U.S. Fish & Wildlife Service

Double-crested Cormorant Western Population Status Evaluation

Final Annual 2018 Report

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by

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to

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Executive Summary

The U.S. Army Corps of Engineers (Corps) developed the Double-crested Cormorant Management Plan and Final Environmental Impact Statement (FEIS) (Corps 2015) to comply with reasonable and prudent alternative action (RPA) 46 in the 2008 Federal Columbia River Power System Biological Opinion, and its 20l0 and 2014 Supplements, issued by National Marine Fisheries Services. Reasonable and prudent alternative 46 in the 2014 Supplemental Federal Columbia River Power System Biological Opinion called for the Corps to *"…develop a cormorant management plan (including necessary monitoring and research) and implement warranted actions to reduce cormorant predation in the estuary to Base Period levels (no more than 5,380 to 5,939 nesting pairs on East Sand Island).*" The Corps selected Alternative C-1 from the FEIS to meet RPA 46 based on feasibility, minimizing impacts to the Western Population of Double-crested Cormorants and other species, and minimizing the potential for Double-crested Cormorant dispersal. Alternative C-1 includes coordination with the U.S. Fish and Wildlife Service (USFWS) and States to implement the Pacific Flyway Council (PFC) Monitoring Strategy (PFC 2013) annually.

The PFC Monitoring Strategy is a coordinated monitoring effort to estimate the breeding population size, trend, and distribution of the Western Population of Double-crested Cormorants, and was implemented for the first time in 2014 and again in 2017. Corps funding was used to survey sites where other PFC Partners would not have otherwise collected data in 2015, 2016 and 2018. Survey methods included ground, boat, and/or aerial (plane, helicopter or drone) direct counting or photo enumeration. Surveys were completed, at minimum once per site, to estimate peak number of breeding Double-crested Cormorants, through nest and adult counts, March through August. USFWS and its contractors, PFC Partners, and Corps contractors monitored a total of 121 colony sites or colony complexes (i.e., collection of closely associated colonies) in 2018. The USFWS assembled and processed all 2018 colony information and derived a 2018 estimate of the Western Population as described in the PFC Monitoring Strategy. This annual estimate was compared to the Double-crested Cormorant Western Population Model prediction (FEIS, Corps 2015).

The 2018 estimate for the Western Population was 61,629 (50,281-72,976; ±95% confidence limit) breeding individuals. This was approximately 39% higher than the 2017 estimate [44,327 (37,842-50,812; ±95% confidence limit) breeding individuals] ($p < 0.01$).

There was little evidence of a difference in breeding population size comparing 2014-2016 and 2018 data ($p>0.1$) (Table 2). The Western Population 2018 estimate was more than one standard deviation above the predicted abundance after culling for Year 4 of the Management Plan (39,034 breeding individuals) provided in Table 5-4 of the FEIS (Corps 2015).

Double-crested and Brandt's Cormorant colony on East Sand Island. Photo credit: USFWS 2012.

Introduction

The Pacific Flyway Council published *A Framework for the Management of Double-crested Cormorant Depredation on Fish Resources in the Pacific Flyway* in 2012 (PFC 2012). The PFC recognized Double-crested Cormorant depredation at localized areas within the Pacific Flyway was creating conflicts with federal Endangered Species Act (ESA)-listed and special status fish and supplemental fisheries. This plan was developed to address these localized conflicts while managing Double-crested Cormorant numbers and distributions at the flyway scale (Figure 1). The goal of the flyway plan was to maintain Double-crested Cormorants as a natural part of the waterbird biodiversity of the Pacific Flyway while minimizing substantial negative ecological, economic, and social impacts of Double-crested Cormorants. The purpose of the plan was to provide agencies with information and guidance to facilitate management of Double-crested Cormorants in the Pacific Flyway. The plan provides a framework for agencies and states to follow when addressing fish depredation issues. Strategies were provided to aid in developing and coordinating research, monitoring, and management of Double-crested Cormorants across the Pacific Flyway (PFC 2012).

In 2013, the Pacific Flyway Council followed up with *A Monitoring Strategy for the Western Population of Double-crested Cormorants within the Pacific Flyway* (PFC 2013). The goal of the monitoring strategy was to establish a coordinated, long-term monitoring effort to estimate the breeding population size, trend, and distribution of the Western Population of Double-crested Cormorants. This information is fundamental for developing effective management recommendations, and for guiding and assessing management actions pertaining to cormorant depredation on fish resources.

The U.S. Army Corps of Engineers (Corps) developed the Double-crested Cormorant Management Plan and Final Environmental Impact Statement (FEIS) (Corps 2015) to comply with reasonable and prudent alternative action (RPA) 46 in the 2008 Federal Columbia River Power System Biological Opinion, and its 20l0 and 2014 Supplements, issued by National Marine Fisheries Services. Reasonable and prudent alternative 46 in the 2014 Supplemental Federal Columbia River Power System Biological Opinion called for the Corps to *"…develop a cormorant management plan (including necessary monitoring and research) and implement warranted actions to reduce cormorant predation in the estuary to Base Period levels (no more than 5,380 to 5,939 nesting pairs on East Sand Island).*" The Corps selected Alternative C-1 from the FEIS to meet RPA 46 based on feasibility, minimizing impacts to the Western Population of Double-crested Cormorants and other species, and minimizing the potential for Double-crested Cormorant dispersal. Alternative C-1 includes coordination with the U.S. Fish and Wildlife Service (USFWS) and States to implement the Pacific Flyway Council (PFC) Monitoring Strategy (PFC 2013) annually. The PFC Monitoring Strategy is a coordinated monitoring effort to estimate the breeding population size, trend, and distribution of the Western Population of Double-crested Cormorants.

The purpose of this document is to provide the updated breeding pair estimate and trend through time for the Western Population of Double-crested Cormorants.

Methods

The dual-frame methodology of sampling and analysis employed in the PFC Monitoring Strategy is modified from Haines and Pollock's 1998 study with bald-eagles, 'dual-frame' referring to the designation of colonies as belonging to either a 'list' or an 'area frame'. The number of active nests counted at these locations provides an index to estimate the total number of breeding adults. The dual-frame sampling approach concentrates sampling effort on the largest, active colonies and ensures that the majority of the population is sampled. The approach also includes sampling outside of known active colonies, which provides a more robust population estimate and can provide additional information on population distribution and dynamics. Double-crested Cormorant colonies on the list frame are active sites ($\geq$5 nests). Area frame sites are historical or sites with < 5 nests, or new sites <500 nests (e.g. found since the beginning of the monitoring effort). Sites were stratified by size, and then randomly selected for monitoring beginning in 2014 according to the PFC Monitoring Strategy (PFC 2013). For 2014-2018 the population estimates were derived from the sum of the total size class (strata) estimates. The estimate of the number of colonies in each size class was determined from the previous year's estimate multiplied by the percentage change of size class shifts for the sites monitored both years. The estimated number of colonies in each size class (strata) and mean colony size were multiplied to determine each total strata estimate. Since the mean colony sizes for each size class are used in creating the population estimate, precision was gained in the population estimate as the number of colonies surveyed increases.

The PFC Monitoring Strategy has the objective to detect a 5% change/year in the Western Population of cormorants with 80% power (β = 0.20) and a 10% Type I error rate (α = 0.10). A power analysis was conducted to identify the most cost-effective sampling scheme that achieved the monitoring objective. In total, a minimum of 44 locations will be monitored per monitoring year. It was recognized that additional locations will likely be monitored under various monitoring efforts and programs. When possible, these data will be included in the database and analyses. This will ensure a more precise population and trend estimate.

Monitoring began in 2014 and will occur every third year thereafter for at least 10 years (i.e., 2014, 2017, 2020, 2023) (PFC 2013). In addition, the Corps has needs for an annual assessment to fulfill monitoring objectives in the FEIS (Corps 2015). The Corps has adopted the methods, and the partnership used by the PFC, for this annual assessment of the Western Population.

The PFC Monitoring Strategy was first implemented in 2014, and 44 colonies were selected for monitoring across nine states and British Columbia using the monitoring strategy sampling protocol. In 2015, 2016, 2017 and 2018, using the same protocol, 46 sites were selected. In all years, additional sites were monitored and are used to derive the population estimate. Additional data are incorporated for any updated analyses. The most up to date population estimates are provided in this report.

Corps funding was used to survey sites where other PFC partners were not acquiring colony survey data in 2015, 2016 and 2018. Survey methods included ground, boat, and/or direct counting from either plane or helicopter, or later enumeration of aerial photographs. Surveys were completed, at minimum once per site, to estimate peak number of breeding Double-crested Cormorants, through nest and adult counts, March through August.

The USFWS assembled and processed all 2018 colony information obtained from the Western Population sites and derived a 2018 estimate of the Western Population as described in the PFC Monitoring Strategy. This annual estimate was compared to the Double-crested Cormorant Western Population Model prediction in Table 5-4 of the FEIS (Corps 2015). Additionally, changes in population indices between the current and previous years were calculated and assessed with a two-tailed z-test using the sum of variances for the two estimates and an alpha level of 0.05.

The analysis methods were updated in 2016 in comparison to the published PFC Monitoring Strategy. First, we made the assumption the number of colonies in the area frame did not change. This accounts for two possible scenarios, 1) that a "new" colony was previously established, but not monitored and 2) new colonies establish at the same rate as they extinguish. Second, sites on the list frame with < 5 pairs recorded were analyzed with the area frame sites for 2014, 2015, 2016, 2017, and 2018 but will be sampled in future years under the list frame sampling schedule.

In 2018, the peak colony abundance of East Sand Island was 5,999 pairs. In consultation with the Pacific Flyway Council Nongame Technical Committee the List 1 Frame Size was adjusted to include the management colony size goal (≥5,000 pairs). In 2017, the peak colony abundance of East Sand Island was only 544 pairs and was analyzed with the other List 2 Frame Sites (6,999-500 pairs). In 2016, the peak colony abundance of East Sand Island was 9,774 pairs; we kept East Sand Island in a separate strata, changing the strata definition from ≥10,000 breeding pairs to ≥7,000 pairs. This maintains consistency across all years (in the PFC Monitoring Strategy, Mullet Island was listed as the next largest colony site at 6,594 pairs in 2012). The variance around the East Sand Island was calculated from the provided 95% confidence interval in 2014 (derived from multiple observers enumerating photos from the same date). For 2015, 2016, and 2018 the variance for East Sand Island was determined for the three largest counts of the season and proportionally adjusted to the peak count. We surmised this was a more likely depiction of peak colony variance.

Colony complexes were defined for groupings originally described in the PFC Monitoring Strategy and list sites that expanded (e.g. Great Salt Lake). Analysis took place at the colony complex level. Wister Island in the Salton Sea was added as a list frame site in 2015; it was larger than 500 pair criteria stated in the PFC Monitoring Strategy. All other new sites have been added as area frame sites. The Woodard Bay colony site (identified in 2016) has been added to the Henderson Inlet – Woodard Bay complex. This changed the analysis for this site 2016-2018 from the Area Frame to List Frame analysis.

Double-crested Cormorant colony along Oregon Coast. Photo credit: USFWS 2018.

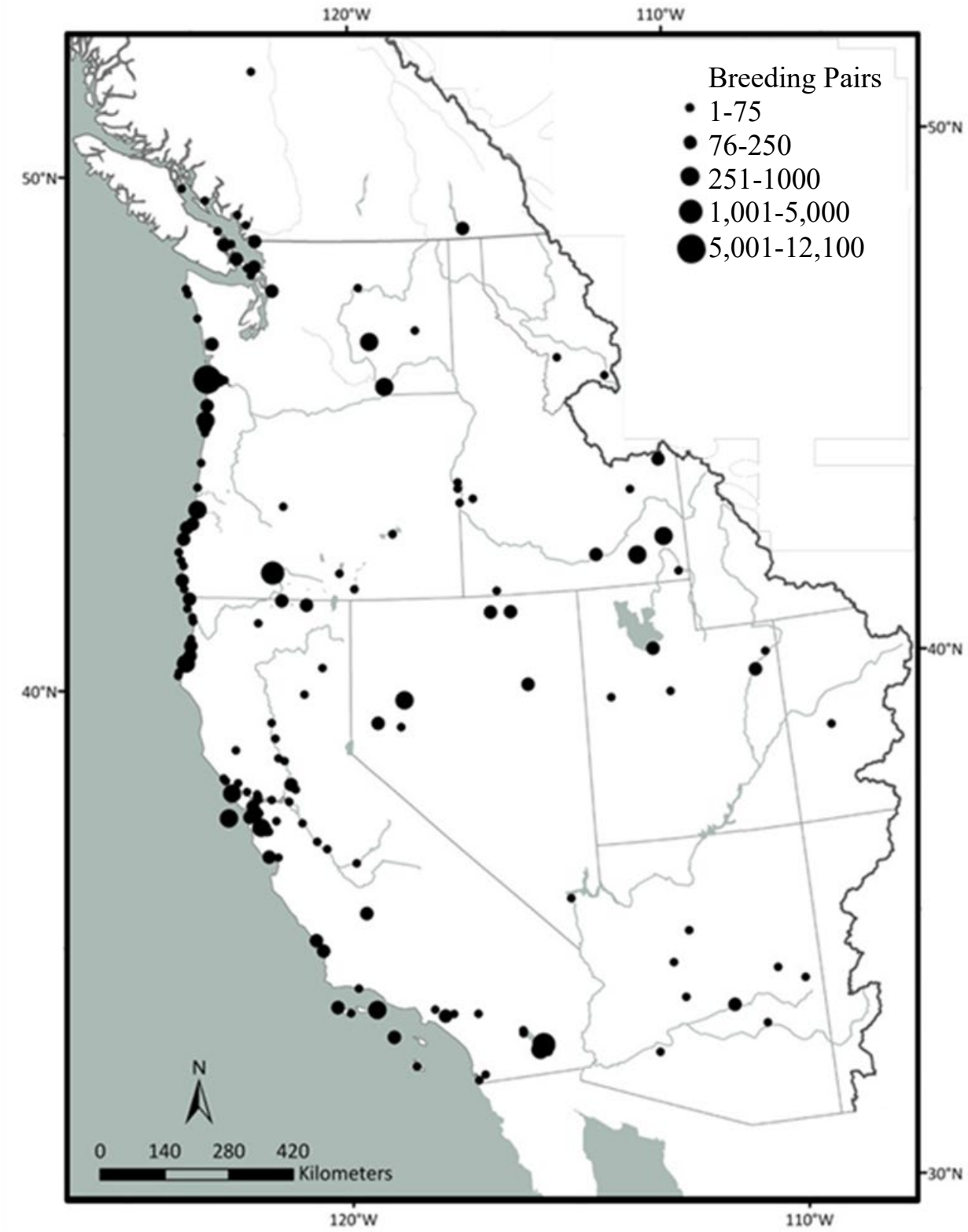

Figure 1. Distribution and relative peak size of Double-crested Cormorant breeding colonies in the Western Population during 1998-2009 (Adkins et al. 2010).

Results

For each year sites were selected for monitoring and additional data for colony sites and colony complexes were contributed by partners and used in the analysis (Table 2). All Columbia River Estuary sites monitored were included in these analyzes; the data were contributed by the Corps.

In 2018, 43 sites were monitored of the 46 selected. Arod Lakes in Montana, and two colony sites in interior California were not monitored (Table 1). An additional 78 sites were also surveyed for a total of 121 colony sites or colony complexes monitored and analyzed (Table 2). Two new breeding colonies were detected, Puloma Ranch Pond in Arizona and Seaside Trees in Oregon.

In 2017, 44 sites were monitored of the 46 selected. Twin Lakes in interior Washington and North Stone Lake, Stone Lakes NWR in interior California were not monitored. An additional 80 sites were also surveyed for a total of 124 colony sites or colony complexes monitored and analyzed (Table 2).

In 2016, 41 sites were monitored of the 46 selected. Anaheim Lakes, Eagle Lake-Pelican Point, Goose Lake, and Indian Valley Reservoir in interior California were not monitored. An additional 69 sites were also surveyed for a total of 110 colony sites or colony complexes monitored and analyzed (Table 2).

In 2015, 45 sites were monitored of the 46 selected. Creston Valley Wildlife Management Area in British Columbia was not monitored. An additional 78 sites were also surveyed for a total of 123 colony sites or colony complexes were monitored and analyzed (Table 2). In 2014, data were reported for 38 of the 44 selected sites, and 77 additional sites were monitored, for a total of 115 colony sites or colony complexes were monitored and analyzed (Table 2).

The 2018 estimate for the Western Population was 61,629 (50,281-72,976; ±95% confidence limit) breeding individuals (Tables 3 and A1). This was approximately 39% higher than the 2017 estimate [44,327 (37,842-50,812; ±95% confidence limit) breeding individuals] ($p < 0.01$) (Tables 3 and A2). The 2017 estimate was approximately 41% lower than the 2016 estimate [74,908 (63,110-86,705; ±95% confidence limit) breeding individuals] ($p < 0.00001$) (Tables 3 and A3). The 2015 estimate was 74,601 (66,265-82,938; ±95% confidence limit) breeding individuals (Tables 3 and A4). The 2014 estimate was 73,437 (67,124-79,751; ±95% confidence limit) breeding individuals (Tables 3 and A5). 2017 was the first year a statistical change was detected. There was little evidence of a difference in breeding population size comparing 2014-2016 and 2018 data ($p>0.1$) (Table 3). The Western Population 2018 estimate was more than one standard deviation above the predicted abundance after culling for Year 4 of the Management Plan (39,034 breeding individuals) provided in Table 5-4 of the FEIS (Corps 2015).

Size class shifts were noted in 2018. In 2017, there were no colonies monitored in ≥5,000 pairs size class and six monitored colonies with 500-4,999 breeding pairs (Tables A2). In 2018, however, there was one colony >5,000 pairs size class and four colonies with 500-4,999 breeding pairs (Table A1).

Double-crested Cormorant colony along Oregon Coast. Photo credit: USFWS 2018.

Table 1. Sites selected for the 2018 Double-crested Cormorant Western Population Survey

State/Province	Area	Colony
BC	Interior	Creston Valley Wildlife Management Area
BC	Vancouver Area	Second Narrows Bridge Power Tower
CA	Central Coast – Outer Coast North	South Farallon Islands
CA	Central Coast – San Francisco Bay	Alviso Plant, Pond Nos. A9 & A10
CA	Central Coast – San Francisco Bay	Bair Island Power Towers (incl. Steinberger Slough)
CA	Interior	Anaheim Lakes
CA	Interior	Mullet Is., Salton Sea (So.)
CA	Northern Coast – North Section	Arcata Bay Sand Islands
CA	Northern Coast – North Section	Big Lagoon
CA	Northern Coast – South Section	Hog Island
CA	Southern Coast	Prince Island
CA	Southern Coast	Santa Barbara Island
CA	Southern Coast	Seal Cove Area
CA	Interior	Tule Lake NWR, Sump 1B
CA	Interior	Mallard Rd Duck Club
CA	Interior	North Butte Country Club, Butte Sink
ID	All	American Falls Reservoir
ID	All	Bear Lake NWR
ID	All	Blackfoot Reservoir
MT	East of Continental Divide	Arod Lake
NV	All	S-Line Reservoir
OR	Central Coast	Parrot Rock
OR	Columbia River Mouth	East Sand Island
OR	Columbia River Mouth	Miller Sands Navigational Aids
OR	Interior	Malheur NWR - Frenchglen Area - Baca Lake
OR	Interior	Rivers End (Lake Abert)
OR	Northern Coast	Unnamed Colony (Cape Lookout)
OR	Southern Coast	Bolon Island
OR	Southern Coast	Hunters Island
OR	Southern Coast	Unnamed Colony (Mack Reef)
OR	Southern Coast	Unnamed Colony (N of Ferry Road Park)
OR	Interior	Malheur NWR - Derrick Lake
OR	Southern Coast	Coos Bay Navigation Marker 8
OR	Southern Coast	Gregory Point (Chief's Island) = 270.004
OR	Interior	Round Lake
OR	Southern Coast	Munsel Lake
OR	Southern Coast	North Bend Trees
OR	Columbia River	McGuire Island
UT	All	Great Salt Lake
WA	Grays Harbor	Grays Harbor Channel Markers

Table 1. (continued)

State/Pro	Area	Colony
WA	Interior	North Potholes Reservoir
WA	San Juan Islands	Bird Rocks
WA	San Juan Islands	Drayton Harbor
WA	San Juan Islands	Secar Rock
WA	Interior	Pend Oreille River - Sandy Shores
WA	Olympic Peninsula Outer Coast	Abbey Island

Double-crested Cormorant colony in the Great Salt Lake. Photo credit: Utah Division of Wildlife Resources 2018.

Table 2. Numbers of colony sites or colony complexes selected for monitoring and total monitored and analyzed according to methods in the PFC Monitoring Strategy; this includes data contributed from partners.

Year	Number of sites selected	Total number monitored and analyzed
2018	46	121
2017	46	124
2016	46	110
2015	46	123
2014	44	115

Table 3. Double-crested Cormorant Western Population Estimates, with Variance 2018, 2017, 2016, 2015 and 2014.

		Population Estimate	Standard Error	CV %	Estimated LCL	Estimated UCL
2018	Pairs	30,814	2895	9.4%	25,141	36,488
	Individuals	61,629	5789	9.4%	50,281	72,976
***2017**	Pairs	22,164	1,654	7.5%	18,921	25,406
	Individuals	44,327	3,309	7.5%	37,842	50,812
2016	Pairs	37,454	3,010	8.0%	31,555	43,353
	Individuals	74,908	6,019	8.0%	63,110	86,705
2015	Pairs	37,301	2,127	5.7%	33,132	41,469
	Individuals	74,601	4,253	5.7%	66,265	82,938
2014	Pairs	36,719	1,611	4.4%	33,562	39,875
	Individuals	73,437	3,221	4.4%	67,124	79,751

*Significantly different from all other years, $p<0.01$

Discussion

The strength in using the PFC Monitoring Strategy was the ability to detect change from 2014 forward. Monitoring methods were standardized for the first time, and a sampling approach was used that does not require monitoring all colonies. This monitoring approach derives an index and trend information on the majority of active colonies (approx. 70% of the known population), coordinated with multiple partners across the Western Population. Additionally, information was collected on the status of historical and small colonies and on the transition rates of colonies between size classes. Furthermore, this monitoring uses a randomized sampling design that allows for a total population estimate, with confidence intervals.

New and updated data will be added to future analyses. This will change the population estimate, but since the main calculations are on mean colony size/class, the change will likely be small.

Caution should be used, however, when comparing the 2014-2018 results to previous assessments and population estimates since different methodologies were used in the past. The 2014-2018 estimates were derived using the list and area frame method. The circa 2009 (2008-2010), estimate was 31,200 breeding pairs (Adkins et al. 2014) and was derived using a whole census method, across multiple years, and which omitted colonies of fewer than 5 breeding pairs. Up to 1992, the estimate was 17,691 breeding pairs (Carter et al. 1995), and this was derived from a whole census method, across multiple years, and only included coastal states and BC. The 1975-1992, estimate was 20,830 breeding pairs (Tyson et al. 1997) and was derived from a whole census method across multiple years. Table A6 compares the population estimates from 2014-2016 with the circa 2009 data (Adkins et al. 2014), using only the list frame sites from 2014-2016; these are the most directly comparable with the earlier data; they are from the same sites. Estimates based on list frame site from 2014-2016 and ca. 2009 are remarkably similar.

There are additional opportunities for analysis within these data sets, including analyses of transition rates between size classes, and between list and area frame classifications. These data might also be used to better define the spatial resolution of colonies, and better define what constitutes a 'new' colony. Distribution changes may be looked at on a broad scale. Since the monitoring is currently taking place on an annual (versus every three year) basis and more colonies surveyed than the minimum, the power analysis could be updated. In addition, the Pacific Flyway Council Nongame Technical Committee has changed the List 1 stratum further, from ≥7,000 pairs to ≥5,000 pairs. This allows East Sand Island to be kept in a separate stratum if the management plan goals continue to be met (no more than 5,380-5,939 breeding pairs is the target colony size).

For the 2018 Western Population analysis, we used the East Sand Island colony peak abundance of 5,999 breeding pairs (active nests) on May 30, 2018. This peak was observed after several weeks of colony use, including after first eggs were observed. This was also the same time period that active nest peaks were observed pre-management (prior to 2015). This metric counts the largest number of active nests in 2018 and follows the metrics used for other colonies in the Western Population and stated in the PFC Monitoring Strategy.

Different metrics may be of use for other partnering agencies. For instance, May 30, 2018 peak does not accurately account for any

management. The 5,999 observed nests includes 714 nests on the east side of the privacy fence (management area with hazing and active nest removal). In addition, most of the nests failed from the May 30 cohort during a time of repeated Bald Eagle disturbance (Turecek et al. 2019). The colony abundance post management was observed on July 25, 2018, during late incubation, with 3,672 active nests. This was well within the Corps described management goal of no more than 5,380-5,939 breeding pairs of Double-crested Cormorants on East Sand Island.

The 2017 breeding pair estimate of the Western Population was statistically lower than the other survey years (Table 2). The colony with the largest decrease in nesting was East Sand Island. In 2017, the peak breeding abundance was only 544 pairs, compared to 13,626 breeding pairs in 2014. The nearby Astoria-Megler Bridge hosted the largest colony in the Western Population in 2017 (834 pairs). A combination of factors likely led to the multiple dispersal events and extremely low breeding abundance of cormorants on the East Sand Island colony in 2017. These factors, including 1) unusually high disturbance and predation by Bald Eagles, 2) high flows in the Columbia River that may have reduced the prey available to cormorants during the breeding season, and 3) potential carry-over effects from past breeding seasons, likely worked in concert (Turecek et al. 2018). The large size of the East Sand Island colony, prior to management, likely provided security, "swamping" Bald Eagles, reducing the effects of disturbance and predation (Anderson and Hodum 1993, Peck-Richardson 2017). Late breeding and late departure from colonies can carry over to future breeding seasons of low nesting success and productivity (Fayet et al. 2016). Repeated nesting attempts, late nesting and late departure from the breeding site were observed for 2016, 2017, and 2018 (Turecek et al. 2018, Turecek et al. 2019). Reduced productivity was part of the implementation USACE's Double-crested Cormorant management plan to reduce predation of juvenile salmonids in the Columbia River Estuary (e.g. nest destruction through egg oiling; active culling of adults on/near East Sand Island during the incubation period). Active management at East Sand Island is another potential factor for 2017, but management occurred at substantially lower levels than in previous years, and at levels below those identified in the management plan. Approximately 20,000 total cormorants were observed on East Sand Island in 2017, but the vast majority did not nest. These nonbreeders are not included in the Western Population estimate of breeding pairs, the metric for this study. The total population was higher. Metrics important to stakeholders may not match with the primary metrics of this study. In particular, total population and predation rates of that total population have been discussed as possible metrics for future monitoring.

Breeding numbers increased from 2017 to 2018 in the Columbia River Estuary; presumably many of the nonbreeders observed in 2017 returned. In 2018, the East Sand Island colony was the largest in the Western Population; the Astoria-Megler Bridge colony was the second largest with 1,736 breeding pairs (Turecek et al. 2019). The 2018 Western Population estimate was larger than predicted in the FEIS (Corps 2015).

Colony sizes within the Columbia River Estuary are of high importance to many stakeholders. All Columbia River Estuary sites monitored were included in these analyzes; the data were contributed by the Corps. Monitoring colony sizes throughout the estuary, and periodically throughout the Western Population should be continued, considering the reduced nesting habitat available on East Sand Island after the habitat modification, increased effects of Bald Eagle disturbance and late breeding.

Structures (e.g. bridges and transmission towers) were predicted to be used at higher rates if Bald Eagle populations continue to grow and reoccupy their historic range (Adkins et al. 2014).

Conclusion

The 2018 estimate for the Western Population was 61,629 (50,281-72,976; ±95% confidence limit) breeding individuals (Tables 2 and A1).

The 2017 breeding pair estimate of the Western Population was statistically lower than the other survey years (Table 2). This was driven, in part, by low breeding colony abundance of the East Sand Island colony; however many nonbreeders were observed in the Columbia River Estuary during the breeding season. There was no evidence of a difference in breeding population size comparing 2014-2016 and 2018 data.

The Western Population 2018 estimate was more than one standard deviation above the predicted abundance after culling for Year 4 of the Management Plan (39,034 breeding individuals) provided in Table 5-4 of the FEIS (Corps 2015).

The FEIS (Corps 2015) stated six primary goals of adaptive management:
"• Achieve baseline levels of predation as described in the FCRPS Biological Opinion (NOAA 2014)
• Reduce DCCO depredation of juvenile salmonids throughout the Columbia River Estuary
• Reduce the potential for shifting DCCO depredation impacts to areas outside the Columbia River Estuary
• Minimize adverse impacts to the western population of DCCO
• Minimize adverse impacts to non-target species during implementation
• Implement passive methods that are cost effective and require less human presence in the long-term"

This study addresses the fourth, "*Minimize adverse impacts to the western population of DCCO*"; this goal is currently being achieved.

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Appendices

Please see the accompanying external hard drive for an index of hyperlinked reference documents, photos, and video.

Appendix A. Estimated Number of Colonies and Double-crested Cormorant Western Population Estimates, 2015-2018 and comparison to past status assessment

Table A1. Estimated Number of Colonies and Double-crested Cormorant Western Population Estimate, 2018.

2018				
Colony Size (Breeding Pairs)	**# of Colonies Sampled**	**Colonies per size class estimate***	**Mean Complex/ Colony Size**	**Population Estimate**
≥5,000	1	1.00	5,999	5,999
4,999-500	4	3.29	919	3,025
499-100	20	49.94	205	10,221
99-5	28	108.70	44	4,833
List Frame	53	162.93		24,078
Area Frame	68	224	30	6,736
Sum of Frames				30,814
Total Individuals				61,629

*Hundredths place used to ensure no rounding errors reported.

Table A2. Estimated Number of Colonies and Double-crested Cormorant Western Population Estimate, 2017.

2017				
Colony Size (Breeding Pairs)	**# of Colonies Sampled**	**Colonies per size class estimate***	**Mean Complex/ Colony Size**	**Population Estimate**
≥7,000	0	0.00	0	0
6,999-500	6	4.11	593	2,441
499-100	19	47.31	222	10,501
99-5	29	96.16	46	4,423
List Frame	54	147.59		17,366
Area Frame	70	224	21	4,798
Sum of Frames				22,164
Total Individuals				44,327

*Hundredths place used to ensure no rounding errors reported.0.00

Table A3. Estimated Number of Colonies and Double-crested Cormorant Western Population Estimate, 2016.

2016				
Colony Size (Breeding Pairs)	**# of Colonies Sampled**	**Colonies per size class estimate***	**Mean Complex/ Colony Size**	**Population Estimate**
≥7,000	1	1.00	9,772	9,772
6,999-500	3	2.47	800	1,976
499-100	26	73.93	240	17,763
99-5	16	73.25	37	2,697
List Frame	46	150.66		32,207
Area Frame	64	224	23	5,247
Sum of Frames				37,454
Total Individuals				74,908

*Hundredths place used to ensure no rounding errors reported.

Table A4. Estimated Number of Colonies and Double-crested Cormorant Western Population Estimate, 2015.

2015				
Colony Size (Breeding Pairs)	**# of Colonies Sampled**	**Colonies per size class estimate***	**Mean Complex/ Colony Size**	**Population Estimate**
≥7,000	1	1.00	12,150	12,150
6,999-500	7	5.76	669	3,853
499-100	15	40.32	265	10,702
99-5	26	107.08	52	5,576
List Frame	49	154.16		32,282
Area Frame	74	224	22	5,019
Sum of Frames				37,301
Total Individuals				74,601

*Hundredths place used to ensure no rounding errors reported.

Table A5. Estimated Number of Colonies and Double-crested Cormorant Western Population Estimate, 2014.

2014				
Colony Size (Breeding Pairs)	**# of Colonies Sampled**	**Colonies per size class estimate***	**Mean Complex/ Colony Size**	**Population Estimate**
≥7,000	1	1.00	13,626	13,626
6,999-500	6	7.20	695	5,002
499-100	23	47.05	225	10,565
99-5	24	87.00	44	3,792
List Frame	54	142.25		32,984
Area Frame	61	224	17	3,735
Sum of Frames				36,719
Total Individuals				73,437

*Hundredths place used to ensure no rounding errors reported.

Table A6. Comparison of 2016, 2015, 2014 and ca. 2009 List Frame Population Estimates

	2016			**2015**			**Pacific Flyway Monitoring 2014**			**Adkins et al. 2014**	
Colony Size (Breeding Pairs)	Estimate of the # of colonies in each size class	Mean Complex/ Colony Size	POP EST (2016)	Estimate of the # of colonies in each size class	Mean Complex/ Colony Size	POP EST (2015)	Estimate of the # of colonies in each size class	Mean Complex/ Colony Size	POP EST (2014)	Mean Colony Size	POP EST (~2009)
≥7,000	1	9,772	9,772	1	12,150	12,150	1	13,626	13,626	12,087	12,087
6,999-500	2	800	1,976	6	669	3,853	7	695	5,002	1,199	7,193
499-100	74	240	17,763	40	265	10,702	47	225	10,565	155	6,991
99-5	73	37	2,697	107	52	5,576	87	44	3,792	44	6,428
List Frame	151		32,207	154		32,282	142		32,984		32,700

Double-crested Cormorant colony in the Great Salt Lake. Photo credit: Utah Division of Wildlife Resources 2018.