associates, Inc.). 2015. Enumeration and monitoring of double-crested cormorants in the Lower Columbia River estuary. 2015 Final Technical Report submitted to the U.S. Army Corps of Engineers in partial fulfillment of Contract No. W9127N-13-D-0005, Task Order No. 001.

Fayet, A.L., R. Freeman, A. Shoji, H. Kirk, O. Padget, and C. Perrins. 2016. Carry-over effects on the annual cycle of a migratory seabird: an experimental study. Dryad Digital Repository http://dx.doi.org/10.5061/dryad.32kc7.

Hatch, J.J., and D.V. Weseloh. 1999. Double-crested cormorant (*Phalacrocorax auritus*). Birds of North America. Available online at http://bna.birds.cornell.edu/bna/species/441.

Leger, C., and R. McNeil. 1987. Nest-site quality and reproductive success of early- and late-nesting double-crested cormorants. The Wilson Bulletin 99: 262-267.

Lyons, D.E. 2010. Bioenergetics-based predator-prey relationships between piscivorous birds and juvenile salmonids in the Columbia River estuary. Unpublished Ph.D. Dissertation, Oregon State University, Corvallis, Oregon. Available on-line at www.birdresearchnw.org.

NOAA (National Oceanic and Atmospheric Administration). 2017. Updated status of federally listed ESUs of West Coast salmon and steelhead. Available at on-line at http://www.nwr.noaa.gov/Publications/Biological-Status-Reviews/Salmon.cfm.

Satterthwaite, W.H., A.S. Kitaysky, and M. Mangel. 2012. Linking climate variability, productivity and stress to demography in a long-lived seabird. Marine Ecology Progress Series 454:221–235.

Turecek, A., B. Cramer, K. Collis, and P. Losch. 2017. Evaluation of UAS for Colonial Waterbird Surveys. Technical Memorandum submitted to the U.S. Army Corps of Engineers – Walla Walla District in partial fulfillment of IDIQ contract # W912EF-14-D-0004, Task Order No. 0007.

USACE (U.S. Army Corps of Engineers). 2015. Double-crested Cormorant Management Plan to Reduce Predation on Juvenile Salmonids in the Columbia River Estuary: Final Environmental Impact Statement, February 2015. U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Weitkamp, L.A., P.J. Bentley, and M.N.C. Litz. 2012. Seasonal and inter-annual variation in juvenile salmonids and associated fish assemblage in open waters of the lower Columbia River estuary. Fisheries Bulletin 110:426–450.

Windels, S. 2012. Bald Eagles as Agents of Cormorant Control in Northern Minnesota. Conference Paper: American Fisheries Society 142nd Annual Meeting, Minneapolis – St. Paul, MN, 19 – 23 August 2012.