Final Annual Report: Double-crested Cormorant Monitoring on East Sand Island and in the Columbia River Estuary, 2018

IDIQ CONTRACT NO. W912EF-14-D-0004 (ORDER NO. W9127N18F0063)

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

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Title: Double-crested Cormorant Monitoring on East Sand Island and in the Columbia River Estuary, 2018

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Project Duration: March 15, 2018 to February 15, 2019

Final Submitted: May 20, 2019

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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 management plan entitled, "Double-crested Cormorant Management Plan to Reduce Predation on Juvenile Salmonids in the Columbia River Estuary". In 2018, the Corps reduced the habitat available to double-crested cormorants (DCCO; *Phalacrocorax auritus*) for breeding to approximately 1.7 acres, which would accommodate approximately 7,322 nests at the historical nest density of 1.1 nest/m^2.

The purpose of this project was to monitor the East Sand Island (ESI) DCCO colony during the 2018 breeding season to provide the Corps with in-season information on the colony that would inform the adaptive management of the plan. The primary objectives of this study were to (1) conduct surveys to monitor and enumerate DCCO and Brandt's cormorants (BRAC; *P. penicillatus*) on ESI without disrupting nesting birds within the designated colony area and (2) conduct surveys of DCCO, BRAC, and pelagic cormorants (PECO; *P. pelagicus*) on the Astoria-Megler Bridge and DCCOs on the Longview Bridge located in the lower Columbia River and estuary.

The ESI cormorant colony was visited at least 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. Aerial photography was orthorectified and analyzed to enumerate cormorant individuals and active nests. Image-derived counts were classified by species (i.e., DCCO or BRAC) based on field observations made during ground-based monitoring, and interpretation of oblique imagery collected during aerial photo surveys.

Pre-breeding season colony preparations on the ESI cormorant colony was completed on 9 April. Monitoring occurred from 25 April – 26 September, with 20 aerial survey flights and 31 colony monitoring surveys conducted. DCCO began loafing on the north beaches of ESI in large numbers on 15 April. They initiated sporadic attempts at occupying the colony area during early to mid-May, and eventually began roosting on the colony overnight and consistently attending the colony during the day on 15 May. The first aerial survey of the colony was conducted on 22 May.

Frequent predator pressure from bald eagles (*Haliaeetus leucocephalus*) limited cormorant colony formation throughout May and June. By 4 July the bald eagle presence on ESI subsided and the DCCO colony subsequently stabilized and grew to its peak colony size of 3,672 active nests (95% CI = 3,662 – 3,682), or breeding pairs, on 25 July. The DCCO colony area was approximately 0.8 acres and occupied 65% of the available breeding habitat within the designated colony area. Efforts by United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) personnel to dissuade DCCOs from nesting outside the designated colony area on ESI in 2018 were successful. In 2018, nest density of ESI DCCO was 1.2 active nests per m^2, slightly higher than the pre-management average for nesting density (1.1 active nests per m^2). Nesting success for the DCCO on ESI was estimated to be 1.8 young raised per active nest (95% CI = 0.98 – 2.66) in 2018, identical to the average nesting success for DCCO on ESI prior to management.

The DCCO colony on the Astoria-Megler Bridge peaked at 1,737 breeding pairs on 7 June, with nesting success estimated to be 2.7 young raised per active nest (95% CI = 2.55 – 2.93). The size of the DCCO colony on the Astoria-Megler Bridge has been increasing in every year since monitoring began in 2004 (which the exception of 2010), with the largest numerical increase in colony size occurring in 2018, when the colony more than doubled as compared to the size of the colony in 2017 (834 nests). Peak DCCO colony size at the Longview Bridge was observed on 4 May, with 201 active nests. This represents a ca. 25% increase in colony size on the Longview Bridge as compared to 2017 (147 active nests).

INTRODUCTION

The number of double-crested cormorants (DCCO; *Phalacrocorax auritus*) nesting on East Sand Island (ESI) 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 (number of breeding pairs) of the DCCO colony 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/active nest per year during 1997-2012; BRNW 2013), perhaps contributing to increases in colony size and predation impacts prior to management.

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" (Management Plan) was released in 2015 and calls for the reduction of the size of the ESI DCCO colony. Colony reductions during Phase 1 of management were to be achieved using lethal strategies (i.e. culling and egg oiling in 2015-2018) and by habitat modifications in the Phase 2 of management (beginning in 2019; 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 2018 breeding season. Specifically, the objectives of this study were to (1) conduct surveys to monitor and enumerate DCCO and Brandt's cormorants (BRAC; *P. penicillatus*) on ESI without disrupting nesting birds within the designated colony area and (2) conduct surveys of DCCO, BRAC, and pelagic cormorants (PECO; *P. pelagicus*) on the Astoria-Megler Bridge and DCCOs on the Longview Bridge located in the lower Columbia River and estuary.

Study Area

East Sand Island is located in the Columbia River estuary approximately 7 river kilometers from the Pacific Ocean (*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*). Since 1997, when DCCO monitoring on ESI began, DCCO have nested throughout the western half of the island, primarily on bare substrate, rip-rap revetment, and amongst large woody debris deposited on the island during winter storms. In 2018 a privacy fence was created on the far western end of the island and cormorants were dissuaded from nesting east of the fence (work carried out by a different Corps contractor), leaving approximately 1.7 acres of habitat available for nesting on the west side of the fence (*Figure 1*).

Figure 1. Aerial view of East Sand Island. DCCO nesting was restricted to the western end of the island, west of a privacy fence (shown in red) that was erected prior to the 2018 breeding season.

METHODS & ANALYSIS

SITE PREPARATION

The Corps constructed a privacy fence on the west end of ESI and implemented an active hazing program to prevent cormorants from building nests east of the fence. Following construction of the fence, an observation blind was relocated from the historical colony area to the southeast end of the privacy fence to facilitate monitoring of the DCCO and BRAC colonies (*Figure 2*).

Figure 2. Oblique image looking west toward the tip of the west jetty on East Sand Island. The privacy fence and observation blind can be seen in the image foreground. Cormorants seen east of the fence in the image were prospecting between active dissuasion missions.

DOUBLE-CRESTED CORMORANT MONITORING ON EAST SAND ISLAND

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 birds within the designated colony area. 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 several locations throughout the colony.

Ground-based surveys

Ground-based monitoring of the ESI cormorant colony area was conducted via on-island and boat-based surveys by a two-person research team. On-island monitoring was conducted from an observation blind that was relocated to the eastern extent of the designated cormorant nesting area prior to the breeding season (*see Figure 2, above*). Monitors accessed the observation blind via a low path along the rip-rap revetment that minimized their visibility by nesting and loafing cormorants in the designated colony area. 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 blind. Ground- and boat-based surveys were conducted 31 times between 24 April to 26 September (*Table 1*).

Table 1. Ground-based surveys and aerial mapping flights conducted on the ESI DCCO colony in 2018.

Week	Ground Survey		Aerial Survey	
	On-island	**Boat-based**	**Fixed-wing**	**UAS**
25-Apr	-	√	-	-
30-Apr	-	√	-	-
2-May	-	√	-	-
7-May	√	-	-	-
11-May	√	-	-	-
14-May	√	-	-	-
18-May	√	-	-	-
22-May	√	-	√	-
30-May	-	-	√	-
1-Jun	√	-	-	√
6-Jun	√	-	√	√
9-Jun	√	-	-	-
12-Jun	-	√	-	-
13-Jun	√	-	-	√
19-Jun	√	-	-	√
22-Jun	√	-	-	-
25-Jun	√	-	-	√
27-Jun	√	-	-	-
3-Jul	√	-	-	√
10-Jul	√	-	-	√
17-Jul	√	-	-	√
20-Jul	√	-	-	-
25-Jul	√	-	-	√
27-Jul	√	-	-	√
2-Aug	√	-	-	√
7-Aug	√	-	-	√
9-Aug	√	-	-	-
15-Aug	√	-	-	√
22-Aug	√	-	-	√
29-Aug	√	-	-	√
12-Sep	√	-	-	√
26-Sep	√	-	-	√
Totals	**27**	**4**	**3**	**17**

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, egg 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) 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 be used to monitor nesting chronology (i.e., pre-egg laying, egg-laying, chick-rearing, and fledging periods) throughout the study; however, a storm on 7 April destroyed all three plots. Following loss of the observation plots the colony monitors selected a network of "focal nests" that were used for tracking nest chronology for the remainder of the season.

Aerial mapping surveys

Aerial mapping flights were flown 20 times during the 2018 DCCO breeding season (*see Table 1, above*). During early nest initiation surveys were flown by a manned airplane with a large-format mapping camera. Beginning on 1 June, aerial surveys were flown with a small unmanned aircraft system (UAS). For both methods of survey, the imagery acquired was orthorectified and mosaicked at 1.1 - 2.0 cm ground sample distance (GSD). 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 colony (i.e., without disturbances to the colony). Orthomosaics were imported into a GIS platform and processed to digitize individual cormorants and attended nests on the colony.

Autonomous camera monitoring

Five autonomous cameras were deployed on and around the colony area to provide real-time imagery of the cormorant colony throughout the breeding season. The cameras recorded still images on a 30-minute 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 general workflow used to enumerate the DCCO and BRAC colonies on ESI is shown below in *Figure 3*.

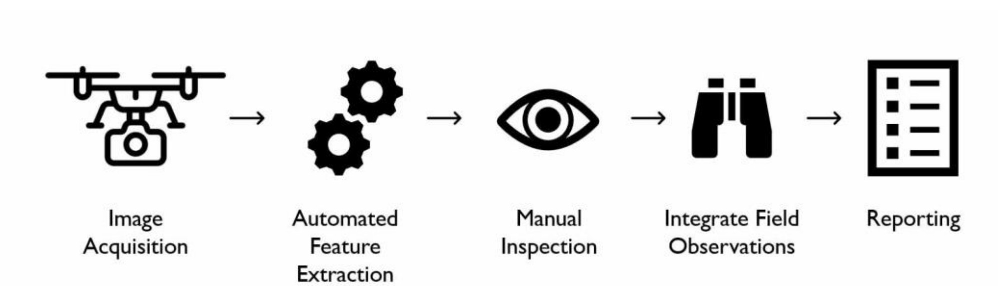

Figure 3. Generalized workflow used to enumerate the cormorant colony on ESI during the 2018 breeding season.

Approximately each week, aerial imagery was acquired and then orthorectified into a single, spatially accurate image mosaic for the colony. The image mosaic was then run through an automated feature extraction process to digitize individual birds. This output was manually inspected and integrated with our biologists' field observations to generate counts and delineations of the DCCO and BRAC colonies. Count metrics included the number of adult cormorants and the number of attended cormorant nests, by species (i.e., DCCO and BRAC). *Figure 4* shows an example of cormorants counts derived from an aerial image.

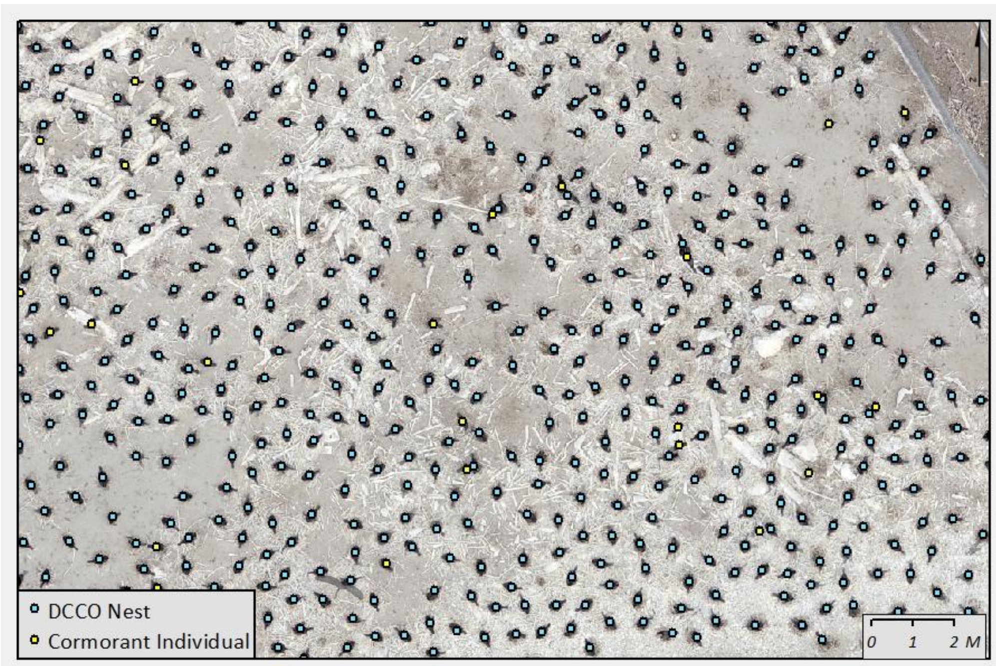

Figure 4. Counts of DCCO on nests (blue dots) and DCCO individuals not associated with a nest (yellow dots) derived from aerial imagery and ground-based surveys of the East Sand Island colony in 2018.

Aerial imagery was orthorectified and mosaiced to a single image covering the entire cormorant colony area, with a GSD of 1.1 – 2.0 cm based on the image acquisition method (i.e., UAS or manned plane), 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 nesting and loafing cormorants. An automated image classification process was applied to the imagery (excluding all masked regions from the classification process), resulting in 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 digitized (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, as well as manual interpretation of oblique imagery.

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. If multiple birds were associated with a single nest; one bird was classified as "nesting" and the other(s) were classified as "individual".

Finally, in addition to the 2-D analysis described above, for the peak nest count stereo models were built to view the imagery in 3-D to aid in further refining species delineations. In a relatively small number of cases this was helpful for differentiating nest composition to aid in assigning species (i.e., DCCO or BRAC).

Colony size (i.e. number of active nests or number of breeding pairs) 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 active nest count from the season was then re-counted, including the final 3-D audit, by two additional analysts to acquire three DCCO active nest counts for the peak nest count. The three peak active nest counts were used to estimate the colony size and the 95% Confidence Interval (CI) for the estimate. This method for estimating colony size in 2018 is comparable to the methods used to estimate the DCCO colony size in 1997 – 2014 and 2017 (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.

DOUBLE-CRESTED CORMORANT MONITORING ON BRIDGES IN THE COLUMBIA RIVER ESTUARY

A total of 15 nest surveys and 6 roost surveys were conducted at the Astoria-Megler Bridge. Nest surveys were conducted from a boat to enumerate DCCO, PECO, and BRAC active nests and individuals. The first of the approximately weekly nest counts was conducted on 2 May. Nesting success for the DCCO colony on Astoria-Megler Bridge was estimated based on chick counts from 5 nests located on each of 10 discrete bridge sections, for a total of 50 nests. Roost surveys were conducted from the Astoria waterfront approximately every two weeks, at the Corps' discretion. As part of the roost surveys the direction of flight to or from the bridge was recorded to try to assess where birds foraged (i.e. downriver or upriver). It was determined that these data were not a reliable indicator of where birds foraged.

Six boat-based DCCO nest surveys were conducted at Lewis and Clark Bridge in Longview, WA. The first survey occurred on 4 May, and subsequent counts were conducted approximately bi-weekly thereafter.

RESULTS & DISCUSSION

SITE PREPARATION AND MAINTENANCE

The Corps and its contractors constructed a privacy fence on the west end of ESI and implemented an active hazing program to prevent cormorants from building nests east of the fence. The habitat available for cormorant nesting was approximately 1.7 acres. Following construction of the fence, an observation blind was relocated from the historical colony area to the southeast end of the privacy fence to facilitate monitoring of the designated colony area for DCCOs and BRACs (*see Figure 2, above*).

DOUBLE-CRESTED CORMORANT MONITORING ON EAST SAND ISLAND

Predator activity

Frequent predator pressure from bald eagles (BAEA; *Haliaeetus leucocephalus*) limited cormorant colony formation throughout May, June, and early July. From 11 May to 3 July researchers observed an average disturbance rate of 2 disturbances per hour during observation periods of at least an hour or more. Results from a previous study suggests that disturbance rates of more than 15 minutes per day or more than 2 events per day may delay or prevent cormorant nesting (BRNW 2013b).

Cormorants responded to disturbance events by dispersing to nearby beaches and elsewhere off colony during complete flushes, and/or retreating across the colony area in partial flushes thereby forming a halo around the BAEA. After egg laying had commenced, BAEA and gulls would walk through the colony area and depredate eggs found in unattended nests during flushes. BAEA presence in the project area on ESI dropped off significantly after 3 July, and only one BAEA disturbance (10 July) was observed during the remainder of the breeding season. No BAEA were observed on ESI after 17 July.

Nesting chronology

The DCCO nesting chronology was roughly one month delayed compared to the chronology observed prior to implementation of the Management Plan (2004-2014; *Figure 6*). Cormorants began loafing on the north beaches of ESI in large numbers on 15 April and were first documented occupying the designated colony area (*see Figure 1, above*) on 9 May. Cormorants began roosting overnight on the colony area on 15 May.

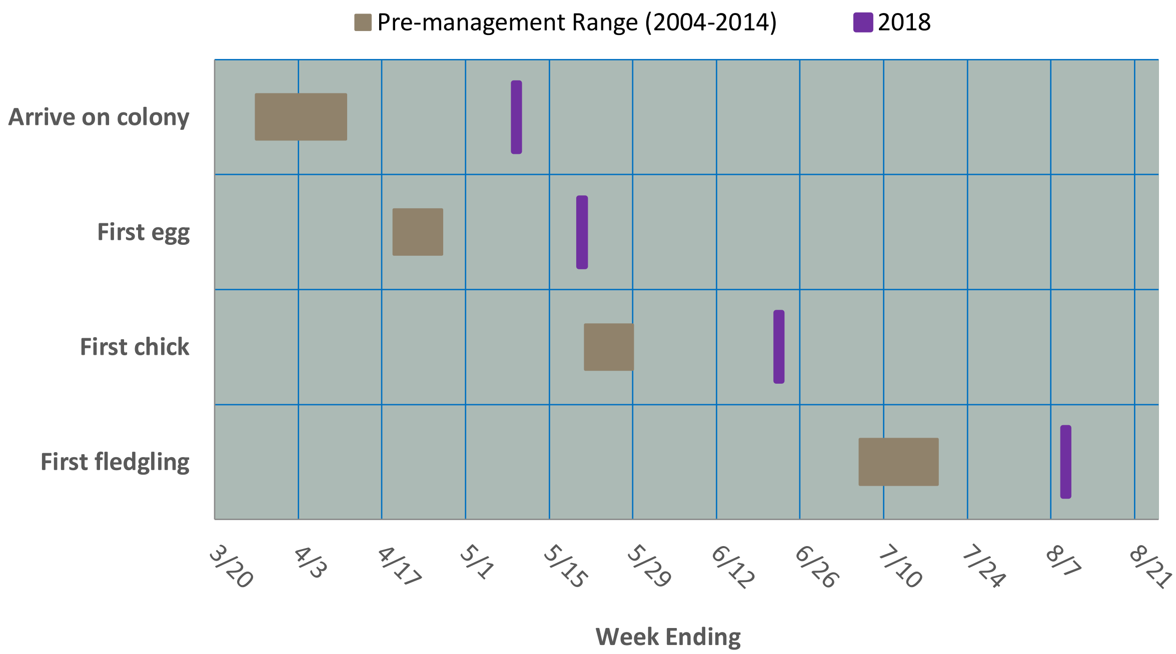

Figure 6. DCCO nesting chronology on ESI in 2018 (purple lines) as compared to the range in nesting chronology (brown boxes) during 2003 – 2014 (pre-management period).

Weekly aerial mapping flights began on 22 May. Nest counts derived from the imagery acquired approximately each week (duration between flights ranged from 2 to 8 days) fluctuated significantly from flight to flight from May through early July. Spatial comparisons of each nest count indicated that relatively few nests persisted from one flight to the next, and colony monitors documented few stable nests with eggs during this time period.

The first DCCO egg was observed on 20 May, and despite frequent BAEA disturbances throughout May and June, the first DCCO chick was observed on 22 June, proving that at least a small number of nests were able to persist through the period of intense BAEA pressure. On 4 July the BAEA presence on ESI subsided and the DCCO colony subsequently stabilized and began growing each week until reaching the peak colony size on 25 July. The first DCCO fledgling was observed on 9 August.

The DCCO colony chronology was asynchronous in 2018 due at least in part to the BAEA pressure that persisted until 4 July. Using the date that chicks first became visible for an individual nest in the weekly orthomosaics, we can estimate the approximate date that eggs were laid in that nest. By applying this image interpretation method throughout the breeding season, we can map at the nest level the approximate date that eggs were laid and visualize where successful clutches were laid. *Figure 7* below shows nest-level estimates of when clutches that eventually produced chicks were laid for both the DCCO and BRAC colonies. In contrast to the DCCO colony, the BRAC colony chronology was relatively synchronous.

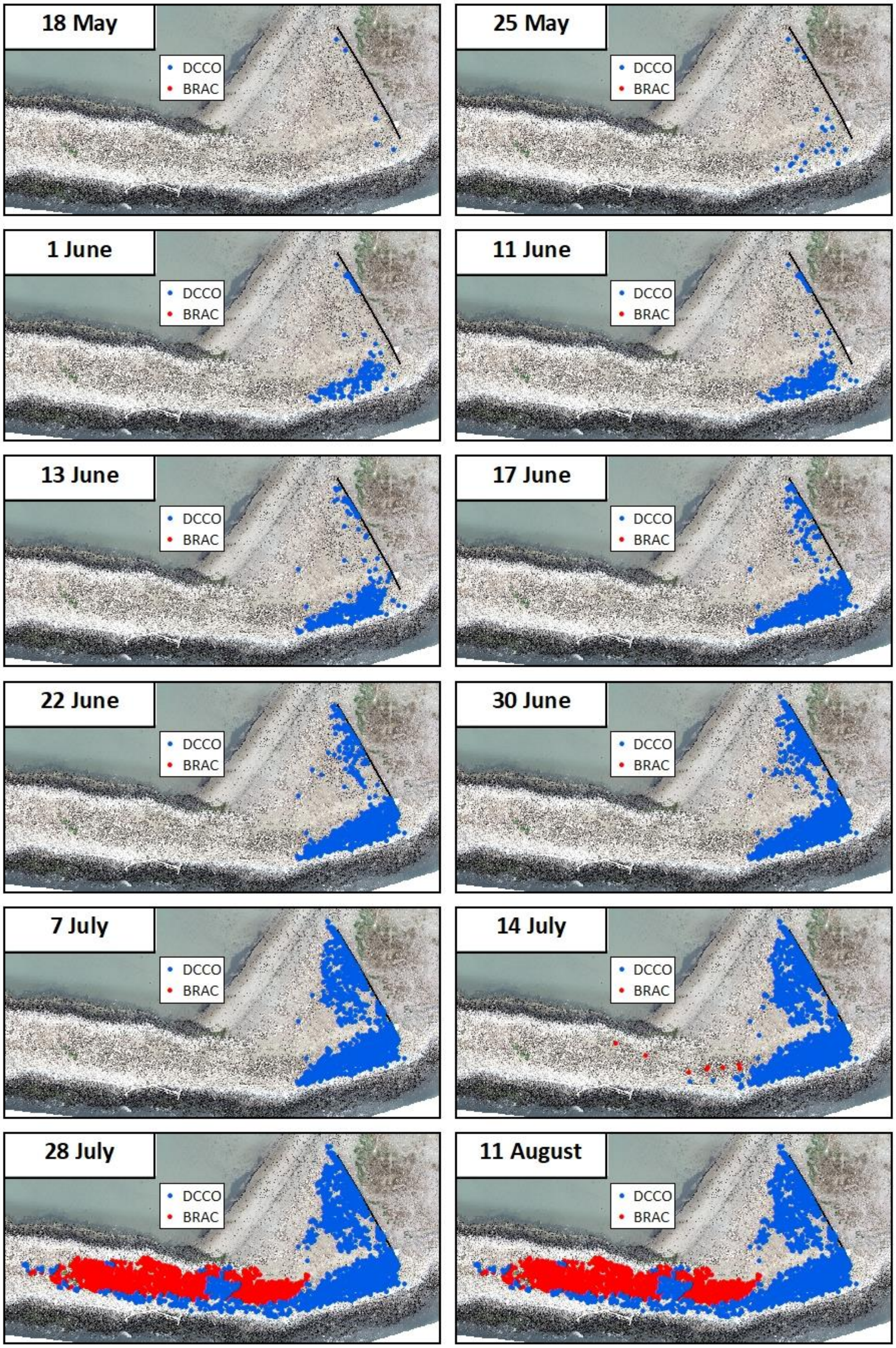

Figure 7. Estimated egg laying for DCCO and BRAC nests that produced chicks.

Attendance and colony size

Nest counts derived from aerial imagery throughout the 2018 breeding season are shown in *Figure 8*. Counts were acquired approximately weekly throughout the breeding season (duration between flights ranged from 2 to 8 days).

From the first nest count on 22 May through the 3 July count, the number of nests fluctuated significantly from week to week due to significant predator pressure. During this period of early colony establishment colony monitors observed that the vast majority of nests were still under construction (i.e. not completed) and did not contain eggs, and nest-level comparisons of the counts derived from orthomosaics indicated that most nests were not present in consecutive surveys. Nest-level egg laying as a function of time illustrated in *Figure 7*, above, demonstrates that a relatively small number of eggs survived from the early nest counts on 30 May and 1 June.

Bald eagle presence on ESI ended abruptly on 4 July. With the departure of the BAEA the cormorant colony stabilized and began to grow each week until reaching peak breeding on 25 July, with 3,672 active nests (i.e. nests with eggs; 95% CI = 3,662 – 3,682). *Figure 9* shows the annual peak DCCO colony size from 1997 to 2018. As in 2018, peak colony size estimates from 1997 to 2014 were based on the number of active nests estimated during the egg laying period, at late incubation (i.e. just prior to hatch).

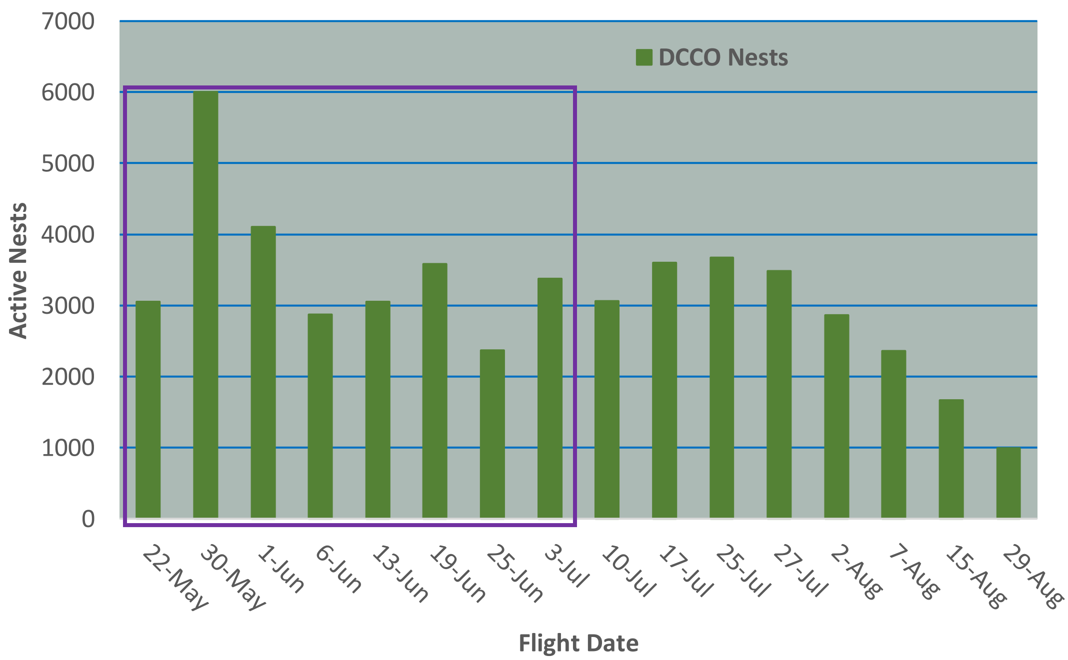

Figure 8. DCCO colony counts derived from aerial photography during the cormorant breeding season on ESI in 2018. Counts from 22 May to 3 July (within purple rectangle) occurred during a period of intense bald eagle pressure on the colony, with significant, repeated dispersals away from the colony by DCCOs each day. During this period very few nests were active from one survey to the next and even fewer had eggs. Peak colony size (i.e. nest with eggs late in the incubation period) occurred on 25 July.

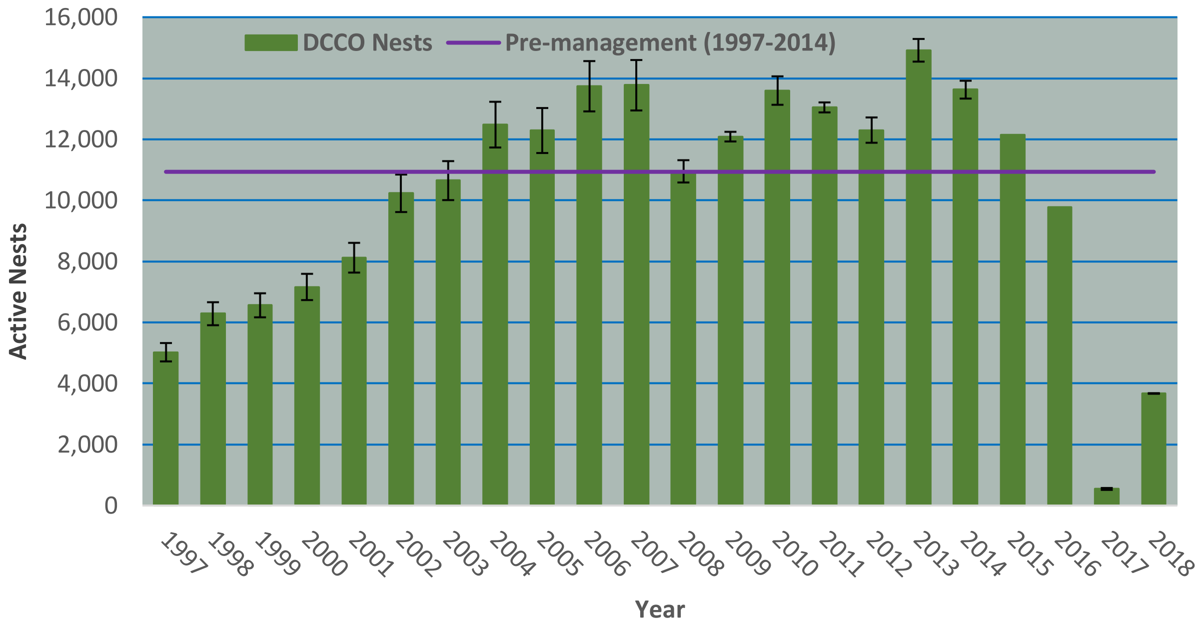

Figure 9. Size of the DCCO breeding colony (number of active nests) on East Sand Island during the 1997-2018 breeding seasons (BRNW 2015, DSA 2015, AQEA 2017, BRNW 2018). Errors bars represent 95% confidence intervals in 1997-2014 & 2017-2018. The purple line represents the average colony size prior to management activities (1997-2014).

The peak nest count for the BRAC colony on ESI in 2018 was derived from the imagery acquired on the 27 July aerial mapping survey, with 2,120 active nests or breeding pairs. The size of the BRAC colony in 2018 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 active nests were counted, with no trend in colony size observed in the years following (*Figure 10*).

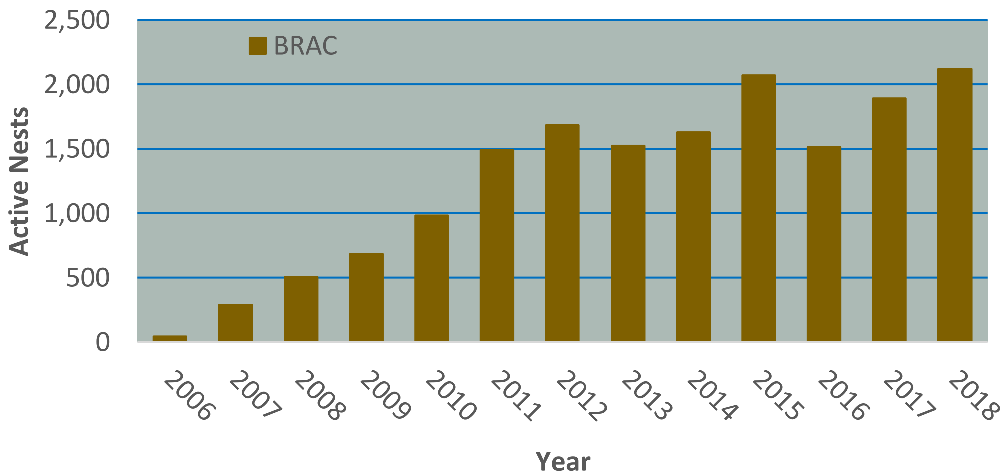

Figure 10. Size of the BRAC breeding colony (number of breeding pairs) on East Sand Island during the 2006-2018 breeding seasons (BRNW 2015, DSA 2015, AQEA 2017,BRNW 2018).

Nest area and density

During peak DCCO nesting on 25 July, the DCCO colony occupied approximately 0.8 acres of the approximately 1.7 acres made available for nesting, while BRAC nests occupied approximately 0.6 acres (*Figure 11*). Nest density during peak DCCO nesting (25 July) was 1.2 active nests/m² for all cormorants (DCCO and BRAC combined), slightly higher than the pre-management average for cormorant nest density of 1.1 active nests/m² (*Table 2*). It is not known why a portion of the available habitat was not used for nesting by DCCO, particularly the rip-rap revetment on the extreme western end of the island, but the presence of communally nesting BRACs in this area suggests that the habitat would have been suitable for DCCO nesting.

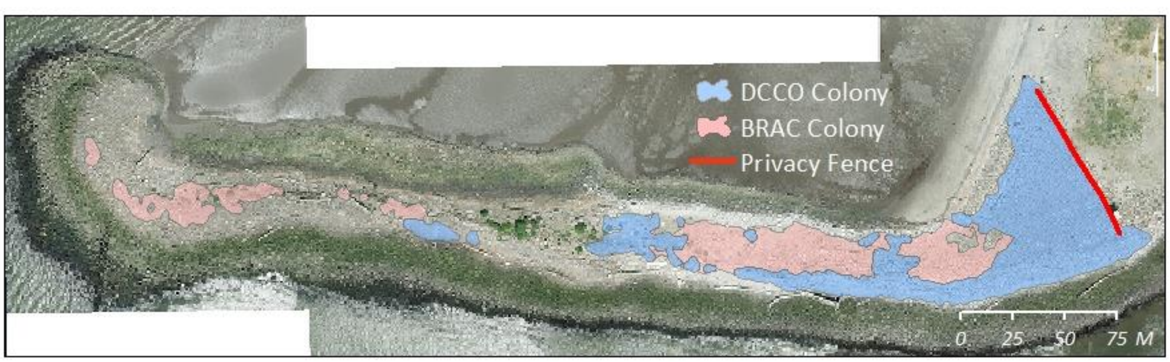

Figure 11. Cormorant (DCCO and BRAC) nesting habitat used on East Sand Island in 2018.

Table 2. Cormorant nest density on East Sand Island. Nest density is calculated for DCCO and BRAC combined (BRNW unpublished data).

	2008	2010	2011	2012	2013	2014	2018
Active nests	11,313	13,388	13,437	14,024	16,207	15,097	5,782
Active nests in colony area	11,305	13,364	13,407	14,003	16,202	15,082	5,767
Colony area (m2)	11,706	13,277	13,589	13,332	13,233	13,617	5,028
Colony area (acre)	2.89	3.28	3.36	3.29	3.27	3.36	1.24
Nest density (# nest/m)	1.0	1.0	1.0	1.1	1.2	1.1	1.2
Nest density (# nest/ac)	3,908	4,073	3,993	4,251	4,955	4,482	4,651

Nesting success

Nesting success (i.e., number of young raised per active nest or breeding pair) for the DCCO on ESI was estimated to be 1.8 young raised/active nest (95% CI = 0.98 – 2.66), which was identical to the average nesting success for the DCCO colony on ESI prior to management (1997 – 2013; BRNW 2013).

DOUBLE-CRESTED CORMORANT MONITORING ON BRIDGES IN THE COLUMBIA RIVER ESTUARY

The Astoria-Megler Bridge was surveyed 15 times during the 2018 DCCO breeding season. The peak DCCO colony size was observed on 7 June, with a total of 1,736 active nests or breeding pairs. *Figure 12* shows the weekly nest survey results at the Astoria-Megler Bridge for the 2018 breeding season. DCCO nesting success was estimated to be 2.7 young raised/active nest (95% CI = 2.55 – 2.93). The peak PECO nest count was recorded on 17 May, with 76 PECO nests. The peak BRAC count of 14 nests was observed on 7 June.

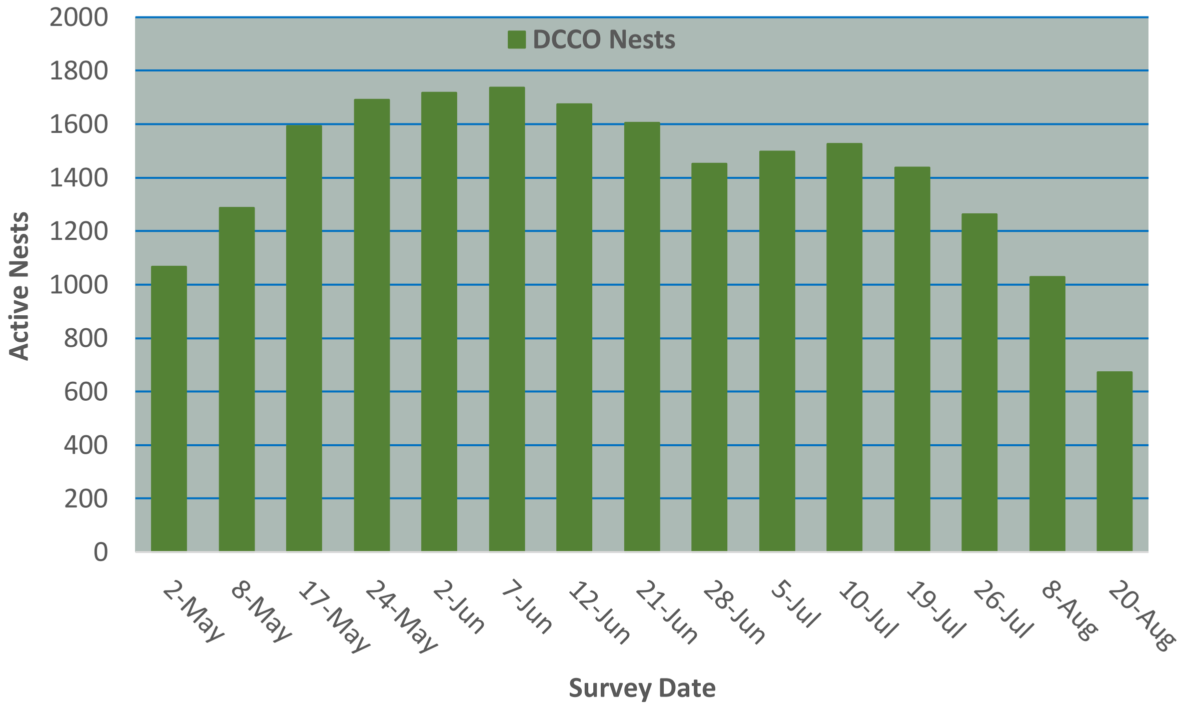

Figure 12. Weekly DCCO nest survey results for the Astoria-Megler Bridge during the 2018 breeding season.

The DCCO colony on the Astoria-Megler Bridge in 2018 (1,736 active nests) was more than double the peak colony size in 2017 (834 active nests). This colony has been growing each year since it first formed in 2004, however the increase in active nests in 2018 marks a significant rise in the rate of increase. *Figure 13* shows the annual peak DCCO colony size on the Astoria-Megler Bridge dating back to 2004. The colony growth from 2017 to 2018 included minor expansion into two areas of the bridge that have not been used by DCCO for nesting prior to this year, however most of the colony growth was the result of DCCO nesting more densely in areas of the bridge that have been used in previous breeding seasons. Bridge maintenance activities that occurred during the breeding season during past years did not occur during the 2018 breeding season. It is possible that the new nesting areas used in 2018 were not used in previous seasons due to the disturbance caused by bridge maintenance efforts.

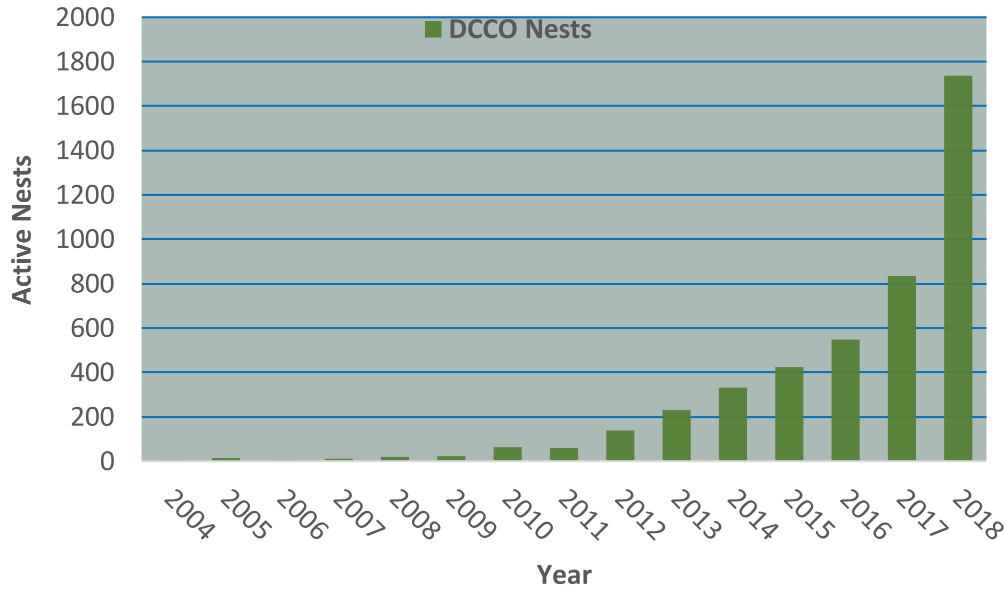

Figure 13. Annual peak DCCO colony size at the Astoria-Megler Bridge.

Nest surveys were conducted at the Longview Bridge six times during the 2018 DCCO breeding season. The peak nest count was observed on 4 May, when 201 active nests or breeding pairs were counted. *Figure 14* shows the weekly nest survey results at the Longview Bridge during the 2018 breeding season. The peak DCCO colony size on the Longview Bridge was approximately 25% larger in 2018 than was observed in 2017 (147 active nests). The annual peak DCCO colony size on the Longview Bridge over the past 5 years is shown on below *Figure 15*.

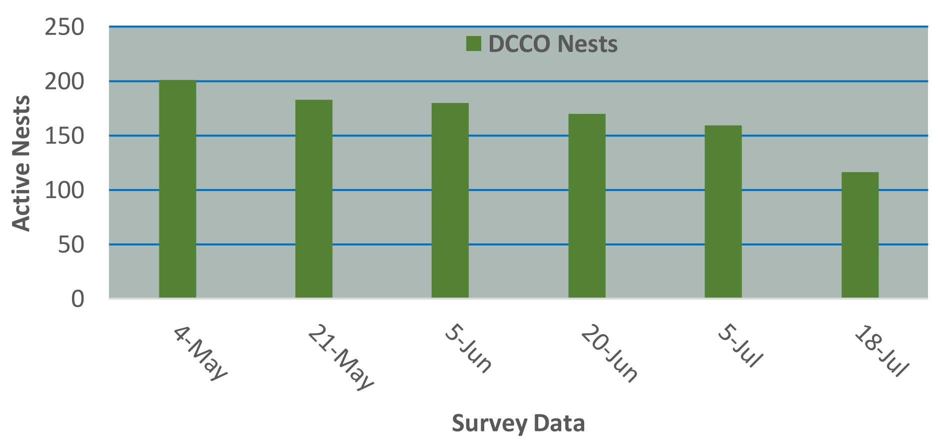

Figure 14. Weekly DCCO nest survey results for the Longview Bridge during the 2018 breeding season.

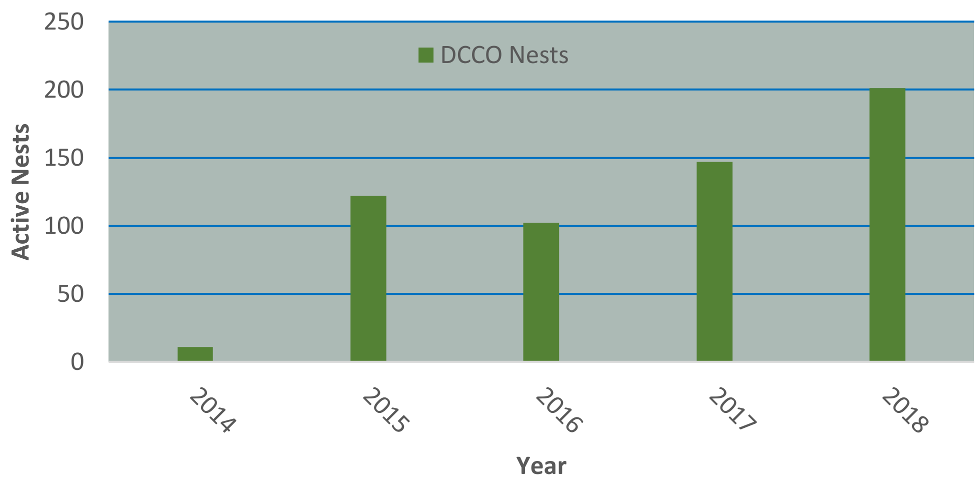

Figure 15. Annual peak DCCO colony size at the Longview Bridge.

CONCLUSIONS

Similar to the previous year, multiple factors likely contributed to delayed DCCO colony formation on ESI in 2018, including: (1) late arrival of DCCOs to the breeding colony; (2) bald eagle disturbance/predation beginning during early nest initiation attempts through early July; and (3) other potential carry-over effects from previous breeding seasons (e.g., delayed breeding attempts and poor productivity in 2017).

Early attempts to initiate nesting 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 and gulls would move through the colony on foot inspecting nests and eating eggs. 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 2018 can cause colony-wide nesting failure and abandonment (Carter et al. 1995, Hatch and Weseloh 1999, Windels 2012, Adkins et al. 2014).

In 2016 and 2017, the DCCO colony on ESI fledged chicks several months later than typical. It is known that late breeding and late departure from breeding colonies can introduce carry-over effects to seabird populations in the following breeding season (Fayette et. al. 2016). Carry-over effects include delayed arrival to breeding sites and reduced fitness, both of which can impact colony size and nesting success. The combination of potential carry-over effects from the abnormally late nesting periods in 2016 and 2017 may have negatively affected cormorant colony size and nesting success in 2018. Given that the breeding seasons during 2016-2018 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 2019 breeding season as well.

The DCCO colony on the Astoria-Megler Bridge was first established in 2004 and gradually grew to approximately 60 breeding pairs by 2011. Since 2011 the colony has grown more rapidly, with an average annual growth rate of 66% from 2011 to 2018. In 2017 and 2018 the bridge colony grew by 285 nests and 903 nests, respectively, the largest numerical increases in colony size ever recorded at that colony. The relatively large increase in colony size the past two seasons have occurred following poor breeding conditions for cormorants on ESI (see above), and it is likely that some of the colony recruitment to the Astoria-Megler Bridge colony has come from the ESI colony. A previous study has shown connectivity between the ESI and Astoria-Megler Bridge DCCO colonies (Peck-Richardson 2017), and DCCOs that were banded on ESI were observed nesting on the bridge during nest counts in 2017 and 2018. There is no data to quantify to what extent the growth in the Astoria-Megler Bridge is due to the recruitment from the ESI colony verses other colonies.

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APPENDIX A: COLONY COUNT TABLES

Cormorant colony counts on East Sand Island

Table A1. Weekly ESI DCCO Nest Counts in 2018

Date	DCCO Nests
22-May	3,049
30-May	5,999
1-Jun	4,103
6-Jun	2,873
13-Jun	3,050
19-Jun	3,586
25-Jun	2,370
3-Jul	3,380
10-Jul	3,060
17-Jul	3,603
25-Jul	3,672
27-Jul	3,488
2-Aug	2,866
7-Aug	2,362
15-Aug	1,664
29-Aug	988

Table A2. Annual ESI DCCO Nest Counts

Year	DCCO Nests	95% CI
1997	5,023	301
1998	6,285	377
1999	6,561	394
2000	7,162	430
2001	8,120	487
2002	10,230	614
2003	10,646	639
2004	12,480	749
2005	12,287	737
2006	13,738	824
2007	13,771	826
2008	10,950	365
2009	12,087	158
2010	13,596	466
2011	13,045	164
2012	12,301	415
2013	14,916	371
2014	13,626	292
2015	12,150	-
2016	9,772	-
2017	544	32
2018	3,672	10

Table A3. Annual ESI BRAC Nest Counts

Year	BRAC Nests
2006	44
2007	288
2008	508
2009	684
2010	985
2011	1,491
2012	1,684
2013	1,523
2014	1,629
2015	2,071
2016	1,515
2017	1,893
2018	2,120

Cormorant colony counts on bridges in the Columbia River Estuary

Table A4. Weekly Astoria-Megler Bridge DCCO Nest Counts

Date	DCCO Nests
2-May	1,066
8-May	1,286
17-May	1,592
24-May	1,690
2-Jun	1,717
7-Jun	1,737
12-Jun	1,675
21-Jun	1,605
28-Jun	1,452
5-Jul	1,498
10-Jul	1,525
19-Jul	1,437
26-Jul	1,263
8-Aug	1,029
20-Aug	672

Table A5. Annual Astoria-Megler Bridge DCCO Nest Counts

Year	DCCO Nests
2004	6
2005	14
2006	7
2007	11
2008	20
2009	24
2010	63
2011	60
2012	139
2013	231
2014	333
2015	425
2016	549
2017	834
2018	1,737

Table A6. Weekly Longview Bridge DCCO Nest Counts

Date	DCCO Nests
4-May	201
21-May	183
5-Jun	180
20-Jun	170
5-Jul	159
18-Jul	116

Table A7. Annual Longview Bridge DCCO Nest Counts

Year	DCCO Nests
2014	11
2015	122
2016	102
2017	147
2018	201